Industry Forum

NIST Research on Monitoring, Diagnostics, and Prognostics for Manufacturing Workcells

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Intelligent Systems Division

Engineering Laboratory

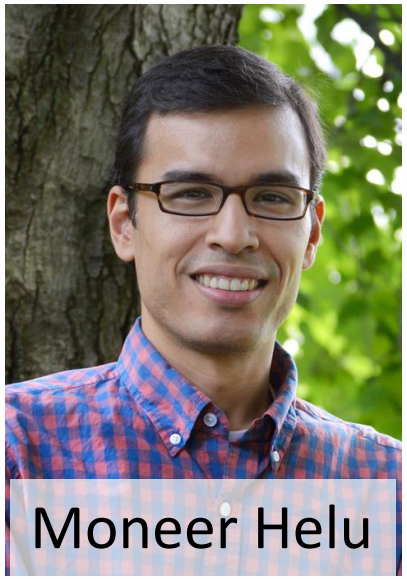
National Institute of Standards and Technology

Images Courtesy of Fotolia

Disclaimer

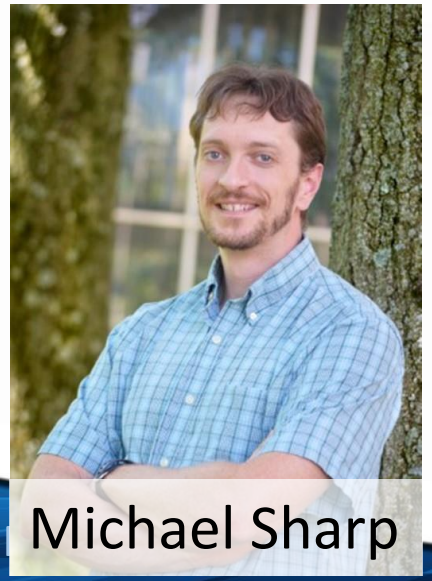
- Identification of commercial systems does not imply recommendation or endorsement by NIST
- Identified commercial systems are not necessarily the best available for the purpose

