Federal Aviation Administration

FAA AM Update

Presented at:

Joint EASA-FAA AM Workshop (*virtual*)

November 8, 2021

Presented by:

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Chief Scientist for Fatigue & Damage Tolerance

Federal Aviation Administration

and

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Federal Aviation Administration

Outline

- History of FAA annual AM workshops
- Evolution of AM landscape
- Engagement with SDOs
- Development of public-domain databases
- R&D
- FAA guidance development
- Summary

Workshop Evolution

2015 → 2017

(joint FAA-USAF workshops)

2015 Workshop

- First in the series (*for FAA*)
- Focus on overview of AM technologies and identification of potential certification concerns and considerations
- First exposure to AM for many FAA attendees
- Main focus on getting perspective from the government agencies and major OEMs

2016 Workshop

- More in-depth discussions on specific qualification approaches reflect industry progress (some presentations are benchmarked by industry working groups)
- Expanded coverage to include supply chain perspective (Tier 1, raw materials, …)
- Continued education of FAA workforce
- Significant coverage of government AM activities

2017 Workshop

- First "global" workshop – open to foreign participants, including several NAAs
- Twice bigger than the prior workshops – significantly expanded industry "demographics"
- Focused Training & Education panel
- Continued Q&C topics coverage, including process monitoring, part family and feature-based qualification etc.
- Progress on AM standardization

Workshop Evolution (cont.)

2018 → 2020

(joint FAA-EASA workshops)

2018 Workshop

- *First joint FAA – EASA workshop*
- *First workshop with parallel breakout sessions*
- Continued focus on Q&C
- Tracking of the key industry trends (in the Q&C context)
- Gradual increase in the industry "demographics" by segment

2019 Workshop

- Continued breakout sessions
- Significant participation from operators, Tier 2/3/… suppliers and machine makers
- Clear signs of Q&C framework maturation and common technical approaches
- Leveraged Machine Makers – End Users knowledge transfer workshop

2020 Workshop

- *First virtual workshop*
- More balanced international participation
- More than 2x increase in participation
- Continued breakout sessions
- *Focus on new technical developments, not "organizational updates"*
- Highly diverse industry "demographics"
- Big focus on standardization

see next slide

2020 Workshop – *General Observations*

- **3rd joint FAA – EASA workshop**
- ***First virtual workshop***
  - More balanced international participation
  - More than 2x increase in the number of participants
  - However…
    - Less time than during F2F meetings (20 min presentation time slots)
    - No networking or side meetings
- **Continued breakout sessions**
- **Focus on new technical developments, not "organizational updates"**
- **Highly diverse industry "demographics"**
  - OEMs, Tier 1/2/… suppliers, machine makers, tools and methods developers, …
- **Big focus on standardization**
  - Day 3 was dedicated to this topic

Agenda at a Glance

- **Opening remarks:**
  - *Ms. Di Reimold, Deputy Director of Policy and Innovation Division, FAA*
- **Keynote -** ***SpaceX***
  - *Dr. Charlie Kuehmann, VP of Materials Engineering and NDE*
  - *Mr. Will Heltsley, Vice President of Propulsion Engineering*
- **22 presentations from the industry, government, academia and SDOs / Consortia / WGs**
- **3 Breakout Sessions**
- **Standardization Day**
- **Regulatory Panel**

1. ***Low Criticality AM Parts***
2. ***F&DT and NDI Considerations***
3. ***Knowledge transfer between machine makers and end users***


Preliminary Agenda (rev. 10/30/20)

Joint FAA – EASA Workshop on Qualification / Certification of Additively Manufactured Parts

November 2-6, 2020

Venue: *virtual (WebEX)*

- **Workshop Co-organizers**: Michael Gorelik (*FAA*) and Simon Waite (*EASA*)
- **Workshop Facilitator**: Rollie Dutton (*ARCTOS*)

Note: all times listed below are in EST

Day 1 – November 2

8:30 – 9:30 Arrival and WebEx Orientation (optional, but recommended to verify system compatibility)

