NIST Smart Manufacturing Programs: Driving Innovation and Reducing Risks of Adoption of New Technologies

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“It is therefore the unanimous opinion of your committee that no more essential aid could be given to manufacturing [...] than by the establishment of the [National Bureau of Standards].”
House Committee report, May 1900

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.

A partner to US manufacturers for more than a century, NIST helps the nation’s manufacturers to invent, innovate, and create through:

- **Measurement science** – manufacturers and technology providers use NIST test methods, measurement tools, performance measures, and scientific data every day

- **Advanced materials** – NIST is building a materials infrastructure to accelerate the timeline from design to deployment of new materials

- **Standards development** – NIST provides the scientific and technical basis for voluntary consensus codes and standards

- **Partnerships** – collaborations with the private sector and academic organizations help advance and disseminate research and support US manufacturers
NIST Helps **Drive Innovation** and **Reduce Risks of Adoption** of Emerging/Disruptive Manufacturing Technologies

...by contributing to **standards** that provide a **common language** and **test methods** that technology suppliers and users can use to assess and communicate **technical capabilities and performance**.
Driving Innovation and Reducing Risks of Technology Adoption Through Measurements and Standards
Example: 3D Sensor Systems

Competitions to Verify & Validate Performance Test Methods

Input to Standards

Innovation through
• Standardized methods of measuring performance to reduce risk of adopting wrong solution.
• Metrics to guide design improvement, with inclusion of manufacturing-relevant objects by NIST.

Draft Metrics & Test Methods

Emerging Technologies

Industry Input
Smart Manufacturing:
The synthesis of advanced manufacturing capabilities and digital technologies to produce highly customizable products faster, cheaper, better, and greener

NIST Smart Manufacturing Program Areas:

- Additive Manufacturing
- Robotic Systems
- Manufacturing System Design and Analysis
- Manufacturing Operations Planning and Control
Measurement Science for Additive Manufacturing

**Metal Additive Manufacturing:** Building metal parts by adding layer upon layer; like 3D printers, but with metals

- What are important measurements for metal Additive Manufacturing materials, and how do you make them?
- How can you get the best performance out of metal Additive Manufacturing processes?
- What measurements are needed to support qualification of metal Additive Manufacturing materials, processes, and parts for critical applications?
- What information is needed to integrate metal Additive Manufacturing into end-to-end manufacturing production?
Standards Contributions

- ASTM Standard Guide for Characterizing **Properties of Metal Powders** used for AM Processes
  - Dimensional – mechanical – thermal – powder bed density – recyclability
  - Mechanical – microstructure – porosity – density – post processing
- Leading ASTM/ISO Joint Working Group for the development of standards for **AM test artifacts**
- Conducting **round robin studies** for AM
- Leading new ASME efforts on **Product Definition for AM**
- Leading new work item in ASTM on **Principles of Design Rules**
- Prototype **Materials Database** for AM accessible by public
- Lead development of **AM standards strategy** within ASTM F42 Executive Committee

Traceable powder bed density (PBD) measurements

Powder property characterization

NIST AM Test Artifact
PHM for AM?

- Initial NIST AM focus is on process understanding, improvement, repeatability, and predictability, rather than PHM aspects
- Early yet to have a good handle on common failure modes for AM
- AM machines are complex, with a number of critical subsystems that each have potential failure modes
  - Powder handling/management and spreading/delivery
  - Gas flows/build environment control
  - Laser/energy control and scanning
- Equipment manufacturers build in sensors, maintenance features, protocols
Robotic Systems for Smart Manufacturing

• How can you measure the performance of robotic capabilities such as **perception, grasping, manipulation, and mobility**?

• How can you measure the effectiveness and safety of new **collaborative** robotic technologies?

• How can you measure and advance the **agility** of robotic systems (ease of teaching new tasks, recovering from errors)?

• What standards are needed to more easily **integrate robot systems** with other factory and control equipment?

