

SAE INTERNATIONAL

GLOBAL MATERIAL & PROCESS SPECS TO SUPPORT CERTIFICATION OF AM PARTS FOR AVIATION

EASA Additive Manufacturing Workshop
28 September 2016

John Clatworthy, SAE International

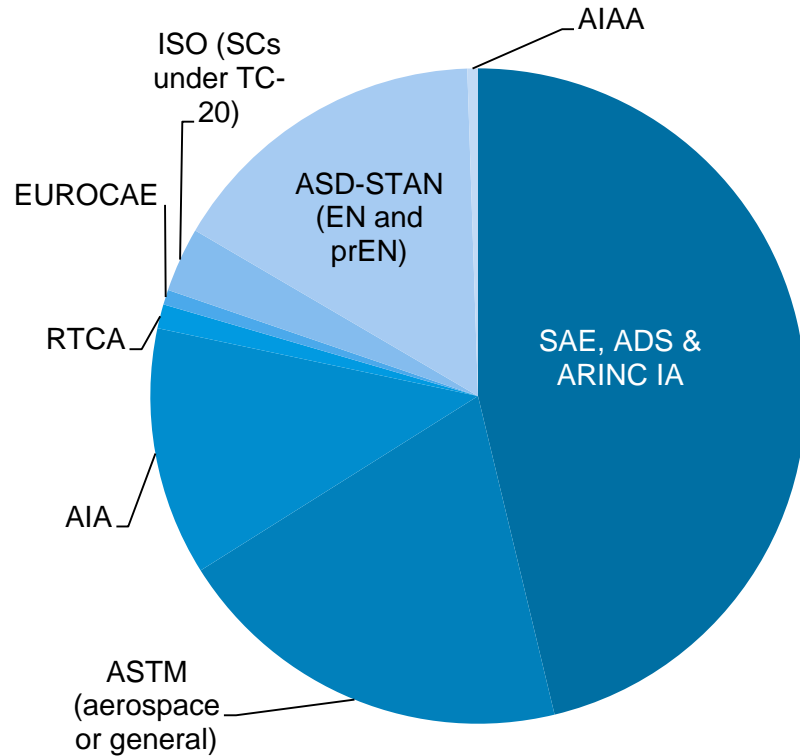


AGENDA

- SAE Aerospace Standards Program Overview
- SAE's Role in Developing AMS Specifications to Support Aircraft Certification
- SAE Additive Manufacturing Committee Overview

SAE AEROSPACE STANDARDS PROGRAM OVERVIEW

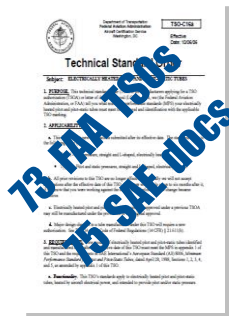
Aerospace Standards Landscape: SAE Global Leadership



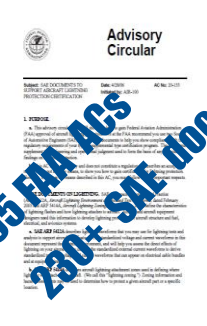
8500+ standards
150+ committees, subcommittees, and task groups
11000+ global participants

Civil and Military
applications addressed

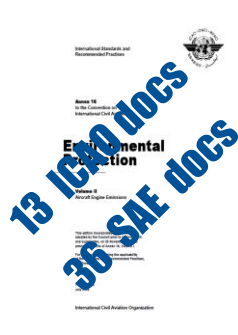
SAE Aerospace Standards Are Referenced in Global Regulations



Example FAA TSO
Mandatory
compliance



Example FAA AC
Guidance material



Example ICAO Annex
Mandatory
compliance



Example EASA ETSO
Mandatory
compliance



Example EASA AMC
Guidance material



SAE'S ROLE IN DEVELOPING AMS SPECIFICATIONS TO SUPPORT AIRCRAFT CERTIFICATION

CS/Part 25.603 Materials

- All materials used to produce structural elements whose failure would have a negative impact on safety must:
 - Be established on the basis of experience or test
 - **Conform to approved specifications that ensure having strength & other properties assumed in the design data**
 - Take into account effects of environmental conditions