9:30 – 9:55 Welcome / Agenda Review / Workshop Format – *M. Gorelik, S. Waite, R. Dutton*
9:55 – 10:10 Opening Remarks by FAA Leadership – *Ms. Di Reimold, Deputy Director of the Policy and Innovation Division*
10:10 – 11:00 Keynote Presentation – *Dr. Charlie Kuehmann, VP of Materials Engineering and NDE, and Mr. Will Heltsley, VP of Propulsion Engineering* – SpaceX

11:00 – 11:20 Break

11:20 – 11:40 FAA Update – *M. Gorelik (FAA)*
11:40 – 12:00 EASA Update – *S. Waite (EASA)*
12:00 – 12:20 "Structural Assessments for Additive Manufacturing of a Bellcrank Family of Parts" – *J. 'Mike' Kasprzak (NAVAIR)*
12:20 – 12:40 "Thales' Application of MASAAG & EASA Guidance - Polymers & 'Systems' " - *S. Catt (Thales)*
12:40 – 13:00 "Evolution of Metal AM Qualification and Certification" - *K. Slattery (Barnes Global Advisors)*

13:00 Adjourn of Day 1

Day 2 – November 3

9:00 – 9:30 Arrival / Log-in / System Checks

9:30 – 9:50 "Effect of Defects on AM Fatigue - Probabilistic Approaches", *J. Mardaras (Airbus)*
9:50 – 10:10 "Fatigue Life Prediction of Additively Manufactured Ti-6Al-4V", *M. Benedict (USAF/AFRL)*
10:10 – 10:30 "Qualification and Certification of a Wire-fed DED Additive Material Process", *H. Løken Larsen (Norsk Titanium)*

10:30 – 10:50 Break

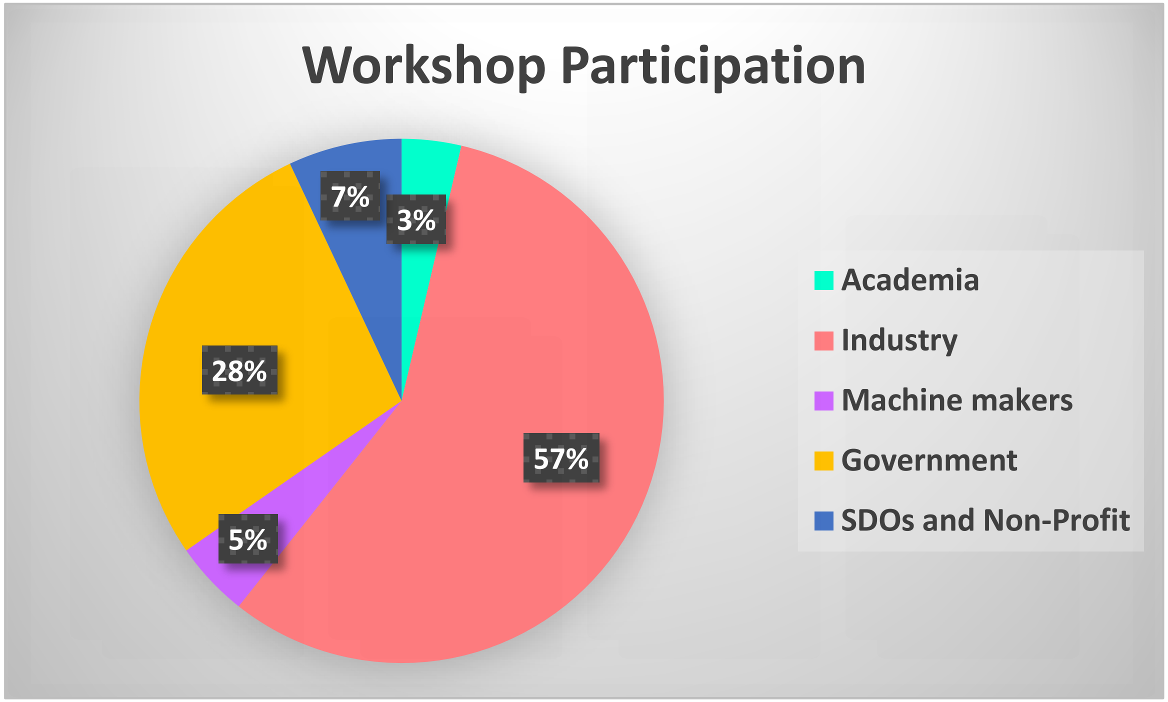
10:50 – 13:00 Parallel Breakout Sessions *(including breaks)*

