

Planning the Next Generation of Measurement Science for Additive Manufacturing

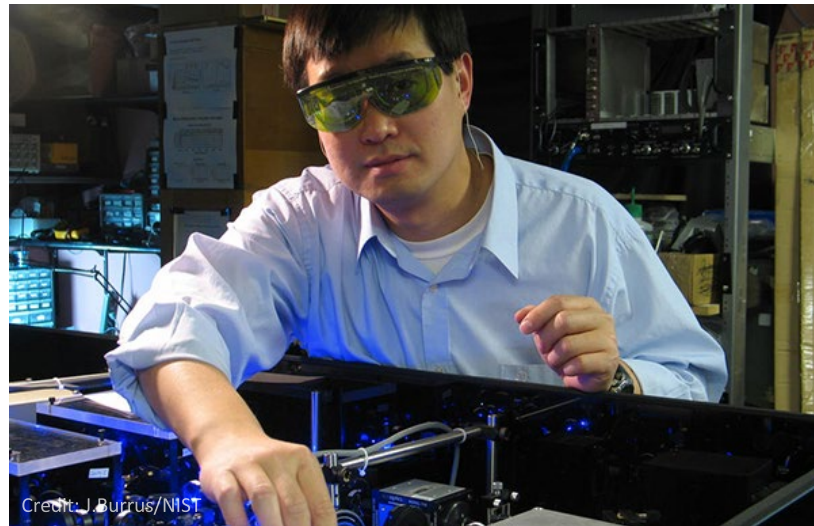


Paul Witherell

Measurement Science for Additive Manufacturing Program
Engineering Laboratory
National Institute of Standards and Technology

NIST Mission

To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life



NIST AT A GLANCE

Industry's National Laboratory



3,400+
FEDERAL
EMPLOYEES



5
NOBEL PRIZES



2 CAMPUSES
GAITHERSBURG, MD [HQ]
BOULDER, CO



2,700+
ASSOCIATES



10
COLLABORATIVE
INSTITUTES



Thousands
BUSINESSES USING
NIST FACILITIES



ManufacturingUSA®

1
NATL OFFICE FOR 16
MANUFACTURING
INSTITUTES



51
MANUFACTURING
EXTENSION
PARTNERSHIP CENTERS

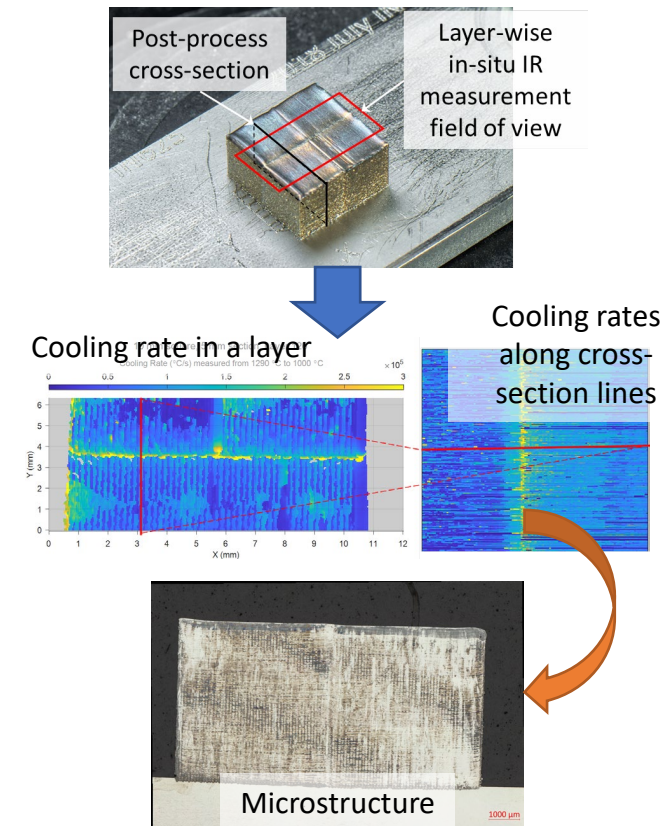


U.S. BALDRIGE
PERFORMANCE
EXCELLENCE PROGRAM

- Full spectrum of materials classes (Ceramics, Polymers, Metals, Concretes, Biological materials)
- Full spectrum of AM process categories

