

Computational Materials for Qualification and Certification of Process-Intensive Metallic Materials (CM4QC)

An Industry – Government – Academia Steering Group

7th World Congress on ICME
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Presented by

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Case Number: TBD



Outline

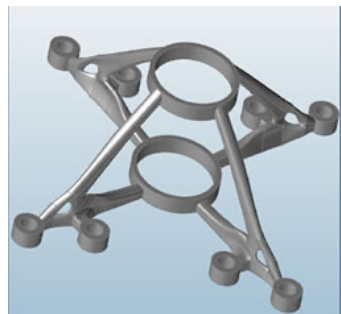


- Background and Motivation
- Engagement with the Community
- Steering Group Goals, Membership, and Operation
- Vision and Key Elements of the Roadmap
 - State of the Art and Requirements
 - Capability Maturation, Assessment, and Increasing Acceptance

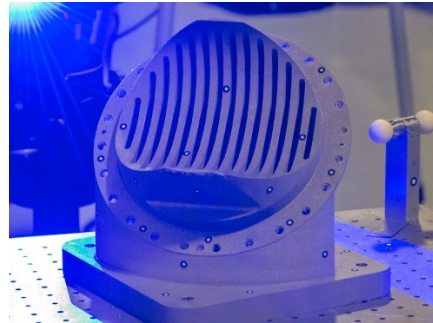
In the context of this presentation:

- The terms **CM** (Computational Materials) and **ICME** (Integrated Computational Materials Engineering) are used *interchangeably*
- *Metal Additive Manufacturing (AM) is used as a representative example of Process-Intensive Materials (PIM)*

