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

An Industry – Government – Academia Steering Group

AIAA Aviation
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Approved for Public Release on TBD
Case Number: TBD

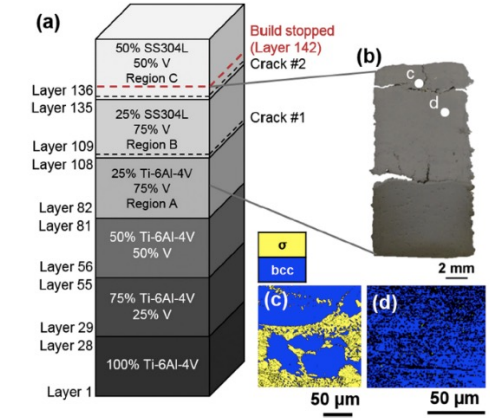
Outline

- 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
- Some Ongoing Work at NASA Langley

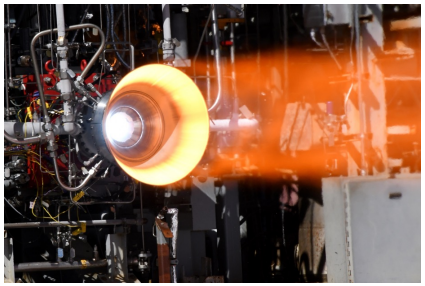
In the context of this presentation:

- 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)*

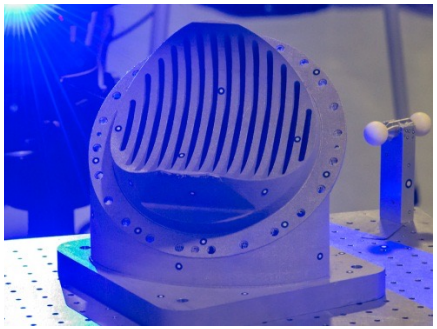
Increasing Complexity of AM Parts



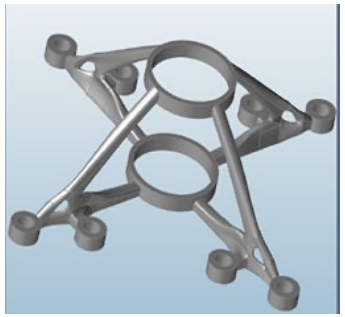
Graded Materials
Image: NASA*



Rocket Engine Components
Image: NASA



Pogo Z-Baffle
Image: NASA

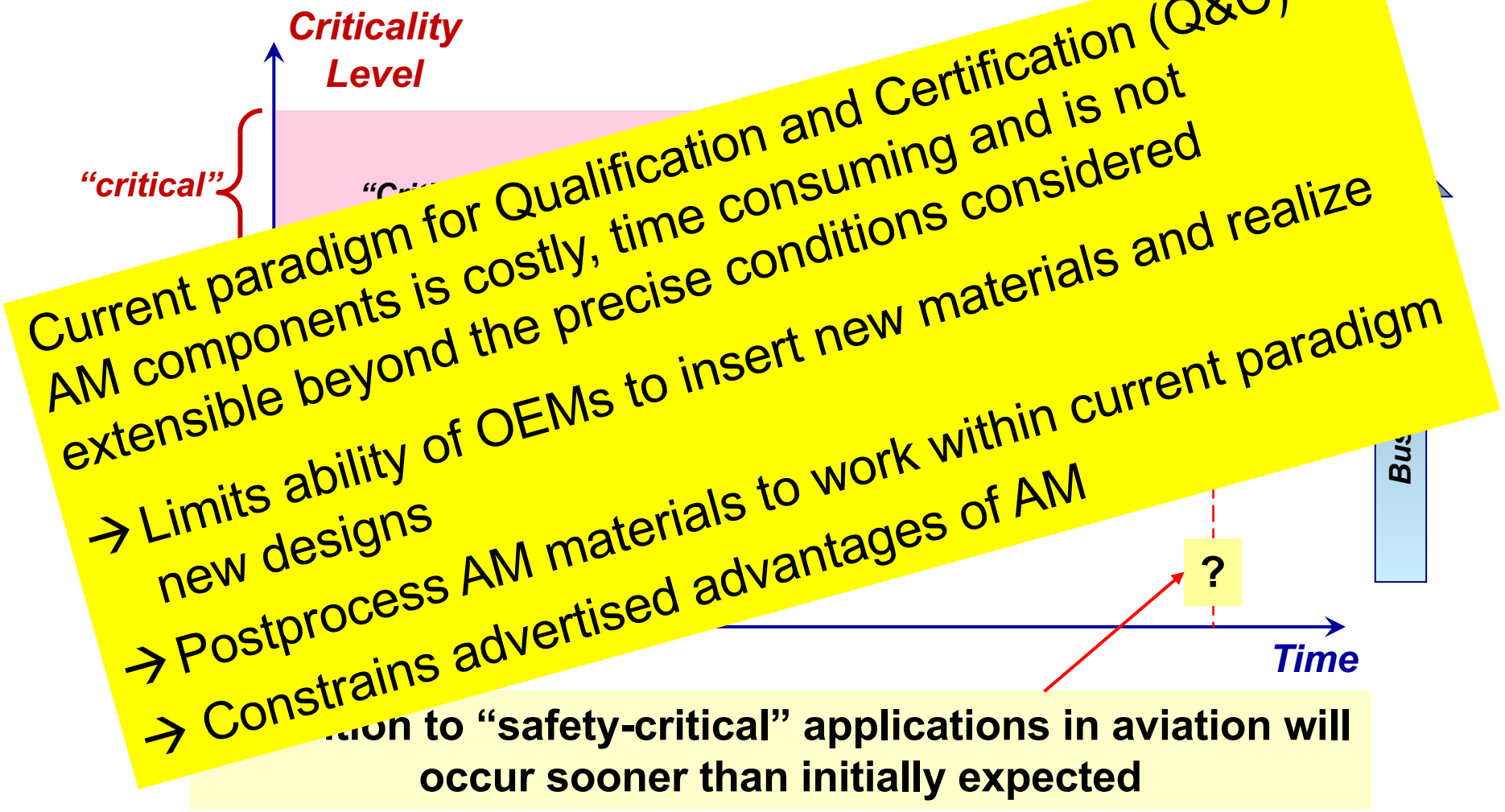


Bracket
Image: NASA

Increasing Complexity

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

Evolution of Criticality of AM Parts



Current paradigm for Qualification and Certification (Q&C) of AM components is costly, time consuming and is not extensible beyond the precise conditions considered

→ Limits ability of OEMs to insert new materials and realize new designs

→ Postprocess AM materials to work within current paradigm

→ Constrains advertised advantages of AM

…tion to "safety-critical" applications in aviation will occur sooner than initially expected

*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**


Image: NASA

- 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"**


Image: NASA

ICME as ~~Emerging~~ *Evolving* Technology

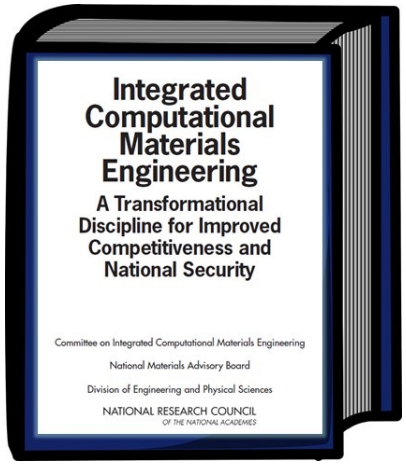
Accelerated Insertion of Materials (AIM) Program DARPA

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.

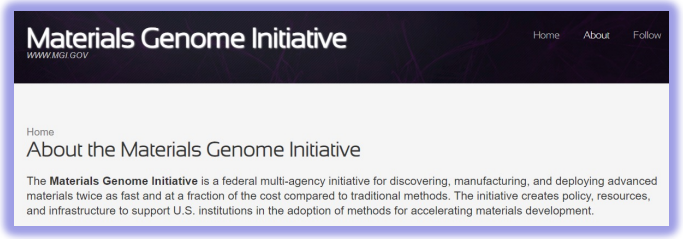
Commonly identified benefits:

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



Keeping pace with industry needs

Requires significant maturation to realize this benefit



Input from the Aerospace Community

NASA/CR—2018-219771

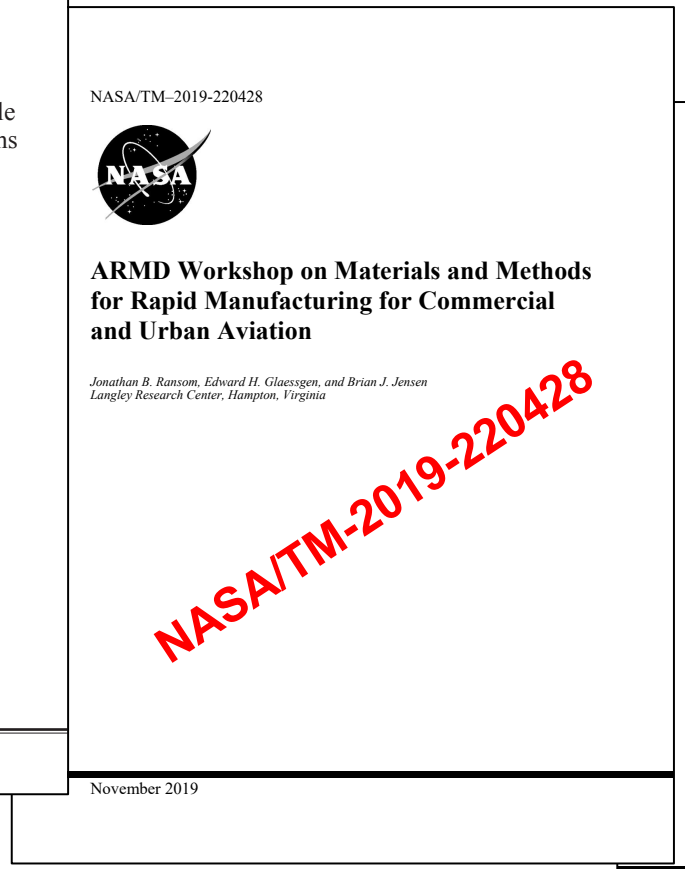
Vision 2040: A Roadmap for Integrated, Multiscale Modeling and Simulation of Materials and Systems

