

Workshop Agenda

Tuesday, December 4, 2012

8:30 am	<p>Opening Plenary Session</p> <ul style="list-style-type: none">• Welcome ~ Shyam Sunder, Director, Engineering Laboratory, NIST• Stage-setting Presentations<ul style="list-style-type: none">➢ Workshop Scope and Objectives ~ Kevin Jurrens, NIST➢ Highlights of Prior Additive Manufacturing Roadmaps ~ Dave Bourell, Temple Foundation Professor, University of Texas at Austin, Co-Chair 2009 Roadmap for Additive Manufacturing➢ ASTM F42 Strategic Framework for Additive Manufacturing Standards ~ Brent Stucker, Professor, University of Louisville, Chair of ASTM F42➢ NAMII Additive Manufacturing Pilot: Priority R&D Needs ~ Gary Fleegle, Vice President and Chief Operating Officer, National Center for Defense Manufacturing and Machining, NAMII Acting Deputy Director for Technology Development
10:00 am	Break
10:30 am	<p>Industry Panel</p> <ul style="list-style-type: none">• Moderated session and Q&A on AM user perspectives<ul style="list-style-type: none">➢ Moderator ~ Ed Herderick, EWI, Chair of Additive Manufacturing Consortium (AMC)➢ Panelists ~ Agnes Klucha, Program Manager, Engineering Innovation Center, Pratt and Whitney John Hunter, Director of Marketing & Sales, Carpenter Powder Products, Inc. Dean Robinson, Manager, Model-Based Manufacturing Lab, GE Global Research Center Hank Phelps, Senior Engineer, Technology Development & Integration, Airframe Design, Lockheed Martin Aeronautics

Workshop Agenda

Tuesday, December 4, 2012

11:40 am	Morning Wrap up and Instructions for Breakout Sessions <ul style="list-style-type: none">➤ Joan Pellegrino, Energetics, Inc.
11:45 am	Lunch
1:00 pm	Breakout Session I: Desired Capabilities for Additive Manufacturing <ul style="list-style-type: none">➤ Envisioned future: What capabilities do we want and need the most
3:00 pm	Break
3:20 pm	Breakout Session II: Challenges and Barriers for Achieving the Capabilities <ul style="list-style-type: none">➤ Barriers limiting the broad use of additive manufacturing➤ Measurement and standards barriers, challenges, and gaps
5:00 pm	Adjourn Day 1



Workshop Agenda

Wednesday, December 5, 2012

8:00 am	Continental Breakfast
8:30 am	Breakout Session III: Prioritization of Challenges <ul style="list-style-type: none">➤ Review, clarify, and vote on the top challenges➤ Determine R&D priorities➤ Identify standardization priorities for ASTM F42
10:15 am	Break
10:30 am	Breakout Session IV: Pathways for Measurement Science Roadmap <ul style="list-style-type: none">➤ Small groups work to develop roadmap elements:➤ R&D, standards, and other approaches for addressing priority challenges➤ Next steps and actionable plan
11:45 am	Lunch
1:00 pm	Breakout Group Reports (Part 1)
1:30 pm	Plenary Talk: Manufacturing the Road to Success <ul style="list-style-type: none">➤ Tom Kurfess, Assistant Director for Advanced Manufacturing, Office of Science and Technology Policy, Executive Office of the President
2:00 pm	Breakout Group Reports (Part 2)
2:15 pm	Workshop Wrap up and Next Steps <ul style="list-style-type: none">➤ Kevin Jurrens, NIST
2:30 pm	Adjourn Workshop
3:00 pm	Interagency Roundtable (government only)



NIST Roadmapping Workshop: Measurement Science for Metal-Based Additive Manufacturing

Workshop Scope and Objectives

Kevin Jurrens
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December 4-5, 2012



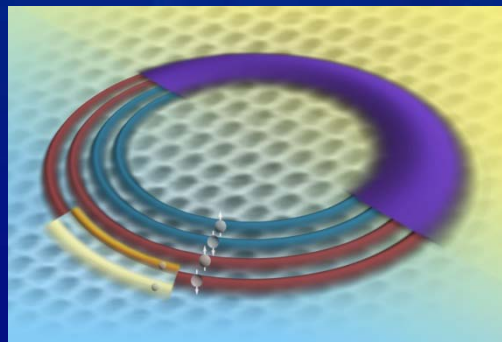
NIST's Unique Mission

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.