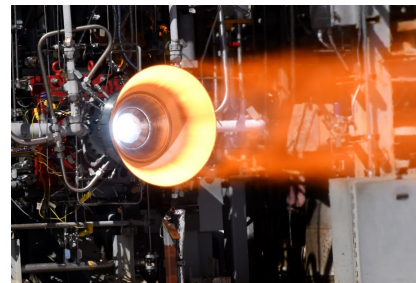
Increasing Complexity of AM Parts



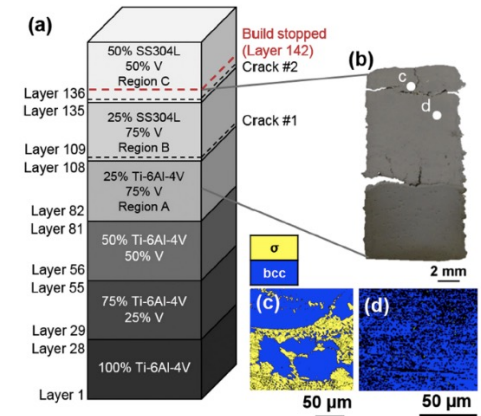
Bracket
Image: NASA



Pogo Z-Baffle
Image: NASA



Rocket Engine Components
Image: NASA

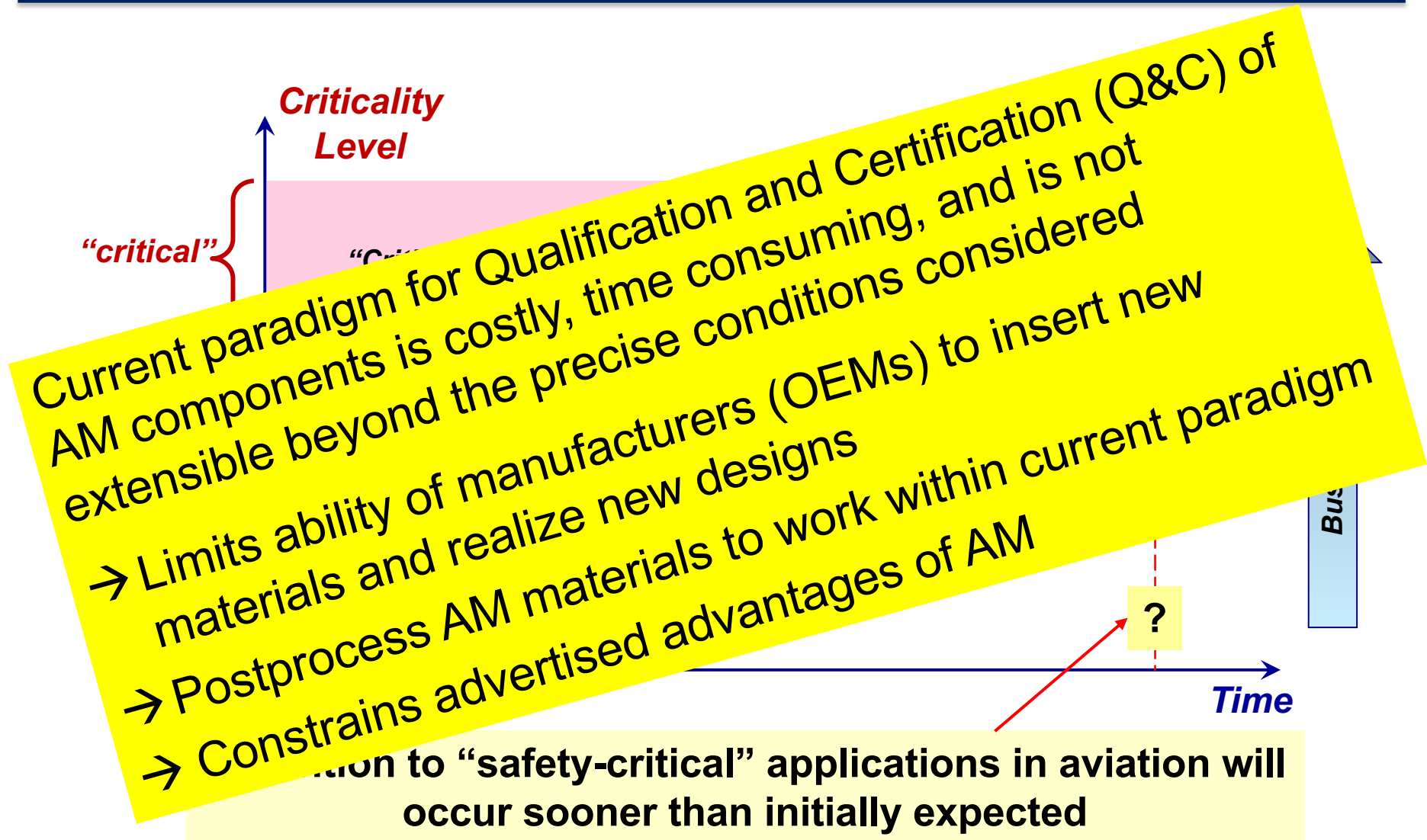


Graded Materials
Image: NASA*

Increasing Complexity

*Bobbio et al. (2018) *J. Alloys and Compounds*, 742 1031

Evolution of Criticality of AM Parts



*CFR - Code of Federal Regulations
PSE – Principal Structural Element
LLP – Life Limited Part

Examples of “Model-Friendly” Domains (in the Context of FAA Regulations)



Reference to Title 14 CFR Parts 25 (Airframe) and 33 (Engines)

- Damage Tolerance → Part 25 (AC 25.571-1D)
 - In general, “**analysis supported by test evidence**” is accepted
- Damage Tolerance → Part 33 (AC 33.70-1)
 - Analysis is accepted (e.g., stress, heat transfer, crack growth, ...)
 - However, “**...the analysis approach should be validated against relevant test data**”



ICME as ~~Emerging~~ *Evolving* Technology



Commonly identified *benefits*:

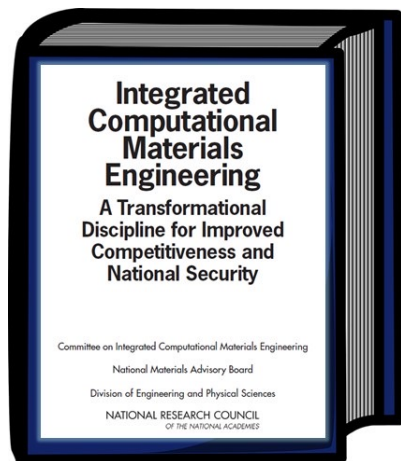
- Cost savings
- Novel fit-for-purposes materials
- Integrated design, certification, and flexible manufacturing
- Risk reduction (*program risk* vs. product safety risk)

Accelerated Insertion of Materials (AIM) Program



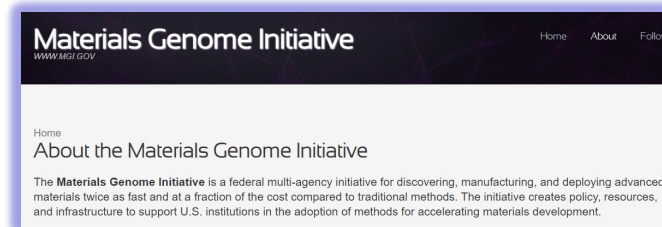
The AIM program initiative created a new materials development methodology that accelerates the insertion of new materials in order to achieve parity with the engine/platform development/design cycles. Accomplishments of the AIM program include:

- Establish design-driven material requirements by tightly coupling design and materials activities and tools.
- Providing earlier information (with confidence bounds) to designers throughout the development cycle.
- Controlling the performance, producibility, and cost of materials.
- Reducing risks of new material insertion risk while also decreasing costly, time-consuming data generation.
- Creating a knowledge base and tool kit for designers that links with computational design tools.



Keeping pace with industry needs

Requires significant maturation to realize this benefit



Input from the Aerospace Community



NASA/CR—2018-219771



Vision 2040: A Roadmap for Integrated, Multiscale Modeling and Simulation of Materials and Systems

*Xuan Liu and David Furrer
Pratt & Whitney, East Hartford, Connecticut*

*Jared Kosters and Jack Holmes
Nextight Group, Silver Spring, Maryland*

March 2018

NASA/CR-2018-219771

NASA/TM—2019-220428



ARMD Workshop on Materials and Methods for Rapid Manufacturing for Commercial and Urban Aviation

*Jonathan B. Ransom, Edward H. Glaessgen, and Brian J. Jensen
Langley Research Center, Hampton, Virginia*

November 2019

NASA/TM-2019-220428

NASA/TM—20210015175

DOT/FAA/TC-20/38



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

*Edward H. Glaessgen
Langley Research Center, Hampton, Virginia*

*Lyle E. Levine, Paul W. Witherell, and M. Alkan Donmez
National Institute of Standards and Technology, Gaithersburg, Maryland*

*Michael Gorelik
Federal Aviation Administration, Scottsdale, Arizona*

*Nathan A. Ashmore
Boeing Research and Technology, St. Louis, Missouri*

*Richard R. Barto
Lockheed Martin Advanced Technology Laboratories, Cherry Hill, New Jersey*

*Corbett C. Battaile
Sandia National Laboratory, Albuquerque, New Mexico*

*Harry R. Millwater
University of Texas at San Antonio, San Antonio, Texas*

*Gerard J. Nanni
Bell, Fort Worth, Texas*

*Anthony D. Rollett
Carnegie Mellon University, Pittsburgh, Pennsylvania*

*Edwin J. Schwalbach
Air Force Research Laboratory, Dayton, Ohio*

*Vasisht Venkatesh
Pratt and Whitney, East Hartford, Connecticut*

May 2021

NASA/TM-2021-15175

NASA / NIST / FAA Technical Interchange Meeting



- Held at NASA Langley Research Center on January 15-16, 2020.
- **Motivated by three related factors:**
 - The **aerospace industry's increasing interest** in expanding the use of computational materials for Q&C of process-intensive metallic materials.
 - The **rapid maturation of computational materials capabilities** across a range of applications.
 - A general **lack of coordination** of development and investment in these capabilities by funding organizations.
- Included 60 subject matter experts (SMEs) representing 8 aerospace manufacturers, 7 government organizations and 2 universities.
- Participation was evenly divided into Processing-Microstructure and Microstructure-Performance tracks.
- **Key objectives were to:**
 - **Understand existing gaps** in model-based, e.g., computational materials, capabilities for processing and performance prediction for aerospace materials and components.
 - Forecast **how capabilities can be matured** to support material, process and part-level Q&C.