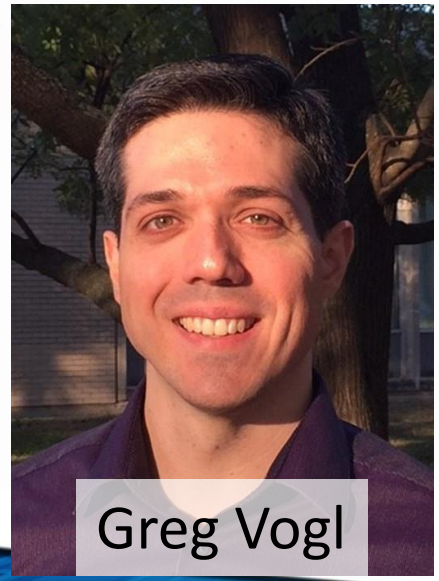
The Most Critical Piece of the Project…

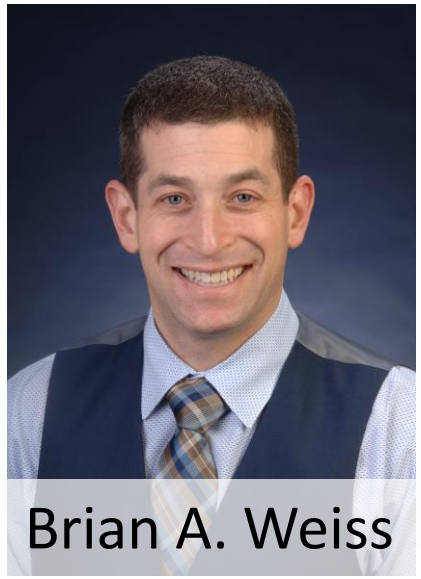

Moneer Helu


Alex Klinger


Helen Qiao


Michael Sharp

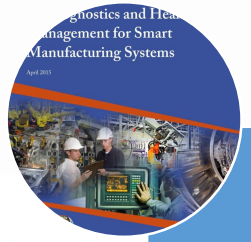

Greg Vogl


Brian A. Weiss

Research Objective and Deliverables

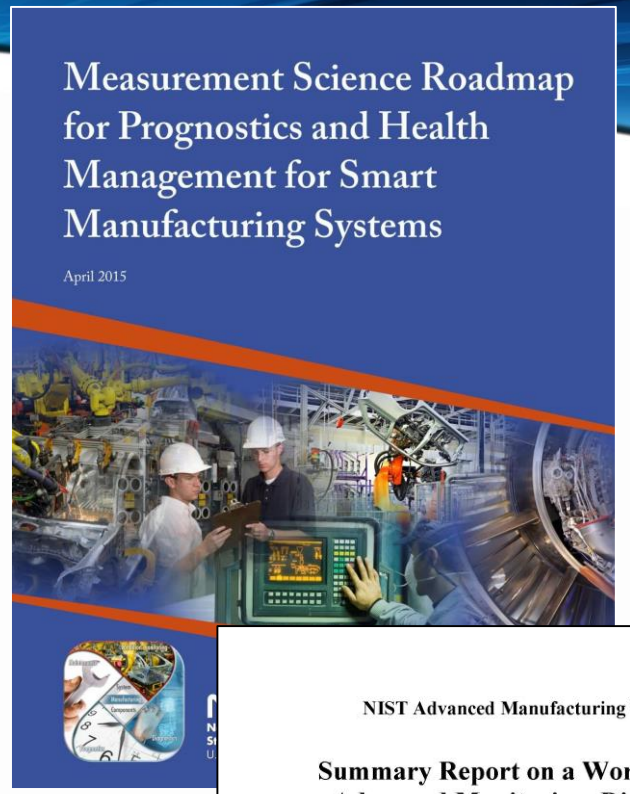
The PHMC project will deliver *Measurement Science Products* for robust sensing, diagnostics, prognostics, and control that **enable manufacturers to respond to planned and un-planned performance changes** thereby enhancing the efficiency of smart manufacturing systems.

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



How do we know this is Important?

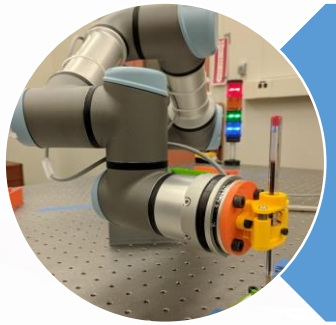
- Measurement Science Roadmapping Workshop
- Manufacturing Standards Requirements Gathering Workshop
- Collaborator studies with university and industry partners
- Interactions with various technical organizations



Research Levels

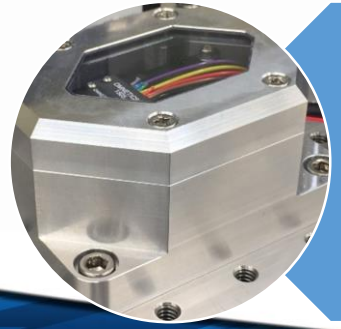
Manufacturing Process and Equipment Monitoring

