• Human error?, faulty sensing?
• Urgent issue or something to put on the ‘to-do’ list?

• Information overload or insufficient data?

We have a long way to go in Monitoring, Diagnostics, Prognostics, and Decision-making…
Developing Measurement Science to Advance Monitoring, Diagnostics, and Prognostics in Manufacturing Operations

Brian A. Weiss, *Project Leader*
Prognostics and Health Management for Reliable Operations in Smart Manufacturing

Intelligent Systems Division
Engineering Laboratory
National Institute of Standards and Technology

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Agenda

- NIST and Smart Manufacturing
- Prognostics and Health Management
- Motivations for Standards
- Building the Subcommittee
- Current and Future Efforts
Engineering Lab’s Mission...

• ...promote U.S. innovation and competitiveness by advancing measurement science, standards, and technology for engineered systems in ways that enhance economic security and improve quality of life

• Carry out mission related activities in...
  • Engineering and manufacturing products, processes, equipment, technical data, and standards
  • Manufacturing enterprise integration
  • Intelligent systems and control
  • Robotics and automation
  • Cyber-physical systems

Above content from: www.nist.gov/el/about-el

Courtesy: Fotolia
More on Measurement Science...

Used in the context of creating critical-solution enabling tools – metrics, models, and knowledge – for U.S. manufacturers. This includes:

• Development of...
  • Performance metrics - Artifacts
  • Measurement and testing methods - Protocols
  • Predictive modeling and simulation tools - Technical data
  • Reference materials (e.g. data sets) - Knowledge modeling

• Conduct inter-comparison studies and calibrations

• Evaluation of technologies, systems, and practices

• Development of the technical basis for standards, codes, guidelines, and/or practices
Benefits of Standards

• Reduce Risk of Technological Adoption
• Anticipate Technical Requirements
• Protect Health and Safety
• Increase Productivity
• Promote Efficiency
• Reduce Costs
• And Many More…
Why Smart Manufacturing?

Enable manufacturers to...

• make what you want, where you want it, and when you want it.

• respond in real time to meet changing demands and conditions

• easily and rapidly reconfigure factory production and supply networks to optimize system performance

• deal effectively with uncertainty and abnormal events and learn from past experience to enable continuous improvement

• maintain seamless interoperability between factory processes and supply networks and between large manufacturers and small manufacturers
Smart Manufacturing Programs

- Model-Based Engineering
- Robotic Systems
- Trustworthy Systems, Components, and Data
- Additive Manufacturing
Trustworthy Systems, Components, and Data

- Cybersecurity for Smart Manufacturing
- High Performance Wireless Systems for Smart Manufacturing
- Prognostics and Health Management for Reliable Operations in Smart Manufacturing
- Supply Chain Traceability for Agri-Food Manufacturing
Research Objective and Deliverables

To develop and deploy measurement science to promote the implementation, verification, and validation of advanced monitoring, diagnostic, and prognostic technologies to increase reliability and decrease downtime in smart manufacturing systems.

- Standards and Guidelines
- Reference Datasets and Software Tools
- Test Methods and Performance Metrics
- Use Cases and Test Scenarios
- Roadmaps and Case Studies
Research Levels and Testbeds

Identification of Robot Workcell Degradation
- Work Cell-Level Research
- PHM for Robot Systems Lab/Testbed

Assessment of Robot Accuracy Degradation
- Robot-Level Research
- PHM for Robot Systems Lab/Testbed

Machine Tool Linear Axes Diagnostics and Prognostics
- Component-Level Research
- Linear Axis Test bed & ‘Shops’ Machine Tools
Research Focus and Plan - FY19

Verification & Validation of Equipment and Process Health Tech...

• Identify sources throughout the workcell that influence performance on positioning tasks using an artifact-based approach

• Enhance capability to measure end-of-robot-arm positional accuracy through development of active smart targets and corresponding test procedures

• Extend single-axis diagnostics to multi-axis prognostics of machine tool linear stages

• Generate datasets from NIST testbeds and external pilot sites

• Contribute to development of guidelines within an ASME Standards subcommittee on Advanced Monitoring, Diagnostics, and Prognostics
How do we know this is Important?

• Measurement Science Roadmapping Workshop
• Manufacturing Standards Requirements Gathering Workshop
• Collaborative studies with university and industry partners
• Interactions with various technical organizations
Complex interactions/relationships make it challenging to determine the specific influences on the health and degradation of equipment and processes.
Increasing interest and ability to leverage data and analysis to **generate actionable intelligence** about system interactions/relationships for control.

**FORECASTING:** predicting future customer behaviour

**DATA MINING:** searching for hidden patterns

**DECISION-MAKING** support

**TRANSFORMING RAW DATA** into useful information

**IMPROVING STRATEGY**
No uniform process exists that guides sensing, monitoring, and control at all levels from the component to the system to the enterprise.
Opportunities are becoming more apparent at **systems level**, especially given the more **distributed nature of manufacturing** (whether that’s at the supply chain level or within a facility).
Proprietary solutions exist, but they apply to systems from one vendor and are often expensive and inaccessible to many manufacturers.
BEST DATA??
- OEE
- Asset Availability
- Quality
- Cycle Time
- Position
- Velocity
- Current
- Temperature
- Vibration

DATA COLLECTION??

STRUCTURE, CONTEXTUALIZATION??

