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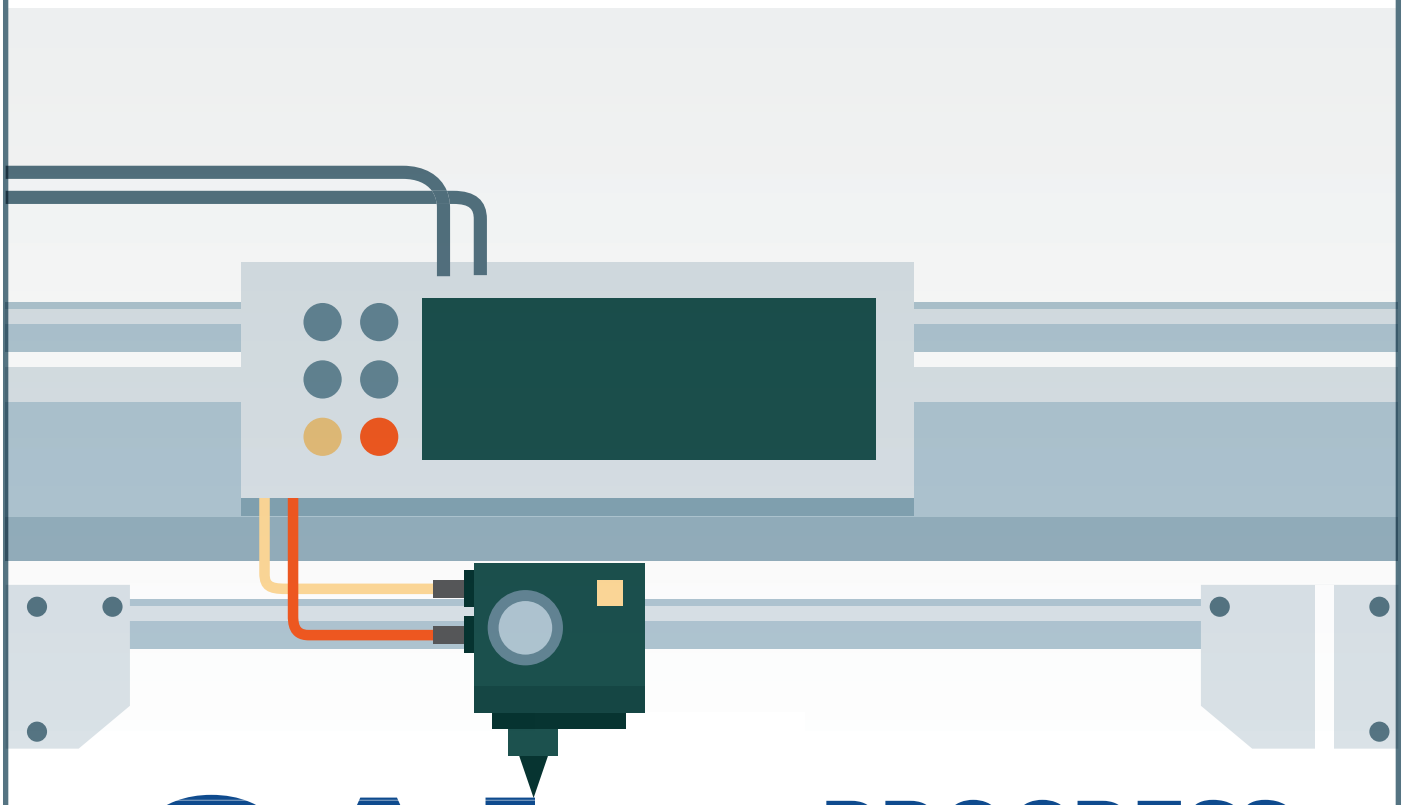

GAPS PROGRESS REPORT

STANDARDIZATION ROADMAP FOR ADDITIVE MANUFACTURING

Version 3.0 | April 2025

Prepared by the America Makes & ANSI Additive Manufacturing Standardization Collaborative (AMSC)

Gaps Progress Reports Version History

The America Makes and ANSI Additive Manufacturing Standardization Collaborative (AMSC) published the Standardization Roadmap for Additive Manufacturing, Version 3.0 in July 2023. The most current information reported on standards activities in the gaps progress reports is retained from version to version. The most current version is retained on the ANSI website at www.ansi.org/amsc. The roadmap and gaps progress reports can be downloaded for free. See the report overview for more information.

S.N.	*Version*	*Publication Date*	*Version Note*
1	April 2024	23 April 2024	1st gaps progress report against Roadmap v3
2	September 2024	27 September 2024	2nd gaps progress report against Roadmap v3
3	April 2025	23 April 2025	3rd gaps progress report against Roadmap v3

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GAPS PROGRESS REPORT OVERVIEW

The America Makes and ANSI Additive Manufacturing Standardization Collaborative (AMSC) is tracking progress by standards developing organizations (SDOs) and others to address the gaps identified in the *Standardization Roadmap for Additive Manufacturing, Version 3.0* (Version 3.0, July 2023). The updates provided in this progress report were derived from various sources: direct inputs from SDO staff and subject matter experts (with attribution), SDO alert mechanisms, and independent research by ANSI staff based on publicly available SDO work programmes and other information. As such, this report should not be viewed as a consensus document and it does not necessarily reflect the views of the individuals or organizations named. It is intended to be a "living document" that will be maintained and periodically re-published as standards development work continues or until such time as the AMSC undertakes to develop a next version of its standardization roadmap. Comments and suggested edits to the gaps are to be addressed at a later date.

Click on any of the roadmap gap titles below for the most recent updates (highlighted and dated) since the deadline for input **(4/9/2025) on the April 2025 progress report which was published 4/23/2025**. You will see fields for updates since roadmap version 3 was published, new published standards, and new in-development standards. In some cases, staff has determined that a published standard or in-development standard may be responsive to an identified v3 gap(s) or topical area based on the standard's title/abstract. In other cases, staff was unable to make such a determination and, in such cases, the standard is listed at the end of a chapter.

Updates, corrections, and suggested edits should be sent to amsc@ansi.org.

SUMMARY TABLE OF GAPS AND RECOMMENDATIONS

Accompanying the roadmap is a ***Summary Table of Gaps and Recommendations*** identified in roadmap version 3.0. This spreadsheet allows users to sort and filter gaps based on the categories such as R&D Needed, Priority, Status of Progress, Lifecycle Area, Sector, Material Type, Process Categories, and Qualification and Certification (Q&C) Categories. In the case of Priority and Status of Progress, there are some instances where more than one value is listed, for example, in relation to different Material Types.

Breakdown of Open Gaps by Lifecycle Area

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**

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*

Closed Gaps v1 to v3

Gap	Status	Rationale
DE1: Decision Support: Additive vs. Traditional	Closed v.3	Closed, with the publication of ISO/ASTM 52910-18 and ASTM F3488
DE2: Decision Support: Additive Processes	Closed v.3	Closed, with the publication of ISO/ASTM 52910-18 and ASTM F3488
DE5: Support for Customizable Guidelines	Withdrawn v.3	Determined no longer needed
DE6: Software-encodable/Machine-readable Guidelines	Withdrawn v.3	Determined no longer needed
D11: Design for 3D Printed Electronics	Closed v.2	Closed, with the publication of IPC 2292
DE19: Organization Schema Requirement and Design Configuration Control	Closed v.3	Closed, with the publication of AMSE Y14.47 and ASTM F3490
DE21: New Terminology in Design Documentation	Closed v.3	Closed, with the publication of AMSE Y14.46, ISO/ASTM 52900, and ISO/ASTM 52921
DE22: In-Process Monitoring	Withdrawn v.3	Was duplicative, content/intent represented in other chapters
D24: An Acquisition Specification	Closed v.2	Closed, with the publication of ISO/ASTM 52901:2017
D25: Configuration Control of Digital Part Design	Withdrawn v.2	Determined no longer needed
PM3: Particle Size and Particle Size Distribution	Withdrawn v.3	Determined no longer needed
PC7: Recycle & Re-use of Materials	Withdrawn v.3	Repositioned to PM18
PC9: Environmental Conditions: Effects on Materials.	Withdrawn v.3	Repositioned to PM13
PC10. Re-use of Material that Has Not Been Processed	Withdrawn v.3	Determined no longer needed
PC11: Re-use of Material that Has Been Processed	Withdrawn v.3	Determined no longer needed
PC17: Motion Control	Withdrawn v.2	Determined no longer needed
QC11: Process Validation for Pigments and Processing Aid Materials	Withdrawn v.2	Determined no longer needed
QC12: Resorbable Materials	Withdrawn v.3	Determined no longer needed
FMP2: Coupon Testing	Withdrawn v.2	Determined no longer needed
NDE5: Data Fusion	Withdrawn v.3	Repositioned & Merged into DA10
M2: Using AM to Print Tools	Withdrawn v.2	Determined no longer needed
M3: AM Level of Repair Analysis	Withdrawn v.3	Determined no longer needed
M7: Cybersecurity for Maintenance	Withdrawn v.3	Repositioned & Merged into DA21

SECTION 2.1 ON DESIGN GAPS

Section #	Gap #, Title and Description	High	Medium	Low
2.1.2.1	Gap DE1: Decision Support: Additive vs. Traditional (Closed)		X	
2.1.2.1	Gap DE2: Decision Support: Additive Processes (Closed)		X	
2.1.2.2	Gap DE3: Process-Specific Design Guidelines (Last updated 04/07/2024)		X	
2.1.2.3	Gap DE4: Design Guides for Specific Applications (Last updated 9/24/2024)		X	
2.1.2.4	Gap DE5: Support for Customizable Guidelines (Withdrawn)		X	
2.1.2.5	Gap DE7: Design Guide for Post-processing (Last updated 9/24/2024)		X	
2.1.3.1	Gap DE8: Machine Input and Capability Report (Last updated 4/14/2025)		X	
2.1.3.2	Gap DE9: AM Simulation Benchmark Model/Part Requirement (Last updated 4/14/2025)	X		
2.1.4.1	Gap DE10: Design for As-built Assembly (Last updated 04/08/2025)			X
2.1.4.2	Gap DE11: Design for 3D Printed Electronics		X	
2.1.4.3	Gap DE12: Imaging Consistency (Last updated 04/09/2025)	X		
2.1.4.3	Gap DE13: Image Processing and 2D to 3D Conversion (Last updated 04/09/2025)		X	
2.1.2.6	Gap DE14: Designing to be Cleaned		X	
2.1.2.7	Gap DE15: Design of Test Coupons (Last updated 3/12/2025)	X		
2.1.2.7	Gap DE16: Verifying Functionally Graded Materials (FGM)		X	
2.1.5.1	Gap DE17: Contents of a Data Package (Last updated 9/27/2024)	X		
2.1.5.3	Gap DE18: New Dimensioning and Tolerancing Requirements (Last updated 4/14/2025)	X		
2.1.5.4	Gap DE19: Organization Schema Requirement and Design Configuration Control (Closed)	X		
2.1.5.5	Gap DE20: Neutral Build File Format (Last updated 9/27/2024)		X	
2.1.5.6	Gap DE21: New Terminology in Design Documentation (Closed)		X	
2.1.5.8	Gap DE23: Documentation of New Functional and Complex Surface Features (Last updated 9/27/2024)			X
2.1.6	Gap DE26: Design for Measurement of AM Features/Verifying the Designs of Features such as Lattices, etc. (Last updated 9/27/2024)		X	
2.1.3.3	Gap DE27: Standardized Design for Additive Manufacturing (DFAM) Process Chain (Last updated 9/19/2024)		X	
2.1.5.8	Gap DE28: Specification of Surface Finish	X		
2.1.7	New Gap DE29: Best Practices for Design for Anti-counterfeiting (Last updated 4/8/2025)		X	
2.1.5.2	New Gap DE30: STEP Based 3D PDF	X		

Section #	Gap #, Title and Description	High	Medium	Low
2.1.5.2	New Gap DE31: Feature-based Support for STEP (Last updated 4/14/2025)	X		
	Section 2.1 Recommendations/Comments Since v3 was Published (Last updated 3/25/2025)			

Gap DE3: Process-Specific Design Guidelines.

Develop AM process-specific design guidelines for binder jetting (including shrinkage factor in final dimensions), material jetting, sheet lamination, and non-polymer material extrusion as well as complete standards work for vat photopolymerization. The objective is to have AM process-specific design guidelines for the 7 types of AM process identified by ASTM and ISO. Guidance to reduce warpage during sintering for post-processing for metal binder jetting is also needed.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: Not yet determined to fill the gaps on the remaining processes and related materials. ASTM to complete WK83109 on vat photopolymerization.

Recommendation: Develop guidelines for the other AM processes defined in *ISO/ASTM 52900:2021, Additive manufacturing -- General principles – Fundamentals and vocabulary*.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM F42/ISO TC 261 JG 57, ASTM F42.04/ISO TC 261 WG4, AWS

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☒Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Organizational level internal practices.

V3 Status of Progress: ☒Green (ISO/ASTM for vat-P); ☐Yellow; ☐Red; ☒Not Started for other processes defined in ISO/ASTM 52900; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Per above, the ISO/ASTM is addressing the PBF, directed energy deposition and material extrusion for polymers. Work is underway on vat photopolymerization.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	04/07/2024, D.Rosen: *ASTM WK83109, New Guide for Additive manufacturing -- Design -- Vat Photopolymerization* will be balloted in early 2024. ASTM F42.04 and ISO TC261 WG4 are working on a design guide for metal binder jetting.

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Gap DE4: Design Guides for Specific Applications.

As industry fields mature in particular AM applications, best practices should be recorded.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: N/A

Recommendation: It is recommended that any application-specific design guides extend available process-independent and process-specific design guides. However, application-specific design guidelines may also need to be developed by their respective communities, and in such cases these guidelines may fall under respective societies or SDOs. For instance, a design guideline for printed electronics may be best suited for an organization such as IEEE or IPC.

Priority: ☐High; ☒Medium; ☐ Low

Organization: ASME, SAE, ASTM F42/ISO TC 261, and potentially other SDOs et al. (e.g., manufacturers, industry consortia)

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Each industry sector is leveraging domain specific guidance.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: See text above.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Is this to be considered a part family / feature family design guide? If so, discussions are ongoing with respect to feature family qualification.

New Published Standards	New In-Development Standards
	9/24/2024, C.Ashforth: CMH-17 is publishing comprehensive information polymer AM. It will include material data, instructions on how to generate data (including recommendations for material and process specifications) and instructions on how to use that data for aviation applications although its use is not limited to aviation.

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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.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: General research about post processing is needed, surface finishing and its correlation to fatigue and fatigue requirements.

Recommendation: Continue work to develop a design guide(s) related to various AM processes, materials, and applications for post processing.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASME B46, ASTM F42/ISO TC 261

Lifecycle Area: ☒ Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Depends on the process used for post-processing.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: See text above. ASTM F3530-22 and ISO/ASTM 52910-18 has been published and includes a high-level discussion of design considerations for post-processing but more detailed design guides addressing specific AM processes, materials, and applications are needed.

ASME B46 Committee is working on measurement and characterization methods for AM surface finish (not a design guide). The measurement and characterization methods that work for relating performance for machined or ground finishes should not be expected to work for relating performance for AM finishes. B46 explains how to find parameters that can describe the topography so they can correlate and discriminate between processing and performance parameters.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)***:**

- **9/24/2024, J.Schmelzle Compiled:** NAVAIR research project is slated for FY25 for metal LPBF coating on aluminum alloys.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Standardization of coating and paint steps for AM metals and AM polymers is required. Perhaps this should be higher priority?

New Published Standards	New In-Development Standards
04/07/2024, D.Rosen: ASTM *F3530-22, Standard Guide for Additive Manufacturing — Design — Post-Processing for Metal PBF-LB* (F42.04) was published.	

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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:

1. Manufacturing residues/contact materials encountered during the manufacturing process may need to be removed (see Gap DE7: Design Guide for Post-processing).
2. Unmelted/unsintered AM material from the manufacturing process may need to be removed (see Gap DE7).
3. For devices that are to be sterilized prior to use, a sterilization test soil can be placed at the most difficult location to sterilize so that the validation will accurately show if foreign bodies picked up during the manufacturing process can either be killed or removed from the device prior to sterilization
4. For reusable devices, a device may need to be adequately cleaned and sterilized prior to subsequent uses
5. For reusable devices, the device materials may need to be maintained for the specified number of cleaning cycles

For medical devices, there may be more specific sterilization needs. This is more directly related to post-processing and testing related aspect and less related to AM design. The need identified within this gap is not solely related to medical. Regarding #4 and #5 above, requirements exist for reprocessing medical devices.

Note: While there may be situations where cleaning is not desired, scenarios that do necessitate it, may consider the above.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: 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.

Recommendation: Develop design guidance within existing published design guidelines to provide general design limits and recommendations that achieve both needed surface structure and allow adequate cleaning. A separate standard may not be needed. See also Gap FMP3 and Gap QC15.

Priority: ☐High; ☒Medium; ☐Low

Organization: AAMI, ASTM F04, ASTM F42/ISO TC 261, ISO/TC 198, ASME (surface metrology), FDA

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Vendors will specify the needs and internal design practices will be leveraged.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: AAMI and ASTM have an interest and are meeting. FDA is also looking at this.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap DE15: Design of Test Coupons.

No AM standards are currently available for the design of test coupons for additively-manufactured structures. There may be application specific needs, which would focus on application specific related stresses. While there are many methods, they are not design related and they would need to be revised for this purpose. Test methods may need to be developed first.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Effects on what is in the build and how well can you replicate your feature of interest.

Recommendation: Develop standard application specific test methods and specifications for the design of test coupons for additively-manufactured porous structures.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM F04 and F42, ISO TC 261

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Standard coupons are being used

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ASTM F42 is working on standards for the compression test and test coupons. Also, ASTM F04 is looking at this. ASME V&V 40 Subcommittee on Verification and Validation in Computational Modeling of Medical Devices is working to form a working group on this item.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- **9/24/2024, C.Ashforth:** Polymer AM aspects of Gap DE15 is being addressed with FAA research, CMH-17, and collaboration with ASTM.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
03/12/2025, R.Bradak: AMPP Technical paper *TR21522 Corrosion Testing of Additive Manufactured Materials* was published in November 2024.	

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Gap DE16: Verifying Functionally Graded Materials (FGM).

Functionally graded materials are materials with variation in the composition or structure in order to vary the material properties (e.g., stiffness, density, thermal conductivity, etc.). Standard methods of specifying and verifying functionally graded materials currently do not exist. Furthermore, existing test methods may be leveraged or need to be modified to address considerations when validating their performance.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Characterizing the functional grades in a way that can be specified and measured and integrating solutions into other design and software tools.

Recommendation: Update existing test guidelines for metals and polymers with considerations for materials that have graded properties. If the grade itself needs to be verified versus only its performance, new test methods may be needed. This is a broad topic however and depends on what is being evaluated.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM F04 and F42, SAE AMS-AM, ASME, ISO/TC 261 JG 67

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Unknown

V3 Status of Progress: ☐Green; ☒Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ASME Y14.46 discusses the specification of functionally graded materials. New efforts are focusing on verification of lattice FGM specifications. *ISO/ASTM TR 52912:2020, Additive manufacturing — Design — Functionally graded additive manufacturing* was published as a technical report that addresses design opportunities and challenges of functionally graded materials.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)***:**

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap DE8: Machine Input and Capability Report.

A standard for reporting machine input requirements and the associated AM machine capabilities is required to support new design tools which will be able to determine manufacturing feasibility, optimize manufacturing solutions, and identify AM equipment which would be able to manufacture the part.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: To be determined.

Recommendation: Develop a standard for reporting machine inputs such as printing parameters, laser track, etc. and machine capabilities such as dimensional accuracy, surface finish, material properties, geometry constraints (over hang angle requirements), size, porosity, etc. These reports would be used by software to accomplish the following:

1. Topology Optimization
2. Optimize manufacturing solutions
3. Identification of suitable AM equipment
4. Build Simulation
5. Lattice structure generation
6. Spatial comparisons (e.g., common standard grid)

See also Gap DE20 on neutral build file format.

Priority: ☐High; ☒Medium; ☐Low

Organization: 3MF, Consortium of industry, ISO/ASTM, IEEE-ISTO PWG, IPP

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒ Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary tools and process documentation as well as ISO/ASTM 52915:2020.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: See standards activities above.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/14/2025, NIST Comments: *ISO/CD 10303-238, Industrial automation systems and integration — Product data representation and exchange Part 238: Application protocol: Model based integrated manufacturing*, (AP238 E4), that addresses PBF has completed CD ballot and will go to DIS end of 2025. Currently testing with engagement from industry and government. **4/14/2025, D.Gibbons:** *ISO/FDIS 10303-242, Industrial automation systems and integration — Product data representation and exchange Part 242: Application protocol: Managed model-based 3D engineering* specifies the application protocol for Managed model based 3d engineering has ongoing work for model-based powder bed fusion product and process definitions and toolpath controls. **04/08/2024, B.Zollo:** ISO/ASTM CD TR 52918, *Additive manufacturing - Data formats - File format support, ecosystem and evolutions* draft progressing through TC261 review for balloting

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Gap DE9: AM Simulation Benchmark Model/Part Requirement.

Standards for process and simulation type-specific AM benchmark models, tests, and/or parts are needed to enable verification and validation (V&V) of applicable process simulation tools.

R&D Needed: ☒Yes; ☐No; ☐Maybe.

R&D Expectations: R&D is needed to identify proper testing and measurement procedures to evaluate the predictive accuracy of simulations, and determine to what extent a simulation 'validated' through controlled physical tests/measurements may be extensible to alternate part designs.

Quantitative (i.e., statistical) metrics need to be defined to appropriately assess model to measurement accuracy and uncertainty. R&D is also needed for development of many computational simulations themselves, with the scale/amount of R&D depending on the simulation type and complexity, and the need for standards rising with the availability of more complex simulation tools.

Recommendation: Develop a set of standardized physical tests (e.g., test artifacts and required controls) and associated measurements that 1) can be quantitatively related to simulation outputs and 2) target or align with the technical objectives of the simulations (e.g., distortion prediction). Develop guidelines and/or metrics for quantifying the accuracy of the models considering measurement uncertainty and model uncertainty, and extensibility to alternate part designs from the validation tests.

Priority: ☒High; ☐Medium; ☐ Low

Organization: NIST, America Makes, ASME V&V 50, ISO/ASTM, AFRL

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Stakeholders are generating data to validate models (i.e., NIST, AFRL).

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: The 2nd AM Bench test series led by NIST occurred in 2022, and measurement results database is being populated and organized. ASME VVUQ 50 is developing VVUQ methods for advanced manufacturing, including additive. NASA, NIST, and FAA held the Technical Interchange Meeting on Computational Materials Approaches for Qualification by Analysis for Aerospace Applications in 2020.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- **9/27/2024, P.Witherell:** A new AM Bench Test series will occur in 2025.
- **9/24/2024, J.Schmelzle Compiled:** A NAVAIR project is working with Ansys to evaluate test artifacts used for distortion calibration.

Other Committees with Relevant Work:

- **04/07/2024, D.Rosen:** ASTM F42.04 on Design is planning the development of a landscape survey of AM process simulation tools and technologies. The survey will identify process simulation needs during product development, describe simulation technologies and tools, and explain relationships between the simulation needs and current capabilities.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/14/2025, NIST Comments: A new modeling and simulation for AM standard effort has been initiated under ISO TC261/WG4/JG73. This effort is in its early stages and looking for contributors. **4/14/2025, NIST Comments:** *ASME VVUQ 50* poised to begin new effort on developing guidance for Verification, Validation and Uncertainty Quantification for AM Models and Simulations

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Gap DE27: Standardized Design for Additive Manufacturing (DFAM) Process Chain.

A standardized design methodology is needed for AM process chain integrating key AM considerations/design tools in each design stage. A standard to address all the stages of a process chain from where the design input would begin (including original or re-design designed part) is needed.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: TBD

Recommendation: Develop a standardized design for AM process chain that specifies and integrates the key AM considerations and suggested design tools in each generic design stage. The process chain can be expanded from *ISO/ASTM 52910-18, Additive manufacturing — Design — Requirements, guidelines and recommendations* stages and complimented with design tools to address specific AM needs for each task within the stages. The standardized design for AM process chain can be used by various industries to roll out site-specific DFAM process and digitalization implementation.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM F42/ISO TC 261 JG 73, NIST

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☒Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Design processes could be sector/agency specific. See standards activities above.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- **9/24/2024, J.Schmelzle Compiled**: There is a large investment in ICME tools and workflows across the DoD.

Other Committees with Relevant Work:

- **04/07/2024, D.Rosen:** ASTM F42.04 on design has done considerable work in this area and is considering the development of a guide on design for the AM process chain.

Comments Received on Gap for Future Consideration:

- **9/19/2024, B. Dutton:** (RE Gap scope) How about design for inspection (to improve inspectability)?

New Published Standards	New In-Development Standards

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Gap DE10: Design for As-built Assembly.

Guidelines do not exist for AM design for as-built assembly which is the ability of an AM process to create an assembly with multiple parts with relative motion capabilities in a single build. Design for Manufacture and Assembly (DFMA) practices do not account for considerations of single build AM assemblies and assemblies constructed from individual AM parts. Design approaches and additional design parameters (meta data) may need to account for complexity of support structures, removal times, post-processing complexity, inter-part tolerances, and manufacturing time/quality using different parameter sets. In regard to parameters sets, factors of interest could include feed rate and diameters for Directed Energy Deposition (DED), layer thickness and laser scan speed for PBF. Furthermore, how these all factors interact must also be considered.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Additional research is needed related to individual AM part definition, including tolerances, and non-contact measurement and inspection methods for AM assemblies. If AM design for as-built assembly is to become a viable alternative for creating functioning assemblies, there needs to be rigorous academic research, practical pilot projects, and real industry use cases. These are critical elements in identifying the gaps that will result in the tailoring of existing standards and the development of new standards for AM design for as-built assembly.

Recommendation: ISO 8887-1:2017, ISO/ASTM 52915:2020 and other DFMA standards can be reviewed and further developed to address AM related issues.

Priority: ☐High; ☐Medium; ☒Low

Organization: R&D: Academia, government, industry, national laboratories. Standards: DoD, ISO, ASME, ASTM, AAMI, NEMA/MITA

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Unknown, as-built assembly is not common because guidance does not currently exist.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ASME Y14.46 was revised in 2022 and ISO/ASTM 52915 was published in 2020 however the gap is still considered open.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)***:**

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/8/2025, B.Zollo: ISO/ASTM TC261 J64 is starting a project to develop application specific meta-data and schema for the purpose of publishing a series of technical reports to provide guidelines on implementing advanced AM applications, including multi-material, multi-component assemblies.

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Gap DE11: Design for 3D Printed Electronics.

There is a need to develop standards on design for 3D printed electronics, including flexible and rigid substrates.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Complete work on IPC-2292, develop standard for 3D based on IPC-2292 requirements

Priority: ☐High; ☒Medium; ☐Low

Organization: IPC

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☒Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: IPC 2292 was published in March 2018 and revised in November 2022 but does not address this gap. With respect to the development of a design standard like IPC-2292, the group is of

the view that it is far too early in the maturation of this technology to develop design requirements, but they will revisit this topic at future meetings. See also Gap DE4.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap DE12: Imaging Consistency.

There are currently no standard best practices for creation of protocols and validation procedures to ensure that medical imaging data can be consistently and accurately transformed into a 3D printed object. Individual companies have developed internal best practices, training programs and site qualification procedures. The details of a device's individual imaging and validation plan is developed specifically for each process or product. However, a set of consensus best practices for developing these plans and key validation metrics could reduce the overhead in developing them and reduce the burden on imaging sites. This framework should rely on input from clinical experts to ensure that it accounts for and defers to clinical best practices where appropriate.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A; The information is housed within individual institutions and could be combined through participation in clinical associations, consortiums or standards development organizations.

Recommendation: Develop a set of best practices for the development and qualification of imaging protocols and imaging sites that provide inputs to patient-matched devices. The focus should be on validation metrics and standard reference parts (phantoms) that can either be simple geometric patterns, or more appropriately designed to mimic the shape and density of natural anatomy so that the fidelity of an imaging sequence can be measured and calibrated. See also gaps QC7, QC9, QC14.

Priority: ☒High; ☐Medium; ☐Low

Organization: RSNA (Radiological Society of North America), ASTM F42/ISO TC 261 JG 70, ISO/IEC JTC 1/WG 12

Lifecycle Area: ☒Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: An RSNA 3D Special Interest Group (SIG) is working on best practices, not a standard. *ISO/ASTM TR 52916:2022 Additive manufacturing for medical — Data — Optimized medical image data* from ISO/TC 261 JG 70 deals with imaging quality. This is a secondary priority for the DICOM WG. ISO/IEC 3532-1 (approved) and ISO/IEC DIS 3532-2 (in development) are addressing critical issues about image quality and consistency.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **4/9/2025, BRipley RSNA:** Medical imaging consistency hinges on data acquisition protocols. These are managed by the provider responsible for patient care. Individual medical societies including the American College of Radiology provide guidance on image protocols (Ref: https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Practice-Parameters-and-Technical-Standards)

New Published Standards	New In-Development Standards

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Gap DE13: Image Processing and 2D to 3D Conversion.