CS/Part 25.605 Fabrication Methods

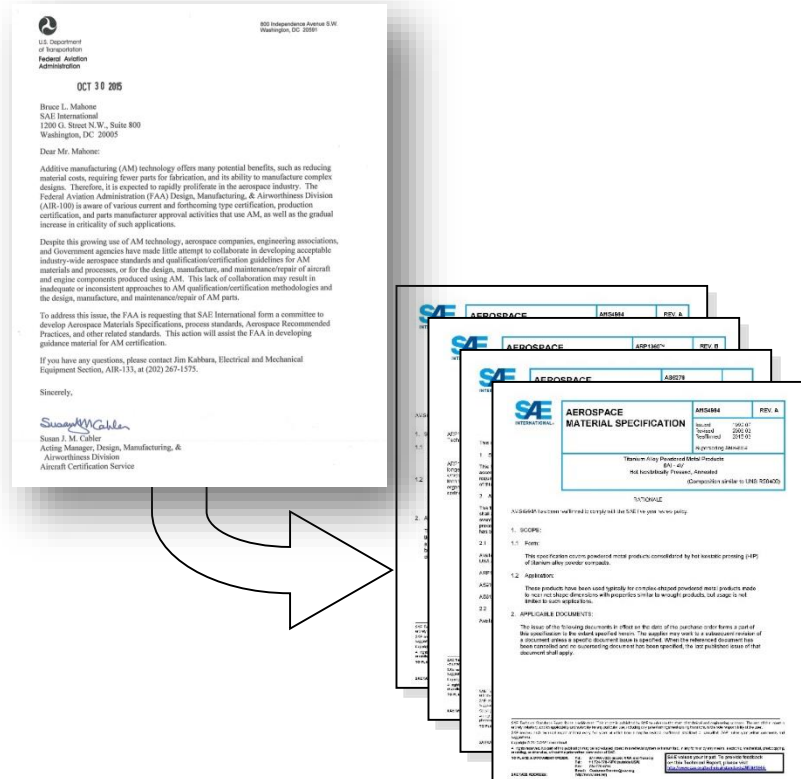
- All manufacturing processes must:
 - Produce a consistently sound structure
 - If a fabrication process(e.g. gluing, spot welding, heat treating) requires close control, **the process must be performed under an approved process specification**
 - Be substantiated by a test programme

CS/Part 25.613 Material Strength Properties & Material Design Values

- Strength and Design values used to design structure must:
 - **Be based on testing of materials meeting approved specifications to establish design values on a statistical basis**

FAA SAE Task Request (STR)

- Signed October 30, 2015
- FAA requested SAE to 'form a committee to develop Aerospace Materials Specifications, process standards, Aerospace Recommended Practices, and other related standards.'
- Addresses FAA concerns regarding inadequate or inconsistent approaches to AM qualification/certification... design, manufacture and repair of AM parts.




AMS = Aerospace Material Specifications

- **Traceable to statistically substantiated material property data in order to support regulatory requirements**
- **Downgrading the properties or characteristics of an existing AMS is not permitted**

Roughly 30% of all SAE aerospace standards are AMS

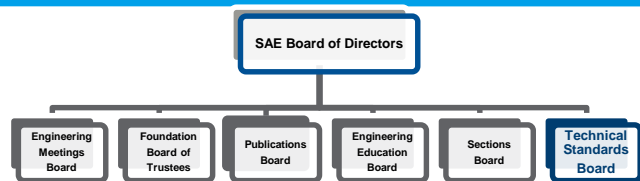
AMS4999A, Titanium Alloy Direct Deposited Products 6Al – 4V Hot Isostatically Pressed, Annealed

- 2002 Initial release by AMS-G, Titanium, Beryllium & Refractory Materials
- 2011 Revision