Computational Materials for Qualification and Certification (CM⁴QC) Steering Group



The *primary goals* of this Steering Group are to

- Provide **coordination for and focus to investments** made by U.S. industry and the U.S. government toward development of computational materials-based approaches for Q&C of process intensive metallic materials.
- Identify key considerations and enablers required to **increase airworthiness / certifying authorities' acceptance of CM methods** used for Q&C of structural or flight-critical PIM parts.
- **Increase dialogue among the stakeholder organizations** and seek opportunities for **collaboration**.

Membership includes subject matter experts from the aerospace industry, various government laboratories and academia

Steering Group Membership



Government

National Aeronautics and Space Administration*
Federal Aviation Administration*
National Institute of Standards and Technology*
Sandia National Laboratory*
U.S. Air Force Research Laboratory
U.S. Army Aviation Command
U.S. Navy Air Systems Command
Oak Ridge National Laboratory

Industry

The Boeing Company*
Lockheed-Martin* / Sikorsky
Raytheon / Pratt & Whitney
General Electric Aviation
Spirit Aerosystems
Honeywell Aerospace
Howmet Aerospace
Southwest Research Institute
Northrup-Grumman Corporation
Textron Aviation

Academia

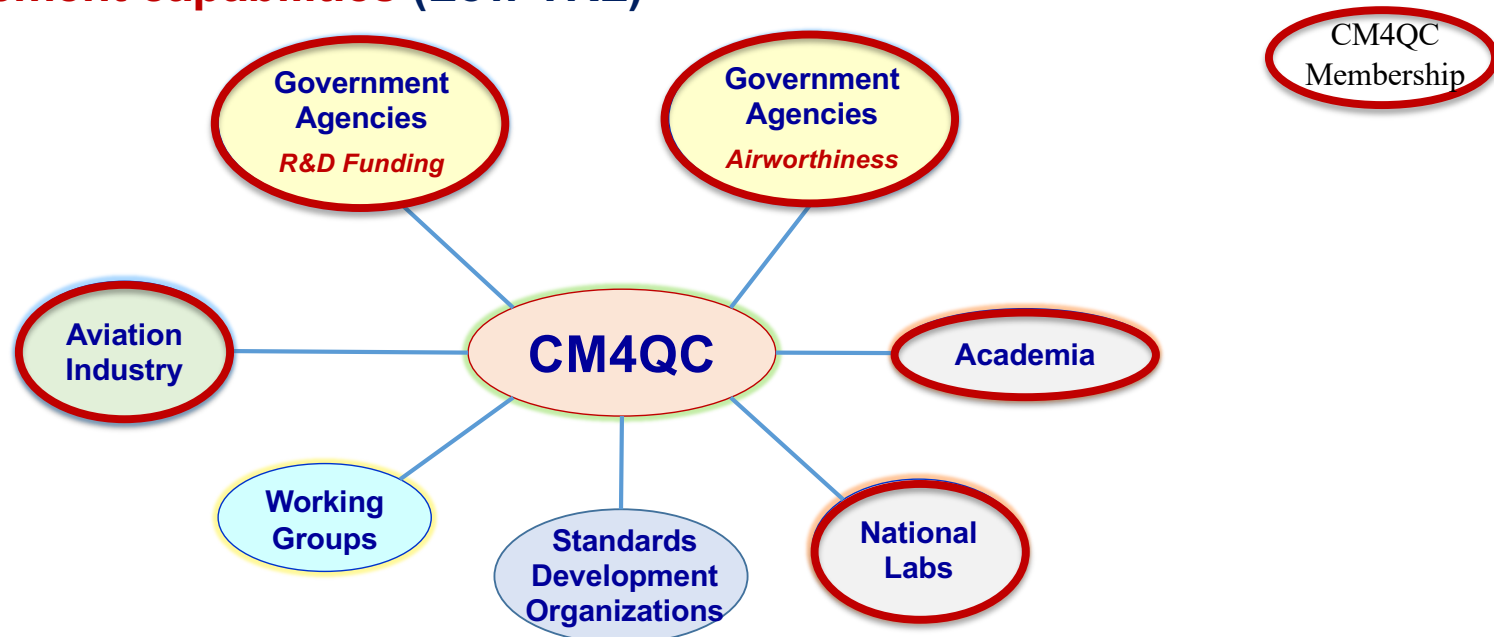
University of Texas at San Antonio*
Carnegie Mellon University*
Vanderbilt University
Pennsylvania State University
Northwestern University