VERIFICATION, VALIDATION??

ANALYSIS??

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EXPECTED IMPACT: Improved decision-making support and automation with a focus on vendor-neutral approaches and plug-and-play solutions.
Challenge – *How much data is enough?*
Challenge – *Do I truly understand my data?*
Challenge – What can I do with the data?
Challenge – How do I quantify the human impact?
## Charter

Develop standards and guidelines that advance the design and implementation of monitoring, diagnostic, and performance, to enhance adaptive maintenance and operational control strategies within manufacturing.

## Officers

| STAFF SECRETARY | Donnie Alonzo |

## Additional Committees

- MAM Manufacturing and Advanced Manufacturing
- MBE Model Based Enterprise
- V&V 50 Verification and Validation of Computational Modeling for Advanced Manufacturing

## Other Links

- ASME Product Catalog
- B94 Committee on Cutting Tools
- Standards & Certification Update - Newsletter
Overall Aim...

• Aid manufacturers in designing, deploying, verifying, and validating PHMC strategies within their manufacturing operations
Questions to Answer During PHM Design & Deployment

• What physical or task degradation has the potential to impact the metrics I care about most in my process?
  *What health degradations can impact my quality, productivity, scrap, etc.?*

• What data, leading to intelligence, do I need about my process to determine where and when health degradation will occur?
  *What can be monitored and how?*

• How do I prioritize the risk of faults and failures in my system and process?
  *Where should I deploy PHM since I can’t put it everywhere?*

• How does the health of my physical system, and its constituent elements, influence the health of my process?
  *How can I map the relationships between the physical and functional to better understand my process?*
Events Leading Up to Today

• First Event (Workshop) – June 2017 at ASME MSEC (Los Angeles)
• Second Event (Workshop) – Oct 2017 at the PHM Society Conference (St. Petersburg, FL)
• Third Event (Standards Meeting) – May 2018 at the NIST Industry Forum (Gaithersburg)

*Approval of the ASME Subcommittee – Summer 2018*

• Fourth Event (Standards Meeting) – Oct 2018 at TechSolve (Cincinnati, OH)
• Fifth Event (Standards Meeting) – May 2019 at NIST (Gaithersburg)
Committee Charter

Develop standards and guidelines that advance the design and implementation of monitoring, diagnostic, and prognostic capabilities, along with ways of verifying and validating their performance, to enhance adaptive maintenance and operational control strategies within manufacturing.
Priority Topic Areas

1. Standardized Terminology for PHM Guideline
2. Guideline to Determine Where and When PHM Capabilities should be added/integrated
3. Guideline to Determine What Health Data to Capture and Collection Strategies to Employ
5. Guideline for Implementing Sensor Data Fusion/Multi-Modal Data Fusion
6. Expand MTConnect/Data Communications
7. Guideline to Determine Where to Perform PHM Data Analyses
8. Natural Language Analysis for Maintenance Documents??
**Guideline Action Plan for Topic 7 – Guideline to Determine the Health of a Process**

**Guideline**

**Description:** The parameters that affect the health of a process are important for maintaining a manufacturing community. This guideline provides processes to identify and monitor the health of a process.

**Guideline Action Plan**

**Plan Steps**

1. **Examine the process and identify key data points.**
2. **Determine how much data is needed and how it should be structured.**
3. **Create a skeleton outline of the guidelines.**
4. **Prioritize high-priority terms associated with specific guidelines.**
5. **Integrate high-priority terms into the guidelines.**

**Milestones/Key Deliverables**

- **Baseline**
  - Identify the processes and data collection criteria.
- **Mid-term**
  - Develop the guidelines with priority terms.
- **End**
  - Finalize the guidelines and integrate them into the PHM community.

**Performance Targets**

- **Standard**
  - Terminology consistent with existing standards.
- **Prioritized**
  - High-priority terms integrated into the guidelines.

**Stakeholders**

- **Industry:** Manufacturers, small and medium enterprises, technology developers, technology integrators, process engineers.
- **Association:** IEEE, PHM Society.
- **Academia:** Data scientists, AI experts.

**Standards Development Organizations:** ASME, SAE, ASTM, ISO 108, OIML, IEC.

**Government:** NIST, DoD.
Significant Outcomes from Last Two Meetings

• Formed WG that drafted a white paper articulating goals, scope, and expected benefit of Guideline to Determine When and Where PHM should be Added/Enhanced

• Formed WG that is researching existing standards and terminology that may be relevant to this effort

• Developed guidelines ‘flow chart’ to highlight the relationships between the priority topic areas
Our Next Steps

• Future Teleconferences – Scheduled ~1/month
• Guidelines Development
  • Terminology
  • Where and when to add/enhance PHM
• Exploring New Areas
  • Natural Language Analysis?
Next Meeting

ASME PHM Subcommittee on Advanced Monitoring, Diagnostics, and Prognostics for Manufacturing Operations

Hosted by: Boeing
November, 2019
St. Louis, Missouri
Upcoming Events

Annual Conference of the Prognostics and Health Management Society 2019
September 23-26, 2019
Scottsdale, Arizona

Measurement and Evaluation for PHM in Manufacturing Operations (ME4PHM) Workshop
Prognostics and Health Management for Reliable Operations in Smart Manufacturing

www.nist.gov/el/maintenance