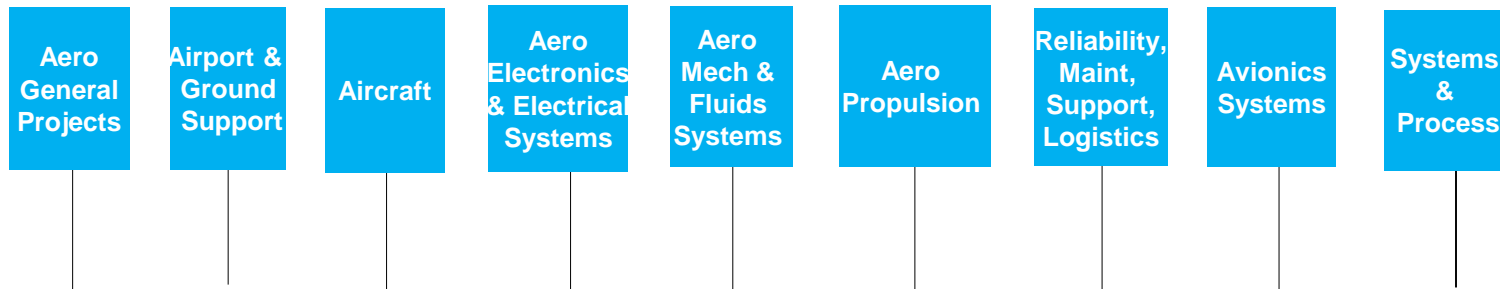
	AEROSPACE MATERIAL SPECIFICATION		AMS4994	REV. A
	Issued	1992-07		
	Revised	2006-03		
	Reaffirmed	2015-03		
	Superseding AMS4994			
Titanium Alloy Powdered Metal Products 6Al - 4V Hot Isostatically Pressed, Annealed (Composition similar to UNS R56400)				
RATIONALE				
AMS4994A has been reaffirmed to comply with the SAE five-year review policy.				
1. SCOPE:				
1.1 Form:				
This specification covers powdered metal products consolidated by hot isostatic pressing (HIP) of titanium alloy powder compacts.				
1.2 Application:				
These products have been used typically for complex-shaped powdered metal products made to near net shape dimensions with properties similar to wrought products, but usage is not limited to such applications.				
2. APPLICABLE DOCUMENTS:				
The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.				
<small>SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its responsibility and liability in any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user." SAE reserves the right to withdraw or amend this report at any time without notice, and it is the user's responsibility to keep abreast of any such changes. SAE does not assume any liability for any loss or damage resulting from the use of this report.</small>				
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<small>TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada) Fax: +1 724-776-6038 (outside USA) Email: CustomerService@saesae.org http://www.sae.org</small>				
<small>SAE values your input. To provide feedback on this Technical Report, please visit http://www.sae.org/technical-standards/SAE4994</small>				
<small>SAE WEB ADDRESS: http://www.sae.org</small>				

SAE AMS-AM COMMITTEE ON ADDITIVE MANUFACTURING

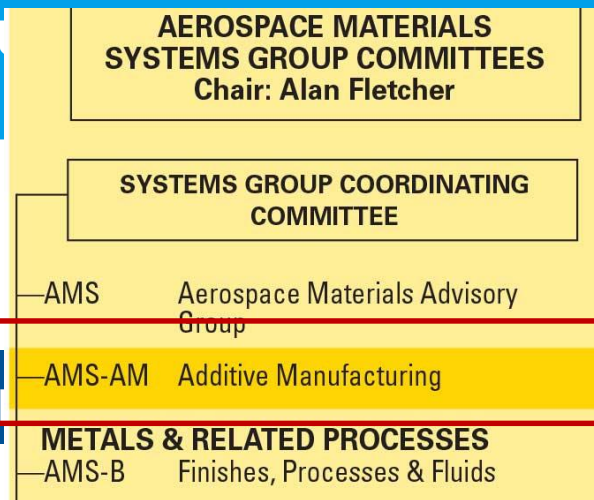
SAE ORGANIZATIONAL STRUCTURE



Systems Groups



Technical Standards Committees



AEROSPACE MATERIALS SYSTEMS GROUP COMMITTEES Chair: Alan Fletcher	
SYSTEMS GROUP COORDINATING COMMITTEE	
AMS	Aerospace Materials Advisory Group
AMS-AM	Additive Manufacturing
METALS & RELATED PROCESSES	
AMS-B	Finishes, Processes & Fluids
AMS-D	Nonferrous Alloys
AMS-E	Carbon & Low Alloy Steels & Specialty Steels & Alloys
AMS-F	Corrosion & Heat Resistant Alloys
AMS-G	Titanium, Beryllium & Refractory Materials
AMEC	Aerospace Metals Engineering
AMEC-SE	Surface Enhancement
NON-METALS & RELATED PROCESSES	
AMS-CE	Elastomers
AMS-P	Polymeric Materials
AMS-P-17	Polymer Matrix Composites
AMS-CACRC	ATA/IATA/SAE Commercial Aircraft Composite Repair Committee
	Repair Materials TG Repair Techniques TG Inspection TG Design TG Training TG Analytical Repair Techniques TG
AMS-G-8	Organic Coatings Corrosion & General Test Methods TG Surface Preparation & Cleaning TG Appearance & Durability TG
AMS-G-9	Aerospace Sealing New Sealant Specification Rqmts TG Sealant Removal Techniques TG Surface Preparation for Sealing & Finishing TG Fuel Cell TG
AMS-J	Aircraft Maint Chemicals & Materials
AMS-M	Aerospace Greases
NON-DESTRUCTIVE EVALUATION	
AMS-K	Non-destructive Methods & Processes Magnetic Particle & Penetrant Methods TF