Data acquired as a stack of 2D images is converted to a 3D model that could be a device by itself or be a template to build the device on. Tissues such as bone, soft tissue and vascular structures are isolated by the process of segmentation. Variability of the output depends on factors such as spatial and grey scale resolution of the images which in turn are driven by other factors such as the x-ray dosage, MRI protocol, operator capability, and reconstruction algorithms. Computational modeling groups, software developers, research laboratories, and the FDA have investigated methods of validating segmentation processes. However, the wide variety of patient geometries, frequent

inability to identify a ground truth due to imaging constraints, and variability in the manual aspects of imaging have caused validation procedures to be developed by individual entities.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Data to develop protocols exists but there is still a need for standardized, physiologically relevant imaging phantoms that can be used to challenge many segmentation techniques. Round robin testing for biomimetic imaging phantoms to validate segmentation techniques for a test method is highly recommended. See also Gap QC14 on Segmentation.

Recommendation: 1) Develop a standard test method to use biomimetic imaging phantoms to validate a segmentation technique. Round robin testing of this type of test method is highly recommended. Best practices may include capturing enough information to set accurate threshold values and understand geometric norms for a data set of interest. 2) Develop training standards that operators must meet to ensure that they are able to adequately reproduce a validated image processing pipeline.

Priority: ☐High; ☒Medium; ☐Low

Organization: Methods: NEMA/MITA, ASME V&V 40, ASTM F4, ASTM F42/ISO TC 261. Phantoms: NIH, NIST, FDA, RSNA, ISO/IEC JTC 1/WG 12

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: On the R&D side, FDA research groups are developing phantoms but haven't yet interfaced with SDOs. On the standards side, *ISO/ASTM TR 52916:2022, Additive manufacturing for medical — Data — Optimized medical image data* from ISO/TC 261 JG 70 covers this gap. ISO/IEC 3532-1 deals with 3D reconstruction and visualization and 2D to 3D conversion calibration and validation. An RSNA SIG is also looking at this.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

4/9/2025, B.Ripley RSNA: The large majority of medical images are volumetric; thus, when a surface mesh file is generated from .DCM data, the conversion does not change data dimensionality. Creating and utilizing imaging phantoms has not been widely incorporated in medical imaging processing and conversion, as the ability to overlay source and mesh data in digital space is sufficient for confirming that dimensional accuracy has been maintained. Imaging phantoms are routinely used for testing the accuracy of the .DCM imaging data with respect to the imaged anatomy.

New Published Standards	New In-Development Standards

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Gap DE17: Contents of a Data Package.

The contents of a data package that is sufficiently complete such that it could be provided to a vendor and result in components that are identical in physical and performance characteristics has not been defined.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: On how to best identify level of granularity and information identification to meet different application and process needs

Recommendation: Develop a standard(s) to describe all required portions of a data package and adopt them into a formal standard(s), regardless of manufacturing process (AM, subtractive, casting). The standard(s) should address issues such as the following (not a comprehensive list):

- Performance/functional requirements (form, fit assembly)
- Qualification requirements
- Definition of “as-designed” part, versus “as-printed” part, versus “finished” part
- Post-processing requirements (including finishing, removal of parts from AM machine such as separation from build plate)
- Applicable AM process as defined in ISO/ASTM 52900
- Tailorable and non-tailorable build parameters
- Cybersecurity requirements (if necessary)
- Long term archival and retrieval process (including acquisition)

Priority: ☒High; ☐Medium; ☐Low

Organization: ASME Y14.46, ASME Y14.47, ASTM F42/ISO TC 261, AWS, DoD (MIL-STD-31000), NIST, SAE G-33

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ASME Y14.46 has been published and it deals with data packages. MIL-ST31000C is in development and will address AM. The ISO/ASTM PWI 52951 is being developed.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)***:**

- **9/24/2024, C.Ashforth:** Anticipated FAA research may assist in this area. A round robin study is planned, requesting multiple venders to build components and test articles per a provided design that references industry specs.
- **9/25/2024, B.Zollo**: Chapter 3.4(c) on Data Management of *DoDI 5000.93, Use of Additive Manufacturing in the DoD* requires the use of a data package standard and format, as appropriate for AM, in accordance with MIL-ST-31000, ISO/ASTM 52915:20 and accepted non-U.S. Governmental standards.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Recommend including MIL-STD-31000 so TDPs procured by the government can include these data elements.

New Published Standards	New In-Development Standards
	9/27/2024, P.Witherell: Version C of MIL-ST31000 on Technical Data Packages is in development and will address AM primarily through references to ASME, ASTM, and ISO standards.

	9/27/2024, P.Witherell: *ISO/ASTM PWI CD 52951, Additive Manufacturing — Data — Data packages for AM parts* is in ballot and will likely be available in 2025. **9/25/2024, B.Zollo**: ISO/ASTM JG64 on File Formats for AM is implementing a new work project to create specifications for meta-data that will address the of technical data requirements listed in the recommendations to this gap. **9/24/2024, J.Schmelzle Compiled:** ASME Y14.46 Rev A is in development and will provide clarify to address many of the issues in this gap.

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New Gap DE30: STEP Based 3D PDF.

PDF is a common means for viewing 3D parts and annotations, but current capabilities are limited by the PRC file. AM geometry and specifications can be complex and are not well handled by PRC. There is a need for a specification for a pdf file based on a STEP file, which handles these additional complexities, as opposed to the PRC file in ISO spec.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Complete work on ISO/DTS 24064.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASME

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Uses current 3D pdf format with a STEP file attached.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: Is the solution limited to just STEP, or could QIF also provide the correct geometry recommendations?

New Published Standards	New In-Development Standards

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New Gap DE31: Feature-based Support for STEP.

There is a need for STEP – 242 to be updated to include feature-based information, which is parametric, to better preserve geometry when developed with AM-specific characteristics (generative design, lattice body).

R&D Needed: ☒~~☐~~Yes; ☐No; ☐~~☒~~Maybe

R&D Expectations: Consider how different software handle the development of AM-specific design strategies and what requirements are necessary for their neutral representation.

Recommendation: ISO revise STEP 242 to address requirements identified in this gap.

Priority: ☒High; ☐Medium; ☐Low

Organization: ISO / NIST

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒~~☐~~Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒~~☐~~Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Use existing STEP - 242

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- **9/27/2024, P.Witherell:** There is an ongoing effort led by NIST with involvement from government, industry, and academia towards this gap (changed to research is needed). AP 238 (STEP NC) Edition 4 will go to ballot in 2024 and will be the first step in addressing this gap.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: Is the solution limited to just STEP, or could QIF also provide the correct geometry recommendations?

New Published Standards	New In-Development Standards
	4/14/2025, D.Gibbons: *ISO/CD 10303-238, Industrial automation systems and integration — Product data representation and exchange Part 238: Application protocol: Model based integrated manufacturing*, (AP238 E4), that addresses PBF has completed CD ballot and will go to DIS end of 2025. Currently testing and validating the proposed model. AM specific feature types are defined and being incorporated parametrically.

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Gap DE18: New Dimensioning and Tolerancing Requirements.

ASME Y14.46 has been published and specifically deals with dimensioning and tolerancing requirements but additional work is needed on verification and validation.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Data to develop new methods and validation practices

Recommendation: Complete work on ASME Y14.46. See also Gap DE26 on Design for Measurement of AM Features/Verifying the Designs of Features such as Lattices, etc.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASME Y14.46, ASME Y14.48, NIST

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: This is a large tasking. It is recommended to address lattice structure first.

New Published Standards	New In-Development Standards
	4/14/2025, NIST Compiled: ASME Y14.46 Rev A is in development and will provide clarify to address lattice structures. Still under development with updated figures and clarified approaches. Availability by 2026. **4/8/2025, B.Zollo:** ISO/ASTM TC261 J64 is starting a project to develop application specific meta-data and schema for the purpose of

	publishing a series of technical reports to provide guidelines on implementing advanced AM applications, including the addition of tolerancing to an AMF format file. **4/8/2025, B.Zollo:** ISO/ASTM 52915:2020 includes reference to an optional tolerance metadata field. J64 plans to develop a schema for tolerance metadata.

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Gap DE20: Neutral Build File Format.

A standard is needed to provide explicit definitions of process specifications that can be directly interpreted and used by different machines for complete part fabrication. Many other parameters remain unsupported. Ideally, the same file could be used as the input into an AM machine regardless of the vendor of the machine and provide for a uniform output. Industry should work to coalesce around one industry standard for (technology specific) am process specification, which will help to better enable qualification of a design across various platforms. However, the unique technologies of the different vendors could make such an effort challenging.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Developing information models that expand current AP238 and 242 capabilities and extend them to AM. Testing these information models at NIST to drive a build.

Recommendation: Update standards content (such as within ISO/ASTM 52915:20; 3MF; or ISO 10303-238:2022) for the computer-interpretable representation and exchange of additive manufacturing product and process information that can represent all of the applicable slice files, build path, print orientation, layer height, precision, tolerances, and feedstock materials, as well as the other applicable parameters into a single neutral file. This file would be used to exchange data between AM vendors and have the capability to be used instead of proprietary file formats and material parameter sets. See also Gap DE8 on machine input and capability report.

Priority: ☐High; ☒Medium; ☐Low

Organization: ISO/TC 184/SC4, ISO/TC 261/ASTM F42, consortium of industry, IEEE-ISTO PWG

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☒Directed Energy Deposition; ☒Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary formats used by individual vendors. Neutral representations are limited to the original geometry files and the orientation and meta data supported in ISO/ASTM 52915:20 AMF format files, including but not limited to: unit of measure, name, author, company, revision, tolerance, producer, constellation(assembly), color(by file, object, component, facet), material,(by object, component, or gradient), elastic modulus, poisson ratio, unique ID, reference .url, orientation of multi-part assemblies; and general meta data fields for adding additional meta data in XML format.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: See standards list above. ISO/ASTM 52915:20 v1.2 was published in May 2020. It specifies the ISO/ASTM additive manufacturing file format that includes specifications for the majority of meta data listed in this gap and methods for incorporating additional information through optional meta data fields, support for inclusion of other files in XML format, as well as support for inclusion of additional files in other formats, and a reference URL for linking to additional files and information, such as a data package.

Since publishing v1.2, the ISO TC261 J64 technical working group on additive manufacturing formats has been working to draft a technical implementation guideline to aid users in utilizing the current specification to address new needs, including the ones listed in this gap, and to develop an expanded set of meta data schema in the next version of AMF to address this and other gaps in a manner that will be acceptable and useful to industry on a global basis.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- **9/27/2024, P.Witherell:** There is an ongoing effort led by NIST with involvement from government, industry, and academia towards this gap (changed to research is needed). AP 238 (STEP NC) Edition 4 will go to ballot in 2024 and will be the first step in addressing this gap.
- **9/25/2024, B.Zollo**: Chapter 3.4(c) on Data Management of *DoDI 5000.93, Use of Additive Manufacturing in the DoD* requires the use of a data package standard and format, as appropriate for AM, in accordance with MIL-ST-31000, ISO/ASTM 52915:20 and accepted non-U.S. Governmental standards.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

SWFNew Published Standards	New In-Development Standards

	4/14/2025, D.Gibbons: *ISO/CD 10303-238, Industrial automation systems and integration — Product data representation and exchange Part 238: Application protocol: Model based integrated manufacturing*, (AP238 E4), that addresses PBF has completed CD ballot and will go to DIS end of 2025. Currently testing and validating the proposed model. AM specific feature types are defined and being incorporated parametrically. **9/27/2024, P.Witherell:** STEP-NC AP238 4E will include support for PBF-LB process in at least the CLI equivalent. Continued work will look to move towards a variation of the Time Stepped Digital Command developed at NIST. **9/25/2024, B.Zollo**: ISO/ASTM JG64 on File Formats for AM is implementing a new work project to create specifications for meta-data that will address the of technical data requirements listed in the recommendations to this gap. New meta-data and schema will be considered for addition to the next version (1.3) of the ISO/ASTM 52915 standard, and the ISO TC261/ASTM JG64 meta data specification work project planned for 2024-2025. **04/08/2024, B.Zollo:** ISO TC261 J64 has begun outreach to industry stakeholders to identify meta data definitions and schema needed to augment current meta data specifications to fully address the needs defined in this gap. Any new meta data and schema will be considered for addition to the next version (1.3) of ISO/ASTM 52915 standard. **04/08/2024:** *ISO/ASTM CD TR 52918, Additive manufacturing - Data formats - File format support, ecosystem and evolutions*

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Gap DE23: Documentation of New Functional and Complex Surface Features.
There is a need for a specification on design documentation for intentionally introducing new bulk or surface geometries which can be created through AM.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: ASME Y14.46 should consider an annex describing a method to document functional and complex geometric features.

Priority: ☐High; ☐Medium; ☒Low

Organization: ASME

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: For documentation for design, unknown. ~~For inspection, micro-CT (measure vs model evaluation) or optical profilometry may be used.~~

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the recommendation. ASME Y14.46-2022 been published but does not address the recommendations at this time.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelze Compiled**: Is this specific to lattices or other types of geometries? Is this a documentation or inspection gap? It's probably both, that is not reflected in the gap description.

New Published Standards	New In-Development Standards
	04/08/2024, B.Zollo: ISO TC261 J64 has begun outreach to industry stakeholders to identify new

	metadata definitions and schema that will aid in addressing this gap to be considered for addition in the next version of ISO/ASTM 52915 (v1.3) additive manufacturing format.

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Gap DE28: Specification of Surface Finish.

There is a need for a specification on desired surface finishes of AM parts that can later be measured and validated against. Current surface finish metrics, such as Ra, do not adequately specify surface finish requirements. A surface metric which can be correlated with fatigue is needed.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Continued characterization of AM surfaces in order to confidently relate to the performance of the part.

Recommendation: ASME revise ASME B46.1 to address specification requirements of AM surface finishes. ASTM to complete its work on ASTM WK66682.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASME, ASTM

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: All machining of critical surfaces, and design point solutions as opposed to process-oriented solutions.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ASME B46.1-2019 was published which added a section to Appendix B of the standard regarding surface texture of AM parts. This is currently a generalized section with several references to ISO, ASTM, and ANSI standards or guides. In the future, the section will be expanded upon, possibly moving to a section within the standard, as opposed to being an appendix. *ASTM AM CoE Strategic*

Roadmap for Research & Development notes that AM CoE Projects 1802 (WK66682) and 1804/1907 (WK65937, WK65929) address AMSC Gap DE28.

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap DE26: Design for Measurement of AM Features/Verifying the Designs of Features such as Lattices, etc.

As noted in Gap DE18, working groups are currently developing methods to standardize the geometric dimensioning and tolerancing (GD&T) of AM parts. As these mature, existing V&V methods of checking part conformance to GD&T specifications must be investigated for their compatibility with AM. As part of the design process for AM, the availability of methods to measure and verify AM-unique features must be considered, especially to meet critical performance requirements. This may result in adapting existing NDE methods or creating new methods. This will likely be relevant when measuring AM features such as helixes or other complex shapes, or internal features that are not compatible with common methods such as Go/No-Go gauges or coordinate measuring machines (CMM). Especially in the case of internal features, assessing the ability of ultrasonic or radiographic methods to validate high tolerances will be required.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Investigation of high resolution radiographic and ultrasonic methods and the maximum achievable resolution and accuracy for GD&T of complex AM designs.

Recommendation: As GD&T standards continue to develop, perform parallel investigations of validation methods to ensure V&V is possible. See also Gap NDE4, Dimensional Metrology of Internal Features.

Priority: ☐High; ☒Medium; ☐Low

Organization: ISO/TC 261/ASTM F42, ASTM E07.01, ASTM E07.02, ASME B89, ASME Y14.46, ISO/TC 10

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Policy and regulations would address this. The medical sector is using FDA guidance and ASTM F1854 for design of lattices although not optimized for CT or AM related. Military leverages contractual agreements.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: A standard on methods to verify that complex AM parts meet design requirements is needed. ASME Y14.46 will address how to document AM-unique design features, but not how to inspect/verify the design. Y14.46 included a non-mandatory appendix with guidance on quality assurance (QA) parameters and references that may be used to develop design validation methods. ASME B89 (dimensional metrology) is working jointly with Y14.46. ISO/ASTM 52910-18 provides guidance for AM designers to "work with their quality groups to ascertain if appropriate inspection and qualification processes are available or need to be developed for the types of parts that they are designing."

STATUS OF GAP PROGRESS

Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*:

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: Recommend making this a high priority to ensure inspection methods are in line with current manufacturing capabilities.

New Published Standards	New In-Development Standards
	9/24/2024, J.Schmelzle Compiled: ASME Y14.46 Rev A is in development and will develop the non-mandatory appendix to address this gap.

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New Gap DE29: Best Practices for Design for Anti-counterfeiting.

Anti-counterfeiting design methods, such as discontinuities, watermarks and even voids, may be intentionally introduced in order to address the concern of counterfeiting, e.g., by inserting other materials or varying internal texture as a hidden signature. Alignment of anti-counterfeiting feature detection with broader quality testing captures the fact that a counterfeit AM part is a quality failure. Standards exist for detection, mitigation, etc., however design standards are needed for intentionally introducing discontinuities for AM parts.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: TBD

Recommendation: Develop best practices which address how to design in covert features, such as internal patterns, physical or chemical, and electronic tags, avoid those vulnerabilities which provide techniques for IP management. Develop standards which provide guidance on how to:

(1) Design anti-counterfeiting features so that their monitoring can be folded into existing test protocols. Counterfeits and quality failures both encompass potential deviations in materials, tolerances, and print parameters.

(2) Design with an eye toward coordinated testing, to reduce the economic burden of separate anti-counterfeiting measures and to enhance the likelihood of adoption of IP protection.

See also sections 2.2.2.13 Anti-counterfeiting (process control), 2.4 NDE Gaps NDE2 and NDE7) and 2.6.7.3 Technical and IP Authentication and Protection (Gap DA22)

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ISO/ASTM

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary efforts.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New
STATUS OF GAP PROGRESS
Updates Since v3 was Published *(Regulations, Research, Qual & Cert, etc.)*: • No updates as of publication of this report. **Other Committees with Relevant Work:** • No updates as of publication of this report. **Comments Received on Gap for Future Consideration:** • No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/8/2025, B.Zollo: ISO/ASTM TC261 J64 is starting a project to develop application specific meta-data and schema for the purpose of publishing a series of technical reports to provide guidelines on implementing advanced AM applications, including the addition of anti-counterfeiting metadata and schema to an AMF format file that could be used as part of an anti-counterfeiting method.

Section 2.1 Recommendations/Comments Since v3 was Published

Additional general recommendations related to the Section 2.1 Design scope, additional gaps, or other considerations since v3 was published are as follows:

- **9/24/2024, J.Schmelzle Compiled:** Suggest a new gap on "Design Guide for mechanically removeable support structures in LPBF"
- **9/24/2024, J.Schmelzle Compiled:** Suggest a new gap on "Standard for implementation of distortion compensated models into TDPs"
- **9/24/2024, J.Schmelzle Compiled:** Suggest a new gap on "Standard method for measuring air quality during polymer material extrusion processes (Health & Safety)"
    - **3/25/2025, F.Richard:** In 2024, two standards on this element were published:
        - ISO/ASTM 52933, Title: Additive manufacturing – Environmental, health and safety – The test method for the hazardous substances emitted from material extrusion type 3D printers in the non-industrial places
        - ISO27548: Title: Additive manufacturing – Environmental, health and safety – The test method for determination of particle and chemical emission rates from desktop material extrusion 3D printer
        - This is in addition to the already published standard UL2904.

Other Design Activity – Relevance to Gaps Not Yet Determined

New Published Standards

- No additional standards provided as of publication of this report.

New In-Development Standards

- No additional standards provided as of publication of this report.

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SECTION 2.2.1 PRECURSOR MATERIALS GAPS

Section #	Gap #, Title and Description	High	Medium	Low
2.2.1.3.2	Gap PM1: Flowability		X	
2.2.1.3.3	Gap PM2: Spreadability (Last updated 4/14/2025)		X	
2.2.1.3.6	Gap PM4: Particle Morphology (Last updated 4/14/2025)		X	
2.2.1.3.7	Gap PM5: Metal Powder Feedstock Sampling (Last updated 4/14/2025)		X	
2.2.1.3.8	Gap PM6: Hollow Particles and Hollow Particles with Entrapped Gas			X
2.2.1.3.9	Gap PM7: Metal Powder Specifications for Procurement Activities in Support of AM (Last updated 4/14/2025)		X	
2.2.1.3.1	Gap PM8: Use of Recycled Polymer Precursor Materials			X
2.2.1.5.3	Gap PM9: Characterization of Material Extrusion Feedstock (Filaments & Pellets)			X
2.2.1.6.3	Gap PM10: Sampling of Open Liquid Feedstock System			X
2.2.1.2	New Gap PM11: Segregation of Powder (Last updated 3/12/2025)		X	
2.2.1.2	New Gap PM12: Requirements for Large Storage and Transport Vessels of Powder Feedstock (Last updated 3/12/2025)		X	
2.2.1.2.1	Gap PM13 (was Gap PC9 in v2): Environmental Conditions: Effects on Materials			X
2.2.1.3.1	New Gap PM14: Test Method to Assess Hydrogen Content in Aluminum Powder Feedstocks		X	
2.2.1.3.1	New Gap PM15: Identification and Quantification of Impurities in Chemical Compositions			X
2.2.1.3.5	New Gap PM16: Universal Reference Standard on Size Distribution (Last updated 9/24/2024)			X
2.2.1.3.5	New Gap PM17: Error Quantification of PSD Measurement Methods (Last updated 9/24/2024)		X	
2.2.1.4	Gap PM18 (was Gap PC7 in v2): Recycle & Reuse of Materials (Last updated 4/14/2025)	X		
2.2.1.4.1	New Gap PM19: Terminology Related to Reuse of Feedstock Materials (Last updated 4/14/2025)	X		
2.2.1.4	New Gap PM20: Recycling the Polymeric Structures to Fabricate Filaments			X
Section 2.2.1 Recommendations/Comments Since v3 was Published (Last updated 3/25/2025)				

New Gap PM11: Segregation of Powder.

A standard practice is not yet established to homogenize powder that may segregate on size or other attributes throughout the lifecycle of handling or usage during an additive manufacturing workflow. This includes activities such as transportation, handling, storage, and consumption within batch and closed-loop AM equipment.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: Evaluation of the effectiveness of different blend methods

Recommendation: Recommended practices should be drafted to address potential scenarios where segregation may occur (e.g., during transport). Techniques and tools may differ based upon those scenarios. The recommended practices will work toward ensuring that the sampling and testing is representative of the bulk powder.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASTM F42, ASTM B09, MPIF, SAE, NFPA

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☒Polymer; ☒Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☒Binder Jetting; ☒Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap PM12: Requirements for Large Storage and Transport Vessels of Powder Feedstock.

Powder produced for additive manufacturing is commonly sold in small metal or plastic containers in weights able to be handled by operators. However, without complicated support equipment and workflows using gloveboxes, the usage of such containers requires the feedstock to be exposed to atmosphere upon introduction into an AM machine. Some users are beginning to request powder be loaded into larger, reusable, metal containers by a supplier, refillable upon exhaustion. These portable storage vessels act as transport, storage, and loading mechanisms into AM machines. Frequently these containers are purged and backfilled with inert atmosphere, sometimes with onboard environmental monitoring and control. No standardization for such vessels, their interfaces, or performance requirements currently exists. Language for this document must be cognizant of DOT requirements (e.g., positive pressure).

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Write a requirements document for large storage and transport vessels of powder feedstock. Ensure requirements are in alignment with new standard NFPA 660 Standard for Combustible Dusts and Particulate Solids.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM, SAE, NFPA 660

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☒Polymer; ☒Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☒Binder Jetting; ☒Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) ___

Current Alternative: None

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **3/12/2025, B.Edwards**: See track changes on gap recommendation and organizations.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PM13 (was Gap PC9 in v2): Environmental Conditions: Effects on Materials.

General guidance is needed to ensure the environmental conditions in which material is stored and used remain within acceptable ranges for all material types. Specific material packaging requirements are addressed in Section 2.2.1.2.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: See recommendation

Recommendation: Develop guidance on the storage of AM materials and their need for protective atmospheres so that AM materials are stored and used in environments with acceptable conditions. Research should be conducted to identify these ranges.

Priority: ☐High; ☐Medium; ☒Low

Organization: ASTM F42/ISO TC 261, NIST, SAE, UL, Powder Manufacturers/Suppliers

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap PM14: Test Method to Assess Hydrogen Content in Aluminum Powder Feedstocks.

Aluminum powder is commonly prone to the accumulation of both moisture and surface salts that affect produced parts via supersaturation of hydrogen upon consolidation via additive manufacturing. Supersaturation of hydrogen within consolidated material may result in material defects such as hydrogen pores at the time of fabrication or hydrogen pore formation with subsequent welding (or other high temperature processing). Measurement of hydrogen content is one method to assess the potential for such deleterious material behavior before usage of powder feedstock. Assessing the hydrogen concentration within and on the surface of aluminum powders requires both a test method and an available calibration standard specimen.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Feasibility of developing a commercially available test specimen for calibrating the test method. Also, determine if low concentrations are repeatably detectable. Establishing hydrogen thresholding also would be desirable.

Recommendation: Develop a test method to spur industry to generate calibration samples and/or specialized test equipment.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) ___

Current Alternative: None

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒ New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap PM15: Identification and Quantification of Impurities in Chemical Compositions.

There is a need to identify the level of impurities in material chemical compositions.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Develop a standard to identify, quantify and report the level of impurities in chemical composition of material specifications for critical and non-critical elements. For aluminum powder and aluminum powder alloys, note the Aluminum Association Purple Sheets registry that captures alloy composition as noted in the text, and ANSI H35.1 / H35.1(M)-2017.

Priority: ☐High; ☐Medium; ☒Low

Organization(s): ISO, ASTM, Aluminum Association

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PM8: Use of Recycled Polymer Precursor Materials.

Feedstock/precursor material can be sourced from either virgin polymer resin, recycled polymer resin, or a combination of the two. Recycled resin can be obtained from a number of different sources including in-house processed product of the same material which may not have met all the requirements when initially produced but is still functional, commercial recyclate from commercial sources, and post-consumer recyclate. Recycled feedstock, depending on its source and usage level, can introduce problems in the printing or end-use application due to the recyclate's thermal/mechanical history, consistency and composition.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: To determine the acceptable limits and other constraints of incorporating reprocessed materials. This may be machine, material, and/or application specific.

Recommendation: Develop a general guidance document to address best practices in regard to sources, handling, and characterization of recycled materials. In some cases, such as medical and aerospace applications, more stringent guidelines may need to be developed such as identification of recycled material use. Complete standards development in ASTM WK75265.

Priority: ☐High; ☐Medium; ☒Low

Organization: ASTM F42/D20, SAE AMS-AM

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☐Metal; ☒Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: The aerospace and medical sectors need to demonstrate compliance to requirements. Organizations use their own internal practices.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PM1: Flowability.

Existing standards for flowability do not account for the range of conditions that a powder may encounter during AM processes.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to collect data as a useful metric regarding flowability, especially with powder bed processing. Current test methods do not represent the flow behavior inside of an AM process, at best correlative but not representative. *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE Project 1803 (WK66030) addresses AMSC gap PM1.

Recommendation: Standards are needed to address test methods which encompass the variety of flow regimes encountered in AM processes. Recommend completion of *ASTM WK55610, New Test Methods for the Characterization of Powder Flow Properties for Additive Manufacturing Applications*, (not specific to metal powders) which addresses dynamic flow, aeration, permeability, consolidation and compressibility test procedures using, for example, a powder rheometer. See also Gap PC12 on precursor material flow monitoring.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM F42/ISO TC 261, NIST, ASTM B09, ASTM E29

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☒Polymer; ☒Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☒Binder Jetting; ☒Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: There are no known alternatives.

V3 Status of Progress: ☐Green; ☒Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text, ASTM WK55610 is in development. Completion of those work items may partially but not fully address the gap.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PM2: Spreadability.

There is no known description of spreadability or standard for how to quantitatively assess powder spreadability.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to (1) measure and quantify spreadability (direct measurement / scoring value) and (2) to correlate powder characteristics with spreadability (performance metric via a combination of measurements of intrinsic properties).

Recommendation: A standard should be created that guides the measurement of a powder's spreadability. This standard may be comprised of a series of tests that together describe a powder's spreading performance.

Priority: ☐High; ☒Medium (direct measurement); ☒Low (characterization aspects)

Organization: ASTM F42/ISO TC 261, NIST, universities, ASTM B09, ASTM E29

Lifecycle Area: ☐Design; ☒Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒ All/Material Agnostic; ☐ Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☒Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None known for powder spreadability specifically. A combination of flowability methods, moisture content, PSD, particle morphology could be loosely applied but is not a direct alternative.

V3 Status of Progress: ☒Green (metals); ☐Yellow; ☐Red; ☒Not Started (other materials); ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ASTM WK71393 is focused on the assessment of powder spreadability for metals. Polymer and ceramic standards and the 2nd part of the recommendation on the performance metrics have not begun.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **4/14/2025, NIST Compiled**: -22 defines approaches for assessing powder spreadability for AM. Also *ISO/ASTM TR 52952-2023, Additive manufacturing of metals — Feedstock materials — Correlating of rotating drum measurement with powder spreadability in PBF-LB machines* provides an example of the relation between the characterization of certain macroscopic properties of metallic powders and their spreadability in an PBF-LB/M AM machines.
- **9/24/2024, J.Schmelzle Compiled:** A different metric (like cohesion) may be needed, measured via FT4.