Focus areas:

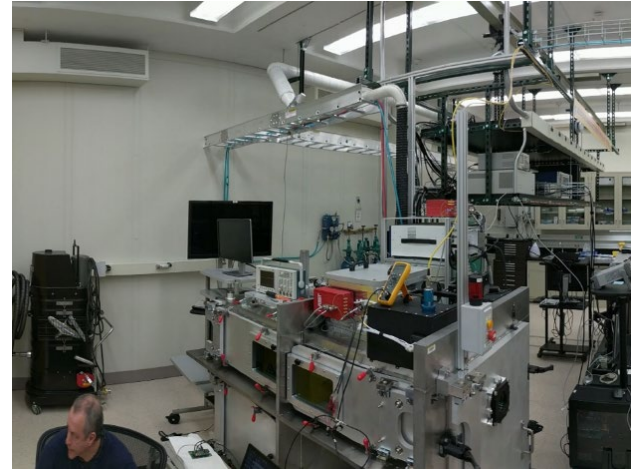
- Unique materials and material properties
 - Comprehensive characterization of processing-structure-properties-performance (PSP) relations
 - Determination of properties affecting printability/manufacturability
 - Provisionment of critical AM materials data to stakeholders
 - Methods to enable the insertion of new materials for additive applications
- Trustworthy in-process monitoring and control
- Verified and validated process and material models and design tools
- Rapid, inexpensive, and effective part inspection techniques
- Rapid and traditional machine and material qualification techniques
- Process and material standards and specification
- Underlying data structure, data science, and data analytics



NIST Dedicated AM Facilities

Additive Manufacturing Research Center

- Powder Bed Fusion
 - EOS M270, EOS M290
 - NIST AMMT/TEMPS Laboratory
- Directed Energy Deposition
 - Optomec LENS MR7
- Binder Jetting
 - ExOne



Powder characterization laboratory

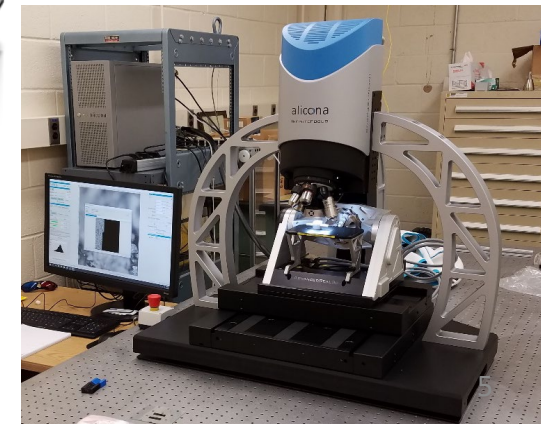
- Dynamic imaging for PSD
- Laser flash for thermal properties
- Rheometer and powder spreading test platform

Post-processing and testing facilities

- High temperature heat treatment furnace, EDM
- XCT, White light interferometry, focus variation microscopy, SEM, XRD

New In Process capabilities

- In Situ monitoring with Cornell High Energy Synchrotron Source
- New test bed modifications for in situ measurements



Many Collaborators Help to Execute Mission

NIST internal collaborations

- **Materials Measurements Laboratory** – AM material property measurements, material testing and modeling
- **Physical Measurements Laboratory** – thermal emissivity measurements for AM processes, laser power measurements
- **Center for Neutron Research** – neutron imaging, residual stress measurements
- **Information Technology Laboratory** – designs of experiments, statistical analyses, AMMD development
- **Manufacturing Extension Partnership** – industry outreach
- **Office of Advanced Manufacturing Programs** – Measurement science for advanced manufacturing awards

United States Government:

- **NSTC Interagency Working Group:** DoD (all branches), DOE, FAA, NASA, NSF, FDA, State
- **Other Federal Collaborators:** NRC, ITA
- **Government Research Laboratories:** LLNL, LANL, ORNL

Consortia: AM-Bench, Ad-hoc AM Data Management Working Group, AMSC, America Makes, Additive Manufacturing Consortium, ASTM Center of Excellence