SAE AMS-AM Committee

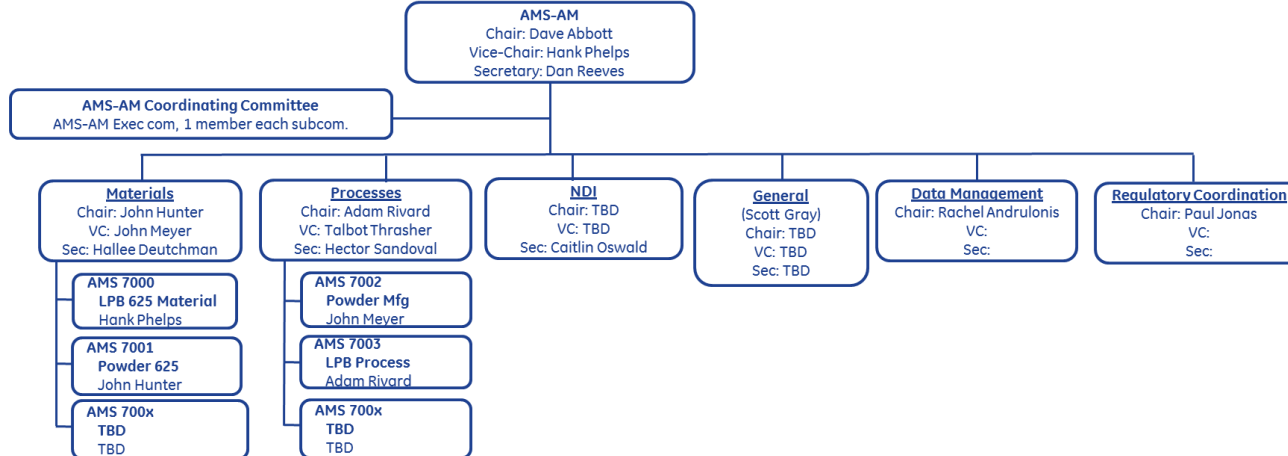
Formed in 2015

Currently:

- 250+ global members
- 6 Subcommittees

4 specifications released for ballot in September 2016:

- Material – AMS 7000 LPBF 625 Finished Part
- Material – AMS 7001 LPBF 625 Powder
- Process – AMS 7002 Powder Manufacturing
- Process – AMS 7003 LPBF Process



Scope:

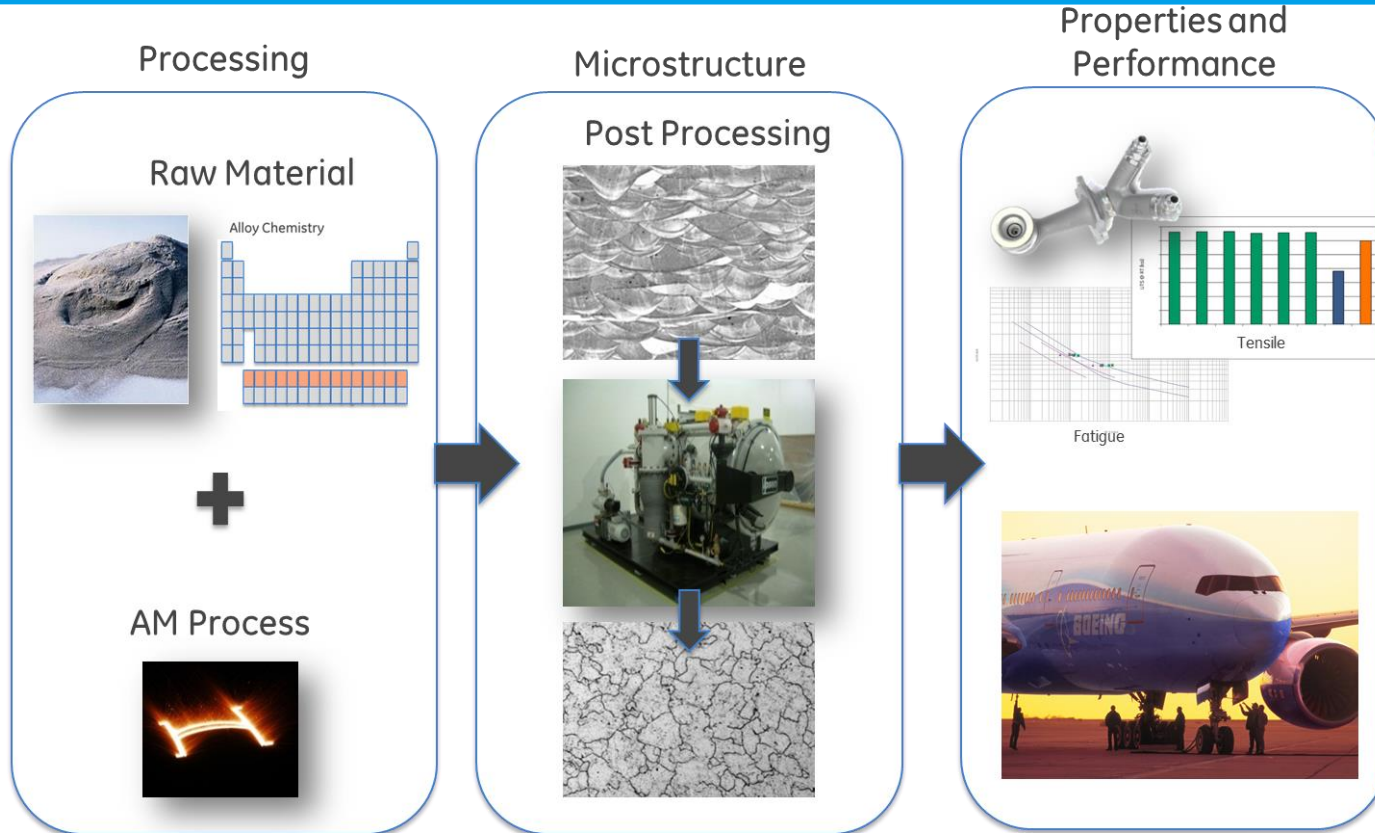
...to develop and maintain aerospace material and process specifications ...for additive manufacturing, including precursor material, additive processes, system requirements and post-build materials, pre-processing and post-processing, non-destructive testing and quality assurance.