New Published Standards	New In-Development Standards

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New Gap PM16: Universal Reference Standard on Size Distribution.

No current product is recognized as a universal reference standard to establish comparisons on precision and accuracy of measurement methods and equipment when assessing particle size distribution. If no one single reference standard is available, a document to relate the results of using different standards for specific, respective tools should be drafted.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Validation of various measurement techniques for reliability, repeatability, and correlation is required when using a proposed reference standard. If none is determined suitable, then a working relationship between different standards and their corresponding measurement method should be generated.

Recommendation: See R&D Expectations

Priority: ☐High; ☐Medium; ☒Low

Organization(s): ASTM F42, ASTM B09, MPIF

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☒Polymer; ☒Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☒Binder Jetting; ☒Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Tradeoff between Static/Dynamic image analysis and XRD. Former is more rare, but gives quantitative shape measurements and can better detect fines. Latter is far more common, but assumes spherical particles and can't detect fines as easily.

New Published Standards	New In-Development Standards

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New Gap PM17: Error Quantification of PSD Measurement Methods.

Round robin and/or analytical examination and uncertainty quantification related to the sources of error for different measurement methods/techniques should be critically examined and documented in a guidance document or standard.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Establish effective repeatability and systematic error associated with measurement methods commonly used in industry. Understand reproducibility, i.e., the sources of error that are introduced by differences in operators, equipment, and techniques.

Recommendation: See R&D Expectations

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASTM F42, ASTM B09, MPIF

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☒Polymer; ☒Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☒Binder Jetting; ☒Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **9/24/2024, J.Schmelzle:** Data exists in the literature around particle size distribution measurement methods and uncertainty calcs.
  - https://doi.org/10.1016/j.cirp.2019.04.075
  - https://doi.org/10.1016/j.powtec.2023.119324

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PM4: Particle Morphology.

There is a need for AM-specific standards describing how to quantitatively assess particle morphology.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to measure and quantify particle morphology as well as determine impacts to process performance. *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE Project 1803 (WK66030) addresses AMSC gap PM4.

Recommendation: Based on the results of R&D, a terms, definitions and taxonomy (which can assist with categorizations and define appropriate/inappropriate uses) standard may be needed for powder morphology and criteria for determining acceptable powder morphology characteristics. Because powder morphology may affect powder flow, powder spreadability, and density of the AM built object, it could possibly be addressed indirectly by standards governing flow and spreadability requirements for a powder, taking into account the density of the powder. Upon completion of this, additional standardization work can be determined.

Priority: ☐High; ☒Medium; ☐Low

Organization: NIST, ASTM F42/ISO TC 261 JG 66, ASTM B09, ASTM E29

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☒Polymer; ☒Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted, ISO/ASTM 52907 has been published.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024 J.Schmelzle:** Traditionally done with optical microscopy or SEM. Dynamic Image Analysis and Rheometry can assist by providing powder shape and flow properties for comparison to optical assessment.

New Published Standards	New In-Development Standards
4/14/2025, D.Gibbons: *ASTM F1877-24, Standard Practice for Characterization of Particles* is applicable. This practice covers a series of recommendations, generally applicable to all medical devices, for characterization of the morphology, shape, size, and size distribution of particles. The methods utilized include sieves, optical, scanning electron microscopy (SEM),	

transmission electron microscopy (TEM), and electrooptical.	

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Gap PM5: Metal Powder Feedstock Sampling.

Existing powder metallurgy standards may be leveraged for AM use; however, they require tailoring for AM-specific situations, such as the following:

1) sampling practices for a reused powder that has been through an AM build cycle are needed to establish how to collect representative powder samples. These practices should take into account the variation caused by build exposure on powder in multiple locations.

2) sampling practices for preparation of small samples (e.g., 15 mg to 20 mg for scanning by electron microscopy) need to be established, including prescribing an acceptable percentage of powder lost during processing. For example, the powder particles can in some cases stick to the vials depending on the equipment used.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: With respect to the reuse of powder during the build. See also gap PM18.

Recommendation: Standards are needed for sampling of powders used for AM, with considerations for unique aspects of AM not considered in powder sampling standards for general powder metallurgy, including reuse of powder.

Priority: ☐High; ☒Medium; ☐Low

Organization: NIST, SAE AMS-AM, ASTM B09, MPIF, ASTM D20 (for polymers), ASTM F42, ASTM E29

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☒Polymer; ☒Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Internally developed best practices

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Recently published and/or updated standards and standards in development are noted above.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/14/2025, D.Gibbons: *SAE WIP ARP7302, Powder Sampling Strategies for Closed Loop Additive Manufacturing Equipment* describes methods to collect powder from an additive manufacturing (AM) powder bed process when executed by closed loop equipment. The methods recommended here are meant to provide opportunities to demonstrate conformance to powder specification requirements when required as part of process control for the associated AM activity.

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Gap PM6: Hollow Particles and Hollow Particles with Entrapped Gas.

No standards exist for measuring how to determine the presence and percentage of hollow particles and hollow particles with entrapped gas or their impact upon part properties and in-service performance.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to establish the impact of hollow powder particles, if any.

Recommendation: Dependent upon R&D, a standard may be needed that specifies how to determine the percentage of hollow particles and hollow particles with entrapped gas in lots of metal powders. Testing may be needed to determine the level of hollow particles and hollow particles with entrapped gas that are acceptable without negatively affecting the properties and performance of finished parts.

Priority: ☐High; ☐Medium; ☒Low

Organization: For R&D: NIST, ASTM, America Makes, Oak Ridge National Laboratory, universities. For standards: ASTM F42/ISO TC 261, SAE, ASTM B09, ASTM E29

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PM7: Metal Powder Specifications for Procurement Activities in Support of AM.

There is a need for more specifications to inform procurement decisions and establish requirements and acceptance criteria of metal powder for purposes of quality assurance.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to determine the effect of powder parameters/characteristics on final part properties and on the suitability of a given powder for use in a given AM machine. Some of these powder parameters may include:

1) Particle Size Distribution
2) Particle Morphology
3) Flow Rate
4) Tap Density
5) Angle of Repose
6) Shear Stress
7) Chemistry
8) Specific Surface Area

ASTM AM CoE Strategic Roadmap for Research & Development (April 2020) notes that AM CoE Project 1803 (WK66030) addresses AMSC gap PM7.

Recommendation: Develop specifications to facilitate procurement of metal powders for use in AM machines.

Priority: ☐High; ☒Medium; ☐Low

Organization: ISO/ASTM, SAE AMS-AM, AWS, industry OEMs, Defense Contract Management Agency, government procurement activities

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Recently published standards and projects started are noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration: • No comments as of publication of this report.	
New Published Standards	**New In-Development Standards** **4/14/2025, D.Gibbons:** *SAE WIP AS7040, Requirements for powder distributors* (3rd party) **4/14/2025, D.Gibbons:** *SAE WIP AIR7359, Additional Guidance for Metal Powder Feedstock for Additive Manufacturing* is a collection of comments on topics relevant to AMS powder feedstock production and procurement. In some instances it provides explanation of characteristics not controlled in AMS-AM powder feedstock specifications and the rationale for exclusion (e.g. limitation of applicability or maturity of standardized inspection techniques). In other cases, it provides additional context on the reason for structuring requirements in AMS documents one way instead of other available options.

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Gap PM18 (was Gap PC7 in v2): Recycle & Reuse of Materials.

There are many practices in the materials industry of how to recycle, reuse, and revert materials in production. They are also highly material dependent. Processes to prepare used powder for reuse can currently only be verified against precursor material specifications defined in their virgin state.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Research should be conducted on testing conditions, properties of concern, and feedstock usage history, to understand the effects of using reused material.

Recommendation: Develop guidance built upon published evidence from white papers as to whether and how reused material may be used when assessed for metrics such as number of build cycles, build cycle exposure time, or some other metric. Parts made from this reused material should factor in such aspects as part criticality, redundancy, environmental conditions, costs, etc. Considerations should be made as to whether the feedstock has been exposed to a build cycle of the AM process or exited the container it was delivered in at the virgin state.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM F42/ISO TC 261, ASTM D20, AWS, MPIF, NIST, SAE, trusted end user-group

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Published standards and standards in development are noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024 J.Schmelzle:** Consider making material specific gaps instead of one broader gap.

New Published Standards	New In-Development Standards
4/14/2025, D.Gibbons: ARP7044 Powder History Metric and Labeling Schema **4/14/2025, D.Gibbons:** *AMS7031, Batch Processing Requirements for the Reuse of Used Powder in Additive Manufacturing of Aerospace Parts*	

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New Gap PM20: Recycling the Polymeric Structures to Fabricate Filaments.

3D-printed polymers (e.g., thermoplastics) can be reused and recycled by an extruder to fabricate filaments. However, the material properties may be reduced. Standards are needed to determine which materials are recyclable, combinable, and the resultant properties thereof.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Determine which polymers are functionally combinable or independently recyclable, such that a feedstock is produced and subsequent parts or coupons can be assessed to determine the quality of the material.

Recommendation: Develop a standard to quantify or measure the degradation of material properties of recycled polymers

Priority: ☐High; ☐Medium; ☒Low

Organization(s): SDOs

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☐Metal; ☒Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☒Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap PM19: Terminology Related to Reuse of Feedstock Materials.

Define terms that today are in practice that may establish a common vocabulary for metallic, polymer, ceramic feedstock materials. A dictionary may include different definitions for the same terms based on the material class. Colloquially, terms such as “recycling” and “reuse” are used interchangeably but have different meanings.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Do a **s**ide-by-side comparison between existing published standards on how to interpret terms and definitions as they relate to their corresponding documents and why they are different.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ISO/ASTM, SAE, MPIF

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Individual documents where defined. For example, ISO/ASTM 52900, SAE AMS7031, SAE AMS7044

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
4/14/2025, D.Gibbons: *AMS7031, Batch Processing Requirements for the Reuse of Used Powder in Additive Manufacturing of Aerospace Parts*	

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Gap PM9: Characterization of Material Extrusion Feedstock (Filaments & Pellets).

There are many classification systems and test procedures that are available and applicable to characterizing the feedstocks used for filaments or pellets. However, these are based on "conventional" processes and requirements and, in many cases, will need to be adapted to AM requirements and, in some cases, new, more specific systems and procedures may be required.

Conventional rheometry is usually torsional while the behavior in AM systems is more accurately represented by capillary rheometry. While a few standards exist for this, their scope is often limited. ASTM D1238 for example only uses a 2.095 mm die while extrusion systems have a wide variety of orifice diameters. Research will need to be done to determine the effect of this difference, as well as other differences in the stress state like potential for back flow, and new standards should be developed accordingly.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: To define the specific requirements and evaluate if these can be addressed by existing systems and procedures and, if not, to develop new ones.

Recommendation: Since this will be very dependent on specific materials and process requirements, existing documents need to be evaluated on a case-by-case basis and, if necessary, new documents need to be developed. This is another aspect that needs to be considered by a possible ASTM F42 and D20 collaboration.

Priority: ☐High; ☐Medium; ☒Low

Organizations: ASTM F42/D20, SAE AMS-AM

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☐Metal; ☒Polymer; ☐Ceramic; ☒Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☒Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: N/A

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Standards published or new projects started since v2 are noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PM10: Sampling of Open Liquid Feedstock System.

There is a need to develop a standard for monitoring and sampling open liquid feedstock systems to ensure the consistent chemical composition and mechanical properties in the final AM part.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: R&D is needed to determine how much the viscosity can change before having a significant effect on the mechanical and chemical properties of the final AM part, how fast the change can happen and the frequency and method for sampling the open liquid feedstock system.

Recommendation: Develop a process-specific standard to indicate how often the liquid feedstock viscosity must be monitored throughout the feedstock's lifetime (both in storage and in an open system).

Priority: ☐High; ☐Medium; ☒Low

Organization: ISO/ASTM, Industry OEMs

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; Metal; ☒Polymer; ☐Ceramic; ☒Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

Section 2.2.1 Recommendations/Comments Since v3 was Published

Additional general recommendations related to the Section 2.2.1 Precursor Materials scope, additional gaps, or other considerations since v3 was published are as follows:

- **4/14/2025, NIST Compiled:** Nadcap AC7143 Manufacture of Metallic Powder for Use in AM processing and *SAE AMS 7002A (2022), Process Requirements for Production of Metal Powder Feedstock for Use in Additive Manufacturing of Aerospace Parts* should be reference somewhere for powder production.

Other Precursor Materials Activity – Relevance to Gaps Not Yet Determined

New Published Standards

- No additional standards provided as of publication of this report.

New In-Development Standards

- No additional standards provided as of publication of this report.

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SECTION 2.2.2 PROCESS CONTROL GAPS

Section #	Gap #, Title and Description	High	Medium	Low
2.2.2.2	Gap PC1: Digital Format and Digital System Control (Last updated 9/24/2024)		X	
2.2.2.3	Gap PC2: Machine Calibration and Preventative Maintenance (Last updated 9/24/2024)	X		
2.2.2.3	Gap PC3: Machine Health Monitoring (Last updated 9/24/2024)			X
2.2.2.4	Gap PC4: Machine Qualification and Re-Qualification (Last updated 4/14/2025)		X	
2.2.2.5	Gap PC5: Parameter Control (Last updated 9/24/2024)		X	
2.2.2.6	Gap PC6: Adverse Machine Environmental Conditions: Effect on Component Quality (Last updated 9/24/2024)			X
2.2.2.7	Gap PC8: Stratification		X	
2.2.2.9	Gap PC12: Precursor Material Flow Monitoring		X	
2.2.2.9	Gap PC13: Flow Parameters for Material Jetting			X
2.2.2.10	Gap PC14: Environmental Health and Safety: Protection of Machine Operators (Last updated 3/25/2025)	X		
2.2.2.11	Gap PC15: Configuration Management (Last updated 9/24/2024)		X	
2.2.2.12	Gap PC16: In-Process Monitoring (Last updated 4/14/2025)		X	
2.2.2.8	New Gap PC18: Powder Blending and Powder Mixing Terminology (Last updated 4/14/2025)		X	
Section 2.2.2 Recommendations/Comments Since v3 was Published				

Gap PC1: Digital Format and Digital System Control.

Existing process control standards do not adequately address digital format and digital system control.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: NIST is putting R&D into the ISO 10303 AP 238 E4 that aims to support (to an extent) process control for PBF AM processes.

Recommendation: Leverage ongoing NIST research and work with SDOs to ensure that AM process control standards include digital format and digital system control.

Priority: ☐High; ☒Medium; ☐Low

Organization: NIST, ISO/ASTM JG 56, ISO TC 184 SC4, SAE, IEEE-ISTO PWG, AWS

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle:** Leveraging various build preparation SW and OEM SW does present challenges with ensuring process controls are implemented and you are building what you intend to build. OEM SW is oftentimes impractical. STEP NC is looking to address neutral build files for LPBF but AM Machine SW could be better standardized as well in order to use and monitor build processes for important characteristics, KPVs, or essential elements.

New Published Standards	New In-Development Standards

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Gap PC2: Machine Calibration and Preventative Maintenance.

Standards are needed to explain how to address machine calibration and preventative maintenance for additive manufacturing in a way that does not inhibit innovation. A challenge is that there may be different process variables by machine and so machine OEM recommended practices are relied upon. Current users may not have established best practices or their own internal standards and often assume that the machine OEM maintenance procedures are sufficient to start/restart production. Additionally, AM machines have many mechanical components that are similar to conventional subtractive machinery. The motion control components are trusted to provide accurate positioning and it is currently unknown how errors in these systems affect the output quality. This is important during machine qualification and could be addressed in a standard. Lastly, there is a need to address Reliability-Centered Maintenance (RCM), Conditioned-Based Maintenance (CBM+), and possibly the Modular Open Systems Approach (MOSA) for DoD applications. Knowing the end user is just as critical

from both a successful maintenance task accomplishment and repeatability of quality products perspective.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Research is required to determine how errors in machine components affect output quality so that tolerances can be developed for machine calibration and preventative maintenance checks

Recommendation: Complete work on standards in development (e.g., ISO/ASTM 52945) addressing machine calibration and preventative maintenance. Machine OEM and end user best practices should ensure adequate and recommended calibration and maintenance intervals that have been documented with data from different materials and process control documents (PCDs). Machine OEMs and SDOs should develop technical reports that incorporate case studies related to machine restart after maintenance. In addition, define benefits/burdens and address standards needs for MOSA, RCM, and CBM+ approaches applied to AM which are specifically relevant to DoD applications.

Priority: ☒High; ☐Medium; ☐Low / There is an urgent need to develop guidelines on day-to-day machine calibration checks.

Organization: AWS D20, ASTM F42/ISO TC 261, SAE AMS-AM, NIST, OEMs, end users, experts in machine metrology

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle:** It's costly to perform Reactive Maintenance and Preventative Maintenance. For laser-based systems, standards should be developed to monitor and check KPVs/essential elements of characteristics greatly impacting build materials. NIAR has selected 5 characteristics at minimum for LPBF as part of PAQCS qualification methods, but users need a way to verify machine is operating correctly without needing to depend on OEM.

New Published Standards	New In-Development Standards

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Gap PC3: Machine Health Monitoring.

Standards are needed to address AM machine health monitoring. Machine health monitoring is a process of observing the machinery to identify changes that may indicate a fault. The use of a machine health monitoring system allows maintenance to be scheduled in a timely manner so as to prevent system failure.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE Project 1901 (WK71395) under F42.01 addresses AMSC gap PC3.

Recommendation: Adapt existing health monitoring (diagnostics and prognosis) standards for use in the additive manufacturing industry. Examples of such standards are the semiconductor industry "Interface A" collection of standards and *ISO 13379-1:2012, Condition monitoring and diagnostics of machines - Data interpretation and diagnostics techniques - Part 1: General guidelines* and *ISO 13381-1:2015, Condition monitoring and diagnostics of machines - Prognostics - Part 1: General guidelines*. Additional information can be found in *NISTIR 8012, Standards Related to Prognostics and Health Management (PHM) for Manufacturing*. Further research/guidelines/specifications may be needed. For example, NIST may be able to identify critical indicators that need to be documented or controlled to assist end users with quality assurance. See also Gap M6 on Tracking Maintenance.

Priority: ☐High; ☐Medium; ☒Low

Organization: NIST, ISO, ASTM, AWS, IEEE-ISTO PWG, ASME

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ASME has a non-AM-specific project concerning Advanced Monitoring, Diagnostics, and Prognostics for Manufacturing Operations which is being conducted by the ASME Prognostics and Health Management (PHM) Subcommittee. Current efforts are focused on the development of a guideline that manufacturers can use to identify opportunities and implement advanced monitoring, diagnostic, and prognostic technologies within their facilities. The guideline is being written in an agnostic manner such that it could be applied to operations involving subtractive machine tools, robotics, or additive processes. The draft guideline will cover: baseline metrics and identification of pain points, PHM readiness characterization, where to deploy and improve existing PHM deployments, and the determination of a PHM business case for manufacturing systems. The PHM guideline is targeted to be published in 2023.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: If properly implemented while truly capturing status degradation of KPVs/Essential Elements, then this could truly save AM users money and time by extending PM to when it is truly needed. This is very impactful, and low a priority. SDOs should consider laser/optics train health and how to monitor throughout a period of time.

New Published Standards	New In-Development Standards

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Gap PC4: Machine Qualification and Re-Qualification.

There have been advances in developing standards related to machine qualification (e.g., SAE AMS7032 and ISO/ASTM TS 52930), largely focused on powder bed fusion and metals. Additional standards may be needed to address machine qualification and re-qualification for different AM processes, materials, and applications.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: In relation to test artifacts, evaluating process monitoring against NDE. More developed machine performance characterization tests (e.g., through test artifacts that enable machine-to-machine comparison of performance, and day-to-day performance of the same machine).

Recommendation: Develop standards for machine qualification and re-qualification for different AM applications, processes, and materials (primarily polymers and ceramics) where they do not currently exist.

Priority: ☒~~☐~~High; ☐~~☒~~Medium; ☐Low

Organization: NIST, AWS, SAE AMS-AM, ASTM F42, NAVSEA, NASA, America Makes

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☒Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/29/2024, NIAR Compiled:** A similar document to AMS7032 is required for IQ and PQ.
- **9/24/2024, J.Schmelzle Compiled:** Consider reducing the burden of qualification. PAQCS (NIAR recommended approach) qualification is a potential option that has been discussed amongst the military services already. Also ties into CMB+ and Gaps PC2 and PC3.

New Published Standards	New In-Development Standards

4/14/2025, D.Gibbons: *SAE ARP7064, Machine Requalification Considerations for Fusion-Based Metal Additive Manufacturing* defines a recommended practice for addressing metal additive manufacturing (AM) machine requalification for all fusion-based metal AM machines. In general, this applies to powder bed fusion (PBF) and wire- or powder-fed directed energy deposition (DED) technologies. Plasma, electron beam, or lasers are applicable energy source(s).	**4/14/2025, D.Gibbons:** *SAE AMS7032, Machine Qualification for Fusion-Based Metal Additive Manufacturing* has Revision A under development **9/24/2024, C.Ashforth:** SAE AMS AM-P committee is working on an IQ/OQ/PQ document, which intends to be an add-on to the one written for metals. The FAA is also sponsoring research into performance-based qualification methods.

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Gap PC5: Parameter Control.

As a result of the many sources of variability within and among AM parts, and because a complete understanding of the specific effects of so many build process parameters on AM part performance is not currently available in the AM industry, standards are needed to identify requirements for demonstrating that a set of build process parameters produces an acceptable part, and for ensuring that those build process parameters remain consistent from build to build.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE Projects 1804/1907 (WK65937, WK65929) address AMSC gap PC5. Develop and establish a set of verifiable, accurate, and unambiguous process parameters for different materials and processes where this is not already available.

Recommendation: Develop a standard(s) that identifies what key build process parameters need to be controlled for AM, taking into account the different processes, materials, industry-specific applications, and machines involved. Parameter control may require detailed standards describing calibration or elements of the equipment such as gas flow, meter, position indicator accuracy, etc. Such a standard(s) would not necessarily describe how to control the parameters due to intellectual property considerations. Some documents already exist, e.g., AWS D20.1, that address process parameters for PBF and DED. It is important to develop standards addressing parameter controls for polymer AM (nylon powder bed fusion, material extrusion, binder jetting, vat photopolymerization). See also Gap QC3 on harmonizing Q&C terminology for process parameters.

Priority: ☐High; ☒Medium; ☐Low

Organization: AWS D20, ISO/TC 261-ASTM F42, SAE AMS-AM, IEEE-ISTO PWG

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **09/24/2024, J.Schmelzle Compiled**: If we cannot calibrate and qualify machines properly yet, this gap really cannot be addressed due to the level of effort and those being prerequisites. DED tends to need parameter control more than other process categories, so perhaps this could focus in on those processes and establish boundaries for different types of DED process parameter regimes. NAVAIR has completed various repair efforts using DED for a couple materials and has data on process parameter ranges that may work for those materials.

New Published Standards	New In-Development Standards

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Gap PC6: Adverse Machine Environmental Conditions: Effect on Component Quality.

There is a need for more research as well as standards or specifications that address AM machines being able to work in adverse environmental conditions. Point of Need Manufacturing (shipboard, expeditionary, etc.) or distributed manufacturing scenarios could have a large military impact.

R&D Needed: ☒Yes; ☐No; ☒Maybe

R&D Expectations: An investigation needs to be conducted to assess the effect and significance of all expected environmental conditions on AM processes. This would likely be limited to one technology but could include several different machines. Such investigation might need to be multivariate- in nature.

Recommendation: Develop standards and specifications to address external environmental factors that could negatively impact component quality.

Priority: ☐High; ☐Medium; ☒Low

Organization: OEMs, DoD for military-specific operational environments, ASTM

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None Specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Published standards and standards in development are noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PC8: Stratification.

There is currently a lack of guidance regarding stratification in virgin and reused metal powder scenarios.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Research should be conducted to understand the effect of stratification on particle size distribution and other metal powder attributes of as-received powder and mixed/blended powder prior to being put into service.

Recommendation: Develop guidelines on how to maintain traceability of metal powder feedstocks or create new lots of powder feedstock across stratification boundaries or gradients throughout the build cycle(s) impacted.

Priority: ☐High; ☒Medium; ☐Low

Organization: ISO/ASTM, SAE

Lifecycle Area: ☐Design; ☒Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☒Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Published and in-development standards are noted in the text

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap PC18: Powder Blending and Powder Mixing Terminology.

Differences exist in definitions of powder blending/mixing in industry standards such as ISO/ASTM 52900:2021 and SAE AMS7031:2022.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Develop a technical report (TR) to clarify for the industry the terminology differences in industry standards on powder blending and powder mixing.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ISO/ASTM, SAE

Lifecycle Area: ☐Design; ☒Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

4/14/2025, D.Gibbons: *AMS7031, Batch Processing Requirements for the Reuse of Used Powder in Additive Manufacturing of Aerospace Parts*	

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Gap PC12: Precursor Material Flow Monitoring.

There is no known standard for defining:

- Method of DED process powder flow monitoring
- Location of monitoring
- Accuracy of flow monitoring
- Standardized calibration process of flow

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Develop a standard for DED process powder flow monitoring so that operators/users will have a way to ensure the powder flow is coming out consistently and with minimal fluctuations so as to not alter the desired build and its properties. See also Gap PM1 on flowability.

Priority: ☐High; ☒Medium; ☐Low

Organization: NIST, ISO/ASTM

Lifecycle Area: ☐Design; ☒Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☒Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None Specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PC13: Flow Parameters for Material Jetting.

No published standards or standards in development have been identified for monitoring and control of all flow related parameters for material jetting.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Develop a standard for monitoring and controlling all flow parameters for material jetting such as flow rate, temperature, viscosity, pressure level, wetting of the orifice plate, etc. This standard should include:

- Monitoring and controlling similar flow in different material feeding channels. This is needed to allow multi-material printing while minimizing cross talk or non-uniformity between channels keeping quality of all printed materials.
- Controlling the thickness of the printed layer. In material jetting, the material flows to the surface and controlling the thickness of each layer is clearly critical to maintain quality. The layer thickness can be controlled by controlling the material flow within the system and within the printing heads as well as by direct measurement after deposition.
- Expanding the performance envelope to enable more degrees of freedom for the flow of material. For example, to enable a wider range of temperatures, humidity control, oxygen level control, ink recirculation in the print heads, etc. All this can allow using more viscous materials, with larger filler particles and exotic materials that might not be compatible with the print head materials in a standard environment.

Priority: ☐High; ☐Medium; ☒Low

Organization: NIST, OEMs, ASTM, IEEE-ISTO PWG

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☒Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap PC14: Environmental Health and Safety: Protection of Machine Operators.

There is a need for standards to address environmental health and safety (EHS) in the AM process.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Develop standards addressing EHS issues relative to additive manufacturing machines and processes.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM F42/ISO TC 261, UL, ASSP, B11, LIA (Z136), ISO/TC 262

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☒~~☐~~Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒~~☐~~Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: General industry standards

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **3/25/2025, F.Richard:** In 2024-2025, some industrial and academic AM installations have been successfully audited for their EH&S compliance by using both ISO/ASTM 52931 and UL 3400. This practice could be spread to additional AM users, mostly for metallic applications.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Engineering controls have been in place for years to protect machine operators and mitigate risk effectively from EHS concerns. A gap with respect to fire protection for water-reactive materials still exists as well as a need for R&D.

New Published Standards	New In-Development Standards
3/25/2025, F.Richard: *ISO 27548: 2024, Additive manufacturing – Environmental, health and safety – The test method for determination of particle and chemical emission rates from desktop material extrusion 3D printer* specifies test methods to determine particle emissions (including ultrafine particles) and specified volatile organic compounds (including aldehydes) from desktop MEX-TRB/P processes often used in non-industrial environments such as school, homes and office spaces in an emission test chamber under specified test conditions. **3/25/2025, F.Richard:** *ISO/ASTM 52933:2024, Additive manufacturing – Environmental, health*	**3/25/2025, F.Richard:** *ASTM WK93787, Practice for Additive manufacturing of polymers -- Environment, health and safety -- General principles for use of polymers with material extrusion* (see also ISO/ASTM PWI 52961) which will provide guidance and requirements for risk assessment and implementation of prevention and protection measures relating to material extrusion-based additive manufacturing with polymer materials. The risks covered by this document concern all sub-processes composing the manufacturing process, including the management of waste.

and safety – The test method for the hazardous substances emitted from material extrusion type 3D printers in the non-industrial places specifies a test method for measuring hazardous substances emitted during the operation of material extrusion type AM machines commonly used in the non-industrial places and includes non-normative suggestions for ways to reduce them. **04/05/2024, F.Richard:** *ISO/ASTM 52931:2023, Additive manufacturing of metals — Environment, health and safety — General principles for use of metallic materials* was published, which add to UL3400 as standards providing guidance for safe installation and operation of AM equipment in industrial applications using powders.	**3/25/2025, F.Richard:** *ISO/ASTM PWI 52938-1 Additive manufacturing— Part 1: Safety requirements for PBF-LB machine using metallic feedstock* a standard on defining the harmonization of AM equipment's EH&S characteristics to the European Union Type-C norm is coming close to publication.