- System-Level Research
- Smart Manufacturing Systems Testbed



Health and Control Management for Robot Workcells

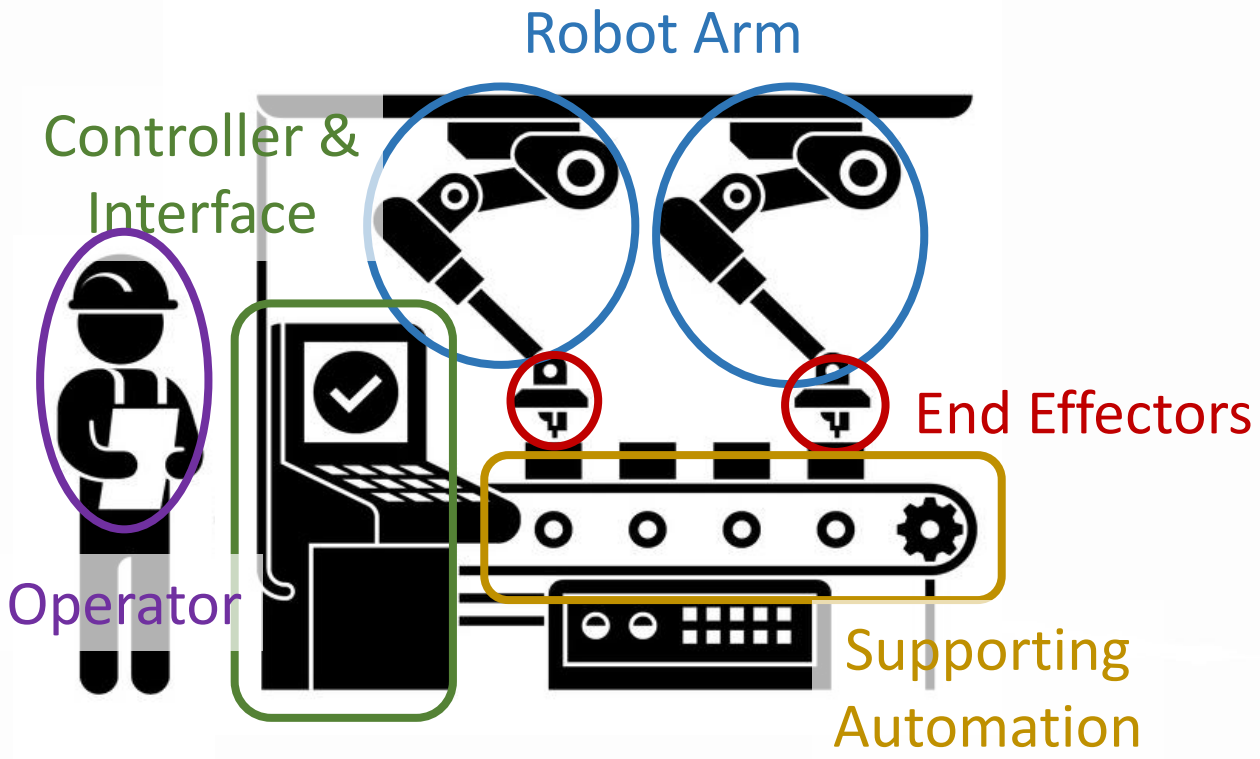
- Work Cell-Level Research
- PHM for Robot Systems Lab/Testbed