...the committee will collaborate with other standards development organizations such as MMPDS, ASTM Committee F42 on Additive Manufacturing, AWS D20, Nadcap Welding Task Group, America Makes, CMH-17, and regulatory authorities such as FAA, EASA, US DoD, and NASA.

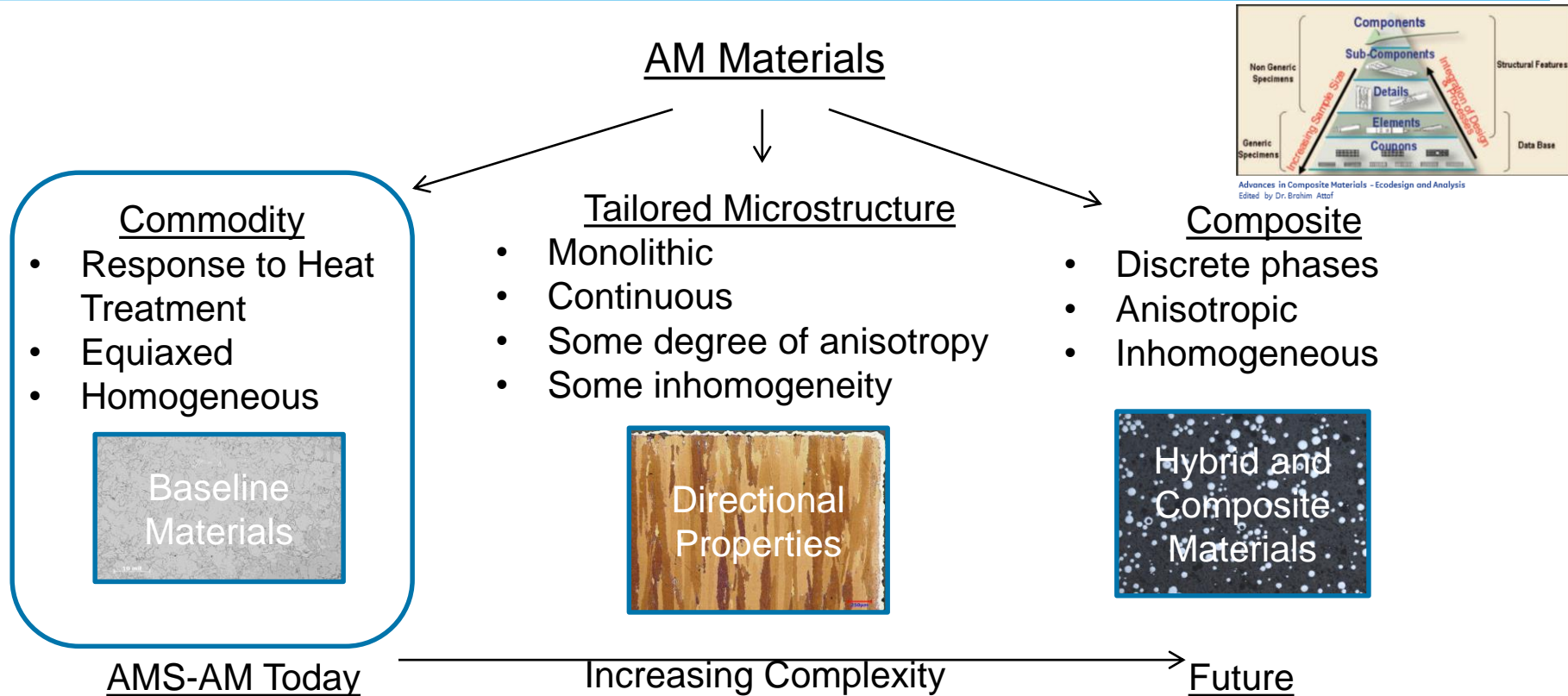
SAE AMS-AM Committee Charter Objectives

- ...**develop Aerospace Material Specifications (AMS)** for the procurement of additive precursor and manufactured materials ...
When applicable, ensure the material specification is tied to the appropriate shared material property database.