- **Mission focus:** Targeting Investments to Advance U.S. Innovation and Boost Economic Recovery
- **Deep research expertise** underpins technological innovation – e.g. lasers, memory, GPS, wireless
- **Non-regulatory status** enables important role as a convener that facilitates collaboration between industry and government



Cybersecurity: Improved response to cyber threats



Nanomanufacturing: New measurement tools for advanced materials manufacturing



Energy: Measurements and standards for energy security

NIST At A Glance

Gaithersburg, MD



Courtesy HDR Architecture, Inc./Steve Hall © Hedrich Blessing

Boulder, CO



©Geoffrey Wheeler

- NIST Research Laboratories
- Manufacturing Extension Partnership
- Baldrige Performance Excellence Program
- ~ 2,900 NIST employees
- ~ 2,600 associates and facility users
- ~ 1,600 field staff in partner organizations
- ~ 400 NIST staff serving on 1,000 national and international standards committees
- Four collaborative Institutes (basic physics, biotech, quantum, marine)



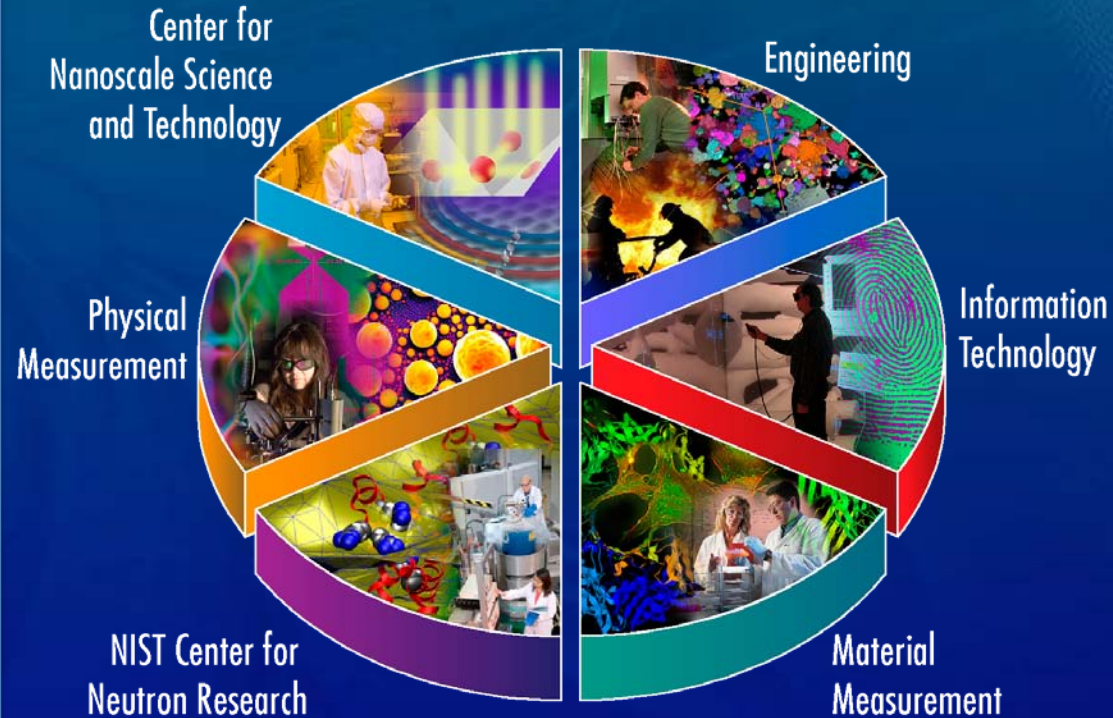
The NIST Laboratories

NIST's work enables

- Advancing manufacturing and services
- Helping ensure fair trade
- Improving public safety and security
- Improving quality of life

NIST works with

- Industry
- Academia
- Other agencies
- Government agencies
- Measurement laboratories
- Standards organizations