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Gap PC15: Configuration Management.

Best practices for maintaining and controlling the programming environment for additive processes are needed to ensure repeatable product quality.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Develop best practices to protect digital files and equipment used in the AM process.

Priority: ☐High; ☒Medium; ☐Low

Organization: ISO/ASTM JG73, America Makes, NIST, UL, IEEE-ISTO PWG, DoD

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: There are a number of published and in-development standards as noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Different process categories have different status with respect to this gap. LPBF tends to be well controlled, with updates being deployed only periodically with advanced notice available. DED programming methods are vastly immature and therefore controlling via CM can be challenging. CM of build files and process parameters could/should include a PLM to protect and lock down files and SW.

New Published Standards	New In-Development Standards

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Gap PC16: In-Process Monitoring.

Few published standards directly address in-process monitoring technologies. More than likely, there will be no "one size fits all" standard for any given additive process, piece of equipment, or material. It would be highly dependent on end user analytics of OEM or internally developed sensing systems.

In-process monitoring instrument design, particularly those that have been commercialized, are relatively high TRL, whereas the processing and analysis of the measurement data results (e.g., identifying flaws) are lower TRL. As such, standards focused on the instrument calibration for repeatability or relating to absolute values such as temperature, or characterization of sensitivity, range, resolution, etc., may likely be developed earlier than those that instruct users on how to process and analyze the measurement data. Additionally, AM in-process monitoring largely utilizes existing instruments (e.g., thermal imagers, machine vision, pyrometry, etc.) which may refer to associated standards developed outside the scope of AM applications (e.g., thermographic standards from ISO/TC 135/SC 8, ASTM E20.02, ASTM E07.10, or BSI Group GEL/65/2, or machine vision standards from ISO/TC 42 on Photography, European Machine Vision Association (EMVA), Association for Advancing Automation (A3)).

Some concepts regarding in-process data preprocessing or organization are known to be critical and can be potentially standardized sooner than guidelines or methods on data analysis. These include

alignment or registration of in-process data (e.g., WK74390 and WK73978), and necessary metadata or schema for transferring or archiving in-process data (e.g., F3490-21).

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: For AM machine condition monitoring, issue standards on in-process monitoring. Aspects to explore include but are not limited to the following examples (not a comprehensive list): the feedstock (supply ratios and other metrics), process conditions (atmosphere, humidity), and performance of systems to achieve accurate process parameters (beam diagnostics such as location, laser power, scan width, scan rate).

For part quality monitoring, issue standards on alignment and registration of in-process measured data with other data (design geometry, post-fabrication NDE, or other in-process data), methods for calibration or characterization of in-process monitoring instruments, methods for evaluating performance or sensitivity of in-process monitoring systems, guidelines for identifying or labelling certain flaws or anomalies within specific in-process monitoring technologies. Issue guidelines or methods on how to determine critical flaw size, magnitude, or concentration thresholds, or statistical process variables and control limits. See also Gap DE9 on the use of physics-based models and simulation tools (analytics).

Priority: ☒~~☐~~High; ☐~~☒~~Medium; ☐Low, given the relatively TRL state of the art

Organization: ASTM E07.10, F42

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** While TRL currently is low, this has a large potential impact if well defined. Need to determine optimal sensor suite for all process categories to make informed NDE/NDI related decisions for part/material quality. NAVAIR has worked on LPBF and DED In-situ Monitoring systems, but more work is needed. UARCs have also been leveraged to help aid in the advancement of this topic. Suggest making this a high priority.

New Published Standards	New In-Development Standards
	4/14/2025, D.Gibbons: *SAE WIP ARP7068, In-Situ Process Monitoring Considerations for Metal Fusion Additive Manufacturing* defines a recommended practice for addressing metal additive manufacturing (AM) In-Situ Process Monitoring (ISPM) for all fusion-based metal AM machines. In general, this applies to powder bed fusion (PBF) and wire- or powder-fed directed energy deposition (DED) technologies. Plasma, electron beam or lasers are applicable energy source(s). **4/14/2025, D.Gibbons:** *SAE WIP ARP7065, Taxonomy and Definitions for Terms Related to In Situ Process Monitoring Modality-Capability Index* describes in situ process monitoring systems of additive manufacturing equipment that assess performance or capability to maintain a stable additive manufacturing process and potentially perform part or all of feed forward control (FFC) for continued operations on an intermittent or sustained basis. It provides a taxonomy with detailed definitions for seven levels of in situ process monitoring systems, ranging from machine input monitoring (Level 0) to in-process flaw detection with correction of such flaw using full process automation (Level 5), in the context of AM machine equipment and their operation in a manufacturing environment.

Section 2.2.2 Recommendations/Comments Since v3 was Published

Additional general recommendations related to the Section 2.2.2 Process Control scope, additional gaps, or other considerations since v3 was published are as follows:

- No recommendations received relation of publication of this report.

Other Process Control Activity – Relevance to Gaps Not Yet Determined

New Published Standards

- No additional standards provided as of publication of this report.

New In-Development Standards

- No additional standards provided as of publication of this report.

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SECTION 2.2.3 POST-PROCESSING GAPS

Section #	Gap #, Title and Description	High	Medium	Low
2.2.3.1	Gap P1: Post-processing Qualification, Validation, and Production Builds (Last updated 9/24/2024)		X	
2.2.3.2	Gap P2: Heat Treatment (HT)-Metals (Last updated 9/24/2024)		X	
2.2.3.3	Gap P3: Hot Isostatic Pressing (HIP) (Last updated 9/24/2024)		X	
2.2.3.4	Gap P4: Surface Texture (Surface Finish) (Last updated 3/12/2025)		X	
2.2.3.6	Gap P5: Use of Post-cure to Reduce Toxic Gases from Uncured Polymer Feedstock			X
2.2.3.6	Gap P6: Guidelines for Post-curing AM Plastics to Address Outgassing and Offgassing			X
2.2.3.2	Gap P7: Heat Treatment (HT)-Polymers			X
2.2.3.7	New Gap P8: EHS Hazards Related to Post-Processing Tasks (Last updated 9/24/2024)	X		
	Section 2.2.3 Recommendations/Comments Since v3 was Published			

Gap P1: Post-processing Qualification, Validation, and Production Builds.

Standards are needed that require post-processing to be applied consistently for qualification, validation, and production builds of AM parts. While a number of standards have been published or are in development that address this issue especially for metals, additional standards work may be needed for other materials and AM processes, to address required part performance.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Develop scientific basis for best practices

Recommendation: New standards and revisions to existing standards should require post-processing for the various materials and AM processes to be applied consistently for qualification, validation, and production builds of AM parts. These standards should be process and material specific and should seek to define minimum best practices for qualification, validation and production builds, along with reporting requirements.

Priority: ☐High; ☒Medium; ☐Low

Organization: AWS D20, ASTM F42/ISO TC 261 JG 55, SAE, ASME

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Each company is setting their own controls with varying degrees of consistency.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: For metals, AWS D20.1 and SAE AMS7000A and AMS7004 have been published and SAE has a number of standards in development. ASME code case 3020 uses the same post weld processing for qualification of additive build procedures (heat treatment, peening, etc.) rules as are used for welds. For polymers, ASTM F42/ISO TC 261 JG 55 is in development for material extrusion but appears to be in Standby according to the ISO/TC 261 website.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Post processing such as HT and surface finishing techniques are likely the main processes requiring R&D at this time and even HT is similar to other materials. This may not be a huge gap because AM materials are like other traditional materials.

New Published Standards	New In-Development Standards

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Gap P2: Heat Treatment (HT)-Metals.

Many of the existing and in-development standards for HT of metals built using PBF state the requirements for a specific metal within the standard, but not all metals have been addressed, and stress relief heat treatments in these standards may not be optimized for AM. In addition, differences between laser-based and electron beam-based PBF processes are insufficiently addressed in the existing standards. Both processes are considered to be the same regarding HT requirements, when in reality PBF-EB is performed at much higher temperature and produces a more uniform microstructure so it may require less or no residual stress relief.

Heat treatment requirements for metals made with non-powder processes such as directed energy deposition (DED) using wire feedstock, sheet lamination, etc., are currently not addressed in any standards except for titanium-6Al-4V via DED (SAE AMS7004).

HT standards for parts produced using binder jetting are also needed. There are multiple steps to go from the printed part to the sintered part and additional heat treatment cycles. Starting microstructures may be different than for an L-PBF part and may require additional research. The starting microstructure and ending microstructure need to be understood. That will depend on the technology used to print the part.

In cases where AM material requires HIP processing, the process may be modified to meet HT requirements as well, negating the need for additional HT standards.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to determine the optimized heat treatments for AM materials as a function of materials and process.

Recommendation: As the need arises for new metals, new standards will have to be written for each one, containing specific HT information. Also, as differences are found in required HT for laser versus electron beam processes, these differences should be added to the existing standard for that metal. Standards for metals made with non-powder (e.g., wire, sheets) or non-melting (e.g., ultrasonic, cold spray, friction stir) processes need to be developed that contain HT requirements specific to that metal and optimized for the appropriate production process. As heat treatments are found to reduce anisotropy in properties for particular metals, these should be added to the existing standards for those metals.

Priority: ☐High; ☒Medium; ☐Low

Organization: R&D: universities, OEMs, government research labs, and others. Standards development: ASTM F42, SAE AMS-AM, MPIF.

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☒Binder Jetting; ☒Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: A number of standards have been published and or are being developed since the publication of AMSC roadmap v2.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Cost effective HT strategies are required for many materials and many process categories still. Getting material data on all possible material and HT conditions could be studied to better inform part design. See also comment on gap P1.

New Published Standards	New In-Development Standards

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Gap P7: Heat Treatment (HT)-Polymers.

Heat treatment is an effective method to modify the properties of AM built polymer parts. Presence of fillers, as in the case of composites, can alter the nucleation rate causing significant increase in tensile strength and hardness of the finished part. It also becomes essential to consider the variation of morphology of the polymer parts and layers because of the difference in the cooling rate from the surface to the center. The outer surface could end up less crystalline due to a rapid solidification rate and result in less resistance to wear. The contraction of volume due to crystallization in the bulk could increase the residual stresses at the interface. Standards are needed on specific heat treatments (heating and cooling rates, anneal conditions) which could guide the AM practitioners to arrive at an optimum anisotropic structure and properties for the polymer parts.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to determine the conditions for optimized heat treatments of AM built parts as a function of materials (semi-crystalline polymers, composites, etc.) and AM post process parameters.

Recommendation: As AM expands to include new and high performance semi-crystalline polymers, polymer nanocomposites and thermosets, advanced machine design and processing, the standards for the measurement of mechanical properties will have to describe specific HT information on the test samples. These HT requirements (slow cooled vs. quenched vs. gradient cooled) will be specific to the polymer and the production process. A guideline on HT treatment procedures followed by sampling for testing would enable achieving optimum polymer microstructure and properties.

Priority: ☐High; ☐Medium; ☒Low

Organization: R&D: NIST, universities, OEMs, government research labs, and others. Standards development: ASTM F42, SAE AMS-AM.

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☐Metal; ☒Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap P3: Hot Isostatic Pressing (HIP).

Just as for heat treatment and Gap P2, the existing HIP standards do not fully address AM material-related issues such as: slow cooling rate and its effect on formation of prior particle boundaries and carbide precipitation at grain boundaries, as well as the effect of thermal exposure on excessive grain growth, carbide size, incipient melting, and the effect of removing the part from the base plate before HIP (in the case of PBF). The HIP parameters in the existing AM standards are often developed for castings, forgings and sintered parts and may not be optimal for AM material since the thermal history, as-printed microstructure and property requirements often is a lot different from materials processed with the conventional manufacturing methods. Generally, the existing standards provide guidance for interpretation of processing parameters, tolerances, and conformance to industry accepted practices such as pyrometry, cleanliness, traceability, etc.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Develop material specific standards based on R&D defined HIP parameters for AM with acceptance criteria for internal discontinuities. Some examples are listed below. It is recognized that this will be difficult to achieve as each material will have parameters that are applicable and those could change as a result of application requirements that are related not just to pores but also to microstructure. It should be possible to develop a standard that defines acceptable end results defined by some of the attributes listed here.

- Effect of max thermal exposure on microstructure evolution (X temperature for more than X hours)
- Effect of cooling rate
- Discontinuities extended to the surface
- Incipient melting with and without voids
- Discontinuities larger than X inches depending on location
- Lack of fusion
- Interconnected porosity
- Nonmetallic contamination
- Cross contamination due to processing of different customer parts in commercial HIP vessels
- Grain morphology
- Material dependent microstructure (e.g., in 718 laves phase, delta phase morphology, etc.)
- Number of discontinuities larger than X in per certain view area (e.g., within 1 sq. inch)
- Number of discontinuities in subsurface area (X microns from the surface) larger than X inch
- Linear formation of discontinuities (other than interconnected porosity) and minimum distance of X inches between adjacent discontinuities

Priority: ☐High; ☒Medium; ☐Low

Organization: R&D: various entities. Standards: ASTM F42, SAE AMS-AM, possibly SAE AMEC

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☒Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Some R&D is taking place in the commercial sector and at the university level. In terms of standards development, the referenced ASTM F42 work items may address the gap. SAE AMS7000A was published in 2022 and SAE AMS AMEC is working on a HIP spec, as noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** USAF Pacer Edge and Army AMPED programs are implementing HIP for various materials and are generating a lot of material data. Cost effective HT strategies are required for many materials and many process categories still. Getting material data on all possible material and HT conditions could be studied to better inform part design.

New Published Standards	New In-Development Standards

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Gap P4: Surface Texture (Surface Finish).

Unique features, such as helixes, spirals, lattice structures, and internal surfaces and cavities, can be manufactured using AM versus subtractive machining. However, the applicability of current measurement methods to the surface of these features is not clear or captured in standards. For example, features such as helixes or lattices may produce wire-like structures that are not as easily measured using stylus instruments as flat surfaces.

Also, the suitability of current specification methods must be investigated for AM.

- *ASME Y14.36-2018, Surface Texture Symbols* may be sufficient, but further investigation is required to determine if AM-specific symbols are necessary (e.g., to control stair-stepping or allowable surface porosity).
- Furthermore, although there are methods available for finishing AM materials, many lack standard practices. Some methods require material removal, such as chemical polishing or abrasive techniques, and it is not known at this time how to accommodate this in AM product specifications in a standard form. Other methods require the addition of material, such as electroplating and coatings but it is also unknown how to accommodate these into AM standards.
- Lastly, as the effects of surface finish on performance become more apparent, material specification recommendations must go beyond “supplier and purchaser agreement,” specifically for as-built, non-machined surfaces.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE Project 1802 (WK66682) addresses AMSC gap P4.

- Standards for reliable NDT, such as XCT, for evaluation of internal passages
- Guidance for validation of surface finish on complex features (such as wires or non-planar surfaces). This is a big gap. How is the surface finish or residual stress determined on a surface that is not accessible?
- Investigation of mechanical techniques such as shot peening or media blasting and their effect on fatigue life for AM materials. There is some work already performed in this area. As expected, compressive stresses are beneficial with respect to fatigue life/limits and corrosion resistance. This is a subject that is being addressed in the AMPP TR21522 report with respect to corrosion fatigue.

Recommendation: Verify if there are certain measurement methods more appropriate to AM-unique features than a stylus approach such as optical 3D scanning. If so, they should be reviewed for their use on AM materials and appropriate standards written.

- The applicability of existing surface texture symbols to AM materials should be investigated.
- Available finishing methods should be reviewed for their effects on final material properties, and improved with standardized practices or guidelines where none exist.
- An AM standard is needed to improve the surface roughness of very complex internal passages like heat exchanger cores but also for uniform material removal of the internal passages to remove partially melted particles and surface asperities.

Priority: ☐High; ☒Medium; ☐Low

Organization: ISO/ASTM, AMPP, ASME (B46 project team 53 on surface finish), IEEE-ISTO PWG, NIST

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☒Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green for R&D (metals); ☐Yellow; ☐Red; ☒Not Started; ☒Unknown for Standards (metals and polymers); ☐Withdrawn; ☐Closed; ☐New.

V3 Update: The ASME B46 committee, through their project team on Surface Finish for AM (PT53), continues to assess the latest research, knowledge gaps, and industry needs as they evolve with the rapidly growing AM technologies. The latest edition of the ASME B46.1 standard, which was approved by ANSI in 2019, contains subsection B-5 "Surface Texture of Parts Fabricated by Additive Manufacturing" as part of Nonmandatory Appendix B focusing on control and production of surface texture. Current priorities for PT53 are clarifying terminology in the B46.1 standard to create a better measurement and data handling procedures when working with AM surfaces, educating the research community on the methods described, and increasing the range of measurement instruments described (e.g., x-ray computed tomography (XCT)).

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- **03/19/2024, L.Feix:** Based upon R&D Expectations bullet that addresses AMPP TR21522, would suggest including AMPP in the Organization list for Gap P4.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: Most AM parts are not fatigue sensitive and therefore surface finishing is not needed. Use cases are limited, therefore priority is perhaps med-low.

New Published Standards	New In-Development Standards
03/12/2025, R.Bradak: AMPP Technical paper *TR21522, Corrosion Testing of Additive Manufactured Materials* was published in November 2024.	

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Gap P5: Use of Post-cure to Reduce Toxic Gases from Uncured Polymer Feedstock.

An evaluation of the toxic gases resulting from uncured reagents in liquid resins used during processes such as Vat Photopolymerization (e.g., SLA) would be warranted to ensure product and environmental safety during and after production.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Augment existing standards with AM-specific recommendations for processes that utilize liquid resins. Evolved gas analysis, an analytical method by which the amount and characteristics of the volatile products released by an AM-built part under controlled temperature variation, is recommended for finished product safety and toxicity. To analyze evolved gas

quantitatively, parameters such as sample chamber volume, thermal/vacuum conditions for releasing/analyzing the volatiles and the techniques for the analysis need to be specified.

Priority: ☐High; ☐Medium; ☒Low

Organization: ASTM D20, ISO/TC 261/ASTM F42

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☐Metal; ☒Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☒Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Standards that have been published or reapproved since the release of version 2 are noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap P6: Guidelines for Post-curing AM Plastics to Address Outgassing and Offgassing.

Guidelines for evaluating the degree of polymerization and outgassing in AM parts, its effect on part properties, and the effects of post-polymerization treatments on them, have not been established

specifically for AM materials. The voids and entrapments that can form in these technologies likely warrant greater testing or modified procedures compared to traditional methods.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Standard procedures for measuring the degree of polymerization and outgassing (thermal vacuum stability) and performance data for some materials may be archived in NASA's Materials and Processes Technical Information System (MAPTIS). In space systems, materials typically undergo outgassing testing for use in external environments and offgassing testing for use in crewed environments.

Recommendation: Extend existing methods with AM-specific recommendations.

Priority: ☐High; ☐Medium; ☒Low

Organization: ASTM E21.05, ASTM D20, ISO/TC 138, ISO/TC 261/ASTM F42

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☐Metal; ☒Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap P8: EHS Hazards Related to Post-Processing Tasks.

In general, there are some existing general standards for health and safety (e.g., machine guarding), but it is unknown if these are sufficient to cover environmental, health, and safety issues related to any unique post-processing tasks encountered in additive manufacturing.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: Detailed hazard assessments are needed for all post-processing tasks to determine whether there are environmental, health, and safety issues for post-processing tasks that are unique to additive manufacturing.

Recommendation: Conduct post-processing task hazard analyses and determine the need to develop standards for any hazards that are unique to additive manufacturing.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): Gov't agencies: NIOSH, EPA (for R&D). ASTM F42.06, ISO TC 261 (for standards).

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

• **9/24/2024, J.Schmelzle Compiled**: What makes post processing different from PC14? Safety should always be a priority, but materials at post-processing are generally the same as other materials. Unsure about the effects of surface finishing techniques and how the surface is removed and what that material looks like after being removed.	
New Published Standards	**New In-Development Standards**

Section 2.2.3 Recommendations/Comments Since v3 was Published

Additional general recommendations related to the Section 2.2.3 Post-processing scope, additional gaps, or other considerations since v3 was published are as follows:

- No recommendations received relation of publication of this report.

Other Post-processing Activity – Relevance to Gaps Not Yet Determined

New Published Standards

- No additional standards provided as of publication of this report.

New In-Development Standards

- No additional standards provided as of publication of this report.

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SECTION 2.2.4 FINISHED MATERIAL PROPERTIES GAPS

Section #	Gap #, Title and Description	High	Medium	Low
2.2.4.2.2	Gap FMP1: Material Properties (Metals) (Last updated 9/24/2024)	X		
2.2.4.5	Gap FMP3: Removal of AM Feedstock from Medical AM Parts (Last updated 9/24/2024)	X		
2.2.4.7	Gap FMP4: Material Allowables (Last updated 4/14/2025)	X		
2.2.4.8	Gap FMP5: Microstructure (Last updated 9/24/2024)	X		
2.2.4.1.1	New Gap FMP6: Finished Material Properties Terminology (Last updated 9/24/2024)			X
2.2.4.2.1	New Gap FMP7: Material Properties: Specification Content Requirements (Last updated 9/24/2024)	X		
2.2.4.2.3	New Gap FMP8: Material Properties (Non-Metals) (Last updated 9/24/2024)	X		
2.2.4.2.4	New Gap FMP9: Material Properties: Test Methods (Metals and Non-Metals) (Last updated 4/14/2025)	X		
2.2.4.9	New Gap FMP10: Catalogs of Process Specific Defect Types (Last updated 9/24/2024)	X		
2.2.4.9	New Gap FMP11: Assessment of Models Linking Defect Structures and Material Performance (Last updated 9/24/2024)	X		
Section 2.2.4 Recommendations/Comments Since v3 was Published				

New Gap FMP6: Finished Material Properties Terminology.

There is inconsistency in how terms (e.g., material allowable, design value, material strength properties) are defined and used to describe design decisions that will inform finished material properties for metallic and non-metallic additively manufactured parts across industry sectors.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Encourage greater consistency in terminology used to establish finished material properties for metallic and non-metallic additively manufactured parts in future revisions of industry standards and guidance materials. The MMPDS and CMH-17 handbooks are accepted industry resources for the aerospace sector.

Priority: ☐High; ☐Medium; ☒Low

Organization: SDOs

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☒Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒ New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled DoD**: Greater consistency is needed, but these terms have firm definitions. They are usually used interchangeably by those not familiar with material selection and design. Recommend utilizing existing aerospace standards listed if others are not readily available.

New Published Standards	New In-Development Standards

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New Gap FMP7: Material Properties: Specification Content Requirements.

Specifications for materials and processes intended for a particular audience need to include minimum material (and maximum as necessary) properties that meet that industry's basic requirements. They also need to consider other requirements such as macro/microstructure for metals, and porosity for metals and polymers. In aerospace, the SAE AMS AM data submission requirements are aligned with the primary material allowable references (CMH-17 and MMPDS) to ensure that material submitted to those programs support aerospace regulations and requirements. At least within an industry, specification content requirements would simplify the material selection process knowing that the framework for specification development is consistent and the output from different specifications are comparable.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: Review existing data generation and analysis methods and document appropriate standard practices at an industry level for minimum material properties, and for microstructure. This

could include a literature survey to review the approaches across different industries. R&D is needed to establish what test(s) should be done ~~as a~~for lot release in AM. (Machined ASTM E8 bars are not sensitive to many LPBF specific processes failures.)

Recommendation: Coordinate activity between SDOs, including the AM data generation and/or data management consortia groups SAE-ITC Additive Manufacturing Data Consortium (AMDC) and ASTM Consortium for Materials Data Standardization (CMDS), so that specifications for specific industries produce comparable content. Each industry may need to have its own standard. The aerospace industry generally complies with CMH-17 and MMPDS.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM International, SAE AMS, CMH-17, MMPDS, DoD, NASA for aerospace, defense, and space.

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☒Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Each user must verify that a public specification meets the requirements of cognizant regulators. This can be cost prohibitive, restricting the opportunities for use of AM.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** There are multiple efforts underway. Ensure aligns with National Institute for Aviation Research (NIAR) Performance-based additive qualification

consolidated strategy (PAQCS) framework. This approach is looking to gain concurrence across all U.S. aerospace regulators: DoD, FAA, NASA.	
New Published Standards	**New In-Development Standards**

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Gap FMP1: Material Properties (Metals).

Standards that address thermal properties, minimum mechanical properties, and degradation properties, and that also contain qualification procedures, are needed for metallic AM materials. Many metals used in aerospace applications will have standardized tables in MMPDS, Volume II when data is submitted to the program.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Developing these standards will require generating data that currently may not exist or may not be in the public arena. The *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE has several projects aimed at addressing this gap. A material specification, ASTM WK82659 for maraging steel, is under development in F42.05 and through an AM CoE project 2006.

Recommendation: Develop standards that identify the means to establish material properties and qualification procedures for metals made using a given AM process, set of parameters, heat treat condition, and build design. Qualification requirements to establish minimum mechanical properties for AM parts need to be developed.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM F42/ISO TC 261, SAE AMS-AM, MMPDS, NIST, ASME, ASTM AM CoE

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; New

V3 Update: ASME research project 0183 has been completed, and shows statistical correlations of some critical properties and property interactions with respect to the essential variables of ASME code case 3020. (ASME code case 3020 provides assumptions of which base metal can be compared to get other properties that weren't tested.) Round robin testing by multiple parties is ongoing. Results from ORNL have been received and the data needs to be incorporated into a report.

The National Center for Advanced Materials Performance (NCAMP) and Joint Metals Additive Database Definition (JMADD) qualification program funded by America Makes and FAA, led by Wichita State University National Institute for Aviation Research (NIAR) is working to develop material property data for Ti-6-4 on laser powder bed fusion process. The program started in early 2021.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Material characterization can be defined by recommended tests and acceptable deviation (as determined by sensitivity analysis), but part requirements are determined by the designer. Reference to AM Parts does not seem appropriate in this gap.

New Published Standards	New In-Development Standards

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New Gap FMP8: Material Properties (Non-Metals).

Standards that address thermal properties, minimum mechanical properties, and degradation properties, and that also contain qualification procedures, are needed for non-metallic AM materials. Non-metals are addressed in CMH-17 Volume VII.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Developing these standards will require generating data that currently may not exist or may not be in the public arena.

Recommendation: Develop standards that identify the means to establish material properties and qualification procedures for non-metals made using a given AM process, set of parameters, and build design. Qualification requirements to establish minimum mechanical properties for AM parts need to be developed.

Priority: ☒High; ☐Medium; ☐Low (Polymers) / ☐High; ☐Medium; ☒Low (Ceramics)

Organization: ASTM F42/ISO TC 261, SAE AMS-AM, CMH-17, NIST, ASME

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☐Metal; ☒Polymer; ☒Ceramic; ☒Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒ New

V3 Update: The NCAMP Polymer AM qualification program includes HexPEKK and Markforged continuous fiber composite material. Both programs started in 2020. NCAMP released public specifications and a material property database of ULTEM 9085/Fortus 900MC in 2018.

The CMH-17 Non-Metallic Additive Manufacturing Coordination Group was formed in October 2018. A CMH-17 committee is drafting tables of material properties to be included in the first release of the non-metallic handbook. Properties are based on NCAMP qualification of ULTEM 9085**.**

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **9/24/2024, J.Schmelzle Compiled:** An NCAMP qualification for Stratasys Antero 800 NA and 840 CN03 is currently in work (started 2023). Modifications were made to the NCAMP qualification program to address additional sources of variability and test method concerns from the Ultem qual.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap FMP9: Material Properties: Test Methods (Metals and Non-Metals).

Existing mechanical test methods for traditionally-manufactured parts are used as needed for AM, and are acceptable for many purposes. Unique testing standards that take into consideration characteristics that are unique to AM parts such as those that use multiple materials (i.e.,

heterogenous/nonhomogeneous), gradients in composition and/or microstructure, surface finish effects, and anisotropy are needed.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Developing these standards will require generating data that currently may not exist or may not be in the public arena.

Recommendation: Develop standards on mechanical property test methods that are specific for AM parts

Priority: ☒High; ☐Medium; ☐Low (Metals, Polymers) / ☐High; ☐Medium; ☒Low (Ceramics)

Organization: ASTM F42/ISO TC 261, SAE AMS-AM, CMH-17, MMPDS, NIST, ASME, AMPP, MPIF

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒ New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **9/24/2024, J.Schmelzle Compiled:** Modified testing in NCAMP non-metallic (polymeric) material qualifications. Trial matrices were tested to address shortcomings of previous test methods developed for fiber reinforced composite materials applied to non-reinforced thermoplastics.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** For metallic applications, isotropy is well understood and tested for. AM surface finish, functionally graded materials, etc. are more novel and require work. Likely emphasis on ASTM to develop test methods. Revise to low priority.

New Published Standards	New In-Development Standards
• **4/14/2025, D. Hall:** *ASTM B769-25, Standard Test Method [STM] for Shear Testing of Aluminum Alloys (Cte B07.05).* The intent of this method is to provide a means of measuring the shear strength of aluminum-alloy wrought and cast products. Data obtained by this method are used to calculate minimum properties that can be utilized in the design of structural members such as found in aircraft. • **4/14/2025, D. Hall:** *ASTM B831:25, Standard Test Method for Shear Testing of Thin Aluminum Alloy Products (Cte B07.05).* The was amended to include an annex "providing a means of measuring the shear strength of additively manufactured products" including orientation codes. (Formerly WK87004)	

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Gap FMP3: Removal of AM Feedstock from Medical AM Parts.

