

SAE INTERNATIONAL

# SMART MANUFACTURING IN AEROSPACE

Standardization Considerations

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SAE Aerospace Standards

# PREMISE

- SAE PHM RELATED STANDARDS
- TYPES OF SAE STANDARDS
- DEVELOPED FOR INDUSTRY SPECIFIC USE
- SAE MANUFACTURING STANDARDS
- RECOGNIZED FOR INTENDED RIGOR

# SAE PHM RELATED STANDARDS

## SAE A-6A3, E-32, G-11R

- **AIR5273** Actuation System Failure Detection Methods
- **AIR5120** Engine Monitoring System Reliability and Validity
- **ARP5580** Recommended Failure Modes and Effects Analysis (FMEA) Practices for Non-Automobile Applications

## SAE AISC-SHM Structural Health Monitoring and Mgmt

- **ARP6461** Guidelines for Implementation of Structural Health Monitoring on Fixed Wing Aircraft
- **AIR6892** Guidelines for Implementation of Structural Health Monitoring on Rotorcraft (WIP)

## HM-1 Integrated Vehicle Health Management Committee

- **ARD6888** Functional Specification of Miniature Connectors for Health Monitoring Purposes
- **ARP6275** Determination of Cost Benefits from Implementing an IVHM System
- **JA6268** Design & Online Communication Standards for Health Ready Components (WIP)

# DEVELOPED FOR INDUSTRY SPECIFIC USE

## ISO 9001

- International Standard intended to be usable by any organization, service or manufacturing, in any industry sector

## AS9100

- Global Industry Standard intended for exclusive use by aviation, space, and defense organizations. Committees are comprised of SMEs from all areas of Aerospace quality community that represent themselves and are often supported by their companies

## Additional Requirements

- Project management, risk management, configuration management of the products
- Design verification and validation
- Verification of production processes and control of the changes to production processes
- Criteria for rejection and special measurement instructions
- Full standards and certification suite

# SAE MANUFACTURING STANDARDS

- **G-23 Manufacturing Management**
- **AS6500** Manufacturing Management Program
  - Encourages the use of best manufacturing management practices aimed at promoting the timely development, production, modification of affordable products
- **G-33 Configuration Management**
  - **EIA511** Manufacturing Message Specification Service Definition and Protocol
- **AMS-B Finishes Process and Fluids**
  - **AMS3084C** Lubricant, Solid Film Minimal Outgassing
  - **AMS2689B** Fusion Welding Titanium and Titanium Alloys
- **AMS-F Corrosion Heat Resistant Alloys**
  - **AMS2774E** Heat Treatment Wrought Nickel Alloy and Cobalt Alloy Parts
  - **AMS2241S** Tolerances, Corrosion and Heat-Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire

# ADDRESSING AVIATION'S RIGOROUS REQUIREMENTS

Aerospace industry and regulatory bodies have required a specific set of specifications needed for aerospace applications.

SAE AMS-AM committee is writing the standards needed to develop acceptable industry-wide aerospace standards and qualification/certification guidelines for AM materials and processes, or for design, manufacturing, and maintenance/repair of aircraft and engine components using AM.

There are currently 4 SAE AMS specifications in process for pre-cursor material, process and post processing of AM.



U.S. Department  
of Transportation  
**Federal Aviation  
Administration**

800 Independence Avenue S.W.  
Washington, DC 20591

OCT 30 2015

Bruce L. Mahone  
SAE International  
1200 G. Street N.W., Suite 800  
Washington, DC 20005

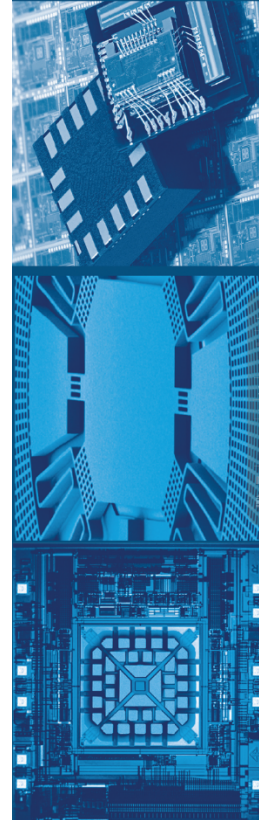
Dear Mr. Mahone:

Additive manufacturing (AM) technology offers many potential benefits, such as reducing material costs, requiring fewer parts for fabrication, and its ability to manufacture complex designs. Therefore, it is expected to rapidly proliferate in the aerospace industry. The Federal Aviation Administration (FAA) Design, Manufacturing, & Airworthiness Division (AIR-100) is aware of various current and forthcoming type certification, production certification, and parts manufacturer approval activities that use AM, as well as the gradual increase in criticality of such applications.

Despite this growing use of AM technology, aerospace companies, engineering associations, and Government agencies have made little attempt to collaborate in developing acceptable industry-wide aerospace standards and qualification/certification guidelines for AM materials and processes, or for the design, manufacture, and maintenance/repair of aircraft and engine components produced using AM. This lack of collaboration may result in inadequate or inconsistent approaches to AM qualification/certification methodologies and the design, manufacture, and maintenance/repair of AM parts.