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

Jared Kosters and Jack Holmes
Nexight Group, Silver Spring, Maryland

March 2018

NASA/CR-2018-219771



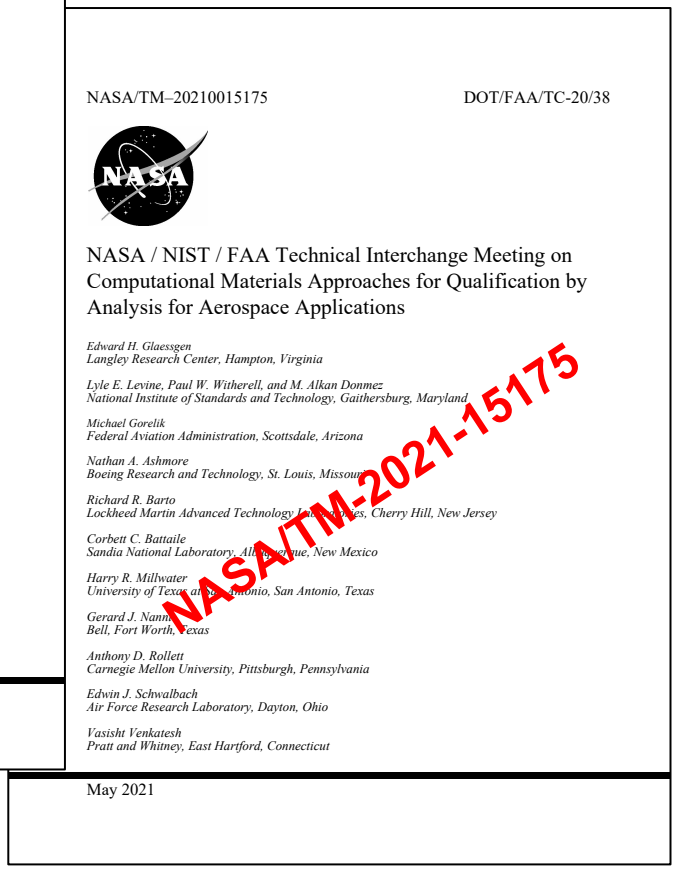
NASA/TM–2019-220428

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
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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