Like many medical devices, medical AM parts must be cleaned of manufacturing residues and contact materials prior to packaging or final use. The cleaning process should ensure that AM materials such as powder are removed before use. Residual AM feedstock left on the parts may include but is not limited to cooling fluids or AM materials (powder or uncured monomer), that may be stuck within small geometric features or lattice structures. There is a need to reproducibly measure and evaluate the residual AM feedstock of a part with relevant, risk-based acceptance criteria.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to establish standards which discern clean from uncleaned parts in terms of AM residual feedstock; specifically, to reliably distinguish unsintered, unmelted, and uncured material from the intended part.

Recommendation: Develop standard test methods, metrics, and acceptance criteria for measuring cleanliness of complex 3D geometries that are based on existing standards but focus on AM-specific considerations. ASTM F42 already has work in progress.

Priority: ☒High; ☐Medium; ☐Low

Organization: AAMI, ASTM F04, ASTM F42/ISO TC 261, ISO/TC 150, ISO/TC 194, ISO/TC 198

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: A number of ASTM F04.15 (material test methods) standards have been updated.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** MMPDS Volume 2 has been released, but the methodology used can add process variability not present in the production configuration of most OEM AM suppliers. Alternative methods are laid out in SYSCOMM process specs and material specs. Likely dependent on Industry, risk profile, and material qualification approach.

New Published Standards	New In-Development Standards

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Gap FMP4: Material Allowables.

Several material and process specifications are now available for use in material allowables programs. In addition, there are multiple public allowables development programs in progress. For metallic additively manufactured material, the MMPDS General Coordination Committee has approved guidelines, definitions, specification content, data generation, data analysis, and presentation guidelines for users. MMPDS continues to work toward compiling the first edition of MMPDS, Volume II. The target release is tentatively forecasted to be July 1, 2024. For polymer based additively manufactured materials, an FAA sponsored research program developed allowables that are currently under consideration for a future publication of CMH-17.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Recommended R&D required to fill this gap includes expansion of current allowables activities and further guidelines to support these activities.

Recommendation: Leverage research to improve existing guidelines as follows:

- Expand on allowable programs in progress
- Include fatigue testing in allowable generation programs
- Develop additional guidelines for best practices
- Expand allowables programs with additional AM processes and alloys
- Additional machine types for a given alloy
- Statistical methodology assessment and validation
- Acceptance and equivalency protocol development and validation

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM F42/ISO TC 261, SAE AMS-AM, AWS, NASA, ASME BPVC, MMPDS, CMH-17, NIST

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary methods are being used in lieu of industry standards.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As described in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **4/8/2025, D.Gibbons:** FAA *AC 33.15-3, Powder Bed Fusion Additive Manufacturing Process for Aircraft Engine Parts* describes an acceptable means for demonstrating compliance with Title 14, Code of Federal Regulations (14 CFR) 33.15 for aircraft engine parts with materials produced by the powder bed fusion (PBF) additive manufacturing (AM) process. Guidance is also presented on closely related design and manufacturing aspects associated with AM.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/29/2024, NIAR Compiled:** Specification template to define material requirements by industry. Material specs for non-AM materials should be used as reference.

New Published Standards	New In-Development Standards
9/20/2024, D.Hall: MMPDS-2024, Volume II was released on July 1, 2024. The first edition defines an aerospace government/industry reviewed and approved data generation and analysis framework for metal AM for use in aerospace.	**9/20/2024, D.Hall:** The last microstructure requirement necessary to propose new entries for Volume II was approved by the committee. When ready, requirements will be included in the edition that is released on July 1, 2025. Seven AM test programs (see below) are currently being executed to meet MMDPS V2 guidelines with the intent to submit data. If everything goes as planned, Battelle will analyze and propose tables for at least one (and up to three) of those programs at the spring and fall 2025 meetings. Approved tables can be included in MMDPS-2026. 1. 21-53: Analysis of 718 Laser Power Bed Fusion per AMS 7038-43S 2. 23-22: 6061-RAM2 per AMS 7054-43S 3. 23-48: Ti-6AI-4V per AMSC 7004/7005 – 43S 4. 24-04: Ti-6AI-4V JMADD Test Plan – 43H including some preliminary analysis 5. 24-05: : Ti-6AI-4V GAMAT Test Plan – 43S 6. 24:40: Ti 6-4 AM Test Plan per xxx – 43S 7. 24-72: 15-5PH AM Test Plan per AMS 7073-44H

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Gap FMP5: Microstructure.

There is an inherent heterogeneity in the microstructure of metallic alloys made by AM that requires a standard for identification and quantification of the spatial variability of various microstructure features.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Develop Calphad databases suitable for non-equilibrium solidification. *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE Projects 1804/1907 (WK65937, WK65929) address AMSC gap FMP5.

Recommendation: Develop ~~a~~standards for characterization and acceptance criteria of AM microstructures (both identification and quantification).

Priority: ☒High; ☐Medium; ☐Low

Organization: NIST, ASTM

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☒Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** This is alloy dependent, but conventional microstructural analysis tools are capable of analyzing AM materials, even if the microstructure is substantially different from wrought or cast materials. Tools like ImageJ can analyze grain size, porosity, etc. without issue if high-definition imaging of etched surfaces are available.

New Published Standards	New In-Development Standards
	9/20/2024: D.Hall: MMPDS has defined micrograph submission requirements necessary to create an entry in the Handbook. The plan is to make those micrographs available to future Handbook users and regulators to qualitatively decide whether the future producer is making material microstructurally consistent with the material used to create Tables and Curves in MMPDS.

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New Gap FMP10: Catalogs of process specific defect types.

Catalogs of process defects would be useful for diagnosing and correcting an AM process or choosing an appropriate post-processing step to eliminate or minimize the deleterious effect of defects on the final part performance. Such catalogs are not generally available for AM processes. See also Gap NDE1 on Terminology for the Identification of AM Anomalies Interrogated by NDE Methods.

R&D Needed: ☒Yes; ☐No; Maybe

R&D Expectations: R&D is required to correctly diagnose the cause of defects for some processes and materials.

Recommendation: Develop catalogs of process specific defects

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM, AWS, SAE, potentially other SDOs, NIST, national labs, DoD, NASA

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **9/24/2024, J.Schmelzle Compiled:** Effect of defect studies have occurred at various SYSCOMMS, but the maturation of CT and the limitations of conventional NDI methods is a shortcoming. Additional work is needed.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:	
• No updates as of publication of this report.	
New Published Standards	**New In-Development Standards**

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New Gap FMP11: Assessment of models linking defect structures and material performance.

Structure-property models for AM defects are needed to support acceptance criteria for part qualification. Guidance and technical reports are needed on the use of existing models and the development of new models.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Develop guides and technical reports on current structure-property models for defects and the development of new models. Publish high fidelity, pedigreed datasets for structure-property model validation.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM, AWS, SAE, potentially other SDOs, NIST, national labs, DoD, NASA

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Non-random defect formation in AM due to process variability can be reduced via better hardware controls and powder quality, but firm linkages between material property requirements and defect size/type/location have not been formalized.

New Published Standards	New In-Development Standards

Section 2.2.4 Recommendations/Comments Since v3 was Published

Additional general recommendations related to the Section 2.2.4 Finished Material Properties scope, additional gaps, or other considerations since v3 was published are as follows:

- No recommendations received relation of publication of this report.

Other Finished Material Properties Activity – Relevance to Gaps Not Yet Determined

New Published Standards

- No additional standards provided as of publication of this report.

New In-Development Standards

- No additional standards provided as of publication of this report.

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SECTION 2.3 QUALIFICATION & CERTIFICATION GAPS

Section #	Gap #, Title and Description	High	Medium	Low
2.3.1	Gap QC1: Harmonization of AM Q&C Terminology (Last updated 4/14/2025)	X		
2.3.3.1.2	Gap QC2: AM Part Risk Classification System for Consistent Qualification Standards (Last updated 9/24/2024)	X		
2.3.3.4	Gap QC3: Harmonizing Q&C Terminology for Process Parameters (Last updated 9/24/2024)		X	
2.3.3.4	Gap QC4: Process Approval for DoD-procured Parts		X	
2.3.3.4	Gap QC5: Machine Operator Training and Qualification (Last updated 9/24/2024)			X
2.3.3.7.2	Gap QC6: Importing 3D Source Data to CAD Application for Creation of Design File (Last updated 4/9/2025)		X	
2.3.3.7.3	Gap QC7: Imaging Protocols (Last updated 4/9/2025)		X	
2.3.3.7.6	Gap QC8 Phantoms(Last updated 4/9/2025)		X	
2.3.3.7.5	Gap QC9: Personnel Training for Image Data Set Processing (Last updated 4/9/2025)	X		
2.3.3.7.13	Gap QC10: Verification of 3D Model (Last updated 4/9/2025)	X		
2.3.3.7.10	Gap QC13: Material Control Data and Procedures (Last updated 9/24/2024)			X
2.3.3.7.4	Gap QC14: Segmentation (Last updated 4/9/2025)		X	
2.3.3.7.14	Gap QC15: Sterilization of AM Medical Products (Last updated 4/9/2025)			X
2.3.3.7.15	Gap QC16: Sterilization of 3D Printed Tissue Engineered Products		X	
2.3.3.1.2	New Gap QC17: AM Part Material Development Timeline (Last updated 4/14/2025)	X		
2.3.3.1.2	New Gap QC18: OQ/PQ Process Know-How (Last updated 9/24/2024)	X		
2.3.3.1.2	New Gap QC19: Workforce Training		X	
2.3.3.1.2	New Gap QC20: Certifying agency KPV Checklist (Last updated 9/24/2024)		X	
2.3.3.1.2	New Gap QC21: Detailed Requirements Integration Document (Last updated 9/24/2024)		X	
2.3.3.5	New Gap QC22: Additively Manufactured Electronics (AME) (Last updated 9/19/2024)	X		
2.3.3.6.1	New Gap QC23: Production and Incorporation of AM Parts in Nuclear Applications and Facilities (Last updated 4/14/2025)	X		
2.3.3.6.1	New Gap QC24: Nuclear AM Component In-service Performance	X		
2.3.3.6.1	New Gap QC25: Nuclear Industry Use of Artificial Intelligence (AI) and Machine/System Learning Technologies to Qualify AM Parts	X		
2.3.3.6.1	New Gap QC26: Nuclear Industry Use of Material and Production Data Combined with Digital Analysis and Diagnostic Informed Qualification of AM Components	X		

Section #	Gap #, Title and Description	High	Medium	Low
2.3.3.6.1	New Gap QC27: Use and Qualification of AM Non-Metallic Advanced Materials in Support of New or Advanced Nuclear Fuel and High-temperature Reactor Applications	X		
2.3.3.6.2	New Gap QC28: Susceptibility of AM Products to Corrosion and Environmental Cracking Mechanisms (Last updated 3/12/2025)	X		
Section 2.3 Recommendations/Comments Since v3 was Published				

Gap QC1: Harmonization of AM Q&C Terminology.

One of the challenges in discussing qualification and certification in AM is the ambiguity of the terms qualification, certification, verification, and validation, and how these terms are used by different industrial sectors when describing Q&C of materials, parts, processes, personnel, and equipment.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Compare how the terms qualification, certification, verification, and validation are used by industry sector. Update as needed existing terminology standards to harmonize definitions and encourage consistent use of terms across industry sectors with respect to AM.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM F42/ISO TC 261, AAMI, ASME, SAE

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: This is an ongoing effort.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **4/8/2025, D.Gibbons:** FAA *AC 33.15-3, Powder Bed Fusion Additive Manufacturing Process for Aircraft Engine Parts* describes an acceptable means for demonstrating compliance with Title 14, Code of Federal Regulations (14 CFR) 33.15 for aircraft engine parts with materials produced by the powder bed fusion (PBF) additive manufacturing (AM) process. Guidance is also presented on closely related design and manufacturing aspects associated with AM.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Standardize around language in PACQS. NIAR proposed updates to AMS7032

New Published Standards	New In-Development Standards

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New Gap QC17: AM Part Material Development Timeline.

Building an entirely new manufacturing process for a full suite of alloys requires a different approach than the historical consensus approach so that industry timelines can be met.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Current state of technology does not allow material data set required. Use predictive modeling to replace testing, for example.

Recommendation: Develop standards, specifications, and allowables in concert to provide the industry a more robust material standards ecosystem.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM, SAE, MMPDS, CMH-17

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion;☐Material Jetting; ☐Powder B d Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **4/8/2025, D.Gibbons:** FAA *AC 33.15-3, Powder Bed Fusion Additive Manufacturing Process for Aircraft Engine Parts* describes an acceptable means for demonstrating compliance with Title 14, Code of Federal Regulations (14 CFR) 33.15 for aircraft engine parts with materials produced by the powder bed fusion (PBF) additive manufacturing (AM) process. Guidance is also presented on closely related design and manufacturing aspects associated with AM.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** It seems like the focus of this gap is on finding ways to minimize the qualification testing required for novel material/equipment/process configurations, but that will require a lot of ICME and modeling tools that do not exist yet. If this is referring to the cost and testing burden to understand material properties without publicly available data sets, see gap FMP4.

New Published Standards	New In-Development Standards

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New Gap QC18: OQ/PQ Process Know-How.

Public research is required to demonstrate in a serial production environment the Key Process Variables (KPVs) and the required process controls to maintain stability. To date such work primarily has been developed privately and is held as a trade secret.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: See recommendation

Recommendation: Carry out research to demonstrate and standardize in a ~~serial~~ production environment the KPVs and required process controls to maintain stability.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): Research institutes, universities, SDOs

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion;☐Material Jetting; ☐Powder B d Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Why not any production environment?
- **9/24/2024, J.Schmelzle Compiled:** There is a lack of validated sensitivity studies and ICME modeling tools.

New Published Standards	New In-Development Standards

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Gap QC2: AM Part Risk Classification System for Consistent Qualification Standards.

A part classification system is used to describe the **level of risk** associated with a part and may therefore be used as a metric to gauge appropriate qualification requirements. The risk level is determined by two factors: (1) the part criticality as defined by the regulator, and (2) the likelihood or probability of the failure as determined by the OEM. A standard is needed to define common AM failure modes and a method for each failure mode to determine qualitative failure likelihood or quantitative failure probability. In most cases, this will provide guidance related to manufacturing variation effect on design margin.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE Projects 1804/1907 (WK65937, WK65929) address AMSC gap QC2.

Recommendation: Develop a standard to define common AM failure modes and a method for each failure mode to determine qualitative failure likelihood or quantitative failure probability. A technical report describing existing risk classification systems for AM parts also would be useful. It could include the recommended minimum process and part qualification requirements commensurate with part risk for each classification level.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM F42/ISO TC 261, AWS, DoD, NASA, SAE

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Published standards since the last roadmap iteration include *ASTM F3572-22, Standard Practice for Additive Manufacturing – General Principles – Part Classifications for Additive Manufactured Parts Used in Aviation* which we understand will be referenced by EASA.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** 1st portion of this need is captured by SYSCOMM specific part triage and classification processes. The latter portion is tied to the maturation of NDI

techniques and impact of defect studies. AM part failures follow the same mechanisms as conventional materials, but the cause of those failures can be specific to AM material and process. Very unlikely to consolidate around a single classification model, because each SYSCOMM has different risk profiles and levels of acceptance.
- **9/24/2024, J.Schmelzle Compiled:** Revision of title suggested to "Risk Assessment based qualification Standards." Permitting reduced Q&C based on risk environment.
- **9/24/2024, J.Schmelzle Compiled:** What is meant by AM failure modes? It is not clear how this would differ from a FMECA.

New Published Standards	New In-Development Standards

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New Gap QC19: Workforce Training.

Publicly accessible OQ and PQ process know-how must first be developed and then be provided to the industry through workforce training programs. Research institutes and universities must play an important role in workforce training.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: For OQ and PQ (see prior Gap QC18).

Recommendation: Develop publicly accessible OQ and PQ process know-how as the basis of workforce training programs.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): Research institutes, universities, SDOs

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion;☐Material Jetting; ☐Powder B d Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap QC20: Certifying Agency KPV Checklist.

Publicly accessible OQ and PQ process know-how must first be developed and KPVs identified and supported with production data. These KPVs can then be used to establish certifying agency checklists.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: For OQ and PQ (see prior Gap QC18).

Recommendation: Develop publicly accessible OQ and PQ process know-how based on production data to establish certifying agency checklists

Priority: ☐High; ☒Medium; ☐Low

Organization(s): Research institutes, universities, SDOs

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion;☐Material Jetting; ☐Powder B d Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, C.Ashforth:** SAE AMS specs have a list of recommended KPVs. What additional needs exist?
- **9/24/2024, J.Schmelzle:** KPVs will need to be process dependent. Some may need to be material dependent as well, since issues like hydrogen embrittlement of in-situ nitriding are specific to certain alloy systems and HT conditions.

New Published Standards	New In-Development Standards

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New Gap QC21: Detailed Requirements Integration Document.

Publicly accessible OQ and PQ process know-how must first be developed and then be published in a detailed requirements integration document.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: For OQ and PQ (see prior Gap QC18).

Recommendation: Develop publicly accessible OQ and PQ process know-how and publish it in a detailed requirements integration document.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): Research institutes, universities, SDOs, regulators

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion;☐Material Jetting; ☐Powder B d Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** SYSCOMMs have their own unique processes and procedures developed, but these have not been unified, likely due to the variability in operating environment and acceptable risk profile mentioned above.

New Published Standards	New In-Development Standards

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Gap QC3: Harmonizing Q&C Terminology for Process Parameters.

In order to enable full understanding of the given processes and to include this type of information in a process-agnostic TDP, and for purposes of qualification and/or certification, there must be standardization of process parameter terminology across machine manufacturers.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE Projects 1804/1907 (WK65937, WK65929) address AMSC gap QC3.

Recommendation: Develop standardized terminology for process parameters for use across all AM equipment. Incorporate terms as appropriate into *ISO/ASTM 52900:2021, Additive manufacturing - General principles – Fundamentals and Vocabulary*. See also Gap PC5 on parameter control.

Priority: ☐ High; ☒Medium; ☐Low

Organization: ASTM F42/ISO TC 261 JG 51, AWS D20, SAE AMS-AM, IEEE-ISTO PWG

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Some of this can be borrowed from conventional M&P terminology, but there will be AM process specific wording that needs to be formally defined and standardized. ASTM/SAE standards for terminology need to be more universally accepted and used.

New Published Standards	New In-Development Standards

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Gap QC4: Process Approval for DoD-procured Parts.

As multiple methods of AM continue to mature, and new AM techniques are introduced, the government will need to fully understand the ramifications of each of these techniques, of what they are capable, and how certain AM procedures might lend themselves to some classes of parts and not others. Thus, not only must the government understand the differences, but how they should be assessed and tested, and what additional checks must be made on the end product before it can be qualified for use in a military platform. High pressures, temperatures, and other contained environments could impact the performance or life of safety-critical parts in ways that are not understood. More research is required to determine the delta between traditional and AM methods.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Starting with the most mature technologies, such as laser powder bed, there is a need to develop standards that assess required checks for levels of criticality and safety as part of the DoD procurement process. DoD should participate in the development of such standards and specify the certification requirements needed.

Priority: ☐ High; ☒Medium; ☐Low

Organization: ASME, ASTM F42/ISO TC 261, DoD, Industry, SAE, Service SYSCOMS

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☐Green; ☒Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap QC5: Machine Operator Training and Qualification.

There is a need for standards or guidelines outlining AM training requirements. AM training programs include but are not limited to those offered by OEMs and other third-party organizations.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Develop AM operator training and qualification standards or guidelines. The provision of equipment-specific training is the purview of OEMs. At a high level, SDO training materials are aimed at covering the various AM materials and processes available in the market and are performance based to ensure consistent AM part quality. Develop additional standards for artisanal levels of competency and experience, delineating an individual's expertise in the field or subsets of the AM field.

Priority: ☐High; ☐Medium; ☒Low

Organization: NASA, SAE, AWS, OEMs, UL, ASTM F42/ISO TC 261, AAMI

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** SYSCOMM training is currently split between OEM training on specific hardware and SDO/Academia training on core technical principles. SYSCOMMs generally define their own requirements and none are currently universal to my knowledge.

New Published Standards	New In-Development Standards

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New Gap QC22: Additively Manufactured Electronics (AME).

No qualification, acceptability, and coupon standards currently exist for 3D AME substrates where traditional AM electrically functional components are created within an electrical PCB-like substrate. See also roadmap section 2.6.2.9 on AME data transfer format and Gap DA7.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Reliability and qualification standards with validating research is required for all industries.

Recommendation: Develop standards for AME technology.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): IPC, IEC

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☒Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: The current alternative is to manufacture AME substrates by extrapolating reliability and qualification requirements from existing IPC printed circuit board specifications and test methods.

V3 Status of Progress: ☐Green; ☒ ~~☐~~Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐ ~~☒~~New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- **9/19/2024, D.Korf:** IPC created committee D-67 Additively Manufactured Electronics Subcommittee in Q4 2023.
- **9/19/2024, D.Korf:** ASTM has initiated work in the F42.07.06 Electronics committee. They have created proposed updates for existing ASTM AM standards.
- **9/19/2024, D.Korf:** IEC, ANSI, ASTM, and IPC have initiated discussions for SDO's to coordinate creating AME standards without contradicting each other.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
9/19/2024, D.Korf: In October 2023, UL 796 Printed Wiring Boards was updated and includes AME substrates.	**9/19/2024, D.Korf:** IPC Task Group D-67A is developing IPC-6911, Acceptability of Additively Manufactured Electronics (AME). Targeted completion is Q4 2025. **9/19/2024, D.Korf:** IPC Task Group D-67B is developing IPC-6905, Qualification and Performance Specification for Additively Manufactured Electronics (AME). Targeted completion is Q4 2025. **9/19/2024, D.Korf:** IPC Task Group D-67C is developing new 3D, STL or AMF-based coupons needed to support IPC-6905, Qualification and Performance Specification for Additively Manufactured Electronics (AME). Targeted completion is Q4 2025.

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New Gap QC23: Production and Incorporation of AM Parts in Nuclear Applications and Facilities.

More research and guidance would likely result in improved AM production capabilities in the nuclear sector including the ability to control grain structures, apply novel geometries, and rapidly produce parts for repair, replacement, and/or production while meeting the requirements of applicable standards and codes under radiological conditions.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: DOE, NRC, and EPRI have solicited research and inputs on the use of AM parts in nuclear applications. DOE Nuclear Energy (NE) has formed a program called the Advanced Materials and Manufacturing Technology (AMMT) to continue work begun under the Transformational Challenge Reactor (TCR) and other similar DOE laboratory programs that began the process of testing materials and designs for nuclear applications, especially utilizing stainless steel. Additional research should include the expansion of materials to include high-heat ceramics, embedded sensors, in-situ

monitoring, stainless and other steels, including radiological effects on them, and the qualification of AM materials and related parts.

Recommendation: Additional guidance and research is required to support codes and standards development, qualification, certification, implementation, disposition, and licensing of nuclear AM parts.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): NRC, DOE (i.e., AMMT), NEI, EPRI, ASME, ASTM

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☒Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☒Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☒Binder Jetting; ☒Directed Energy Deposition; ☒Material Extrusion; ☒Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☒Other (specify)

Current Alternative: Individual efforts to incorporate AM parts through regulatory processes may require additional testing and qualification.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- **04/08/2024, M.Russell:** The DOE Nuclear Advanced Materials and Manufacturing Technologies Program has published their program status.
- **04/08/2024, M.Russell:** ORNL 3D-printed a highly efficient neutron collimator. This is an advancement in the study of energy and matter at the atomic scale, leveraging neutron beams to gain insights in the structural and dynamic properties of materials.
- **4/14/2025, NIST Compiled:** An AM Standard Committee has been formed under the Board on Pressure Technology Codes and Standards (BPTCS) as of February 2025. The Committee on AM has drafted criteria for two Code Cases for Additive Manufacturing:
  - Construction of Pressure Equipment using Direct Energy Deposition with Wire Feedstock
  - Construction of Pressure Equipment using Powder Bed Fusion

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	04/08/2024, M.Russell: NRC Guidance documents are in draft status, see all here and specific documents as follows: • *ML21074A040, Guidelines Document for AM – LPBF* • *ML22143A951, Guidelines for AM – Laser DED* • *ML22143A952, Guidelines Document for Cold Spray*

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New Gap QC24: Nuclear AM Component In-service Performance.

Monitoring the performance of AM parts, when installed in nuclear applications depends on the component's intended function, location and access. Due to the mechanism of layering powder in AM systems like Powder Bed Fusion and Directed Energy Deposition, in-situ monitoring systems can be embedded within the parts during the production process that allows real-time monitoring of part and reactor performance. The process of embedding sensors within AM parts has been tested with some success at the national laboratories, but additional research is needed to mature the process to production scale and initiate testing within the U.S. nuclear fleet. The embedding process and equipment maintainability should be considered during the design process before incorporating this technology.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Both DOE and the NRC have solicited research and inputs on the use of in-situ monitoring of AM components in nuclear applications. DOE Nuclear Energy (NE) has formed a program called the Advanced Materials and Manufacturing Technology (AMMT) to continue work begun under the Transformational Challenge Reactor (TCR) and other similar DOE laboratory programs that began the process of testing in-situ monitoring combined with ex-situ examination techniques as inputs into AI and machine learning algorithms to rapidly detect potential quality anomalies during the manufacturing process and monitor in-service performance.

Recommendation: Additional guidance and research is required to ensure the development, qualification, certification, implementation, disposition, and licensing of nuclear AM parts utilizing advanced monitoring and intelligent systems combined into a digital platform to help inform the quality of AM parts.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): NRC, DOE, NEI, EPRI, ASME, ASTM, AMMT

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☒Automotive; ☐Construction; ☒Defense; ☐Electronics; ☒Energy; ☐Medical; ☒Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☒Other (specify) Combines computer controls, in-situ monitoring, and artificial intelligence.

Current Alternative: Traditional in-service part monitoring may require costly techniques and processes or removal from service for inspection.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap QC25: Nuclear Industry Use of Artificial Intelligence (AI) and Machine/System Learning Technologies to Qualify AM Parts.

There is a need for additional research, guidance, and standards on the use of Artificial Intelligence and Machine/System Learning technologies and techniques to rapidly inform AM part qualification and acceptance for high quality and safety applications in the nuclear industry. AM part design and production allows for real-time monitoring of AM machine performance and part quality that can inform production and quality personnel of potential issues with the machine, build, and part performance. The use of modern intelligent computer and system learning applications to rapidly identify potential AM quality and conformance issues has begun development and testing in the

national laboratories and private industry but needs additional support and research to mature for application and acceptance by regulatory bodies, standards organizations, and quality organizations.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Both DOE and the NRC have solicited research and inputs on the use of AI and machine learning in AM nuclear applications. DOE Nuclear Energy (NE) has formed a program called the Advanced Materials and Manufacturing Technology (AMMT) to continue work begun under the Transformational Challenge Reactor (TCR) and other similar DOE laboratory programs that began the process of testing in-situ monitoring combined with ex-situ examination techniques as inputs into an AI and machine learning algorithms to rapidly detect potential quality anomalies during the manufacturing process. Additional support and research are needed to mature application and acceptance by regulatory bodies, standards organizations, and quality organizations.

Recommendation: Additional guidance and research is required to ensure the development, qualification, certification, implementation, disposition, and licensing of nuclear AM parts utilizing advanced monitoring and intelligent systems combined into a digital platform to help inform the quality of AM parts.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): NRC, DOE, NEI, EPRI, ASME, ASTM, AMMT

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☒Other (specify) Combines digital twin, computer controls, in-situ monitoring, and artificial intelligence.

Current Alternative: Traditional part qualification may require additional testing and qualification processes.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap QC26: Nuclear Industry Use of Material and Production Data Combined with Digital Analysis and Diagnostic Informed Qualification of AM Components

There is a need for additional research, guidance, and standards on the use of analysis and diagnostic tools to analyze AM materials and build data combined with AM digital twin, in-situ monitoring, Artificial Intelligence and Machine/System Learning technologies, and techniques to rapidly inform AM part qualification and acceptance in the nuclear industry. AM technologies and processes produce a significant amount of build and potential performance data and information. Mining and analyzing this data from in-situ and ex-situ sources, material properties, testing, and quality inputs can introduce a much more efficient system for identification of part issues, rapid qualification decisions, and future references under a digital twin model. Additional work on digital platforms/systems that can rapidly assimilate, mine, analyze and store AM part data is needed.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Both DOE and the NRC have solicited research and inputs on the use of AM parts in nuclear applications. DOE Nuclear Energy (NE) has formed a program called the Advanced Materials and Manufacturing Technology (AMMT) to continue work begun under the Transformational Challenge Reactor (TCR) and other similar DOE laboratory programs that began the process of integrating material and test data combined with production data into AI and machine learning algorithms in a digital platform to rapidly detect potential quality anomalies during the manufacturing process.

Recommendation: Additional guidance and research is required to ensure the development, qualification, certification, implementation, disposition, and licensing of nuclear AM parts utilizing advanced monitoring and intelligent systems combined into a digital platform to help inform the quality of AM parts.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): NRC, DOE, NEI, EPRI, ASME, ASTM, AMMT

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☒Other (specify) Combines digital twin, computer controls, in-situ monitoring, and artificial intelligence.