Breakout Session #1 – "Qualification of Low-Criticality AM Parts"
Co-chairs: S. Waite (EASA) and J. Mallory (Delta TechOps)

13:00 Adjourn of Day 4

Workshop "Demographics"

over 300 participants



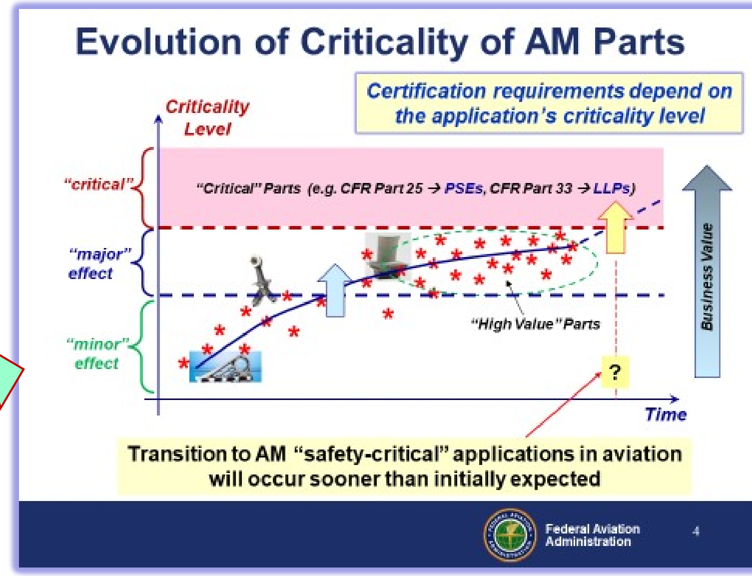
16 Countries

Austria
Belgium
Brazil
Canada
Finland
France
Germany
Italy
Netherlands
Norway
Portugal
Singapore
Spain
Sweden
UK
US

Continuing Evolution of AM Landscape…

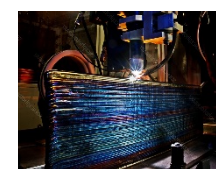
- **By product type**
  - Engines
  - Transport Airplanes
  - Rotorcrafts
  - GA Airplanes
  - UAVs / UAMs

- **By criticality level**



- **By AM process type**

  Example of "cross-pollination" between engine and airframe OEMs by AM process type:
  - **Engines: PBF →** *adding* **wire-based DED**
  - **Airframes: wire-based DED →** *adding* **PBF**

Other Trends in AM Applications

- **Multi-laser systems**
- **In-situ process monitoring**
- **More aggressive parameter settings**
  - Increased throughput / lower cost
- **Application in new aircraft architectures (UAV / UAM)**
  - Novel methods of compliance - regulatory requirements span across Parts 23, 27/29, 33

H.R. 302 “FAA Reauthorization Act of 2018” and OMB Circular A-119

One Hundred Fifteenth Congress
of the
United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Wednesday, the third day of January, two thousand and eighteen

An Act

To provide protections for certain sports medicine professionals, to reauthorize Federal aviation programs, to improve aircraft safety certification processes, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE; TABLE OF CONTENTS.

(a) SHORT TITLE.—This Act may be cited as the “FAA Reauthorization Act of 2018”.

SEC. 329. PERFORMANCE-BASED STANDARDS.

The Administrator shall, to the maximum extent possible and consistent with Federal law, and based on input by the public, ensure that regulations, guidance, and policies issued by the FAA on and after the date of enactment of this Act are issued *in the form of* ***performance-based*** *standards*, providing an equal or higher level of safety.