- Coordinate requirements for publishing data in shared material property databases with **MMPDS** Emerging Technology Working Group for new metallic materials and **CMH-17** for new composite materials.
- Establish a system to ensure material specifications are **controlled and traceable**.

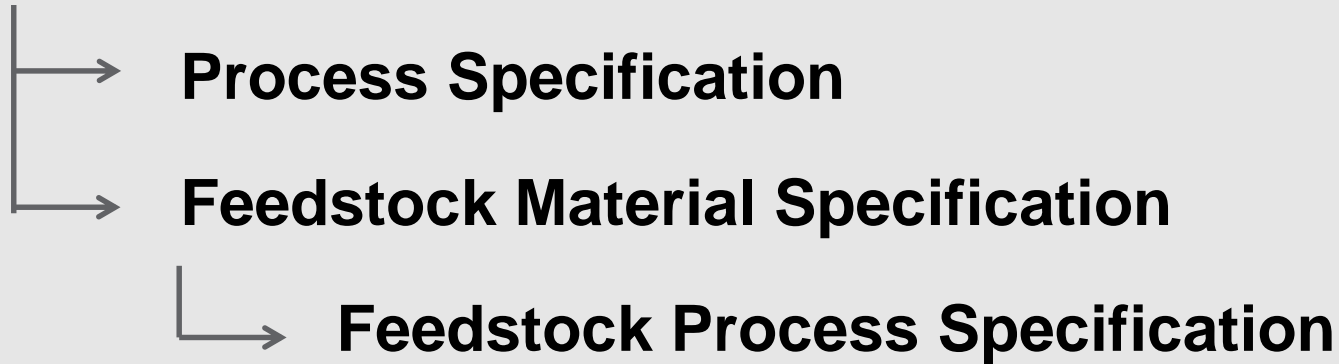
Additive Manufacturing Process Basics



Increasing Degree of Complexity...



Material Specification ... material requirements



- **Hierarchical**
- **Defines requirements and establishes controls**
- **Performance-based and Pseudo-prescriptive (establish controls and provide substantiation)**

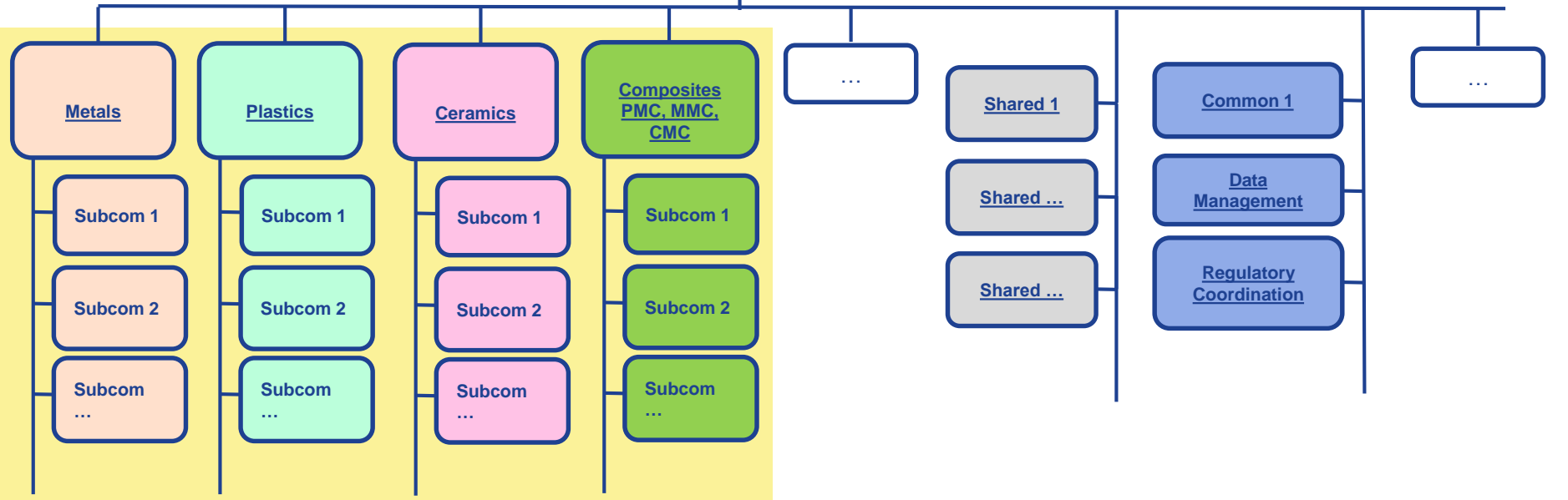
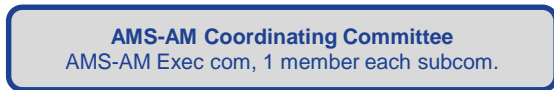
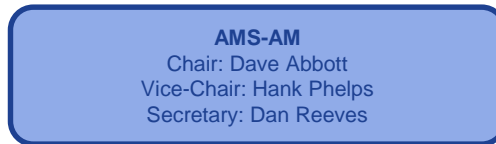
SAE AM Material Specifications