Current Alternative: Traditional part qualification may require additional testing and qualification processes.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap QC27: Use and Qualification of AM Non-metallic Advanced Materials in Support of New or Advanced Nuclear Fuel and High-temperature Reactor Applications.

The new line of advanced reactors for potential application in the U.S. nuclear energy fleets may operate at a much higher temperature than the current U.S. fleet. The nuclear industry (and other industries) can benefit from the use of additively manufactured non-metallic materials such as silicon carbide are being evaluated by the DOE and industry for use in nuclear fuels and core components potentially replacing stainless or other steels and materials in certain high-heat applications. These ceramics lend themselves to AM application and the benefits of rapid design and production of complex geometries never before attempted.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Both DOE and the NRC have solicited research and inputs on the use of AM parts in nuclear applications. DOE Nuclear Energy (NE) has formed a program called the Advanced Materials and Manufacturing Technology (AMMT) to continue work begun under the Transformational Challenge Reactor (TCR) and other similar DOE laboratory programs that began the process of development and testing of non-steel materials for use in AM nuclear applications. The ORNL TCR program utilized previous DOE laboratory techniques and research originally developed in the 1960s to improve the use of silicon carbide and similar ceramics in AM applications (typically, binder jetting) to produce and test new forms of the high-heat tolerant fuels like the Tri-structural ISOtropic (TRISO) encapsulated fuel and potential reactor core components. The TRISO fuel is the favorite of potential

new reactor designs due to its compact fuel density, high-heat tolerance, and improved radionuclide retention capabilities combined into a much safer fuel form.

Recommendation: Additional guidance and research is required to ensure the development, qualification, certification, implementation, disposition, and licensing of nuclear AM parts utilizing advanced non-steel materials for high-heat applications.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): NRC, DOE, NEI, EPRI, ASME, ASTM, AMMT

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☒Energy; ☐Medical; ☒Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☒Other (specify) Combines digital twin, computer controls, in-situ monitoring, and artificial intelligence.

Current Alternative: Traditional part manufacturing and qualification may require additional testing and qualification processes.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap QC28: Susceptibility of AM Products to Corrosion and Environmental Cracking Mechanisms.

There are no standards or reliable guidance for testing additively manufactured products for service where a corrosion related mechanism is a major consideration. The resistance to corrosion and environmental cracking mechanisms is often the limiting factor in applying AM to Oil and Gas products. From a search of several industry sectors, this lack of guidance or standard is not isolated to Oil and Gas products or to any particular industry.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: The scope of AMPP TR21522 is to present the current state of knowledge and gap analysis on corrosion testing of metallic materials for products that are manufactured using AM processes. The report will include testing recommendations and identify existing applicable testing standards that may need to be modified to address AM and where a suitable standard does not exist.

The scope of the report is not limited to any specific AM market sector and includes the state of the art with respect to general corrosion, localized corrosion, high temperature oxidation, corrosion fatigue, hydrogen or hydrogen sulfide associated cracking mechanisms, and stress corrosion cracking.

The TR21522 report is currently in the text drafting stage and the target date for ballot is June of 2023. The work to date has revealed technology and knowledge gaps related to the subject. The current assessment summary indicates that the existing AMPP and ASTM standards for corrosion and environmental cracking are acceptable but will require some modifications to address the specifics associated with additive manufacturing. The largest identified gap pertains to the selection and specifics of the test sample used to measure resistance/acceptability.

The next step will be to assess and edit the identified corrosion test standards from the TR21522 report to better address testing with respect to AM products. It is anticipated that a new standard will be required to provide guidance on the selection of test specimens from AM builds/products.

Recommendation: Complete work on AMPP TR21522 and use the results to inform future work.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): AMPP

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☒Other (specify) AM details, testing & prediction of product perform with respect to corrosion related phenomena

Current Alternative: Each user lacking guidance on how to select specimens and how to test for resistance to corrosion related degradation/failure mechanisms makes those decisions.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Expand this to include AM test methods for corrosion and comparative testing between conventional and AM alloys. Currently limited and some of the toughest environments lack sufficient data.

New Published Standards	New In-Development Standards
03/12/2025, R.Bradak: *API Standard 20S, Additively Manufactured Metallic Components for Use in the Petroleum and Natural Gas Industries* (1st Edition) was published in December 2024. This new standard provides requirements for qualification of the manufacturing process, production, marking and documentation of metallic components. **03/12/2025, R.Bradak:** AMPP Technical paper *TR21522 Corrosion Testing of Additive Manufactured Materials* was published in November 2024.	**03/12/2025, R.Bradak:** API 20S, work continues to incorporate references to API 20S in the API product specifications.

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Gap QC6: Importing 3D Source Data to CAD Application for Creation of Design File.

There is a need for a standard to enable 3D source data to be imported to the CAD application for creation of a design file. There is a concern that the data coming from the ultrasound equipment similar to the CT scan or MRI data may not be providing adequately detailed images but this cannot be assessed until the interoperability concerns are eliminated.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: TBD

Recommendation: Develop a standard for importing 3D source data to the CAD application for creation of a design file.

Priority: ☐High; ☒Medium; ☐Low

Organization: IEEE, ASTM F42/ISO TC 261 JG 70, ISO TC150/ASTM F04 JWG1, RSNA 3DP SIG

Lifecycle Area: ☒~~☐~~Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☒~~☐~~Aerospace; ☐Automotive; ☐Construction; ☒~~☐~~Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text ISO/ASTM 52915 and 52916 have been published. ISO/IEC 3532-1, ISO/IEC DIS 3532-2, ISO/IEC CD 8803, and ISO/IEC CD 16466 address/will address importing 3D source Data to CAD application.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **4/9/2025, B.Ripley RSNA:** Image segmentation systems provide standardized data importing and conversion for CAD applications. Image segmentation systems are designated Class II medical devices and are cleared by the US Food and Drug Administration for this intended use. Cleared tools therefore do not require additional validation methods when utilized within the scope of their intended use. This is inclusive of all imaging modalities utilized (e.g. CT, MRI, Ultrasound). Therefore, cleared image segmentation systems should be used for all patient care.

New Published Standards	New In-Development Standards

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Gap QC7: Imaging Protocols.

Problems associated with data acquisition for 3D modeling either individually or in combination contribute to image inaccuracies that will result in inaccuracies of the 3D model and eventually the final device produced. Imaging protocols typically prioritize patient exposure for patient safety and then consider resolution. Therefore, alignment is needed between the imaging resolution requirements, the printer resolution, and the final part accuracy and quality requirements.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: TBD

Recommendation: Develop standard protocols for acquiring data for 3D modeling to ensure image accuracy, precision, and quality of source files for validation of the AM design file.

Priority: ☐High; ☒Medium; ☐Low

Organization: IEEE, ASME, ASTM F42/ISO TC 261, RSNA (Radiological Society of North America), American College of Radiology (ACR)

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: *ISO/ASTM TR 52916, Additive manufacturing for medical-- Data --Optimized medical image data*, was published. ASME V&V 40 Subcommittee on Verification and Validation in Computational Modeling of Medical Devices is working to form a working group on this item. ISO/IEC 3532-1 and ISO/IEC DIS 3532-2 address imaging protocols.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **4/9/2025, B.Ripley RSNA:** Medical imaging consistency hinges on data acquisition protocols. These are managed by the provider responsible for patient care. Individual medical societies including the American College of Radiology provide guidance on image protocols (Ref: https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Practice-Parameters-and-Technical-Standards)

New Published Standards	New In-Development Standards

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Gap QC14: Segmentation.

There are currently no standards for patient imaging files including the methods from standard-of-care medical images to print-ready files.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Research on segmentation for patient imaging is needed because segmentation is a critical step for initiation of 3D printing for medical devices.

Recommendation: There is a need to create an augmented file specification for input into the DICOM file format. Incorporation of 3D files into the DICOM format will facilitate integration of 3D models into standard-of-care medical image databases present at all institutions. 3D models should include enough information to facilitate standardized methods for validation. DICOM itself addresses the process and also addresses consistency by enabling only a small subset of appropriate files.

Priority: ☐High; ☒Medium; ☐Low

Organization: RSNA SIG, ISO TC 261/ASTM F42, ISO/IEC JTC 1/WG12

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ISO/IEC DIS 3532-2 is in development.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **4/9/2025, B.Ripley RSNA:** This gap calls out a lack of standards for validating segmentation. In hospital-based 3D printing, the accuracy of segmentation is verified using methods of data overlay (e.g., DCM overlays onto surface mesh files). The 3D printing provider holds the final responsibility and reporting accountability for verifying the segmentation of parts, utilizing their clinical expertise.

New Published Standards	New In-Development Standards

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Gap QC9: Personnel Training for Image Data Set Processing.

Currently, there are only limited qualification or certification programs (some are in process of formation) available for training personnel who are handling imaging data and preparing for AM printing.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Develop certification programs for describing the requisite skills, qualification, and certification of personnel responsible for handling imaging data and preparing for printing. The SME organization currently has a program in development.

Priority: ☒High; ☐Medium; ☐Low

Organization: SME, RSNA, ASTM F42/ISO TC 261

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **4/9/2025, B.Ripley RSNA:** The RSNA SIG provides training opportunities for its membership as well as training via both the annual meeting of the RSNA, spotlight courses, and webinars.

New Published Standards	New In-Development Standards

Back to Section 2.3 / Back to Table of Contents

Gap QC8: Phantoms.

Material and process guidelines are needed for phantoms to provide reliable models for imaging experiments and to check the accuracy of the process. These would include which materials and AM process to use, based on what is being imaged and the modality in use (e.g., X-ray vs. ultrasound).

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Develop guidelines for creating and using phantoms to include material and process used, based on use. Similar to Gap QC7, they may make use of standard image formats that capture enough information to facilitate size, orientation and color normalization and/or validation in post-processing of data.

Priority: ☐High; ☒Medium; ☐Low

Organization: Biomedical Engineering Society, NEMA/MITA, ISO, ASTM, RSNA

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **4/9/2025, B.Ripley, RSNA:** Phantoms are well-suited for standardizing practice in future efforts for practice accreditation. Existing medical imaging phantoms may be leveraged to achieve some of the goals identified in this gap.

New Published Standards	New In-Development Standards

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Gap QC13: Material Control Data and Procedures.

There is a need for well-established material control data and procedures. Materials are primarily manufactured through proprietary methods and, while recommended handling practices exist for each company and each product, standard procedures or standardized considerations are not available. See also FMP4.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: A standard or specification describing a data set for material pedigree, recommended testing, and handling procedures would simplify evaluation of material suitability.

Priority: ☐High; ☐Medium; ☒Low

Organization: Material providers, ASTM

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: Some guidance and requirements will be hardware specific, but general best practices have been capture in some SYSCOMM specs and SDO standards.

New Published Standards	New In-Development Standards

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Gap QC10: Verification of 3D Model.

There are currently no standards for the final verification of a 3D model after it is created from source imaging. The 3D model that goes into the AM fabrication system must also be verified.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: In terms of tolerances

Recommendation: Develop standards for verification of the 3D model.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM F42/ISO TC 261 J64, AAMI, ASME, NIST, ACR, RSNA 3DP SIG, ISO/IEC JTC 1/WG12

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ISO/IEC 3532-1, ISO/IEC DIS 3532-2, ISO/IEC CD 8803, and ISO/IEC CD 16466 address/will address quality, verification, and validation of medical product 3D models.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **4/9/2025, B.Ripley RSNA:** When parts are 3D printed in a hospital or medical center, the 3D printing provider holds the final responsibility and reporting accountability for the verification of the model and all 3D printed parts used for patient care. When an FDA-cleared or

approved medical device is 3D printed, the verification is inherent in the cleared pathway for an intended use.	
New Published Standards	**New In-Development Standards**

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Gap QC15: Sterilization of AM Medical Products.

AM medical products, such as anatomic models, can be made in a healthcare setting. In some instances, these medical products may enter a sterile environment and would therefore require sterilization. The effects of sterilization on the geometric fidelity of the medical product should be assessed. While many standards and industry best practices exist, procedures and protocols for determining appropriate materials, sterilization cycles, and validation tests are available. There is a need for test methods to assess critical geometric features that can be implemented in non-traditional manufacturing environments (e.g., healthcare facilities).

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Develop test methods, guides, and best practices for AM medical products to help identify critical parameters (e.g., geometric features) and apply existing sterilization standards in a clinical setting.

Priority: ☐High; ☐Medium; ☒Low

Organization: AAMI, AOAC International, ASTM, ISO, Parenteral Drug Association (PDA), USP, RSNA 3DP SIG.

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☐Metal; ☒Polymer; ☒Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: N/A

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **4/9/2025, B.Ripley RSNA:** When a 3D printed part has an intended use that includes sterilization, the part must go through sterilization validation, ideally performed by a 3rd party laboratory. It is the responsibility of the provider or manufacturer that created the part to provide sterilization instructions. The 3D printing provider holds the final responsibility and reporting accountability.

New Published Standards	New In-Development Standards

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Gap QC16: Sterilization of 3D Printed Tissue Engineered Products.

3D printed tissue engineered products present a particularly challenging circumstance for sterility assurance. While using a validated aseptic processing protocol for tissue engineered products can maintain sterility, it is not always sufficient or practical. Risk management standards applied during the 3D printing process can help decrease the risks of contamination but do not provide defined measures to ensure sterility or to assess contamination.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: A wide variety of aseptic processing and sterilization protocols exist for tissue engineered products; however, no standards have been published to address validation and testing of these protocols in 3D printed tissue engineered products.

Recommendation: Develop and validate standard methods of sterilizing and verifying the sterility of 3D printed tissue engineered products, especially those that can be applied in healthcare settings.

Priority: ☐High; ☒Medium; ☐Low

Organization: R&D: OEMs, FDA, BioFabUSA. Standards: AAMI, ISO, ASTM, AATB.

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: N/A

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Section 2.3 Recommendations/Comments Since v3 was Published

Additional general recommendations related to the Section 2.3 Qualification & Certification scope, additional gaps, or other considerations since v3 was published are as follows:

- **9/24/2024, J.Schmelzle Compiled:** Equivalency – manufacturing method and material
- **9/24/2024, J.Schmelzle Compiled:** Create guidance for the use of parts-based or situational (life-limited / limp home)

Other Qualification & Certification Activity – Relevance to Gaps Not Yet Determined

New Published Standards

- No additional standards provided as of publication of this report.

New In-Development Standards

- No additional standards provided as of publication of this report.

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SECTION 2.4 NONDESTRUCTIVE EVALUATION (NDE) GAPS

Section #	Gap #, Title and Description	High	Medium	Low
2.4.2	Gap NDE1: Terminology for the Identification of AM Anomalies Interrogated by NDE Methods (Last updated 4/17/2025)	X		
2.4.2	Gap NDE2: Standard for the Design and Manufacture of Physical Reference Standards, Image Quality Indicators, and Representative Quality Indicators to Demonstrate NDE Capability (Last updated 9/24/2024)		X	
2.4.3	Gap NDE3: Standard Guide for the Application of NDE to Objects Produced by AM Processes	X		
2.4.4	Gap NDE4: Dimensional Metrology of Internal Features (Last updated 9/24/2024)		X	
2.4.6	Gap NDE6: NDE of Polymers, Ceramics, and Composite Materials		X	
2.4.7	Gap NDE7: NDE of Counterfeit AM Parts			X
2.4.8	Gap NDE8: NDE Acceptance Criteria for Fracture Critical AM Parts	X		
2.4.9	New Gap NDE9: Effect-of-Defect of AM Defects Detectable by NDE (Last updated 9/24/2024)		X	
2.4.10	New Gap NDE10: In-service Inspection		X	
2.4.3.1	New Gap NDE11: Reliability of NDT		X	
2.4.3.2	New Gap NDE12: 3D Image Quality Indicator for Determining the Sensitivity of a CT System	X		
2.4.3.3	New Gap NDE13: Reference Radiographic Images and Standards for Additive Manufacturing Anomalies (Last updated 9/24/2024)	X		
Section 2.4 Recommendations/Comments Since v3 was Published				

Gap NDE1: Terminology for the Identification of AM Anomalies Interrogated by NDE Methods.

Industry driven standards related to defects have been developed. Many anomalies have been identified but more effort is needed to adopt and reference harmonized anomaly terminology, with appropriate names and descriptions, by the AM industry in standards. The logical repository for AM defect terminology is ISO/ASTM 52900. Therefore, effort needs to be made to adopt consensus anomaly terminology drawn from the existing published standards and from the in-development standards mentioned above so that there is consistency across all voluntary consensus organizations. See also Gap FMP10.

R&D Needed: ☐Yes; ☒No; ☒Maybe

R&D Expectations: There may be open ended questions arise as the AM industry considers adoption of the NDE terminology because the effect of an anomaly (e.g., quasicrystalline microstructure) may need to be studied.

Recommendation: ASME BPVC Section V NDE, ASTM F42, SAE AMS K, ISO TC 261 adopt standardized defect terminology which identify and describe anomalies, and typical locations in a build.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM E07, ASTM F42/ISO TC 261, SAE AMS K, ASME BPVC, AWS D20, NIST

Lifecycle Area: ☒ Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒ Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: E3166 and ISO / ASTM ~~D~~TR 52905 and 52906

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: Standards development has matured, as noted in the text, and contain preliminary definitions for AM anomalies, including pictures of technologically important anomalies, processing and post-processing factors related to their generation and removal, and applicable NDE methods. The ultimate goal is to ballot vetted definition for AM anomalies in ISO/ASTM 52900. Additionally, NDE methods for welded metals are well established and should be reviewed for AM needs. The techniques, minimum flaw sizes indicated and the naming conventions are used for welded metals to join metals together and for weld metal buildups

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/17/2025, B.Dutton: *ISO/ASTM JG59 NP 52971 'Additive manufacturing - NDT - Dimensional measurements on XCT images'*. This document

	addresses how to carry out metrological inspection of additively manufactured parts containing internal cavities which erased from the industrial need. **4/17/2025, B.Dutton:** ISO/ASTM JG59 DIS 52969 / *ASTM WK90673, 'Additive manufacturing for metals — Non-destructive testing and evaluation — Imperfections classification in DED parts'*. This document specifies the classification imperfections likely to be generated during an additive manufacturing process by DED for metallic parts. This document also indicates the most probable causes of the formation of imperfections and includes illustrations. Acceptance criteria for imperfections are not included in this document. **9/19/2024, B.Dutton:** *ISO/ASTM DIS 52948, Additive manufacturing for metals — Non-destructive testing and evaluation — Imperfections classification in PBF parts* is in development. This document specifies a classification of the imperfections likely to be generated during an additive manufacturing operation by PBF-LB (laser beam powder bed fusion) or PBF-EB (electron beam powder bed fusion) for metal parts. This document also indicates the most probable causes of the formation of imperfections and gives some illustrations taken from feedback. This classification applies to both PBF-LB and PBF-EB processes and can be extended to other additive manufacturing processes.

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Gap NDE2: Standard for the Design and Manufacture of Physical Reference Standards, Image Quality Indicators, and Representative Quality Indicators to Demonstrate NDE Capability.
One published standard exists (ISO/ASTM TR 52906) for the design or manufacture of specimens that contain intentionally seeded flaws that can be used to calibrate NDE equipment or demonstrate detection of naturally occurring and intentionally introduced anomalies (lack of fusion, porosity, etc.), or intentionally added features (watermarks, embedded geometrical features, etc.). ISO/ASTM JG59 (previously JG60) has published 52906 which includes ways to design and manufacture artefacts or parts with such defects. ISO/ASTM ~~CD~~ TR 52905 JG59 is partially addressing this with seeded "imperfections" (or flaws) and demonstration of NDT detectability. This standard should identify the

naturally occurring anomalies and intentional features. This standard should also include recommendations regarding the use of existing subtractive machined calibration standards or AM representative artifacts or phantoms. When Image Quality Indicators (IQI) do not work which are representative of the material and process, Representative Quality Indicators (RQI) may be used that are representative of the production part and expected anomaly state. The use of IQIs and RQIs is common in X-ray-based NDE methods such as RT [including digital radiography (DR) and computed radiography (CR)], and in CT. The use of RQIs should be considered for incorporation into the standard(s). See also NDE12.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: (1) Consistently and successfully printing phantoms and measuring them inside the RQI bodies. (2) R&D to define all anomalies that affect the performance of a product and calibration of NDE methods for quantitative analysis of durability of the AM products. (3) Methods to develop phantoms for X-ray CT probability of detection (POD) analysis using AM, traditional manufacturing, and advanced micro/nano-fabrication techniques. The approach of generating artificial flaws may be different for different NDT methods as well.

Recommendation: Complete work on applicable ASTM F42/ISO TC 261 standards (JG59) and ISO/ASTM ~~D~~TR 52905.

Priority: ☒~~☐~~High; ☐~~☒~~Medium; ☐Low

Organization: ASTM F42/ISO TC 261

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☒Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Internal practices

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text. See also sections 2.1.7 Design for Anti-counterfeiting (Gap DE29); 2.2.2.13 (process control); and 2.4.2 Gap NDE7

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap NDE3: Standard Guide for the Application of NDE to Objects Produced by AM Processes.

There is a need for an industry-driven standard led by nondestructive testing experts and supported by the additive manufacturing community to assess current inspection practices and introduce nondestructive testing and inspection requirements.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Round robin testing is underway under ASTM WK78773 (revision of E3166-20e1) to bring in new resonant ultrasonic spectroscopy (RUS) method for whole body characterization of parts. that complements the existing process compensated resonance testing (PCRT) method. ASTM E3397 involves impulse excitation resonance frequency testing. Also, reference radiographs used for radiographic testing of castings and welds are needed for additive manufacturing (see Gap NDE10). A future need will be to spin off test methods from E3166 and ISO/ASTM 52905 guides, which contain precision and bias statements that can be used in accept/reject and in procurement of AM parts.

Recommendation: Complete work on in-development standards listed above.

Priority: ☒High; ☐Medium; ☐Low

Organization: ASTM E07, ASTM F42/ISO TC 261, ASME, NIST

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☒ Other (specify) Test coupons and phantoms

Current Alternative: Current draft of ASTM E3166

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ASTM WK78773 and ISO/TC 261/JG 59 are in development. ASME is also looking at NDE vis-a-vis its boiler and pressure vessel code. The International Committee for Non-Destructive Testing (ICNDT) has formed a specialist international group on NDT reliability to address the deficiencies. There are working groups on standardization of reliability evaluations, human and organizational factors, and reliability for NDE 4.0. Additive manufacturing is one of the interests in this group.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap NDE11: Reliability of NDT.

Current standards only cover binary and signal response ($\hat{a}\ vs\ a$) POD analysis methods based on logistic or linear regression. There are needs for standards and guidance documents dealing with more advanced statistical models, physics-based simulation models, and applications incorporating other factors affecting NDT inspection. Complex AM designs can pose challenges to developing physical reference standards, IQIs and RQIs with representative flaws, and the uses of NDT simulation tools and advanced statistical models are expected for model-assisted or model-based qualification. Guidance on incorporation or assessment of human factors and the evaluation of automated detection/measurement algorithms are also needed.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to improve POD analysis using advanced statistical model, using realistic simulation models, incorporating human factors, and incorporating automated/assisted flaw detection algorithms.

Recommendation: Develop standards or guidance documents on using advanced statistical model for POD analysis. Develop standards or best practice documents on implementing model-assisted or model-based approach POD analysis or NDT qualification. Topics such as physics-based model validation, calibration of the simulation model, statistical models to combine experimental and simulation results are expected to be discussed for various NDT techniques. Develop or improve physics-based simulation tools for emerging NDT techniques and develop workflows/tools to computationally seed desired type of flaws in realistic part geometry. Standards or guidance

documents on carrying out POD analysis for different parameters of the flaws or NDT inspection process may be needed. Extension of NDT from binary flaw detection to flaw characteristic measurements (e.g., flaw sizing accuracy) may be discussed. Develop standards or guidance documents on estimating and incorporating human factors or organizational factors into POD analysis. Standards or guidance documents on assessing accuracy of automated/assisted detection algorithms and incorporation to POD analysis are needed.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): API, ASTM, DIN

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☒Aerospace; ☐Automotive; ☐Construction; ☒Defense; ☐Electronics; ☒Energy; ☐Medical; ☒Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☒Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☐Binder Jetting; ☒Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐ Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Internal procedures, NASA-STD-5009 imposes POD requirements; or USAF is using MIL-HDBK-1823A

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap NDE12: 3D Image Quality Indicator for determining the sensitivity of a CT system.

A 3D IQI will provide objective evidence for the sensitivity of a CT system independent of the final part geometry scanned.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: An 3D IQI that produces CT image data sets which accurately represent system sensitivity.

Recommendation: Complete work on ASTM WK84836 to publish a 3D Image Quality Indicator for CT systems standard

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASME; ASTM E07.01.02 Radiology (X and Gamma) Method, Non-Film Methods

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary methods for comparing CT system sensitivity.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap NDE13: Reference Radiographic Images and Standards for Additive Manufacturing Anomalies.

To standardize the radiographic inspection of additive manufactured components, reference radiographic data (2D and 3D) of common anomalies in AM need to be developed.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Reference radiographic images (2D and 3D) for additive manufacturing anomalies.

Recommendation: Develop reference radiographic images (2D and 3D) and acceptance standards for additive manufacturing anomalies.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM E07.02 Reference Radiological Images

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☐All/Process Agnostic; ☒Binder Jetting; ☒Directed Energy Deposition; ☐Material Extrusion; ☒Material Jetting; ☒Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary test methods and acceptance criteria

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: Recommend medium or low priority. Focus should be on the specs required to inspect AM parts such as volumetric IQI/RQI development. Reference images do not help with inspection process qualification, where the current challenges exist.

New Published Standards	New In-Development Standards

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Gap NDE4: Dimensional Metrology of Internal Features.

The utility of existing and draft CT standards is needed for the dimensional measurement of AM internal features and surface roughness.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Characterization of machine performance and task specific measurement uncertainty on AM parts.

Recommendation: ASTM E07 should address the applicability of current and draft CT standards (E1570, E1695, and WK61161) for measurement of internal features and surface roughness in additively manufactured parts, especially parts with complex geometry, internal features, and/or embedded features. Current CT metrology state-of-the-art needs to be tailored to evolving AM part inspection requirements. See also Gap DE26, Measurement of AM Features/Verifying the designs of features such as lattices, etc. Standard methods need to be developed for assessing surface roughness from CT and structured light data from AM surfaces. See also Post Processing section 2.2.3.4 Gap P4.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM, ISO/IEC JTC 1/WG12

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Ultrasonic and hall effect wall thickness measurements can be used for walls with one external surface. Company specific internal procedures, as well as other existing standards and CT software to determine dimensional accuracy of topology optimized complex geometry AM parts are used.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: As noted in the text. Also, E1570 and E1695 are more general in their approaches and are not specific to AM. There is guidance for testing; however, it does not provide a definitive method for internal features.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: Recommend moving surface roughness into a separate gap, with a lower priority. This does not seem achievable using CT.
- **9/24/2024, J.Schmelzle Compiled**: Concur with the recommendation, however the intent of ASTM E1695 may not be to qualify a scan technique for dimensional metrology. Would look to understand how ASTM E3375 could more broadly cover dimensional metrology in addition the current qualification to inspect specified discontinuities.

New Published Standards	New In-Development Standards
	9/19/2024, B.Dutton: ISO/ASTM JG59 PWI 'Additive manufacturing — NDT — Dimensional measurements on XCT images'

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Gap NDE6: NDE of Polymers, Ceramics and Composite Materials.

No published or in-development standards or specifications have been identified for NDE of polymers, ceramics and composite materials.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Research who uses filaments, powder, or pellets with and without continuous fiber, chopped fiber, and particle reinforcement. Of interest are low density, high specific strength plastics used in secondary structural applications, and polymers with a high degree of fiber or particle loading in applications requiring strength, toughness and low weight. Users and manufacturers of such materials need to be surveyed to determine what requirements they are anticipating for NDE inspection of parts made from polyetherimides (PEI), polyaryl ether ketones (PAEK), composite non-metallic AM parts (for example, carbon-filled nylon), unfilled thermoplastics (ABS, PC, PLA, nylon, etc.), and SLA UV-curable resins. Polymers such as Ultem® 9580 PEI, which is used in FFF/FDM parts (air ducts, wall panels, seat frameworks) and is flame, smoke and toxicity (FST) compliant and has excellent specific strength are noteworthy. Ceramic materials of interest are those with high flexural strength and hardness, such as alumina, zirconia and silicon nitride, fabricated using photocurable resin or other aqueous and non-aqueous-based, sheer thinning feedstocks.

Recommendation: There is a need for an industry-driven standard led by NDE experts and supported by the additive manufacturing community to assess current inspection practices and introduce NDE inspection requirements for structural or load bearing polymers, ceramics, and composite materials. Use ASTM E2533 as a starting point and guideline when applicable.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM F42/ISO TC 261, ASTM E07, ASTM D20, ASME, SAE AMS AM

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☐All/Material Agnostic; ☐Metal; ☒ Polymer; ☒Ceramic; ☒Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Company specific internal methods

V3 Status of Progress: ☒ Green; ☒Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; New

V3 Update: As noted in the standards list above, ASTM WK85121 will address polymers and ASTM Interlaboratory Study 1814 will recommend standards needs for ceramics.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap NDE7: NDE of Counterfeit AM Parts.