CIRCULAR NO. A-119 Revised

February 10, 1998

MEMORANDUM FOR HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

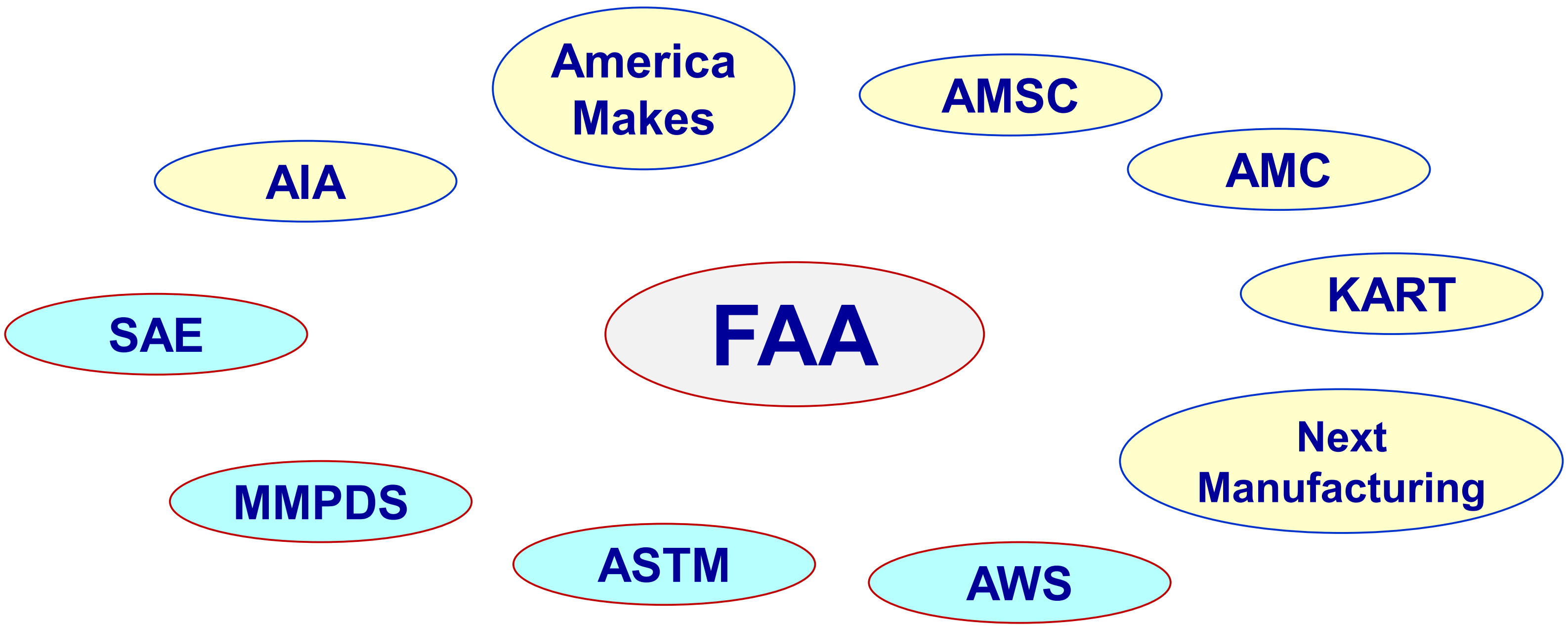
SUBJECT: Federal Participation in the Development and Use of Voluntary Consensus Standards an in Conformity Assessment Activities

Revised OMB CircularA-119 establishes policies on Federal use and development of voluntary consensus standards and on conformity assessment activities. Pub. L. 104-113, the "National Technology Transfer and Advancement Act of 1995," codified existing policies in A-119, established

All federal agencies must use *voluntary consensus standards* in lieu of government-unique standards in their procurement and regulatory activities, except where inconsistent with law or otherwise impractical.