Machine Tool Linear Axes Diagnostics and Prognostics

- Component-Level Research
- Linear Axis Test bed & 'Shops' Machine Tools

Manufacturing Workcells



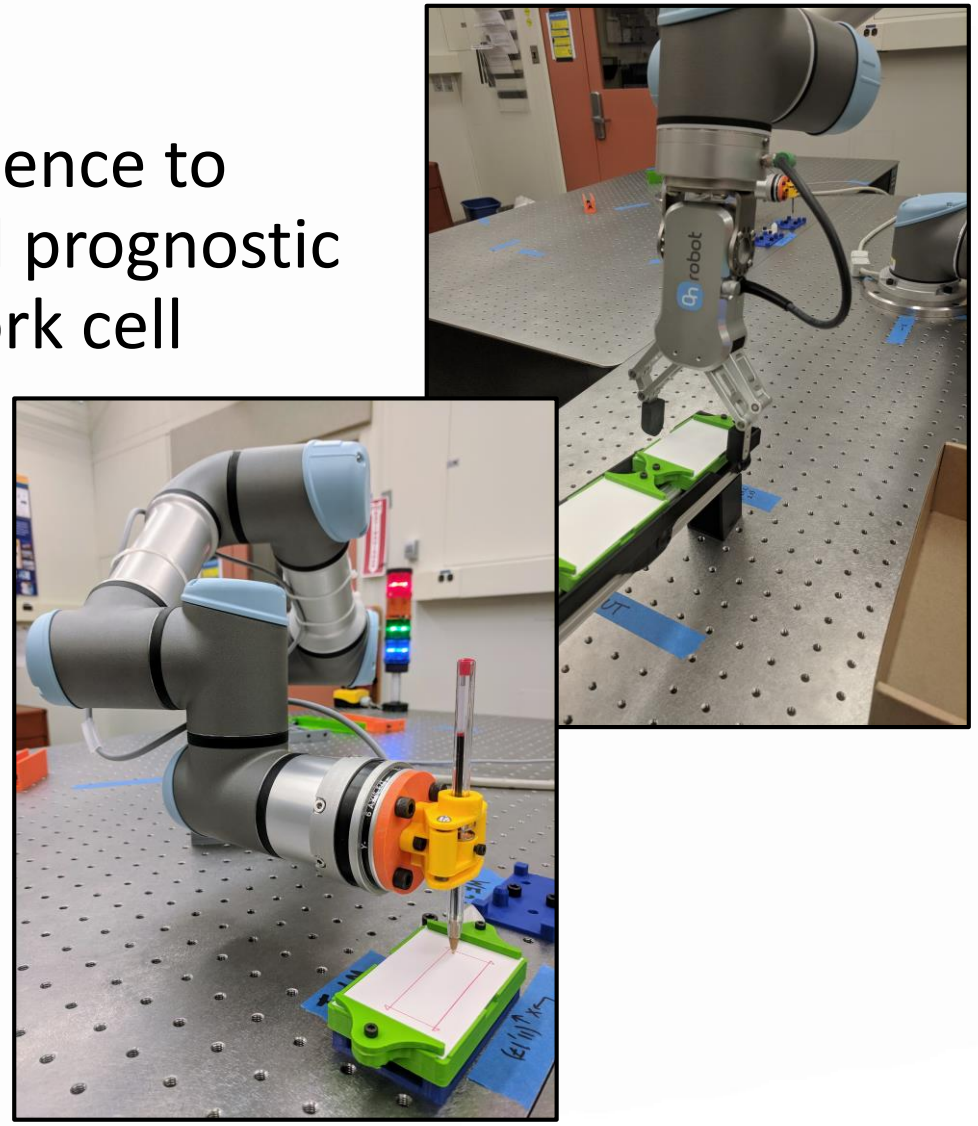
Potential Fault/Failure Sources

- Human
- Control/Software
- Mechanical
- Electrical
- Environmental

Images Courtesy of Fotolia

Robotic Workcell

- **Goal:** Develop the necessary measurement science to enable the V&V of monitoring, diagnostic, and prognostic technologies within a manufacturing robot work cell
- **Impact:** Increase equipment and process health intelligence through advanced monitoring, diagnostic, prognostic, and control strategies to optimize planned maintenance and minimize unplanned maintenance of manufacturing workcells



Robotic Workcell – Use Case

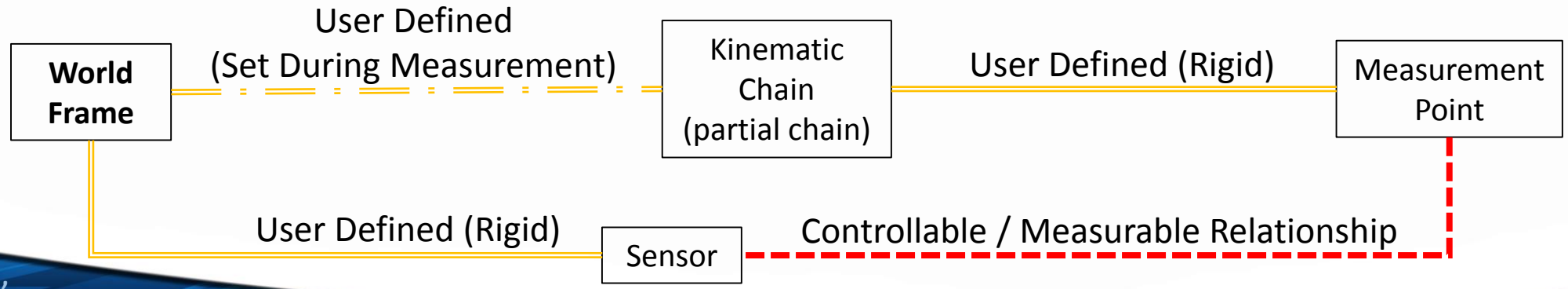
Identifying Process Repeatability Degradation via Position

Goal: To develop a **low cost in situ** method to identify **source of process repeatability degradation** within industrial robot enabled workcells with **minimal process disruption**.

Method: Workcells self-inspect at select points along kinematic chains to provide insight on if repeatability is degrading and where the degradation is occurring.