There are no published or in-development NDE standards for methods used to verify anti-counterfeiting methods.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: Future R&D may be needed if an anti-counterfeiting method is developed which cannot be verified by existing NDE methods or standards.

Recommendation: Develop NDE methods and standards for anti-counterfeiting that are not addressed by existing methods or standards. See also sections 2.1.7 Design for Anti-counterfeiting (Gap DE29); 2.2.2.13 Anti-counterfeiting (process control); and 2.4.2 Gap NDE2.

Priority: ☐High; ☐Medium; ☒Low

Organization: ASTM F42/ISO TC 261, ASTM E07, SAE AMS-AM

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☒Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: ISO 22380 has been published and SAE AS5553B has been revised, the current edition, D, was approved in 2022.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap NDE8: NDE Acceptance Criteria for Fracture Critical AM Parts.

There is a need for an industry standard that establishes NDE acceptance criteria and classes for fracture critical AM production parts. The classes could be based on:

1) fracture criticality (NASA-STD-5009)
2) consequence and likelihood of failure (NASA-STD-6030)
3) design loads (JAXA and LMCO)
4) NDE inspection capability (ASTM WK75329)
5) other factors such as mission or safety criticality

Potential stakeholders are NASA, its international space partners, the aerospace industry, the commercial aviation industry, the FAA, the DoD, the DOE (for example, the NRC), the nuclear industry, or any entity that produces or uses fracture critical AM hardware.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: This gap interfaces with Gap NDE9 described in Section 2.4.9 and focuses on the acceptance of AM production parts destined for service. Acceptance consists of NDE of production parts or components. It is anticipated that parts will be made using optimized processes (for example, NASA-STD-6060 qualified material processes), which contain minimal or otherwise controlled loadings of technologically important AM defects. These in-family parts will then be compared to out-of-family parts, which either contain excessive loadings of technologically important AM defects, or have been made with questionable feedstock, or have been subjected to a known process anomaly, thus compromising their acceptance and subsequent use in service. Research can then focus on identifying what feedstock or process (or post-process) conditions led to nonconformance and out-of-family behavior. The role of NDE will be to distinguish between in-family (nominal) versus out-of-family (non-nominal) production parts possessing different characteristic damage states. For example, one of the key questions to answer would be to determine which process variable(s) are relevant and have the greatest effect on the performance of the part. Also, the type of scanning (i.e., X-ray radiography, CT, micro-CT, PCRT) relative to the material type/thickness and design complexity of the part should be considered.

Recommendation: Develop an industry standard that establishes different acceptance classes and NDE acceptance metrics for high fidelity of finished production parts and components depending on feedstock, and process (or post-process) conditions. The acceptance metrics (criticality, consequence and likelihood of failure, loads, etc.) are expected to be industry specific (aerospace, medical, energy sectors). Part and component level NDE inspections may be corroborated with effect-of-defect coupon (or witness specimen) level testing described in Gap NDE9 using specimens that have the appropriate level of fidelity, i.e., sufficient similarity between the defect state and mechanical response in sacrificial samples (for example, ASTM E8 compliant dog bones, and witness coupons showing the same level of defects) with natural flaws in actual production parts.

Priority: ☒High; Medium; ☐Low

Organization: ASTM F42 / ISO TC 261 JG 59, ASTM E07, ASTM E08 on Fracture and Fatigue

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify)

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: AWS D20.1 contains acceptance criteria but is also planning to address internal flaws matched with surface finish for fatigue applications. ASTM WK75329 will be a standard practice for NDE of PBF-LB aerospace components, establishing NDE acceptance classes and acceptance criteria. The criteria are based on the practical limits of NDE technology, not effect-of-defect.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap NDE9: Effect-of-Defect of AM Defects Detectable by NDE.

There is a need for an industry standard to determine the effect of technologically important flaws unique to AM, which are considered to relevant and have a significant effect on end-use properties. Contrary to Gap NDE8, which uses acceptance criteria based on NDE capability developed for production parts or components, Gap NDE9 investigates the effect-of-defect at the coupon level (or witness specimen level). Direct cause-and-effect relationships between process (and/or post-processing), the resulting defect state, and final properties is established (process-structure-property relationship). Important questions such as whether defects can be healed through hot isotactic

pressing (HIP) or heat treatment can also be examined if necessary. Questions about equivalency between subscale and production parts can be accomplished by verifying or augmenting subscale part with production part data.

To obtain meaningful results, control coupons (or witness specimens) are made using the same materials and processes as used for the production part. The defect state is then intentionally altered using guidance in ISO/ASTM TR 52906-EB. The specimens so obtained will possess a range of defect states, which will be characterized by NDE. The specimens called out in this standard can be fabricated in the form of standard test specimen geometries for tensile testing (ASTM E8, D638, D5766, D6742), compressive testing (ASTM D395), fatigue life (ASTM E466, E606), fracture toughness (ASTM E399, E1820), etc., as outlined in Tables 13 through 16 in NASA-STD-6030.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: A multidisciplinary effort is needed encompassing feedstock selection, AM processing and post-processing, NDE, and physical and mechanical property testing. Coupons (or witness specimens) are made at one or several manufacturers are analyzed by NDE and finally by destructive testing (mechanical and physical property testing). Round robin testing following the outline of than ASTM interlaboratory study (ILS) would be ideal subscale test coupons are interrogated by NDE at several labs to assess NDE reproducibility and repeatability and leading to NDE Precision and Bias statements. This gap interfaces and with proper coordination can be combined with Gap NDE8 by fabricating witness coupons at the same time as production parts. The coupon-level test specimens fabricated by this standard will contain controlled loadings of technologically important AM defects, which are then used to determine the effect-of-defect in order to assess relevance or nonrelevance. The relevance of flaw type, size and distribution as characterized by NDE is compared to part performance as indicated by mechanical and physical property test results. The goal thus is to develop acceptance criteria based on knowledge of the characteristic defect state rather than on NDE reliability and fracture mechanics and has application to both metallic and polymeric (including composite) AM parts.

Recommendation: Develop an industry standard that allows fabrication of subscale test specimens (standard test coupons) that directly link the characteristic defect state with end-use performance properties such as strength, modulus, fracture toughness, and part density.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM F42 / ISO TC 261 JG 59, ASTM E07 on NDT, ASTM E08 on Fracture and Fatigue, NASA

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) ☒Test coupons and artefacts

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled**: This should be high priority. AM materials should be better understood in order to utilize for more application spaces and for higher performing or higher criticality parts. This is currently a large gap.

New Published Standards	New In-Development Standards

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New Gap NDE10: In-service Inspection.

There is a need for standards for in-service inspection of safety-critical AM components. Some installed AM parts (e.g., nuclear industry applications) cannot be removed for inspection. The effects of chemical, heat, and radiation degradation on AM materials and components, and the service life and inspection intervals thereof, are presently unknown.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D is needed to demonstrate which in-service NDE methods or techniques can identify critical flaws in safety-relevant AM components. Prior to implementing in-service NDE, critical flaw types and locations should be identified in addition to degradation mechanisms. The effects of material microstructure and geometry should be explored. New or emerging NDE techniques, such as ultrasonic full matrix capture, targeted micro-CT, and PCRT, may need to be tested. An increased understanding about how surface finish issues common with additive parts would affect eddy current measurement states is needed.

Recommendation: Develop standards for in-service inspection of AM components. Standards may describe issues including, but not limited to, what types of flaws to look for, where critical flaws might occur (i.e., the relevant inspection volume), how critical flaws might propagate (i.e., rates of propagation, degree of branching), the level of component surface finish that is needed, methods for inspecting complex geometries, and guidelines for reference mockups and standards. It is

recommended that exemplar AM components used in critical applications (nuclear, aerospace, and/or medical) that present unique NDE inspection challenges will be fabricated with known relevant flaws (e.g., porosity) and distributed to stakeholders in a round robin study conducted over the course of a component's life cycle. For example, components with accumulated service as measured by time and number of cycles would be inspected at intervals characteristic of 1) post—fabrication/pre-installation (new or early life), 2) periodic-remove and inspect (mid-life), 3) decommissioning/component replacement (near end-of-life), and 4) ultimate failure (end-of-life).

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASME, ASTM

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☐Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☒Energy; ☐Medical; ☐Spaceflight; ☒Other (specify) Nuclear

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion;☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Use existing in-service inspection standards developed for non-AM parts and materials.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

Section 2.4 Recommendations/Comments Since v3 was Published

Additional general recommendations related to the Section 2.4 NDE scope, additional gaps, or other considerations since v3 was published are as follows:

New Gap Suggestions

The following gap(s) was suggested during comments against the gaps progress report. This language did not go through AMSC working group or public review. It is for information only and has not been assigned an AMSC gap number but may be considered by the AM standardization community.

9/29/2024, NIAR Compiled: A new gap on NDE method to characterize surface inspection shown to relate as-printed fatigue specimens.

Other Nondestructive Evaluation Activity – Relevance to Gaps Not Yet Determined

New Published Standards

- No additional standards provided as of publication of this report.

New In-Development Standards

- No additional standards provided as of publication of this report.

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SECTION 2.5 MAINTENANCE AND REPAIR GAPS

Section #	Gap #, Title and Description	High	Medium	Low
2.5.2	Gap M1: AM Analyses in RCM and CBM (Last updated 9/24/2024)		X	
2.5.4	Gap M4: Physical Inspection of Parts Repaired Using AM		X	
2.5.5	Gap M5: Model-Based Inspection (Last updated 9/24/2024)		X	
2.5.6	Gap M6: Tracking Maintenance (Last updated 9/24/2024)			X
2.5.7	Gap M8: Surface Preparation for Additive Repair (Last updated 9/24/2024)		X	
2.5.3	Gap M9: Laser Based Additive Repair (Last updated 9/24/2024)	X		
2.5.7	New Gap M10: Best Practices on Repair using Additive Manufacturing (Last updated 9/24/2024)			X
Section 2.5 Recommendations/Comments Since v3 was Published				

Gap M1: AM Analyses in RCM and CBM.

With respect to maintenance and sustainment of AM machines, standards for AM analyses in Reliability Centered Maintenance (RCM) and Conditioned Based Maintenance (CBM^+) are needed. CBM^+ is built upon RCM. See also PC13.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Update SAE JA 1012-2011, a guide to provide analytics for AM trade-offs in RCM and CBM^+.

Priority: ☐High; ☒Medium; ☐Low

Organization: SAE, ISO, ASTM

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: OEM preventative maintenance requirements outlined in maintenance manuals.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: SAE G-11M, Maintainability, Supportability and Logistics Committee, will consider inclusion of analytics for AM trade-offs in the next update of JA1012.

See also Gap PC2 on machine calibration and preventative maintenance, and Gap PC14 on environmental health and safety issues and protection of AM machine operators.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap M9: Laser Based Additive Repair.

Current standards do not specifically address the use of laser-based systems (metal powder or wire feedstock) to additively repair parts or tools.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Ensure that laser based additive repair processes are included in AWS D20.1 and SAE AMS-AM Additive Repair for Aerospace Applications.

Priority: ☒High; ☐Medium; ☐Low

Organization: AWS, SAE AMS-AM, DoD

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Qualifying repair documents provided to customers.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: AWS D20.1 contains requirements for qualifying wire-fed and powder-fed laser DED procedures. In paragraph 5.2.3.2, AWS D20.1 requires that tension test specimens that include the material interface in the gage region be removed from procedure qualification builds used to qualify repairs.

SAE's AMS-AM Additive Manufacturing Committee established the Additive for Repair Working Group in September 2018. Currently developing a scenario to establish the specification framework utilizing a damaged airframe component requiring a directed energy deposition repair. Once finalized, the working group plans to develop material and process specifications for aerospace repair applications.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Unsure how repair changes compared to new part manufacture other than needing to know condition of existing part (wear, dimensions/distortion, material condition) and the current gap of how to heat treat that repaired part once additive material is deposited. AWS D20 can be used for repair applications as is.

New Published Standards	New In-Development Standards

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Gap M4: Physical Inspection of Parts Repaired Using AM.

A standard inspection process for component or tooling defects is needed to consider additive manufacturing technologies as potential solutions for preventative and corrective maintenance actions.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Update SAE JA1011/1012 to include an inspection process for additive manufacturing repairs.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM, ISO, SAE

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Existing inspection methods being used to determine if it still meets the original requirements of the original part.

V3 Status of Progress: ☐Green; ☒Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: SAE G-11M, Maintainability, Supportability and Logistics Committee, will consider inclusion of an inspection process for AM repairs in the next update of JA1011 and JA1012.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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Gap M5: Model-Based Inspection.

Standard practices for model-based inspection methods using AM are needed for repair assessments and scheduling.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Develop standard practices for assessing level of damage for end-use parts.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASME, ISO/ASTM, Dimensional Metrology Standards Consortium

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Existing inspection methods being used to determine if it still meets the original requirements of the original part.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Is there a role for - Digital Twin of inspected parts and monitoring/recording keeping of those results?

New Published Standards	New In-Development Standards

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Gap M6: Tracking Maintenance.

A standard is needed for how preventative maintenance operations of AM machines are tracked (e.g., monitoring printer health, need for servicing, etc.). See also Gaps PC2 and PC3.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Develop a standard for tracking maintenance operations to ensure a printer is ready when needed. See also Gap PC2 on machine calibration and preventative maintenance and PC3 on machine health monitoring. Develop a standard to address emergency repair/limited life parts for urgent cases in the field.

Priority: ☐High; ☐Medium; ☒Low

Organization: AWS, ASTM, ISO, TAPPI

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Machine operations and maintenance manuals

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: No general machine maintenance standard is in development. Individual standards may have sections within them that recommend maintenance. Additionally, each machine will have its own maintenance manual which should be followed. Lastly, *ASTM AM CoE Strategic Roadmap for Research & Development (April 2020)* notes that AM CoE Project 1901 (WK71395) under F42.01 addresses AMSC Gap M6.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:	
• No comments as of publication of this report.	
New Published Standards	**New In-Development Standards**

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Gap M8: Surface Preparation for Additive Repair.

Standards are needed for chemical compatibility with additively manufactured materials for surface cleaning in preparation for an additive repair process. Additionally, standards are needed for removal of coatings, including paints and powder coating, and plating (chrome, zinc, etc.) for additively manufactured parts.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Develop standards for approved chemical substances and mechanical processes used for the removal of coatings and plating on additively manufactured components, to include metals, polymers, ceramics, and other materials.

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM, SAE, ISO, AMPP, AWS D20.1

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Agreement between customer and organization performing repair.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☒Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** There are best practices out there already. NAVAIR has performed various types of excavation and media blast treatments in addition to surface cleaning to prepare for AM repair. Similarities can be made for welding best practices. Not sure if this needs to be a high priority since every part and material is different.

New Published Standards	New In-Development Standards

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New Gap M10: Best Practices on Repair using Additive Manufacturing.

Currently, there is no standardized guidance on the maintenance and repair using additive manufacturing. This could be a horizontal guidance applicable to all sectors detailing the best practices for manufacturers or servicers performing maintenance and repair using AM.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Develop best practices on maintenance and repair using additive manufacturing covering topics such as safety and reliability parameters, certification of product, and qualifications of AM parts. Considerations for moving repairs from machine to machine (e.g., for DED) should be included.

Priority: ☐High; ☐Medium; ☒Low

Organization: ASTM, NEMA, ISO, SAE

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☐Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Agreement between customer and organization performing repair.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New
STATUS OF GAP PROGRESS
Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.): • No updates as of publication of this report. **Other Committees with Relevant Work:** • No updates as of publication of this report. **Comments Received on Gap for Future Consideration:** • **9/24/2024, J.Schmelzle Compiled:** This is a widely broad topic that depends on so many factors. Perhaps each process category could receive a specification for outlining best practices for repair? Every part/material is different and might require different steps for preparing for repair.

New Published Standards	**New In-Development Standards**

Section 2.5 Recommendations/Comments Since v3 was Published

Additional general recommendations related to the Section 2.5 Maintenance and Repair scope, additional gaps, or other considerations since v3 was published are as follows:

- No recommendations received relation of publication of this report.

Other Maintenance & Repair Activity – Relevance to Gaps Not Yet Determined

New Published Standards

- No additional standards provided as of publication of this report.

New In-Development Standards

- No additional standards provided as of publication of this report.

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SECTION 2.6 DATA GAPS

Section #	Gap #, Title and Description	High	Medium	Low
2.6.2.1	New Gap DA1: Standard Data Format for Material Characterization (Last updated 4/6/2025)	X		
2.6.2.2	New Gap DA2: Process Specific Common Data Dictionary (Last updated 4/6/2025)	X		
2.6.2.3	New Gap DA3: Digital Format for In Process Monitoring Data (Last updated 4/14/2025)	X		
2.6.2.4	New Gap DA4: Data Capturing for Machine Logs During a Build (Last updated 4/6/2025)	X		
2.6.2.5	New Gap DA5: Extended Design Specifications for Meta-Data Format Standardization (Last updated 9/25/2024)	X		
2.6.2.6	New Gap DA6: Specifications and Representations for AM Big Data (Last updated 4/6/2025)		X	
2.6.2.7	New Gap DA7: Additively Manufactured Electronics (AME) Data Transfer Format (Last updated 4/8/2024)	X		
2.6.2.8	New Gap DA8: Customizable Standard AM Data Collection Templates (Last updated 4/14/2025)	X		
2.6.3.1	New Gap DA9: Best Practices and/or Specifications for Registering and Fusing Data Sets During the AM Manufacturing and Inspection Process (Last updated 4/14/2025)	X		
2.6.3.1	Gap DA10 (formerly NDE5 in V2): Standard Guideline for NDE Data Fusion (Last updated 9/24/2024)		X	
2.6.3.2	New Gap DA11: Best Practices for Anomaly Characterization and Localization for Part Defect Prediction Purpose	X		
2.6.3.3	New Gap DA12: Consistent Part Traceability and Provenance (Digital Twin) (Last updated 4/14/2025)		X	
2.6.3.4	New Gap DA13: Data Visualization		X	
2.6.4.1	New Gap DA14: Best Practices and Guidance for AM Data Collection (Last updated 9/24/2024)	X		
2.6.4.2	New Gap DA15: Data Aggregation of Time Series and Object Data (Last updated 4/14/2025)		X	
2.6.4.3	New Gap DA16: Data Retention Guidelines		X	
2.6.5	New Gap DA17: Assessment and Specifications of AM Data Quality		X	
2.6.6.1	New Gap DA18: Reference Workflow (Digital thread) for AM Part Fabrication (Last updated 4/14/2025)		X	
2.6.6.2	New Gap DA19: Context and Scenario-specific Data Selection		X	
2.6.7.1	New Gap DA20: AM-Specific Security Guidance (Last updated 4/14/2025)		X	
2.6.7.2	Gap DA21 (formerly M7 in V2): Additive Manufacturing Supply Chain Security		X	
2.6.7.3	New Gap DA22: Technical and IP Authentication and Protection	X		

Section #	Gap #, Title and Description	High	Medium	Low
2.6.8.1	New Gap DA23: AM Machine Data Framework and Guideline for Automated AM Data Integration and Management	X		
2.6.9.1	New Gap DA24: Medical AM Design File Retention (Last updated 4/8/2025)		X	
2.6.9.2	New Gap DA25: Quality Management of Medical AM Files (Last updated 4/18/2025)	X		
Section 2.6 Recommendations/Comments Since v3 was Published (Last updated 3/25/2025)				

New Gap DA1: Standard Data Format for Material Characterization.

There are no standard material characterization data models and formats supporting the curation and exchange of AM material test, inspection and characterization results and metadata.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: R&D activities are needed to collect various material characterization reporting requirements and to develop a unified data model as well as type specific models to represent AM material characterization data and metadata.

Recommendation: Various SDOs, professional organizations, their technical committees' members should get together to harmonize the existing data reporting requirements and turn them into standards data formats. Multiple standards should be developed to capture 1) (standard practice) General data structure for AM material characterization; 2) Type specific standards format for AM material characterization data representation.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM, ISO, SAE, ASM

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☐Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- **04/06/2025, Y.Lu:** AM Common Data Modeling (CDM) group is working on a common data model for Test/Inspection/Characterization.
- **04/06/2025, Y.Lu:** ASTM CMDCS is working on creating a common data template for tensile test data curation.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	04/08/2024, B.Zollo: ISO TC261 J64 has begun outreach to industry stakeholders seeking to identify AM material definitions and schema to add to the next version of ISO/ASTM 52915 additive manufacturing format specification for file meta data.

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New Gap DA2: Process Specific Common Data Dictionary.

There are no standard process specific common data dictionary supporting the curation and exchange of data associated with a specific process type, for example, data terms used specifically for PBF, DED, BJ, FDM etc.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: R&D activities are needed to explore type-specific process data and equipment data elements, which also depend on the vendors of the equipment.

Recommendation: Develop process specific common data dictionary standards. ASTM COE, SAE ITC AMDC and America Makes etc. are creating standard data collection templates to curate data contributed by their members. The standard efforts should leverage on those efforts.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM F42, ISO TC 261, SAE AMS

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary data dictionaries.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- **04/06/2025, Y.Lu:** ASTM CMDS is working on creating a common data template for PBF process data curation.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA3: Digital Format for In Process Monitoring Data.

No published or in-development standards have been identified for "digital format for in process monitoring" for additive manufacturing technology. See also section 2.6.4.1 / Gap DA14 for AM Data Collection.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Possible development of a protocol /procedure to standardize processing monitoring data format to facilitate data/knowledge sharing for process monitoring.

Recommendation: Develop standard protocol for "digital format for in process monitoring" and address process-specific needs and/or variations in how process technologies could be monitored. The process data collected from diversified sensing systems and different machines can be transformed into a unified format with standardized data importing/exporting and sharing routines to facilitate broader collaboration.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): unknown

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☒~~☐~~Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ~~☐~~☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

04/06/2025, Y.Lu: AM Common Data Modeling (CDM) group is working on a common data model to capture AM Process data as data objects.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** Does this include data collected from the sensors *and* the machine's galvos/servos or is this included in Gap DA4?

New Published Standards	New In-Development Standards
4/14/2025, NIST Compiled: *ASTM F3605-23, Standard Guide for Additive Manufacturing of Metals-Data-File Structure for In-Process Monitoring of Powder Bed Fusion* has been published- may be noted elsewhere.	**03/31/2025, Y.Lu:** *ISO/ASTM AWI 52970, Additive manufacturing - Data – Data capturing and structure for PBF-LB/M machine log* specifies the uniform structure of the machine log file for PBF-LB/M machine operations, aimed at facilitating further processing. It is confined to the data provided by a PBF-LB/M machine during or after the production process.

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New Gap DA4: Data Capturing for Machine Logs During a Build.

No published or in-development standards have been identified for "Data Capturing of Machine Logs During A Build" for additive manufacturing technology. See also Gap DE9 on AM Simulation Benchmark Model/Part Requirement

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: Possible development of a service to standardize machine log data outputs.

Recommendation: Develop standards for "Data Capturing for Machine Logs During a Build." The machine's status can be communicated through OPC-UA, MT Connect, MQTT, RESTful API calls to local databases (or equivalent) where data is being logged, reports generated from vendor software, or clear text log files on the machine itself. This new standard should pick one that provides the most well-rounded machine data results and provide a standard format for the output and a method to declare what outputs should be generated.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM, ISO

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☒Other (specify) Additional machine sensors

Current Alternative: Adoption of OPC-UA, MQTT, or log file parsing on a company-by-company basis.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- OPC Foundation Working Group Additive Manufacturing

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
4/14/2025, NIST Compiled: *ASTM F3605-23, Standard Guide for Additive Manufacturing of Metals-Data-File Structure for In-Process Monitoring of Powder Bed Fusion* has been published- may be noted elsewhere. **03/31/2025, Y.Lu:** *ISO 14649-17: 2020, Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers Part 17: Process data for additive manufacturing* (TC184/SC1) specifies the process data for additive manufacturing. This document describes additive manufacturing at the micro process plan level without making a commitment to particular machines, processes or technologies.	**03/31/2025, Y.Lu:** *ISO/ASTM AWI 52970, Additive manufacturing - Data – Data capturing and structure for PBF-LB/M machine log* specifies the uniform structure of the machine log file for PBF-LB/M machine operations, aimed at facilitating further processing. It is confined to the data provided by a PBF-LB/M machine during or after the production process. **9/27/2024, P.Witherell:** JG83 has been established between ASTM F42 and ISO TC 261 on "Digital Quality Assurance" and the first draft standard to go to ballot with be on a standardized machine log for PBF-LB monitoring. **9/24/2024, J.Schmelzle Compiled:** OPC 40540 for Additive Manufacturing is working on this for OPC UA Companion Specification — MTConnect

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New Gap DA5: Extended Design Specifications for Meta-Data Format Standardization.

There is a need to standardize the type, naming conventions, and schema meta data used in design and work flow and is essential to additive manufactured part and assembly quality, cyber-security and intellectual property protection. This includes for example, meta data specifying unique file ID number, file source, material attributes, color attributes, dimension attributes, tolerance attributes, surface characteristics, assembly characteristics, intellectual property attributes, cyber-security attributes and any additional meta data needed to meet quality specifications, such as layer height, print orientation, support structure attributes, and embedded labeling requirements.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Standardize definitions and meta data schema for essential design, print, cybersecurity and intellectual property specification information for inclusion in the ISO/ASTM 52915:20 standard. Utilize and expand this standard's current list of meta data definitions and schema. The standard specifies meta data fields in XML v1 format for "material, color, tolerance, ID numbers, source "and other attributes, but lacks schema specifications for these meta data types. The standard includes a general purpose "meta data" attribute that allows for inclusion of additional types

of meta data. Create definitions and schema for additional meta data identified necessary to ensure quality, cyber-security and intellectual property protection through the AM work flow to be listed in this "meta data" attribute.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM F42.08, ISO/ASTM TC261, J64, NIST

Lifecycle Area: ☒Design; ☐Precursor Materials; ☒Process Control; ☒Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photo polymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☒Other (specify): Design specifications and design file, meta-data

Current Alternative: Ad-hoc proprietary methods

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **9/25/2024, B.Zollo**: Chapter 3.4(c) on Data Management of *DoDI 5000.93, Use of Additive Manufacturing in the DoD* requires the use of a data package standard and format, as appropriate for AM, in accordance with MIL-ST-31000, ISO/ASTM 52915:20 and accepted non-U.S. Governmental standards.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	9/25/2024, B.Zollo: ISO/ASTM JG64 on File Formats for AM is implementing a new work project to create specifications for meta-data that will address the of technical data requirements listed in the recommendations to

	this gap. New meta-data and schema will be considered for addition to the next version (1.3) of the ISO/ASTM 52915 standard, and the ISO TC261/ASTM JG64 meta data specification work project planned for 2024-2025. **04/08/2024, B.Zollo:** TC261 J64 has begun outreach to stakeholders seeking input on new candidate meta data definitions and schema that can be added to the next version(v1.3) of ISO/ASTM 52915.

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New Gap DA6: Specifications and Representations for AM Big Data.

There currently exists no best practices or standard specifications for capturing and curating the "Big Data" in AM. Emerging uses of this data, including part qualification and digital twins, will require standardized structure and best practices for consistent interpretability and analysis. See also Gap DE9 on AM Simulation Benchmark Model/Part Requirement

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Identifying if a single specification, set of specifications, or a guide that best meets this gap. Identifying ways to meet the gap in a neutral format that can be accessed by different parties.

Recommendation: Develop standards which leverage the FAIR principles and ad hoc approaches, engage with software vendors, practitioners, and acceptance authorities to determine best way forward.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASTM/ISO, NIST

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Ad hoc

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **03/31/2025, Y.Lu:** The *NIST AMS Metadata Modeling for Manufacturing Enterprise Integration report* was published (Jan 6, 2025) on metadata modeling for manufacturing data objects, including big data generated and used throughout AM development lifecycle.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- **9/24/2024, J.Schmelzle Compiled:** What is the definition for Big Data? Size? Isn't this captured elsewhere in this section or does this include post-processing, summarizing, compressing too?

New Published Standards	New In-Development Standards

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New Gap DA7: Additively Manufactured Electronics (AME) Data Transfer Format.

AME substrates create traditional 3D components and interconnect structures, e.g., antennas and coaxial cables, within and/or the surface of the substrate. To create a true design to manufacturing high reliability automated data transfer process requires the 3D CAD information to be incorporated into the 2.5D electrical CAD data.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Both ECAD and MCAD software will require development to define test and then implement the new data standard. Existing PCB layout software only allows trace routing on X-Y layers with vias connecting the layers. AME technology allows signal routing in the X, Y, &Z axis simultaneously without the use of vias. Also, 3D structures, such as coils, can be created within the structure and connected to signal nets at any z-axis coordinate, such as surface mounted components.

Recommendation: The industry needs to start the data format definition based on IPC-2581. It will take 1-2 years to define the standards, another 1-2 years to fully implement and another 4+ years for industry adoption using traditional new data format development cycle times. See also Section 2.3.3.5 and Gap QC22.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM, IPC, ISO TC261

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Using multiple industry and proprietary data formats, email, and ePaper for data transfer with human intervention to interpret and transcribe the data.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐ Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- **04/08/2024, B.Zollo:** ISO TC261

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	04/08/2024, B.Zollo: ISO TC261 has begun discussions with AME industry stakeholders to explore technical collaboration to augment ISO/ASTM 52915 specifications to address 3D support in future IPC-2581 revisions.