Engagement with SDOs and Consortia

A partial list…

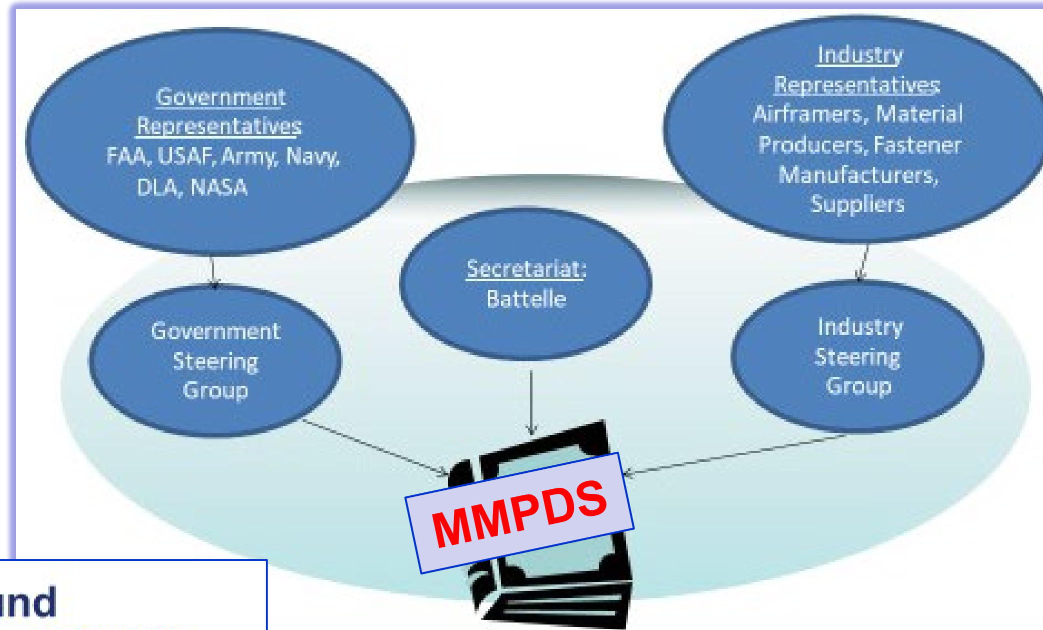


SDOs

Consortia / WGs

Material Allowables Considerations

- Generation of design allowables is ***contingent upon mature material and process specifications***
- Cross SDOs and WGs collaboration is essential



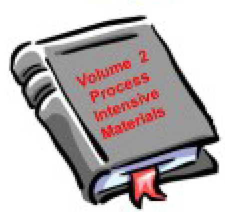
PIM Historical Background

FAA Proposal to Create Separate Document for PIM

PIM = Process Intensive Materials

- General agreement within the MMPDS to adopt the FAA recommendation to split the current Handbook into two Volumes,
  - Traditionally produced Materials.
  - Process intense produced materials (PIM).
    - ✓ New process intensive and associated guidance would be contained in Volume 2.
- Battelle developed draft outline for the PIM volume

Doesn't require "further showing"



Requires "further showing"

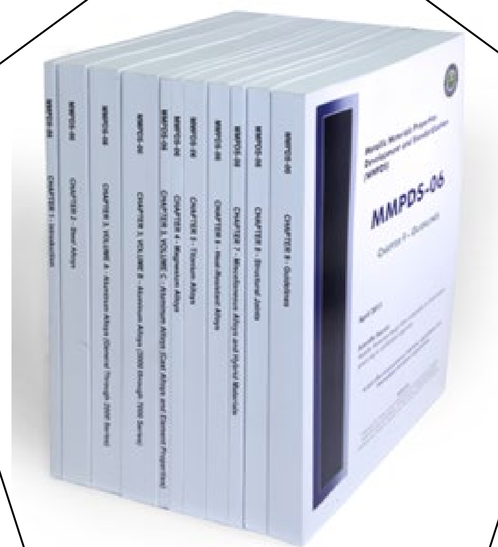
DRAFT

Example: MMPDS Interaction with SDOs and WGs

SDOs
WGs

SAE
- AM Material and Process Specs (AMS-AM)
- Use of MMPDS data analysis tools for spec min values

AWS
- Welding Specs
- AM Specs



ASTM
- Testing Specs
- AM Material Specs
- *Signed MOU with Battelle*

AIA AM WG
Developing best practices for Q&C of metal AM parts

CMH-17 AM WG
Coordination to explore synergies and streamline communication between two groups

Example: Development of Part Families Framework

- **Concept of Part Families discussed in prior FAA – co-sponsored AM Workshops by both airframe and engine OEMs**
- **Referenced in the 2020 AIA AM Working Group's report:**
  - "A part family may be established by defining the key characteristics (e.g., geometric features, feedstock, and processing window), and developing design values representative of the part family features and criticality. The resulting design values would then be applicable to any part defined to be within that family. This approach is more efficient than creating unique allowables and design values for every part."