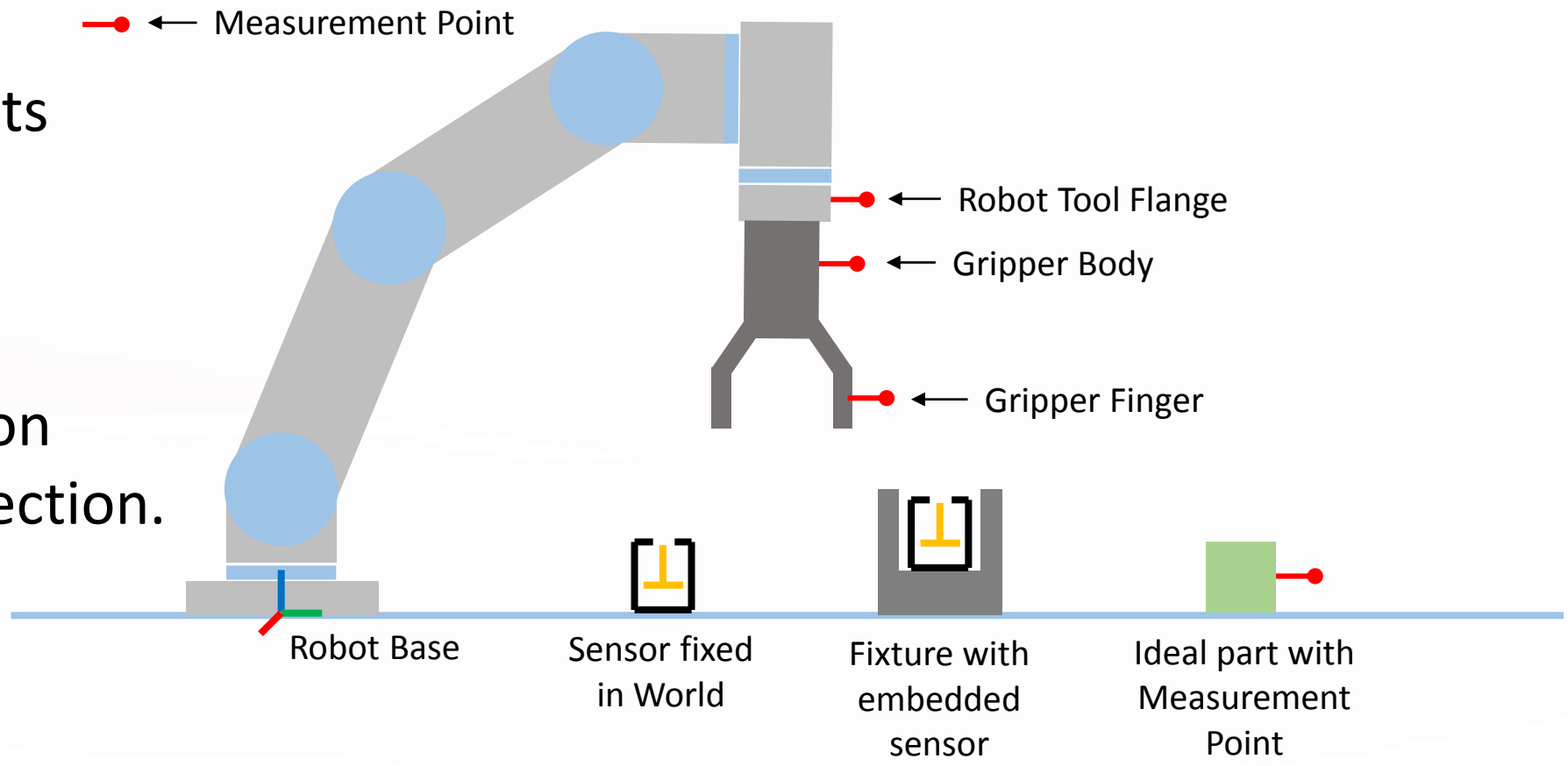
Challenges:

1. Identifying the points that should be measured / monitored along the kinematic chain
2. Choosing / developing sensing technology