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New Gap DA8: Customizable Standard AM Data Collection Templates.

There is no standard or customizable data collection template that simplify the data acquisition process and support AM process (e.g., DED would be different than PBF) and material (during product

development) activities. This gap focuses on simplifying the acquisition of data, where gap DA19 Context and Scenario-specific Data Selection focuses on the selection of relevant AM requirements.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Data templates should be created for AM material, system, process and part qualification and requalification. Standardized and customizable AM data collection templates, with the use of AM common data dictionary like ASTM F3490-21, then can be established for various process categories, material types and part type.

Recommendation: Develop multiple standard data collection templates for material, process and parts respectively. Standard templates can then be customized for various material types, process categories and different part types. See also gap DA1.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): America Makes, ASTM CoE, NIST, ASTM F42

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary data collection templates, or consortium developed data collection templates, for example, AMNOW data templates, ASTM CMDS data entry excel sheets.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- **03/31/2025, Y.Lu:** ASTM CMDS PBF data curation templates (Excel sheets).

Other Committees with Relevant Work:

- **4/14/2025, NIST Compiled**: Ongoing efforts in development of common data models in AM, not yet under a specific SDO

Comments Received on Gap for Future Consideration:

• No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA9: Best Practices and/or Specifications for Registering and Fusing Data Sets During the AM Manufacturing and Inspection Process.

There are no data registration and fusion standard supporting AM data registration and data fusion for process monitoring and control, part inspection and testing, and AM qualification and certification.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D activities are needed to explore the equality of multi-modality data fusion for part qualification compared to the traditional test intensive qualification methods.

Recommendation: Multiple methods are needed to address the gap:

- AM data registration standards
- Specific industry data fusion standards for integrative AM data analysis for process monitoring, qualification and part certification
- Expert education, training, and certification for AM data fusion for process control, NDT and qualification.

Collaborative efforts should be made by government agencies, academia and industry to develop new data registration and fusion methods to support process control, NDE data fusion for post process part inspection and qualification, and material and process development based on both simulation and measurement data from various material and processes.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): IEC, ISO, ASTM, NIST

Lifecycle Area: ☒Design; ☐Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☒Binder Jetting; ☒Directed Energy Deposition; ☒Material Extrusion; ☒Material Jetting; ☒Powder Bed Fusion; ☒Sheet Lamination; ☒Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary solutions.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/14/2025, NIST Compiled: ASTM/ISO JG73 standard *ISO/ASTM FDIS 52953, Additive manufacturing for metals — General principles — Registration of geometric data acquired from process-monitoring and for quality control* should be finalized by 2025. This document sets and defines the minimum requirements for registration of data acquired from process monitoring and for quality control in additive manufacturing (AM), including the description of a procedure. **9/24/2024, J.Schmelzle Compiled**: *IDETC/CIE 2021, In-Process Data Fusion for Process Monitoring And Control of Metal Additive Manufacturing*

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Gap DA10 (formerly NDE5 in V2): Standard Guideline for NDE Data Fusion.

NDE data plays an important role in product acceptance/rejection, validation of simulation/predictive models, process improvement, and potentially process control. Since multiple sources and results are combined in data fusion, there is a possible issue of a non-linear data combination that can produce results that can be influenced by the user. Additionally, data fusion may employ statistical techniques that can also introduce some ambiguity in the results. While likely more accurate than non-data fusion techniques, introduction of multiple variables can be problematic. Data fusion techniques also require a certain level of expertise by the user and therefore there might be a need for user certification. The demand is not NDE specific, but instead more for fusing NDE data with in-process

data to correlate to determine effectiveness of methods or to create more of a digital record of the part. Some considerations are:

- What data is recommended to be exported out of these standards?
- What data processing and visualization come into play?
- What are the expected/necessary data outputs, CT, and/or other methods?
- What are the needs for real time vs not real time data fusion. These demands would be very different (alignment and processing of data) than going offline. Process data with fusion does relate to other real time needs. What are the cross correlations?

See also gap DA9.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A, information theory sciences are well established.

Recommendation: The following are needed to address the gap:

- Specific industry standards for data fusion in AM NDT techniques
- Expert education, training, and certification for AM data fusion in NDT

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; Finished Material Properties; ☐Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☒Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: None provided.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA11: Best Practices for Anomaly Characterization and Localization for Part Defect Prediction Purpose.

There are no standard AM process anomaly detection methods for part defect prediction for different AM processes.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Various technical committees should get together to consolidate a list of existing anomaly detection and location methods, categorized by different sensing capacity and different AM processes. Since different AM processes may present completely different anomaly, defect, and corresponding failure modes, multiple standards should be developed to summarize: 1) standard practice for sensing capability requirement determination for AM process anomaly detection; 2) standard operation procedure for anomaly detection method assessment in different AM processes; 3) labeling strategy for both qualitative (e.g., microstructure characterization) and quantitative (e.g., X-ray CT inspection for porosity size, morphology, and distribution) post-manufacturing characterizations.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM, ISO, SAE

Lifecycle Area: ☐Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Data analytics is handled on a case-by-case basis.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA12: Need for Consistent Part Traceability and Provenance (Digital Twin).

New methods are needed to define and guide how AM data can be associated with different phases of an AM part fabrication so that this data can be readily and consistently interpreted to establish traceability (including in-service) and part, process, facility, and supply chain provenance. An established approach to the development of an AM digital twin will help address this need.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: R&D to establish the guidance/meta model for development of an AM digital twin that explicitly establishes traceability and provenance of an AM part. Also, need to consider in-service life tracking and prediction using digital twin.

Recommendation: New efforts needed to focus on standard development that relates qualification gaps to data representations, including addressing formats, data structure, and digital thread. Standards which augment the connection between engineering intent and manufacturing systems (i.e., neutral file format, STEP, XML, HDF5, AMF, or others) and enable digital twin are needed.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASTM, ISO, NIST

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Ad hoc.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- **04/05/2025, Y.Lu**: ISO TC261 /ASTM F42 JG73 and WG4 have initiated work on standards in simulation/computational modelling in additive manufacturing.

Comments Received on Gap for Future Consideration:

- **4/14/2025, NIST Compiled:** Efforts in development of STEP NC AP 238 model for PBF ongoing under WG15 in TC 184, which were ISO standardized digital twins for manufacturing. AP 238 PBF model to provide a foundation for PBF DT effort.

New Published Standards	New In-Development Standards
	4/14/2025, NIST Compiled: *ISO/ASTM DIS 52951, Additive Manufacturing — Data — Data packages for AM parts* addresses relationship between Digital twin and digital thread and appropriate data selection

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New Gap DA13: Data Visualization.

Data visualization technologies are used in other manufacturing processes and have shown benefits in controlling and visual verification. Standards can help address advanced visualization technologies of immersive, interactive virtual reality software systems from laboratory research to commercial applications, especially to make related visualization systems more readily and cost-effective to small- and medium-sized enterprises.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: General 3D immersive visualization theory sciences are well established. Specific AM data is lacking for visualization for AM processes.

Recommendation: Further discussions on specific standards to support data visualizations is needed. The following could be considered to help address the gap are:

- Defining data visualization system (i.e., heads up display, 2D screen), types, or methods to help with human interpretation
- Metrics (quantitative and/or qualitative)
- Data visualization across the AM lifecycle (more than in-process monitoring is needed)
- Available or needed software tools and considerations
- Control limits, data types and sources.
- Expert education, training, and certification for AM data visualization

Priority: ☐High; ☒Medium; ☐Low

Organization: ASTM, ISO, IEC

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary implementations for visualization of select data sets. Paraview (software tool) for open data sets.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA14: Best Practices and Guidance for AM Data Collection.

Data from AM machines varies in its format, level of detail, and interoperability. A standard set of data formatting and available data types needs to be developed. See also gap DA8.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: Collect A wider array of machine data examples should be gathered to provide further examples of the disparity and data available across various implementations.

Recommendation: Create a data standard that addresses at a minimum the expected minimum data availability from a machine, a variable and file naming structure for the data, and ensures interoperability on timestamp formats, data encoding, and packaging pertinent meta-data about the machine and the build. The goal should be to have a methodology that ensures that if, for example, two LPBF machines are being used and you receive similar data, that you can leverage that data in a common way. Ensure that the developed guidance works to use existing data standards where applicable, the format of the data is supported by common industry tools (similar to F3560-22's use of JSON), and that there is guidance on how to test methods and equipment that provide the data.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM, All applicable SDOs

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☒Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA15: Data Aggregation of Time Series and Object Data.

No published or in-development standards have been identified for "Aggregation / Data Fusion of time series and object data" for additive manufacturing technology.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Develop guidance on the aggregation of time series and object data. Identifiers can be obtained from most 3D Printer devices as a result of a job instantiation. Identifiers can also be obtained from a chosen manufacturing execution system (MES) in relation the jobs to be performed. However, choosing which, both, or another separate identifier is a matter of the solution identified to properly close this gap.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASTM, ISO

Lifecycle Area: ☐Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☒Other (specify) Additional machine sensors

Current Alternative: Individual application development or manual data aggregation/fusion

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/14/2025, P.Witherell: ASTM/ISO JG73 standard *ISO/ASTM FDIS 52953, Additive manufacturing for metals — General principles — Registration of geometric data acquired from process-monitoring and for quality control* should be finalized by 2025.

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New Gap DA16: Data Retention Guidelines.

No published or in-development standards have been identified for "Data Retention Guidelines" for additive manufacturing and related technologies.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: Possible development of algorithms for data size reduction with minimal data loss (e.g., akin to the .jpeg format being a lossy format but still high quality enough for the naked eye).

Recommendation: Develop standards for "Data Retention Guidelines." New algorithms or recommendations for proper use of existing algorithms that target AM data (e.g., melt pool h5 data, optical tomography .raw or .tiff imagery). A standard cloud provider agrees to data reduction and lowest cost storage tiers. Also, recommendations to industries for duration data should be retained based on analysis and regulatory needs.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASTM, ISO, applicable regulatory and certifying bodies

Lifecycle Area: ☐Design; ☒Precursor Materials; ☐Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☐Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☒Other (specify) Additional machine sensors & imagery

Current Alternative: Complex architectures and agreements both with internal organizations and external cloud providers. Data simply retained for as long as possible because a standard is not declared.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA17: Assessment and Specifications of AM Data Quality.

There are no standard metrics to measure AM data quality and the impact on AM decision making; There is no standard specification on AM data quality for data driven AM qualification and certification.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: Efforts should be made to review the existing data quality standards and identify the needs of AM data quality management and develop guidelines for AM data quality control.

Recommendation: Develop standards which define aspects of data quality specific to AM. NIST to assist with a review on existing data quality standards and their applicability to AM, as well as the gaps to enable data driven AM decision makings.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASTM, ISA, ISO, NIST, SAE

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specific for AM but sector agnostic standards listed above may be used.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA18: Reference Workflow (Digital thread) for AM Part Fabrication.

With AM workflows becoming increasingly important, for instance in establishing part provenance or integrating supply chains, new standardized references are needed. A standardized AM workflow, or digital thread, is needed to provide a consistent refence for the various processes and activities associated with AM part fabrication. A major concern relative to an AM manufactured repair part versus an OEM (or DLA) supplied part is the confidence the end user has in the part quality. Configuration management and acceptance thresholds of processes, machines and materials could be considered under this gap (as well as Gap DA12 on digital twin) to help build confidence in the supply chain. These are all areas where standards can contribute.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: R&D to establish what level of detail for a reference makes sense, and the role of data representation/formats when referencing the workflow.

Recommendation: Continue to develop ISO/ASTM PWI 52951 and then create additional guidance as needed.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASTM, ISO, NIST

Lifecycle Area: ☒Design; ☒Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Ad hoc

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/14/2025, P.Witherell: *ISO/ASTM DIS 52951, Additive Manufacturing — Data — Data packages for AM parts* is in ballot and will likely be available in 2025. Draft standard includes

	comprehensive workflow of PBF-LM process as well as guidance on configuration management. (already in recommendation). Standard is in balloting process.

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New Gap DA19: Context and Scenario-specific Data Selection.
Approaches to develop and communicate scenario-specific data requirements, scoped by areas such as technology, application, or even product family, are needed to support the common interpretation of AM data within the necessary context. This gap focuses on the selection of relevant AM requirements, where gap DA8 Customizable Standard AM Data Collection Templates focuses on simplifying the acquisition of data. **R&D Needed:** ☐Yes; ☒No; ☐Maybe **R&D Expectations:** N/A **Recommendation:** Develop standards to help develop and communicate scenario-specific data requirements which address technology, application, and/or product family. **Priority:** ☐High; ☒Medium; ☐Low **Organization(s):** ASME (e.g., code cases), ASTM, ISO **Lifecycle Area:** ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data **Sectors:** ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____ **Material Type:** ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite **Process Category:** ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization **Q&C Category:** ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☒Personnel/Suppliers; ☐Other (specify) _____ **Current Alternative:** Ad hoc implementations which are under or over specified. **V3 Status of Progress:** ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New
STATUS OF GAP PROGRESS
Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA20: AM-Specific Security Guidance.

Although numerous groups have standardized IT cybersecurity and privacy guidance, and a growing number of standards address OT security, no standardized guidance specifically addresses AM security.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: More research needed on security for non-extrusion AM processes. More research needed on applying content management technologies to security guidance publications to better manage dependencies of process-specific guidance on general AM security guidance, AM security guidance on OT security guidance, etc.

Recommendation: Complete work on ASTM F42.08 WG WK78322, whose guidance should not be AM process-specific. Subsequent guidance standards should address specific process technologies.

Priority: ☐High; ☒Medium; ☐Low

Organization(s): ASTM, America Makes, NIST

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☐Processes/Procedures; ☐Machines/Equipment; ☐Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/14/2025, D.Gibbons: *ASTM WK78322, New Guide for Additive Manufacturing -- General Principles -- Guidelines for AM Security* is expected to go to ballot at the end of 2025 and will establish AM Security practices necessary to protect additive manufacturing parts structural integrity, provenance throughout production chain, and protection of technical data. The standard will identify and categorize security threats in AM, highlight characteristic aspects of AM security that require special considerations, and describe the technical and other means that should mitigate security threats through the manufacturing life cycle. Relationships between AM security and other standards will be identified and indexed.

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Gap DA21 (formerly M7 in V2): Additive Manufacturing Supply Chain Security

Guidance is needed that addresses cyber and non-cyber threat (i.e., side channel attacks) security considerations for ordering, maintenance, repair and replacement parts that have 3D models ready to print to ensure that a build has not been sabotaged and that IP has not been stolen. Secure storage should ensure that only authorized personnel can access files and print parts. Maintenance security guidance for AM machines should be similar to that of other industrial machines. However, AM machines could be used in environments where maintenance may not be executed with the same degree of rigor or with the same quality control checks as in conventional settings. For example, a military organization could use a 3D printer at a battle location to print replacement parts. AM security guidance could perhaps suggest compensating controls in such scenarios where the usual controls are infeasible.

R&D Needed: ☒Yes; ☐No; ☐Maybe

R&D Expectations: TBD

Recommendation: Guidance is needed to ensure the confidentiality, integrity, and availability of AM data as procurement, maintenance and repair operations may take place in an uncontrolled environment. See also Gap PC15 Configuration management.

Priority: ☐High; ☒Medium; ☐Low

Organization: NIST, NEMA/MITA, NDIA JWG, ASTM, IEEE-ISTO PWG

Lifecycle Area: ☐Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☐Qualification & Certification; ☐Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☒Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: None specified.

V3 Status of Progress: ☒Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☐New

V3 Update: See full list of documents above. Since Roadmap v2.0, PWG 5199.10 was published. New ASTM WK78322 will establish AM Security practices necessary to protect additive manufacturing parts structural integrity, provenance throughout production chain, and protection of technical data. The standard will identify and categorize security threats in AM, highlight characteristic aspects of AM security that require special considerations, and describe the mitigations the manufacturing life cycle. This gap in AMSC Roadmap v2 was originally "cybersecurity for maintenance" however the issue was broader than maintenance, and instead across the supply chain and AM process. Updates have been made for v3 to better reflect the intent and need for standards.

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA22: Technical and IP authentication and protection.

This gap is distinct from cybersecurity issues. There is currently no standardized method of labeling, securing and authenticating the intellectual property ownership and related rights to AM designs, files and metadata. This creates an opportunity for unauthorized use and/or counterfeiting of AM printed objects. There is no standardized method of authenticating printed parts for counterfeiting.

R**&D Needed:** ☐Yes; ☐No; ☒Maybe

R&D Expectations: TBD

Recommendation: Complete and publish WK76970. Revise ISO/ASTM 52915 to include support for technical guidance and meta data specifications in WK76970.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ASTM F42.08, ISO/ASTM TC261, J64, NIST

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☒Post-processing; ☐ Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photo polymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☒Other (specify): Source file data, meta-data

Current Alternative: Ad hoc proprietary methods

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒ New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA23: AM Machine Data Framework and Guideline for Automated AM Data Integration and Management.

Even though both AM machine builders and industrial automation software providers are creating partnerships to push the development of AM integration and data management solutions, the applications are not reported, and standard practices have not been established and shared on how AM machines can be easily integrated with existing manufacturing systems for industrialization, including supervisory control and data acquisition (SCADA), MES, product lifecycle management (PLM) and enterprise resource planning (ERP) systems. In addition, there are no communication specifications defined to integrate and stream high-speed and high volume in-process data.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: The following are needed to address the gap:

- Standardized AM machine data framework to support AM in-process data integration for real-time manufacturing operations
- Specifications for communication protocols for high-speed AM in-process big data streaming and analysis
- Extended existing system and data integration architecture, for example, ISA 95, for AM data and system integration for industrialization
- Guidelines, best practices and tools for AM data integration and management, including research data, engineering data, production data, inspection data and testing data.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): IEC, ISO, ASTM, OPC, UMATI

Lifecycle Area: ☒Design; ☐Precursor Materials; ☒Process Control; ☒Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☒Nondestructive Evaluation; ☒Maintenance and Repair; ☒Data

Sectors: ☒All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☐Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☒Materials; ☒Processes/Procedures; ☒Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☐Other (specify) _____

Current Alternative: Proprietary solutions.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards

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New Gap DA24: Medical AM design file retention.

Standards are needed on how to store, label and provide access to medical AM design files derived from radiologic scans.

R&D Needed: ☐Yes; ☒No; ☐Maybe

R&D Expectations: N/A

Recommendation: Draft standard guidance for storing, labeling and publishing medical AM design files to meet HIPAA and FDA regulatory requirements.

Priority: High; ☒Medium; ☐Low

Organization(s): ISO/ASTM TC261, DICOM

Lifecycle Area: ☒Design; ☐Precursor Materials; ☐Process Control; ☐Post-processing; ☐Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☒Other (specify) Design File Data

Current Alternative: The information is discarded except the design file (STL, OBJ or other format) information addressed by DICOM. The DICOM specification for storing an encapsulated .STL file does not address all HIPAA and FDA quality management requirements for creating a regulated medical device.

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; ☐ Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/8/2025, B.Zollo: ISO/ASTM TC261 J64 is starting a project to develop application specific meta-data and schema for the purpose of publishing a series of technical reports to provide guidelines on implementing industry specific AM applications. This includes the addition of medical design and quality metadata and schema to an AMF format file that could be used to store, label and provide access to HIPAA required design metadata and all FDA required quality management requirements.

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New Gap DA25: Quality Management of Medical AM Files.

There is no comprehensive standard method for recording, transmitting and maintaining AM quality related meta data from radiologic scan to final part. This information is needed to comply with FDA quality validation and verification requirements for AM medical device manufacturing.

R&D Needed: ☐Yes; ☐No; ☒Maybe

R&D Expectations: TBD

Recommendation: Revise ISO/ASTM 52915 and ISO/ASTM 52916 to address this gap. Draft revisions to augment specified standards to provide guidance on how to implement a method to record, transmit and maintain design file quality related meta data from radiologic scan to final part; including but not limited to: file resolution, accuracy, dimensional tolerances, surface characteristics, and any additional FDA specified meta data, such as device labeling, as well as work-in-process file retention to retain any revisions to such meta data. Standardization of meta data terminology will facilitate programmatic transmission of meta data through the entire work flow.

Priority: ☒High; ☐Medium; ☐Low

Organization(s): ISO/ASTM TC261, RSNA, NIH, American College of Radiology (funding)

Lifecycle Area: ☒Design; ☐Precursor Materials; ☒Process Control; ☐Post-processing; ☒Finished Material Properties; ☒Qualification & Certification; ☐Nondestructive Evaluation; ☐Maintenance and Repair; ☒Data

Sectors: ☐All/Sector Agnostic; ☐Aerospace; ☐Automotive; ☐Construction; ☐Defense; ☐Electronics; ☐Energy; ☒ Medical; ☐Spaceflight; ☐Other (specify) _____

Material Type: ☒All/Material Agnostic; ☐Metal; ☐Polymer; ☐Ceramic; ☐Composite

Process Category: ☒All/Process Agnostic; ☐Binder Jetting; ☐Directed Energy Deposition; ☐Material Extrusion; ☐Material Jetting; ☐Powder Bed Fusion; ☐Sheet Lamination; ☐Vat Photopolymerization

Q&C Category: ☐Materials; ☒Processes/Procedures; ☐Machines/Equipment; ☒Parts/Devices; ☐Personnel/Suppliers; ☒Other (specify) Source file data quality

Current Alternative: Ad hoc proprietary methods

V3 Status of Progress: ☐Green; ☐Yellow; ☐Red; Not Started; ☐Unknown; ☐Withdrawn; ☐Closed; ☒New

STATUS OF GAP PROGRESS

Updates Since v3 was Published (Regulations, Research, Qual & Cert, etc.):

- No updates as of publication of this report.

Other Committees with Relevant Work:

- No updates as of publication of this report.

Comments Received on Gap for Future Consideration:

- No comments as of publication of this report.

New Published Standards	New In-Development Standards
	4/8/2025, B.Zollo: ISO/ASTM TC261 J64 is starting a project to develop application specific meta-data and schema for the purpose of publishing a series of technical reports to provide guidelines on implementing industry specific AM

	applications. This includes the addition of medical design and quality metadata and schema to an AMF format file that could be used to store, label and provide access to all FDA required quality management requirements. **9/25/2024, B.Zollo**: ISO/ASTM JG64 on File Formats for AM is implementing a new work project to create specifications for meta-data that will address the of technical data requirements listed in the recommendations to this gap.

2.6.10 Data Gaps for Future Consideration

This contains several topic areas identified by the working group members as gaps in standardization. However, discussions for these areas did not mature enough to result in content development. It is recommended that the AM industry discuss these further and be considered for a future iteration of the AMSC roadmap.

2.6.2 Data Formats and Representation
Evaluating data maturity for usage and adoption
2.6.3 Data Registration, Fusion and Visualization
Digital twin (virtual machine) framework for testing models in simulation
2.6.4 Data Management
Exchange and reuse of AM data
Feedback of data
2.6.6 AM Value Chain Data Usage and Management
Capability of machine data sheets
2.6.7 AM Data Security & IP Protection
Cybersecurity framework profile / meta data provisions specifications
2.6.8 Data Architecture Integration and Interoperability
Guidance to integrate varying data sources
Guidance on high-volume and high-speed data integration
AM Data for Models and Machine Learning
Guidance for establishing correlation models
Data Through Part Development Lifecycle
Evaluation of data quality
Using in-process data
Product and coupon handling and management

Section 2.6 Recommendations/Comments Since v3 was Published

Additional general recommendations related to the Section 2.6 Data scope, additional gaps, or other considerations since v3 was published are as follows:

New Gap Suggestions

The following gap(s) was suggested during comments against the gaps progress report. This language did not go through AMSC working group or public review. It is for information only and has not been assigned an AMSC gap number but may be considered by the AM standardization community.

4/9/2025, B.Ripley, RSNA: New Gap Suggestion: Quality Management of Medical AM Files.
- Requirements for AM medical device manufacturers submitting applications to FDA is outside the scope of RSNA SIG. When 3D printing is performed in hospitals and medical centers, quality management under the supervision of the provider has ensured a longstanding track record of safety.

Other Data Activity – Relevance to Gaps Not Yet Determined

New Published Standards

- **9/27/2024, P.Witherell:** *OPC 40540 UA for Additive Manufacturing*. The OPC 40540 series was developed to facilitate the exchange of information between AM machines and software systems such as MES, SCADA, ERP or data analysis systems. OPC 40540 and VDMA 40540 were initiated by a sub-working group of the VDMA Additive Manufacturing Working Group with about 200 participating companies. The first version of UA4AM initially only deals with the interfaces of the printing systems. The VDMA Additive Manufacturing working group covers the entire process chain, thus also generating potential for corresponding expansion of the Specification.

New In-Development Standards

- No additional standards provided as of publication of this report.

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GENERAL COMMENTS & UPDATES RELATED TO THE AMSC ROADMAP

Additional general recommendations for gaps in standards and codes related to Electric Vehicles.

New Gap Suggestions

The following gap(s) was suggested during comments against the gaps progress report. This language did not go through AMSC working group or public review. It is for information only and has not been assigned an AMSC gap number but may be considered by the AM standardization community.

4/9/2025, T.Robertson, UL: New Gap Suggestion: Assessment of electrical, mechanical, thermal, and combustible safety of industrial additive manufacturing equipment

International safety standard is needed for assessment of electrical, mechanical, thermal, and combustible safety of industrial additive manufacturing equipment

Current standards such as IEC/UL 62368 provide safety evaluations for 3D additive manufacturing printers but are only applicable to electrical and electronic equipment within the field of audio, video, information, and communication technology and business and office machines and does not apply to industrial environments.

International standards referenced for industrial additive manufacturing machines include IEC 60204-1 which is applicable to electrical safety only and does not reference protections or tests when using combustible materials.

We are aware of *ISO/ASTM FDIS 52938-1, Additive manufacturing of metals — Environment, health and safety* currently under development but we do not know if the document includes technical specifications and testing criteria for certification and listing of the machines. This particular standard seems relevant to metal technology only and does not address all types of additive manufacturing machines and technologies including the use of polymers.

UL Standards & Engagement has developed *UL 2011 Outline of Investigation for Machinery* which addresses electrical, fire, shock, thermal, and mechanical hazards and includes Appendix B – Requirements For Powder Bed Additive Manufacturing Machines And Associated Powder Handling Equipment. This standard is in the process of ANSI adoption for the US.

Even if UL 2011 is adopted, there remains a gap for international certification of industrial additive manufacturing equipment.

(UL 2011) APPENDIX B – REQUIREMENTS FOR POWDER BED ADDITIVE MANUFACTURING MACHINES AND ASSOCIATED POWDER HANDLING EQUIPMENT

- **B1 Scope**
- B1.1 These requirements address identified hazards associated with handling combustible particulate solids, or combustible dusts associated with powder bed additive manufacturing machines and the powder handling equipment associated with such a process, to comply with the requirements found in NFPA 484, NFPA 652, NFPA 654 or NFPA 499, as is applicable, to minimize the risk of flash fire or explosion.
- B1.2 These requirements address the risk of ignition of flammable liquids and flammable vapors from materials used as a part of the additive manufacturing process to comply with the requirements found in NFPA 497 or NFPA 30.
- B1.3 The basic assessment for the risks involved and the means used to reduce the risk is applicable to Additive Manufacturing machines intended for use in any unclassified location.
- B1.4 These requirements cover:
- Ignition Hazard Assessment to determine potential sources of ignition of the combustible particulate solids or flammable vapor,
- Construction requirements applied to potential ignition sources,

- Testing requirements to determine that the construction is effective for minimizing the risk of ignition,
- Marking requirements,
- User instructions.
- B1.5 Certain combustible particulate solid materials, binders and cleaners can be classified as a risk to human health. Such hazard is not addressed herein.

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ASMC Overview

Formally launched in March 2016, the America Makes & ANSI Additive Manufacturing Standardization Collaborative (AMSC) is a cross-sector coordinating body whose objective is to 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. The AMSC was launched because a number of standards developing organizations (SDOs) are engaged in standards-setting for various aspects of additive manufacturing, prompting the need for coordination to maintain a consistent, harmonized, and non-contradictory set of additive manufacturing standards. The AMSC is not developing standards or specifications. Rather, its purpose is to help drive coordinated standards development activity.

AMSC Standardization Roadmap

On July 17, 2023, America Makes and ANSI announced the publication of the ***Standardization Roadmap for Additive Manufacturing, Version 3.0***, developed by the AMSC. The roadmap describes the current and desired future standardization landscape for additive manufacturing (AM), and focuses on industrial market sectors using AM technologies. A total of 141 standardization gaps (including 60 new gaps) are identified with corresponding recommendations across the AM lifecycle areas of: design; precursor materials; process control; post-processing; finished material properties; qualification and certification; nondestructive evaluation; maintenance and repair; and data.

The roadmap provides prioritized timeframes for when standards work should occur. Of the 141 gaps, 54 gaps/recommendations are identified as high priority, 64 as medium priority, and 23 as low priority. In 91 cases, additional pre-standardization research and development (R&D) is needed. The roadmap also identifies SDOs or others that may be able to develop the standards or perform the R&D. The hope is that the roadmap will be broadly adopted by the user community to facilitate a more coordinated approach to the future development of AM standards.

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