• How can we help make robotic technologies **more easily adoptable by small and medium-sized manufacturers**?
Standards Contributions

- Performance evaluation of 3D Imaging Systems, including two test methods for 6D pose measurement systems
- Revision of Automatic Guided Vehicle safety standard to enable non-contact obstacle sensing
- New ASTM Committee on performance standards for industrial vehicles
- New international technical specification for collaborative robots safety in industrial settings
- New Robotic Industries Association effort on mobile manipulator safety standards
- New IEEE standard for knowledge representation for robot systems
Smart Manufacturing Systems Design and Analysis

- What standards are needed to support new models of distributed or service-oriented manufacturing?
- What standards are needed to streamline information flow for food manufacturing?
- How can different kinds of modeling software be integrated effectively to support Smart Manufacturing systems?
- What are the best ways to measure the overall performance of manufacturing operations?
- What standards are needed to support data analytics for Smart Manufacturing systems?
Standards Contributions

• ASTM E60.13 *Guide for Sustainability Characterization of Manufacturing Processes*
  • Will provide a common basis for **sustainability assessment of manufacturing processes**.

• Semantic Refinement methodology published as OAGI Working Group specification
  • Enables platform-specific **manufacturing applications to interoperate** based on a common standard (e.g., Mobile vs Enterprise applications)

• Smart manufacturing in the cloud workshops
  • *OAGi-NIST workshop on Open Cloud Architectures for Smart Manufacturing*: identified and prioritized technology and standards’ gaps for **cloud-enabled manufacturing services**
  • *NIST Workshop on Cloud-Based Applications for Sustainable Manufacturing*: defined a standards’ strategy to use data from process measurements to **quantify manufacturing process sustainability**.
Smart Manufacturing Operations Planning and Control

• How can you use **sensors, data, and computation** to **assess machine health**, optimize maintenance, and **avoid downtime**?
• How can you use **wireless communications** in **industrial environments** for more flexible manufacturing?
• How do you **secure** the computers and networks that **control manufacturing operations**?
• How can you use the same **digital model** to **support the entire product lifecycle**, from design to production to service and sustainment?
• How can you integrate different **analysis tools** to **improve manufacturing operations**?
Standards Contributions

• STEP AP 242 (ISO 10303-242) standard on Managed Model Based 3D Engineering
  • Provides for interoperability of Product Lifecycle Management (PLM) information to enable the “digital thread” of model-based information for manufacturing, to reduce costs and improve responsiveness.

• NIST Special Publication 800-82 Guide to Industrial Control Systems Security
  • Provides guidance on how to secure industrial control systems while addressing their unique performance, reliability, and safety requirements

• Quality Information Framework (QIF) standard
  • Streamlines the flow of quality information across the complete product-quality lifecycle.

• Industrial Wireless Fundamentals
• Business Case for Wireless
• Wireless Lifecycle
• Wireless for Safety
• Industrial Wireless Security
• Best Practice Considerations
• Checklists
• Wireless Applicability Matrix

Acknowledgement: NIST industrial wireless technical working group (IWSTWG) members
Prognostics, Health Management, and Control Project

- Manufacturing Process and Equipment Monitoring
- Health and Control Management for Robot Systems
  - Robot Positioning Performance Degradation
  - Workcell-level PHM V&V
- Machine Tool Linear Axes Diagnostics and Prognostics

IMU for Linear Axis Monitoring
ASME Standards Meeting – Monitoring, Diagnostics, and Prognostics for Manufacturing Operations

Here, Friday! Discussion of:

• Standardized Terminology for PHM Guideline on Data and Collection Strategies
• Guideline to Determine What Health Data to Capture and Collection Strategies to Employ
• Guideline to Determine What Sensors and Where They Should Be Employed to Inform on Process/Equipment Health
• Guideline for Implementing Sensor Data Fusion/Multi-modal Data Fusion
• Guideline to Determine When and Where PHM Should Be Added/Integrated
• Expand MTConnect/Data Communications
Working With Others

Major stakeholder groups
- Manufacturing enterprises
- Software vendors & equipment providers
- Small and medium sized enterprises (SMEs)
- Industry consortia and standards developing organizations
- Government agencies
- Universities and research organizations

Modes of engagement
- Consortia, standards developing organizations
- Workshops, conferences, summits
- Site visits
- Cooperative Agreements
Question for this forum:

What measurement science and standards are needed to drive innovation and reduce risks of adoption of emerging/disruptive PHM technologies?
Thank you!

Questions?

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