- Results oriented
- Contain chemistry, microstructure, mechanical properties, heat treatment and NDI requirements

SAE AM Process Specifications

- Establish controls to ensure quality and consistency of material produced
- Key requirement is process control documentation (PCD)
 - Collection of fixed revision-controlled documents and procedures
 - Validated and substantiated through chemical, metallurgical and mechanical testing protocols to demonstrate equivalency and repeatability
- Fixed process enables establishment of lot acceptance values, specification minimums and design allowables

AMS-AM Committee Expansion



- A very busy, productive and successful first year for AMS-AM:
 - 5 get-together meetings
 - Approved charter, established organization, developed specification framework, initiated first specification projects, brought first four specifications to 28-day ballot.
- Next on the list:
 - Introduction of at least two new materials under the AMSAM framework
 - Expansion of the committee organizational structure to accommodate non-metallics
 - Completion of the Data Submission Guidelines for Specification Minimums
 - Issuance of the first set of specifications (targeting end of year 2016).

Upcoming SAE AMS-AM Meetings

- When: October 25 – 27, 2016
 - Sponsor: 3D Systems
 - Where: Rock Hill, SC USA
 - Who: Open registration
-
- When: April 25 – 27, 2017
 - Sponsor: Renishaw plc
 - Where: Wotton-under-Edge, UK
 - Who: Open registration

Register online at www.sae.org.



QUESTIONS?

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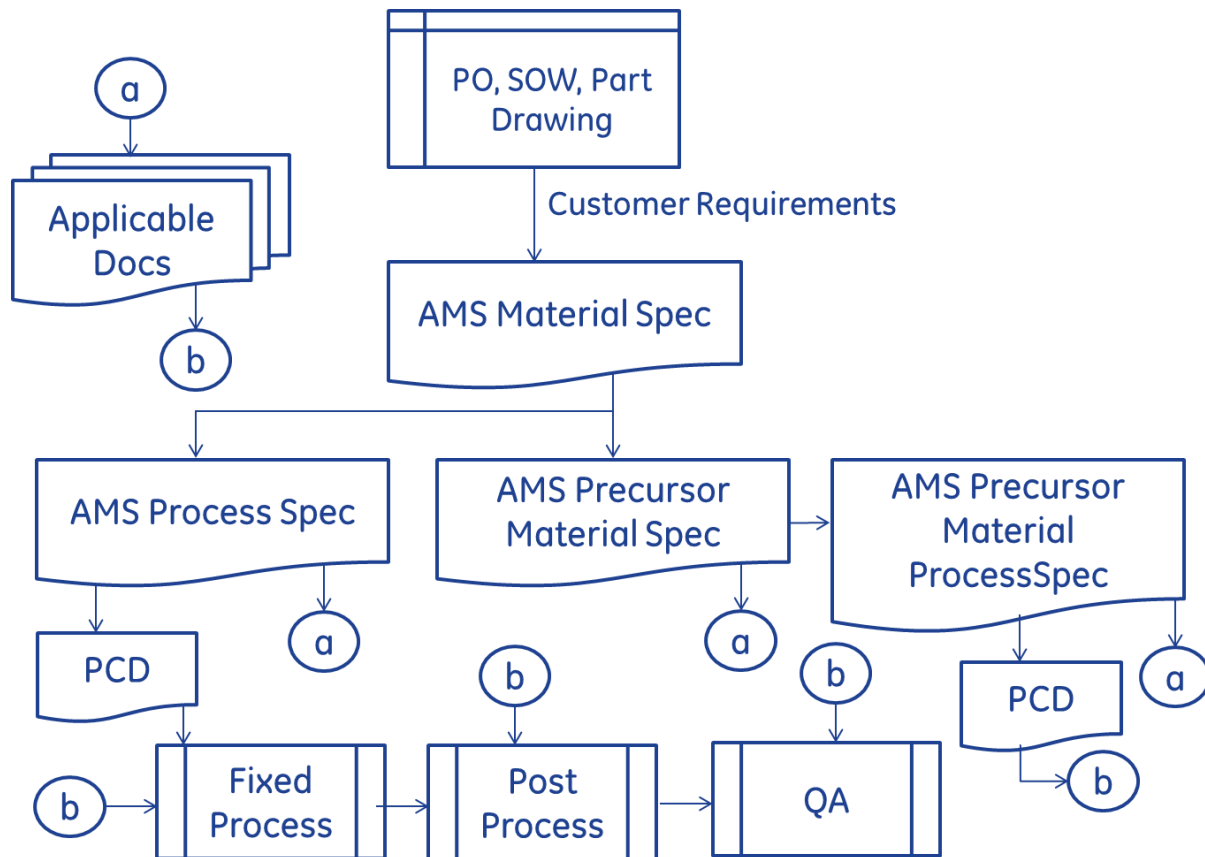
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BACKUP SLIDES