Providing measurement solutions for industry and the Nation

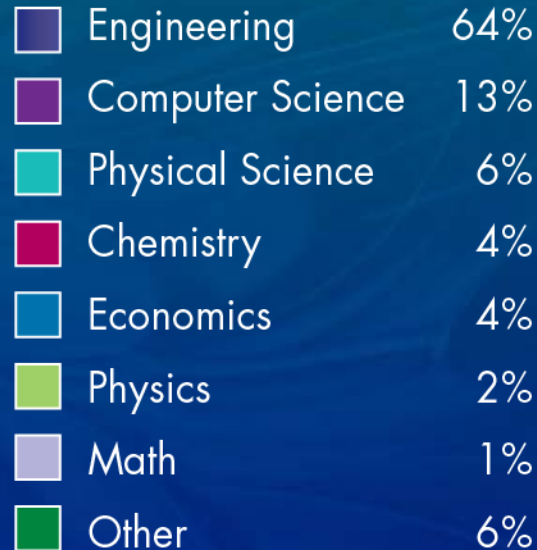
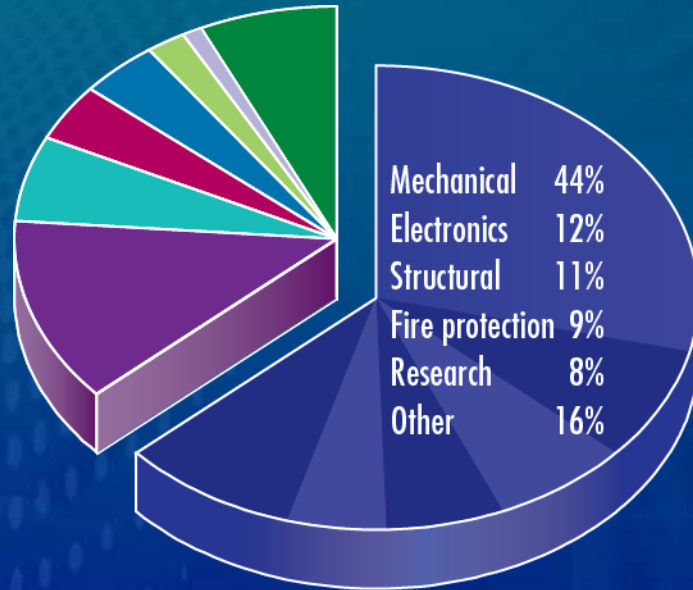


NIST Engineering Laboratory



EL Scientists and Engineers

2012 Professional Staff



EL Staff:

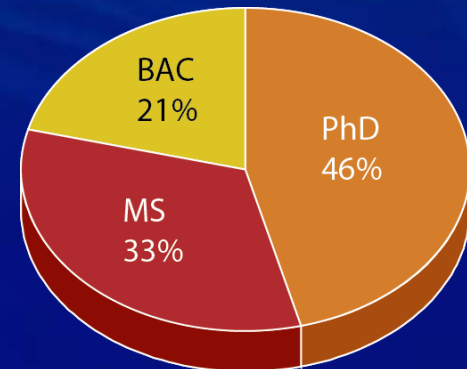
Full-time Permanent: 236

- Scientists and Engineers: 179
- Technicians: 21

Non Full-time Permanent: 30

EL Associates 137

Total EL Staff and Associates 403



Unique Role of NIST Laboratory Research Programs



Measurements and Standards

- Emphasis on **infrastructural metrology** and non-proprietary, standardized metrology methods that address a broad class of measurement challenges
- Emphasis on rigorous and generic procedures to characterize **measurement uncertainty** that comply with international standards
- Long-term **commitment, expertise, and neutrality** essential for harmonized and unbiased national and international standards
- Leverage NIST **core competences** in measurement science, rigorous traceability, and development and use of standards -- as well as specific expertise in measurements and standards for manufacturing systems, processes, and equipment



Primary Outputs of NIST Research Laboratories

- Measurement methods
- Performance test methods and metrics
- Calibration services
- Documentary standards
- Standard reference materials
- Standard reference data
- Technology transfer: technical publications, industry workshops, collaborations



NIST Focus on Measurement Science

Measurement science research and services include:

- Development of performance metrics, measurement and testing methods, predictive modeling and simulation tools, knowledge modeling, protocols, technical data, and reference materials and artifacts
- Conduct of inter-comparison studies and calibrations
- Evaluation of technologies, systems, and practices, including uncertainty analysis
- Development of the technical basis for standards, codes, and practices—in many instances via testbeds, consortia, standards development organizations, and/or other partnerships with industry and academia



NIST Contributions to Additive Manufacturing

- NIST Laboratory Research Programs
 - Engineering Laboratory (EL)
 - smart manufacturing systems, processes, and equipment
 - discrete mechanical parts manufacturing
 - Materials Measurements Laboratory (MML)
 - materials evaluation / materials processing
 - chemical analysis / chemical processes
- NIST Extramural Programs
 - Manufacturing Extension Partnership (MEP)
 - nationwide network of field staff; focused on solving challenges and identifying growth opportunities, including for AM



EL Projects in Additive Manufacturing

Powder



Uncertainties
in the Input
Materials



Process



Uncertainties in
Equipment and
Process Performance



Part



Uncertainties in
the Final Parts



EL Projects in Additive Manufacturing

Powder



Uncertainties
in the Input
Materials



Process



Uncertainties in
Equipment and
Process Performance



Part



Uncertainties in
the Final Parts

1. Fundamental Measurement Science for Additive Processes
2. Materials Standards for Additive Manufacturing



Research Focus for EL Projects

Fundamental Measurement Science for Additive Processes

➤ *Research Focus:*

- Standard test methods to evaluate and improve AM equipment performance
- Standard test methods to evaluate fundamental process characteristics
- Standard test artifacts
- Physics-based modeling of AM processes and material transformation
- *In-situ* measurements of AM parts

Materials Standards for Additive Manufacturing

➤ *Research Focus:*

- Standard test methods for metal powder characterization
- Standard test methods to obtain material properties of AM parts
- Test protocols, procedures, and analysis methods for industry round robin testing of AM materials for consensus material property data



Substantial Stakeholder Interactions

- Additive Manufacturing Consortium (AMC)
- National Additive Manufacturing Innovation Institute (NAMII)
- Industry: EWI, Morris Technologies, GE Aviation, GE Global Research, ExOne, United Technologies, others
- Universities: CMU, Virginia Tech, Louisville, NC State, Georgia Tech, others
- Federal agencies: OSTP, NASA, NSF, DARPA, Army, Navy, Air Force, DOE, ORNL, LLNL, FBI, others
- Events: ASTM F42, SFF Symposium, JDMTP Metals AM Workshop, SAMPE Direct Parts Mfg Workshop



Workshop Objectives

- Build on prior AM roadmaps and other efforts that have identified technology challenges and R&D requirements
 - In-depth coverage of measurement science needs
 - Create actionable plans: what's needed and how to get there
- Provide direction and input to ASTM F42 strategic planning
- Influence and coordinate with NAMII development of national AM roadmap
- Specific objectives are to identify:
 - Future measurement and standards related targets/goals for metal-based AM
 - Measurement science barriers, challenges, and gaps that prevent the broad use of metal-based AM
 - Priorities and timing for ASTM F42 standards development
 - R&D needed to address the priority measurement and standards challenges



Workshop Scope

- Workshop focused on Metals-Based AM
 - Need to focus our efforts and best allocate resources
 - Assertion: larger growth potential and biggest opportunity for future impact
- Workshop focused on high-priority Measurement Science needs
 - Largely infrastructural
 - Example areas out of scope:
 - Development of new AM processes
 - Economic policy or tax incentives
 - Workforce issues



Definition of Measurement Science

The term measurement science is used in the context of creating **critical-solution enabling tools – metrics, models, and knowledge** – for U.S. manufacturers.