Industry: GE Aviation and GE Research, Sigma Labs, SLM Solutions, EWI, Granutools, Mercury Scientific, LAM Research, and others

Academia: Penn State, UTEP, Georgia Tech, Purdue, Northeastern, NIU, U of Michigan, Wright State University, UNCC, UDC, Arizona State, U of Wisconsin, U Waterloo, CHESS

Local outreach: Maryland DOC

Two Upcoming Workshops



**Empowering Small and Medium
Size Enterprises Through
Effective Additive
Manufacturing Data
Management**

June 6-8

National Cybersecurity Center of
Excellence (NCCoE)
Rockville, MD

**Planning for the Next
Generation of Measurement
Science for Additive
Manufacturing**

August 29-31

National Cybersecurity Center
of Excellence (NCCoE)
Rockville, MD

Empowering Small and Medium Size Enterprises Through Effective Additive Manufacturing Data

NIST

The workshop will explore how best to empower the productive working relationship of small and medium size Enterprises (SMEs) with top tier manufacturers through effective additive manufacturing (AM) data management.



The goal is to examine the AM data management "Pain Points" associated with SME interactions with large system integrators (LSI) and government procurement agencies.



<https://www.nist.gov/news-events/events/2023/06/empowering-small-and-medium-size-enterprises-through-effective-additive>

Empowering Small and Medium Size Enterprises Through Effective Additive Manufacturing Data Management



Premise: The complex, diverse and frequently parochial relations between LSIs, SMEs, and customers tend to inhibit facile working relationships. This increases the cost and time required to bring a product to market while concomitantly inhibiting innovation and profitability.

To facilitate the maturation of these relationships the workshop will :

- Explore three major phases of the AM lifecycle
 - Development,
 - Production,
 - Delta Qual./Requalification
- Identify interactions and data exchanges among stakeholders to enable existing or innovative business models needed to accelerate the adoption of AM
- Examine mechanisms that support these interactions, including:
 - Computational tools,
 - Data repositories used, and
 - Collaborative platforms
- Identify political, economic, social, and technological (PEST) challenges

Workshop results will inform a NIST programmatic strategy and assist in the development of needed standards.

Connecting LSIs and SMEs

NIST



JOHN DEERE



Agenda: Day 1

Day 1 June 6, 2023:

Time	Theme	Activity
0730	Badging	Registration, Badging, Refreshments
0800	Welcome	Opening remarks by organizers & sponsors
0830	Business/Procurement	Keynote Speakers <ul style="list-style-type: none">• Chris Deluca (OUSD)• Neil Orringer (ASTRO)
0930	Networking	Refreshment Break
1000	SME Challenges	Panel 1: SME Perspective Moderator: Bill Bihlman (Aerolytics) <ul style="list-style-type: none">• Carl Dekker (Met L Flo)• Neil Goldfine (Jentek Sensors)• Derek Hass (CCAM)
1130	Lunch	Lunch / Networking
1300	LSI Challenges	Panel 2: LSI Perspective Moderator: William Frazier (Pilgrim Consulting) <ul style="list-style-type: none">• Dave Abbott (GE)• Jesse Boyer (P&W)• Nick Mule (Boeing)• Abdala Nassar (John Deer)
1430	Identification of Data Management Challenges	Working Groups <ol style="list-style-type: none">1. R&D Phase (SME & LSI)2. Production Phase (SME & LSI)3. Restart Phase (SME & LSI)
1700	Working Group Report	Working Group Brief Outs
1730		Adjourn
1800	Networking	No host social

Day 1 will explore the role of data in AM-driven services and supply chains and where challenges exist