Flowchart – Specification Hierarchy



Customization – Specification Minimums

- Specification Minimums:
 - Statistically-based methods
 - Conventional methodology.
 - Standard Number of Heat and Lot requirements.
- May customize to better capture natural variation of process.
- Heat and Lot definitions tailored to AM.
- Heat – chemistry can be single heat or homogeneous blend heat of heats.
- Lot – Single-build or contiguous number of builds.

Mechanical Property	Statistical Basis	Minimum Data Requirements per orientation			Format ²
		Sample Size ¹	No. of Heats (chemistries)	No. of Lots	
Tensile Yield or Ultimate Strength, or Compression Yield Strength	Specification minimum	30	3	3	Excel (may use MMPDS tensile data template)
Elongation	Specification minimum	30	3	3	Same template as tensile data
Reduction in Area	Specification minimum	30	3	3	
Plane-Strain Fracture Toughness ³	Specification minimum	30	3	3	Excel (may use MMPDS fracture template)

1. For additively manufactured products, minimum per as-built thickness range. Exception when there is a significant thickness effect and regression analysis may be used per MMPDS guidelines. A reasonable number of samples should be used to span the thickness range. Small sample sizes must meet guidelines for uniformity across thickness range as detailed in SAE guidelines noted above and MMPDS. True uniformity is not required. Contact www.mmpds.org with questions.
2. For MMPDS data templates, contact www.mmpds.org.
3. See AMS statistical guidelines for aluminum materials regarding use of K_q.

Table 2. Example data sheet information (should include the following information)

Alloy Trade Name <i>Required</i>	Temper / Thermal Treatment <i>Required</i>	Product Form <i>Required</i>	Supplier <i>Required</i>	Reference Number	Specimen Location	Agenda (Max 10 Char)
Process <i>Required</i>	Feedstock Specification <i>Required</i>	Process Specification <i>Required</i>	Material Specification <i>Required</i>	Power Source Type	Machine	

ADD MATERIAL INFORMATION ABOVE*

*Only one material allowed per worksheet.

Independent Variable Name	Independent Variable Unit
Thickness	in
Reuse (Powder)	%

INDEPENDENT VARIABLE ABOVE FOR REFERENCE ONLY*

*Only one independent variable allowed per worksheet. Independent variable not utilized by MIDAS.

Property Name	Property Unit	Property Desc
TUS	ksi	Tensile Ultimate Strength
TYS	ksi	Tensile Yield Strength
ELG	%	

ADD PROPERTY INFORMATION ABOVE*

*Up to four properties are allowed per worksheet.

Build Orientation ¹ (Max 2 Char) <i>Required</i>	Thickness(in) <i>Required</i>	Recycle (%) (for Powder)	Lot No. <i>Required</i>	Heat No. <i>Required</i>	TYS(ksi)	TUS(ksi)	ELG(%)
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¹ See ASTM F2971 for build orientation descriptions