  https://www.aia-aerospace.org/wp-content/uploads/2020/02/AIA-Additive-Manufacturing-Best-Practices-Report-Final-Feb2020.pdf
- **Submitted as an "idea" for the America Makes Rapid Innovations Call (RIC) → *selected by the Executive Committee for funding via open solicitation***
- **Award announced on *Nov. 2, 2021***
  - *Awardee*: ASTM CoE – "Best Practices for Additive Manufacturing Part Families Relating to Product Qualification and Certification"

Example: Development of Computational Materials (CM) Capabilities for Metal AM

NASA/TM–2020-
NIST/publication info
FAA/publication info

DRAFT

NASA / NIST / FAA Technical Interchange Meeting on Computational Materials Approaches for Qualification by Analysis

E.H. Glaessgen
NASA Langley Research Center, Hampton, Virginia

L. Levine, P. Witherell, A. Donmez
National Institute of Standards and Technology, Gaithersburg, Maryland

M. Gorelik
Federal Aviation Administration, Scottsdale, Arizona

N.A. Ashmore
Boeing Research and Technology, St. Louis, Missouri

R. Barto
Lockheed Martin Advanced Technology Laborator

C.C. Battaile
Sandia National Laboratory, Albuquerque, New Mex

H. Millwater
University of Texas at San Antonio, San Antonio, Texas

G.J. Nanni
Bell, Fort Worth, Texas

Will be discussed in Nov. 10 presentation

Co-organizers: NASA and FAA

Membership

Government	Industry	Academia
NIST	Boeing	Carnegie Mellon
AFRL	Lockheed-Martin / Sikorsky	UTSA
Sandia NL	Raytheon / P&W	Vanderbilt
NAVAIR	GE Aviation	Penn State
ORNL	Spirit Aerosystems	Northwestern
Army Aviation	Honeywell Aerospace	
	Howmet Aerospace	
	SwRI	
	Northrup-Grumman	
	Textron Aviation / Bell	

Sample R&D Themes

- **Development of material databases (joint with DoD, NASA and industry) → MMPDS, JMADD, NCAMP / CMH-17** → *see pp. 17-19*
- **Seeded defect studies / effect of defects**
- **Surface integrity**
- **Understanding of process variability drivers (KPVs)**
- **Round-robin studies**
- **Probabilistic DT framework for AM (collaboration with NASA, USAF and NAVAIR)**
- ***Benchmarking* of NASA ULI Program (PI: CMU)**
- **Modeling and Simulation (collaboration with NASA, NIST, DOD, industry) →** **see p.17**

FAA-DoD JMADD Research

- **Joint Metal Additive Database Development (JMADD)**
  - To produce a set of publicly available statistically substantiated material property data of bulk material properties for metallic AM material with a corresponding material and process specification as well as a framework for future database development projects
  - The selection of a single material and process is necessary; initial process and material combination for the scope of this project is Laser Powder Bed Fusion (L-PBF) of Ti6Al4V alloy.
  - The overall objective is to achieve B*) and A *) -basis (T90 and T99) design allowable data and establish a best practice for developing AM allowables and specifications that is publicly available for L-PBF of Ti6Al4V.

*) **Note:** MMPDS introduced the terms C- and D-basis allowables for the corresponding statistical definitions of metal AM properties

Database Development

Material Control,
Process Control,
and Databases

are all intertwined

- **While primary goal is to develop a public database, the framework is equally important**
  - Material definition
  - Specification/document structure: feedstock, finished material, printing process, post-print processes, role of PCDs
  - Test matrix: lots, batches, print direction, test methods, number of specimens, statistics
  - Understanding limits of database: printing equipment, post-print process, effects of defects, print direction, etc.