Agenda: Day 2

Day 2 June 7, 2023

Time	Theme	Activity
0730	Badging	Registration, Badging, Refreshments
0800	Welcome	Opening remarks by organizers & sponsors Mcee: Paul Witherell & Yan Lu (NIST)
0830	Customer/End User	Keynote Speakers Moderator: Bill Frazier (Pilgrim Consulting) <ul style="list-style-type: none">• David Furrer (P&W)• Slade Gardner (Big Metal Additive)
0930	Networking	Refreshment Break
1000	Consortium Activities.	Panel 3: Consortium Perspective Moderator: Brandon Ribic (America Makes) <ul style="list-style-type: none">• Kareem Aggour (GE)• Mahdi Jamshidinia (ASTM)• Afina Lupulescu (ASM)• Kevin Slattery (Barnes GA)
1130	Lunch	Lunch / Networking
1300	Software & Data Analytic Tool	Panel 4: Software & Data Analytic Tool Provider Perspective Moderator: Alex Kitt (EWI) <ul style="list-style-type: none">• Anil Chaudhary (AO)• Goldy Kumar (Intact Solutions)• Michael Taylor (Hexagon)• Mike Vasquez (3Degrees)
1430	Identification of Approaches to Data Management Challenges	Working Groups <ol style="list-style-type: none">1. R&D Phase (SME & LSI)2. Production Phase (SME & LSI)3. Restart Phase (SME & LSI)
1700	Working Group Report	Working Group Brief Outs
1730		Adjourn

Day 2 will explore the organizations and solution providers that can help address gaps and facilitate LSI and SME interactions

Agenda: Day 3

Day 3 June 8, 2023

Time	Theme	Activity
0730	Badging	Registration, Badging, Refreshments Mcee: Chris Cosgrove (RAMP MD)
0800	Keynote Speakers	Keynote Speakers Moderator: Bill Frazier (Pilgrim Consulting) <ul style="list-style-type: none">• Jason Bridges (LM)• Wayne King (Barnes Global Advisors)
0900	Negotiations.	Working Groups <ul style="list-style-type: none">• R&D Phase (SME & LSI)• Production Phase (SME & LSI)• Restart Phase (SME & LSI)
1030	Working Group Report	Working group Report <ul style="list-style-type: none">• R&D Phase (SME & LSI)• Production Phase (SME & LSI)• Restart Phase (SME & LSI)
1200		Adjourn

Day 3 will investigate how Day 2 capabilities can be adopted and extended to help overcome Day 1 challenges and accommodations willing to be made

<https://www.nist.gov/news-events/events/2023/06/empowering-small-and-medium-size-enterprises-through-effective-additive>

- FY23 a transition year for MSAM Program
 - Continue to move forward, but with an open mind
 - Planning for new 5-year program focused on AM
 - Incorporate feedback from upcoming Additive Manufacturing Standards Collaborative Roadmap refresh
 - Potential for measurement science road mapping workshops
 - Engagement with key stakeholders to identify emerging AM measurement science needs



Current MSAM Program

Objective: To develop and deploy measurement science that will enable rapid design-to-product transformation through advances in: material characterization; in-process process sensing, monitoring, and model-based optimal control; performance qualification of materials, machines, processes and parts; and end-to-end digital implementation of metal Additive Manufacturing processes and systems.

Data Integration and management for AM

Models, methods and best practices for data management, data integration and fusion in AM

Data driven decision support for AM

Metrics, models, and best practices for using product definition, advanced analytics, and machine learning methods in AM design and process planning

AM Feedstocks, Machine and Process Qualification

Test methods and protocols for characterizing the feedstocks, machines, and processes to enable optimum usage and to reduce the cost and time needed for qualification

AM Part Qualification

Test methods and protocols, standard test artifacts, data, and data processing tools for robust post-process measurements



AM Machine and Process Control Methods

Algorithms, methods, and standard protocols for Additive Manufacturing (AM) process control, and software and hardware tools for open control of AM systems

Metrology for Multi-Physics AM Model Validation

Reference data for the validation of models of metal additive manufacturing processes

Metrology for Real-Time Monitoring of AM

Metrology methods, tools, data, and standards for in-situ monitoring of AM processes

- Planning stages for MSAM Program Workshop
 - Anticipated expansion in areas:
 - Larger Integration- Production and Supply Chain (OEM to SME)
 - Broader Adoption (PBF, DED, BDJ)
 - More application specific (medical, nuclear, etc.)
 - More AM-specific
 - Functional grades
 - context / situational awareness

August 29-31 in Rockville, MD



Q&A

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