*CM4QC Leadership Team

Operation of the CM4QC Steering Group



- Working Group 1: Understanding **industry priorities** / timeline and key regulatory implications (High TRL*)
- Working Group 2: Strategies for **maturation and transition** of research to engineering (Mid TRL)
- Working Group 3: Development of required **computational materials and measurement capabilities** (Low TRL)



**Expected initial outcome → Multi-year implementation plan
Symposium at MS&T 2024 (planned)**

Outline of Key Elements of the Roadmap (1/2)



Part 1: State of the Art and Requirements

- Identify **key stakeholders**
- **Industry's vision** (including timeline, extent of application and key drivers) for adopting CM as a component of Q&C framework for PIM
- Identification of **key CM and enabling technologies** that are needed (based on a phased approach) to achieve the industry vision.
- Identify **key regulatory gaps** that must be addressed to enable broader use of CM in Q&C for relevant applications and product types
- **“State of industry” assessment** of CM tools including level of validation and maturation

Outline of Key Elements of the Roadmap (2/2)



Part 2: Capability Maturation, Assessment, and Increasing Acceptance

- Define **CM maturity assessment framework**
- Identify key elements and associated methods for **CM verification and validation (V&V) framework** including data, testing and characterization requirements
- Identify **acceptable levels of V&V** from the regulatory and industry perspective
- **Technology maturation path** by TRL including simulation, testing, and characterization
- Identify key elements and timeline of the **CM ecosystem's maturation path**
- Identify **key stakeholder organizations and funding opportunities**

Anticipated Key Drivers by Stakeholder



• Industry

- Reduced time and resources for new materials development → **time to market**
- Reduced level of Q&C testing → **\$\$ and time savings**
- Enhanced process control and quality assurance capabilities → **improved product safety and reliability**

• Government

Note: in the context of this discussion, the government agencies' considerations include – (a) R&D funding; (b) regulatory; (c) end user.

- To understand **R&D investment priorities** for developing CM capabilities for Q&C of advanced metallic materials (across the TRL scale)
- To understand **industry's plans** (including timeline and extent of application) **for adopting CM capabilities** for Q&C of advanced materials. To use this understanding in identification of the **corresponding regulatory enablers and gaps**.
- The **same key drivers as listed above for Industry** (due to some of the Government agencies' perspective as *end-user* of advanced metallic materials)

• Academia

- To understand **R&D priorities and key technology gaps** for developing CM capabilities for Q&C of advanced metallic materials
- Understand **educational needs** (including continuing education) of industry and academia

Computational Materials-Informed Q&C of Additively Manufactured Flight Hardware



Small deviations in processing parameters may result in large differences in performance

**Current approaches for Q&C of metallic materials (including AM)
are entirely based on test data**

Goal is to change the paradigm for Q&C: Develop a computational materials-informed ecosystem for quantifying sources of variability in fatigue performance of additively manufactured metallic materials through integrated multi-scale, multi-physics simulation, characterization and monitoring

Summary



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Questions: Please contact us at...



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