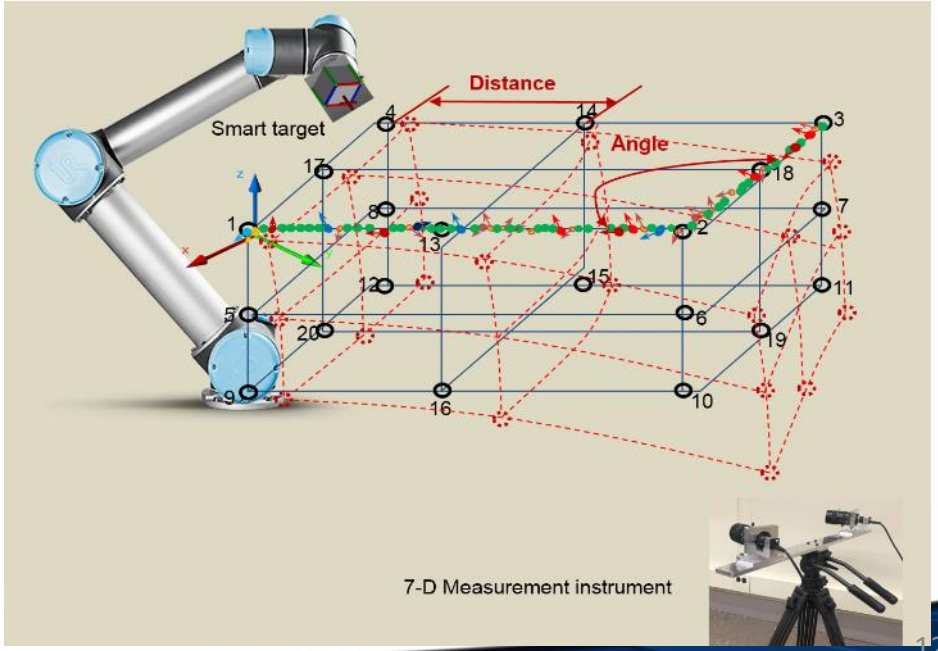
Selection of Measurement Points – Material Handling Use Case

- Measurement Points chosen at specific locations along the kinematic chain to enhance information gained during inspection.