To address this issue, the FAA is requesting that SAE International form a committee to develop Aerospace Materials Specifications, process standards, Aerospace Recommended Practices, and other related standards. This action will assist the FAA in developing guidance material for AM certification.

- **Smart Sensors**
  - Sensors that not only collect data but also analyze and communicate with other systems.
  - The manufacturing process has the opportunity to embed sensors for manufacturing PHM
  - AND for smart operational use (e.g. embedded SHM sensors in additively manufactured or composite structures)
  - These will require standards to address the safety requirements for aviation use



# QUESTIONS?

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# SAE STANDARDS STATUS CATEGORIES

Status	Definition	Identifier
Issued	First time published	Issue date
Revised	Updated or modified	Revision letter designator
Reaffirmed	Reviewed and deemed current with no need for immediate revision	Reaffirmation date noted after last active revision level
Stabilized	<ol style="list-style-type: none"><li>1) Mature technology not likely to change</li><li>2) No known users</li><li>3) Retain to support legacy platforms or design reuse but industry moving towards newer technology for new design</li></ol>	Contains Stabilization Notice and Rationale statement including committee recommendations
Cancelled	<ol style="list-style-type: none"><li>1) Not fit for use due to technical reasons</li><li>2) Technical requirements totally superseded by another document</li></ol>	Cancellation Notice and Rationale statement including supersession information

# Current AMS-AM Works in Progress (WIPs)

<u>Project</u>	<u>Title</u>	<u>Date</u>
<a href="#">AMS7000</a>	Additive Manufacture of Aerospace parts from Ni-base Superalloy 625 via the Laser Powder Bed Process	Aug 11, 2015
<a href="#">AMS7001</a>	Ni Base 625 Super Alloy Powder for use in Laser Powder Bed Add Mfg Machines	Oct 05, 2015
<a href="#">AMS7002</a>	Process Requirements for Production of Ni-base 625 for Production of Aerospace parts via Laser Powder Bed Additive Manufacturing	Oct 28, 2015
<a href="#">AMS7003</a>	Laser Powder Bed Fusion Process	Oct 28, 2015



The Specification Framework...

# SAE AMS7000 – Finished product

## AMS7000

### **Additive Manufacture of Aerospace parts from Ni-base Superalloy 625 via the Laser Powder Bed Process**

#### Scope

This Aerospace Standard cover the additive manufacture of parts from Ni-base superalloy 625 via the laser powder bed process. It will contain the technical requirements for chemistry, microstructure, heat treatment, and mechanical properties along with quality assurance provisions to ensure quality and compliance.

#### Rationale

This Aerospace Standard is intended to provide technical requirements and quality assurance provisions and to reference additional required specifications for precursor materials, process and all secondary operations for the laser powder bed processing of the Ni-base superalloy 625. No such standard currently exists.

## AMS7001

### **Ni Base 625 Super Alloy Powder for use in Laser Powder Bed Add Mfg Machines**

#### Scope

This material specification will cover both the precursor or feedstock Ni base 625 powder and part specifications for material to be used in the manufacture of aerospace parts under SAE Aerospace Standard AMS7000.

#### Rationale

The Aerospace Material Specification is intended to provide the technical requirements such as alloy composition, particle size distribution for both feedstock and as-built part materials via the laser powder bed additive manufacturing process. No such specification currently exists.

# SAE AMS7002 – Powder manufacturing process

## AMS7002

### **Process Requirements for Production of Ni-base 625 for Production of Aerospace parts via Laser Powder Bed Additive Manufacturing**

#### Scope

This material specification will cover both the production of precursor Ni base 625 powder feedstock for material to be used in the manufacture of aerospace parts under SAE Aerospace Standard AMS7000. This process/practice specification is necessary to define standard practices for topics that may include training, powder handling, process cleanliness, process environment, packaging, storage, shipping, material changes, traceability, calibration, maintenance, etc. This specification is to be production process agnostic and non-prescriptive.

#### Rationale

The Aerospace Material Specification is intended to provide the process requirements for production of Ni-base 625 precursor powder for use in production of aerospace parts via the laser powder bed additive manufacturing process. No such specification currently exists.

## AMS7003

### **Laser Powder Bed Fusion Process**

#### Scope

This specification will be used in conjunction with AMS 7000, Additive Manufacturing of Aerospace Parts from 625 via Laser Powder Bed process. It is intended to provide required specifications and best practices for process parameters, NDI and post processing of the aerospace parts.

#### Rationale

The manufacturing process is unique relative to traditional or 'subtractive' methods and this documents is intended to provide technical information on laser powder bed process specifications, NDI methods, and generally accepted best practices to produce parts capable of service in critical and non-critical aerospace service. No such document currently exists.

# TYPES OF SAE STANDARDS

- **AS Aerospace Standards** – specific performance requirements used for design standards, parts standards, minimum performance standards, quality and other areas conforming to broadly accepted engineering practices or specs for a material, product, process, procedure or test method
- **AMS Aerospace Material Specifications** – specific performance requirements for material and process specifications
- **ARP Aerospace Recommended Practices** – documentations of practice, procedures, and technology that are intended as guides to standard engineering practices. May be of a more general nature or propound data that have not yet gained broad acceptance
- **AIR Aerospace Information Reports** – compilations of engineering reference data, historical information, or educational material useful to the technical community