This includes:

- Development of
 - Performance metrics
 - Measurement and testing methods
 - Predictive modeling and simulation tools
 - Knowledge modeling
 - Protocols
 - Technical data
 - Reference materials
 - Artifacts
- Conduct of inter-comparison studies and calibrations
- Evaluation of technologies, systems, and practices, including uncertainty analysis
- Development of the technical basis for standards, codes, and practices



Expected Workshop Results

- AM Measurement Science Roadmap
 - Actionable plan: beyond a list of research needs
 - Address one slice of overall AM roadmap
 - Integrate with NAMII national AM roadmap
- Workshop Final Report
 - Summary of results, including presentation slides, white papers, break-out group results, etc.
- Foundation for ASTM F42 Strategic Plan



Impacts of Workshop

- Influence the national research agenda for metal-based additive manufacturing
- Influence the selection, priorities, and timing of new standards developed with ASTM F42
- Establish consensus needs and priorities based on inputs from AM technology suppliers and users, university researchers, government agencies, and other stakeholders
- Advance AM capabilities for U.S. manufacturers



Workshop Break-Out Groups

- AM Materials
- AM Processes and Equipment
- Qualification and Certification of AM Materials, Processes, and Products
- AM Modeling and Simulation

- Mapping of attendees to break-out groups made based on preferences indicated at registration



Workshop White Papers

- Optional, two pages maximum
- Workshop attendance not required to submit white paper
- Purpose of white papers:
 - Stimulate thinking in advance of the workshop
 - Influence workshop discussions and results
 - Allow mechanism for sharing perspectives in written form
 - Helped workshop organizers formulate the break-out groups
- Two questions:
 - Question 1: What are the key measurement science barriers that prevent innovation in metal-based additive manufacturing?
 - Question 2: What are the most important areas where R&D is needed – particularly in measurements and standards – to overcome these barriers and to accelerate innovation in metal-based AM?



11 White Papers Received

- Stacey Kerwien, U.S. Army
- Dan Maas and Jesse Blacker, ExOne
- Shane Collins, GROWit
- Frank Liou, Missouri University of Science and Technology
- Jennifer Bryant, John Benfer, and Anthony Petrizzo, NAVAIR
- Ken Patton and Ed Tackett, RapidTech
Imelda Cossette and Frank Cox, MatEd
- Kevin Chou, University of Alabama
- Jyoti Mazumder, University of Michigan at Ann Arbor
- Tom Campbell, Virginia Tech University
- Vito Gervasi, Milwaukee School of Engineering
- Connie Philips, NCMS

Excellent and thoughtful white papers! Thank you for the great input and your extra efforts to stimulate our thinking! Good foundation to begin our discussions later today.



Conclusion

- Open discussion is encouraged throughout workshop
- Your perspectives and inputs are extremely important – everyone has the opportunity to contribute
- Consensus-building is difficult (and sometimes frustrating), but an essential part of roadmap development
- Thank you for your support and for your help



Partnering with NIST

- NIST partners with industrial consortia, individual companies, other government agencies, and universities
- The NIST stake in partnerships tends to focus on issues that can benefit industry sectors in a broad sense
 - typically relating to measurements and standards
- Several mechanisms available:
 - e.g., cooperative agreements, contracts, MOUs, guest researchers, letters of agreement, grants, sabbaticals



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Back-up Slides



EL Strategic Goals

Smart Manufacturing, Construction, and Cyber-Physical Systems:

- To enable the next generation of innovative and competitive manufacturing, construction, and cyber-physical systems through advances in measurement science

Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure:

- To enable sustainable and energy efficient manufacturing, materials, and infrastructure through advances in measurement science

Disaster-Resilient Buildings, Infrastructure, and Communities:

- To reduce the risk and enhance the resilience of buildings, infrastructure, and communities to natural and manmade hazards through advances in measurement science



EL Programs Aligned with EL Strategic Goals

- **Smart Manufacturing, Construction, and Cyber-Physical Systems**
 - Smart Manufacturing Processes and Equipment
 - Next-Generation Robotics and Automation
 - Smart Manufacturing and Construction Systems
 - Systems Integration for Manufacturing and Construction Applications
- **Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure**
 - Sustainable Manufacturing
 - Sustainable, High-Performance Infrastructure Materials
 - Net-Zero Energy, High-Performance Buildings
 - Embedded Intelligence in Buildings
- **Disaster-Resilient Buildings, Infrastructure, and Communities**
 - Fire Risk Reduction in Communities
 - Fire Risk Reduction in Buildings
 - Earthquake Risk Reduction in Buildings and Infrastructure
 - Structural Performance Under Multi-Hazards

Our programs are identified, developed, carried out, the results implemented, and consequences measured in partnership with key customer organizations