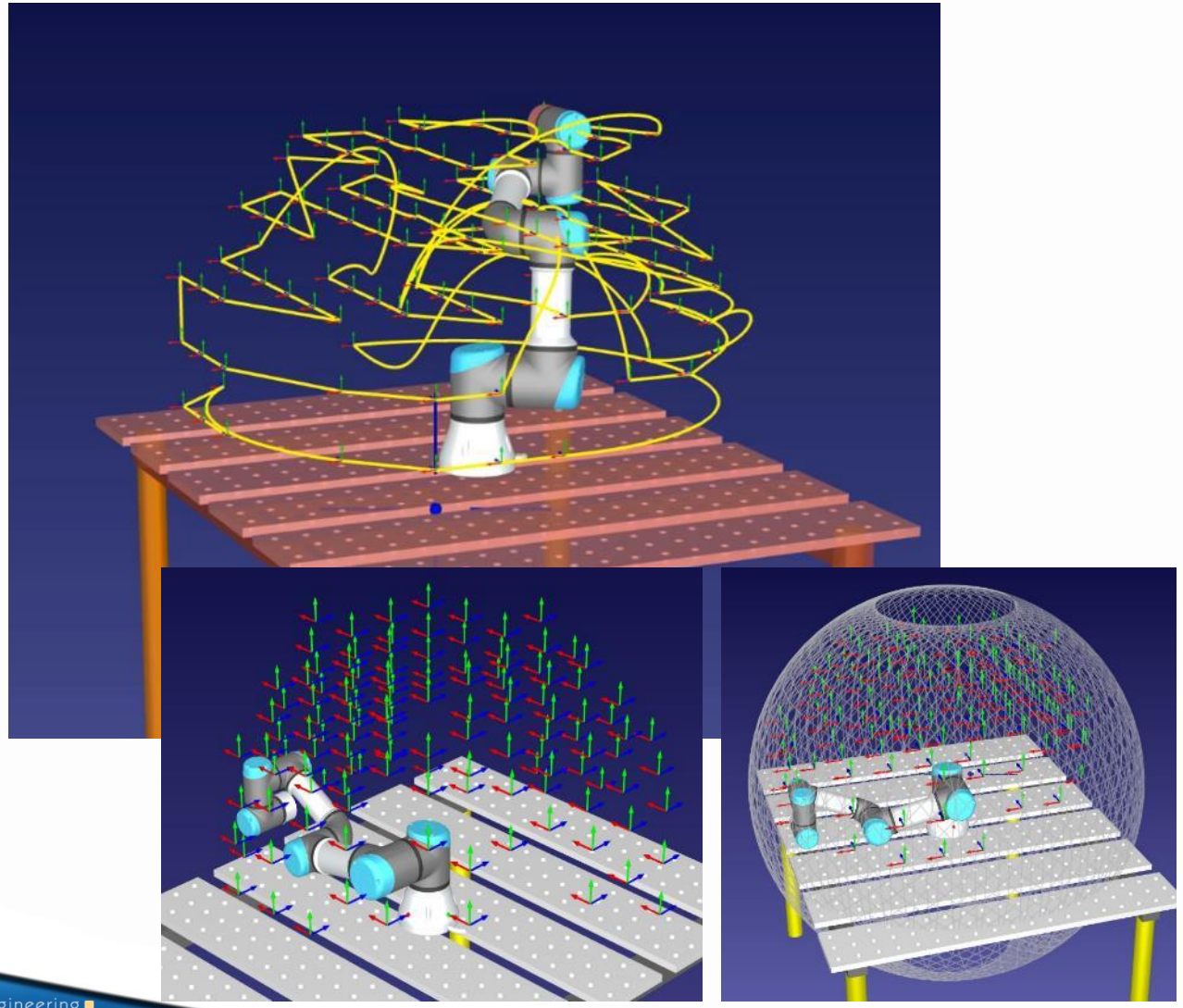


Work Cell Level Research – Quick Health Assessment Methodology

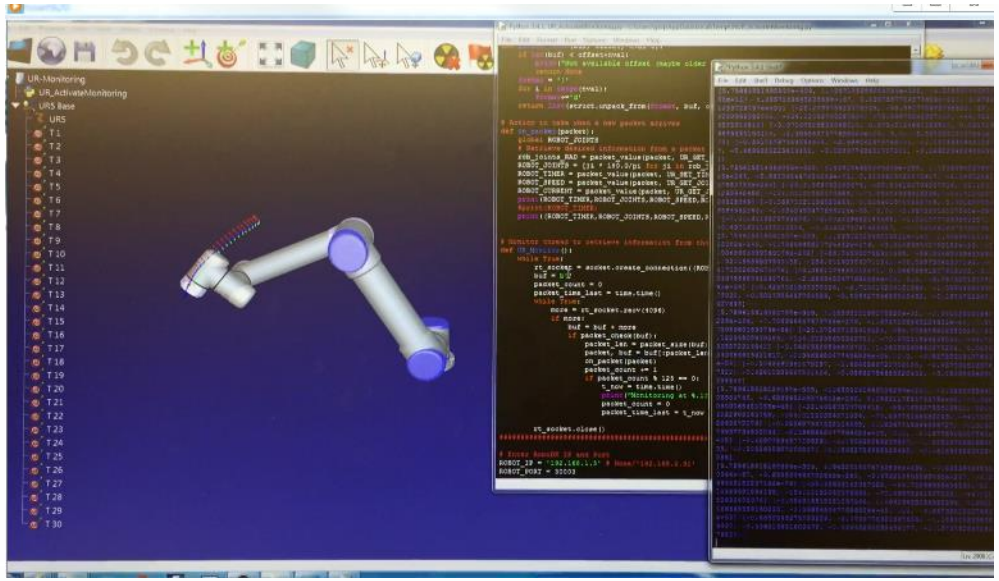
- **Research Objective**: Develop a quick health assessment methodology to provide manufacturers with robot health intelligence to enhance maintenance and control decisions
- **Key Output to Date:**
  - Advance sensing - 7-D measurement system
  - Innovative target – smart target
  - Algorithms and test method for quick robot position and orientation accuracy assessment
- **Impact:**
  - Reference test methods will educate and guide manufacturers in deploying PHM to quickly assess robot health promoting greater employment of predictive maintenance strategies (e.g. robot system calibration, joint and gear box replacement etc.) that will increase efficiency and productivity while decreasing downtime.