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

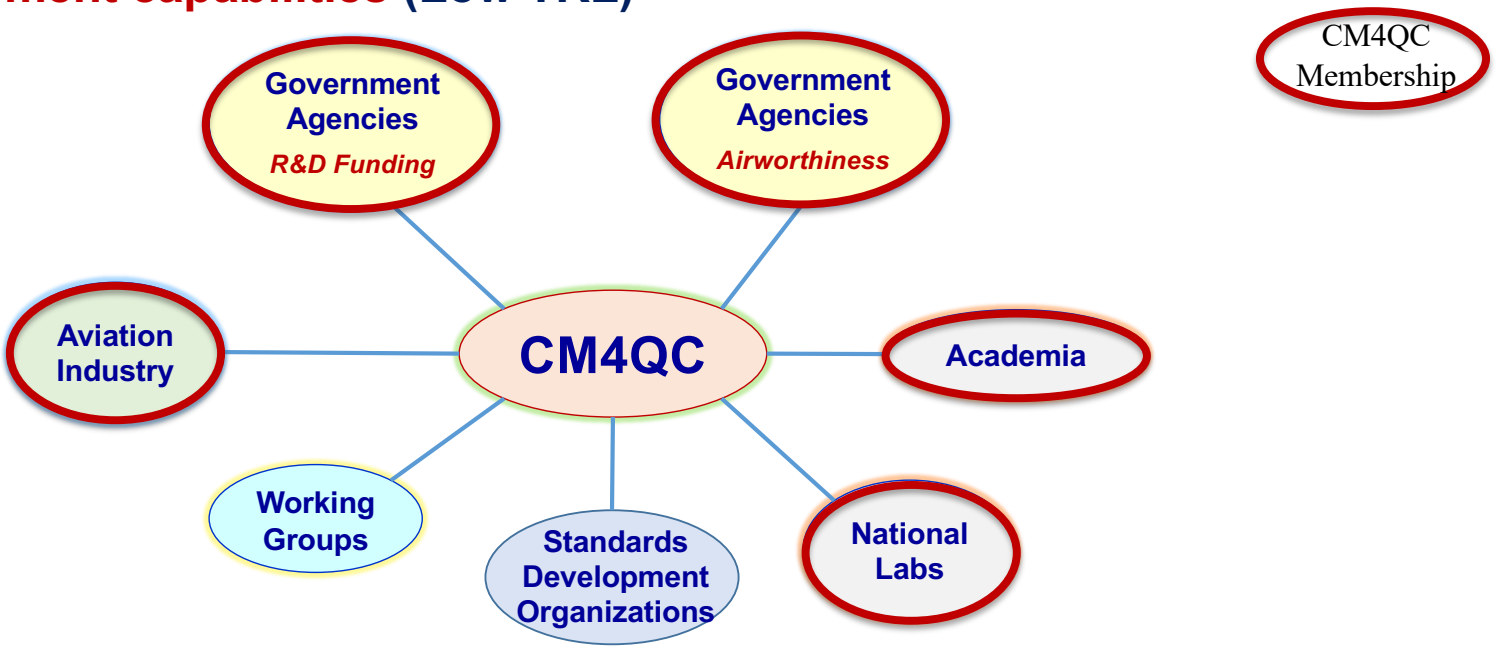
Industry
The Boeing Company*
Lockheed-Martin* / Sikorsky
Raytheon / Pratt & Whitney
General Electric Aviation
Spirit Aerosystems
Honeywell Aerospace
Howmet Aerospace
Southwest Research Institute
Northrup-Grumman Corporation
Textron Aviation

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)

*Technology Readiness Level

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

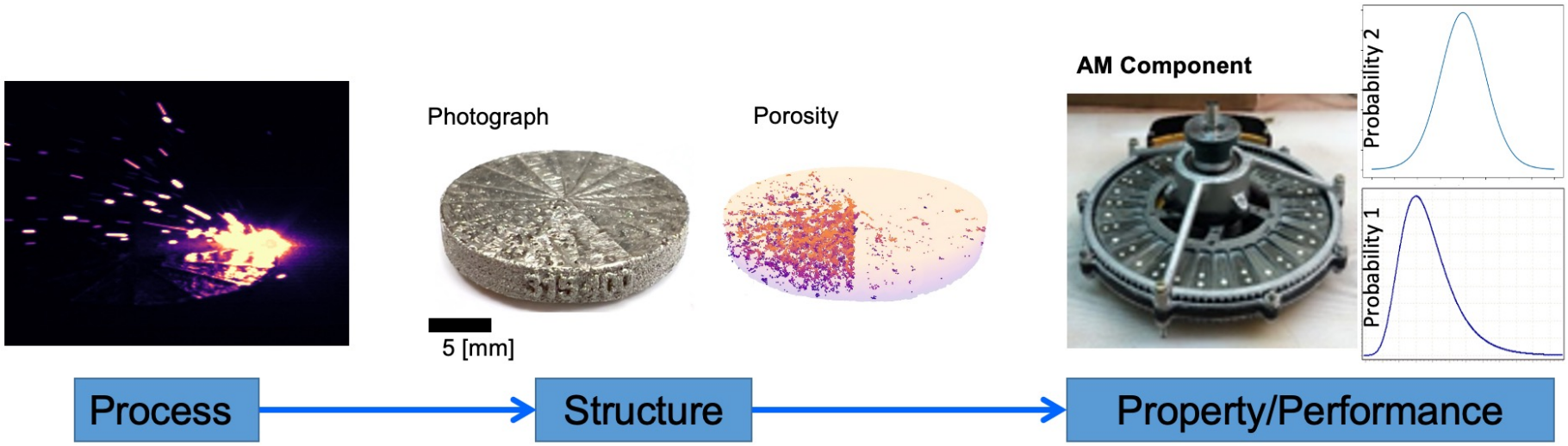
- Define CM **maturity assessment framework**
- Identify key elements and associated methods for CM verification and validation **(V&V) framework** including data, testing and characterization requirements
- Identify **acceptable levels of V&V** from the regulatory and industry perspective
- **Technology 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 Qualification and Certification 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

All images courtesy of Samuel Hocker at NASA Langley

Summary

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Questions: Please contact us at…

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*EHG gratefully acknowledges the Transformational Tools and Technologies Project of the NASA Aeronautics Research Mission Directorate for supporting the work discussed on Slide 15.