Database Development

- **Similar research led to development of the public Ultem 9085 database** [Stratasys ULTEM 9085 (wichita.edu)]
- **Many follow-on projects active**
  - Database equivalence (different equipment, process parameters, effects of defects)
  - Additional metallic and non-metallic AM materials – e.g., is the framework appropriate for reinforced AM materials, ceramics, etc.?
  - Public advisory groups help steer activities

The metal AM project will have similar follow-on activities as well

FAA AM Guidance Development

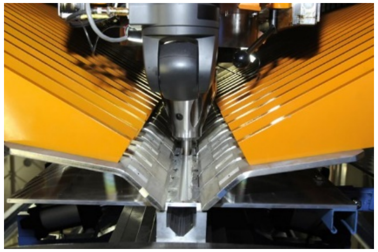
- **Applicant-Specific Guidance Memo**
  - Used on several projects
  - ➢ *Will be discussed in R. Grant's presentation*

- **Advanced Manufacturing Policy**
  - Not limited to AM
  - Status: *going through internal review process*

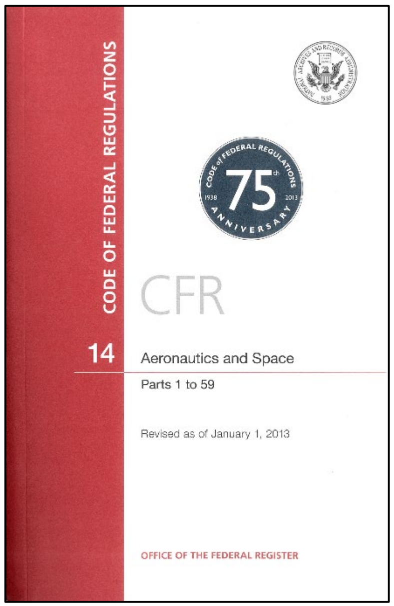
→ *see pp. 21-23*

Advanced Manufacturing Policy

- **Reviews the regulatory requirements, certification considerations, and FAA expectations applicable to parts produced using advanced manufacturing techniques**
  - **Advanced Manufacturing =** *methods where incoming material consolidates using a series of process steps requiring strict controls to achieve near-final part geometry and the desired repeatable performance characteristics, and where variation in any process step may have measurable effects on the material characteristics that in turn affect product performance*
  - Examples of advanced manufacturing techniques include, but are not limited to: composites, additive manufacturing (AM), and friction stir welding
  - Expect that new advanced manufacturing techniques will be introduced in the future



Advanced Manufacturing Policy



- **Purpose:** Highlight the fundamental requirements for type design and quality control of advanced manufacturing techniques
- **Audience:** Design and production approval applicants and holders who implement advanced manufacturing
  - TC/STC, TSO, PMA, repairs, etc.

Advanced Manufacturing Policy

- **Provides considerations that should be addressed when demonstrating compliance to specific airworthiness standa**
  - Identifies importance of adequate material and process control
  - Provides limited methods of compliance (MOC), but identifies “wha worry about and why” for typically affected regulations (strength, fa and damage tolerance, maintenance, flammability, etc.)
  - Explains why different MOC may be required for various regulations so applicants know what to address in cert plans; relies on industry standards (or historical FAA guidance, when applicable) for additional details
  - Highlights importance of identifying criticality of the application, as it directly relates to level of FAA involvement and degree of rigor in compliance findings

Summary

- All existing FAA *rules* apply to AM
- *However*… need to consider unique / *AM-specific attributes*, especially for higher criticality components
- Leverage experience with other relevant material systems and historical “lessons learned”
- Increasing role of public standards, specifications and data – *part of the performance-based regulatory landscape*
  - *Support development of Means of Compliance (MOCs)*
- Significant increase in FAA-funded R&D activities over the past 1-2 years
- Increasing industry’s interest in developing Computational Materials / ICME capabilities

Discussion

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Proceedings of the FAA – EASA AM Workshops (2018-2020)

Principal Organizers: Dr. Michael Gorelik (FAA) and Dr. Simon Waite (EASA)

- **2018 Joint FAA – EASA AM Workshop (Wichita, KS)**

  http://www.tc.faa.gov/its/worldpac/techrpt/tc20-16.pdf
- **2019 Joint FAA – EASA AM Workshop (Cologne, Germany)**

  https://www.easa.europa.eu/newsroom-and-events/events/2019-easa-faa-workshop-additive-manufacturing
- **2020 Joint FAA – EASA AM Workshop (*virtual*)**

  https://ksn2.faa.gov/avs/airpi/pires/csta/2020am/SitePages/Home.aspx

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