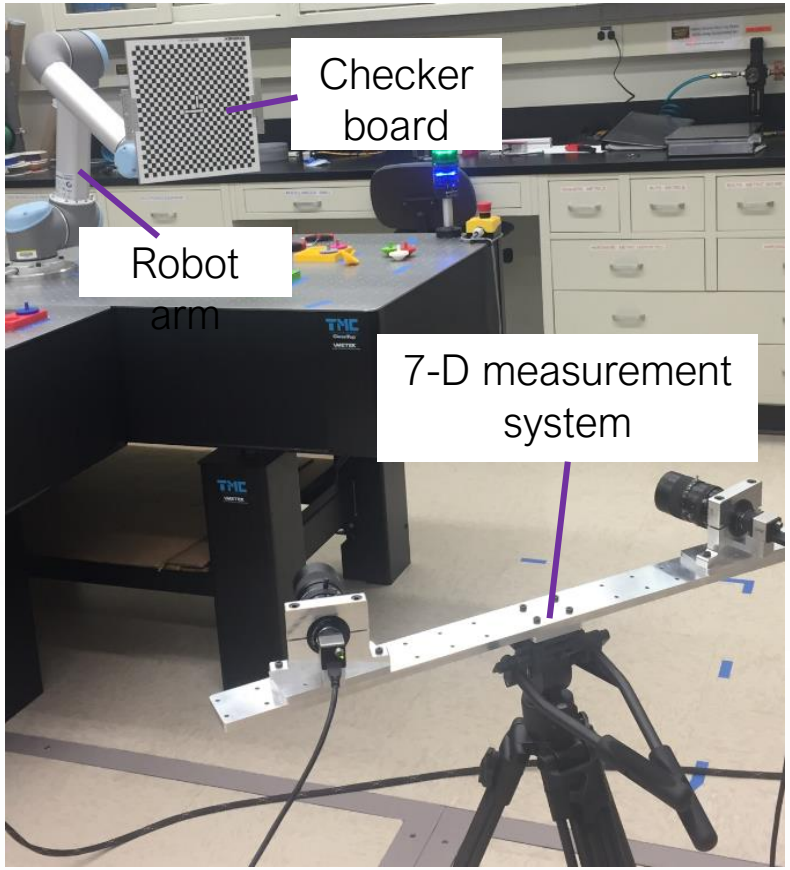
Test Method Development and Reference Data Collection

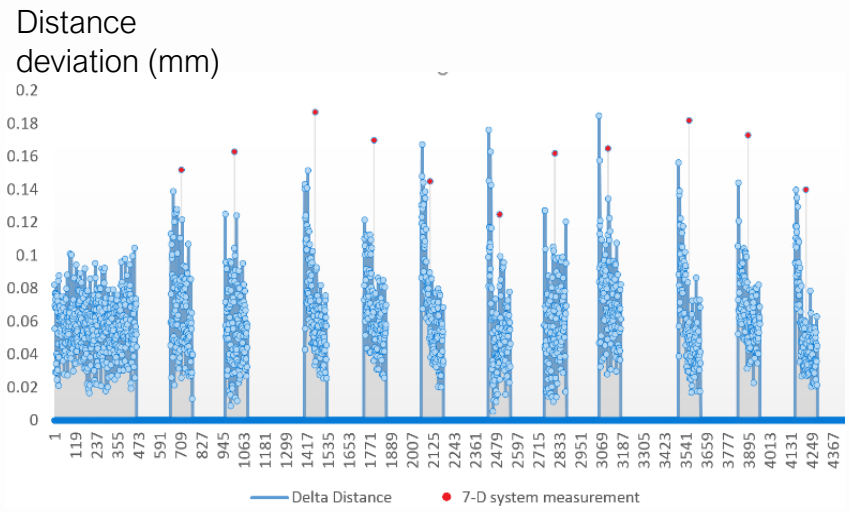


Real-time controller data collection



Robot – Reference Data Sets

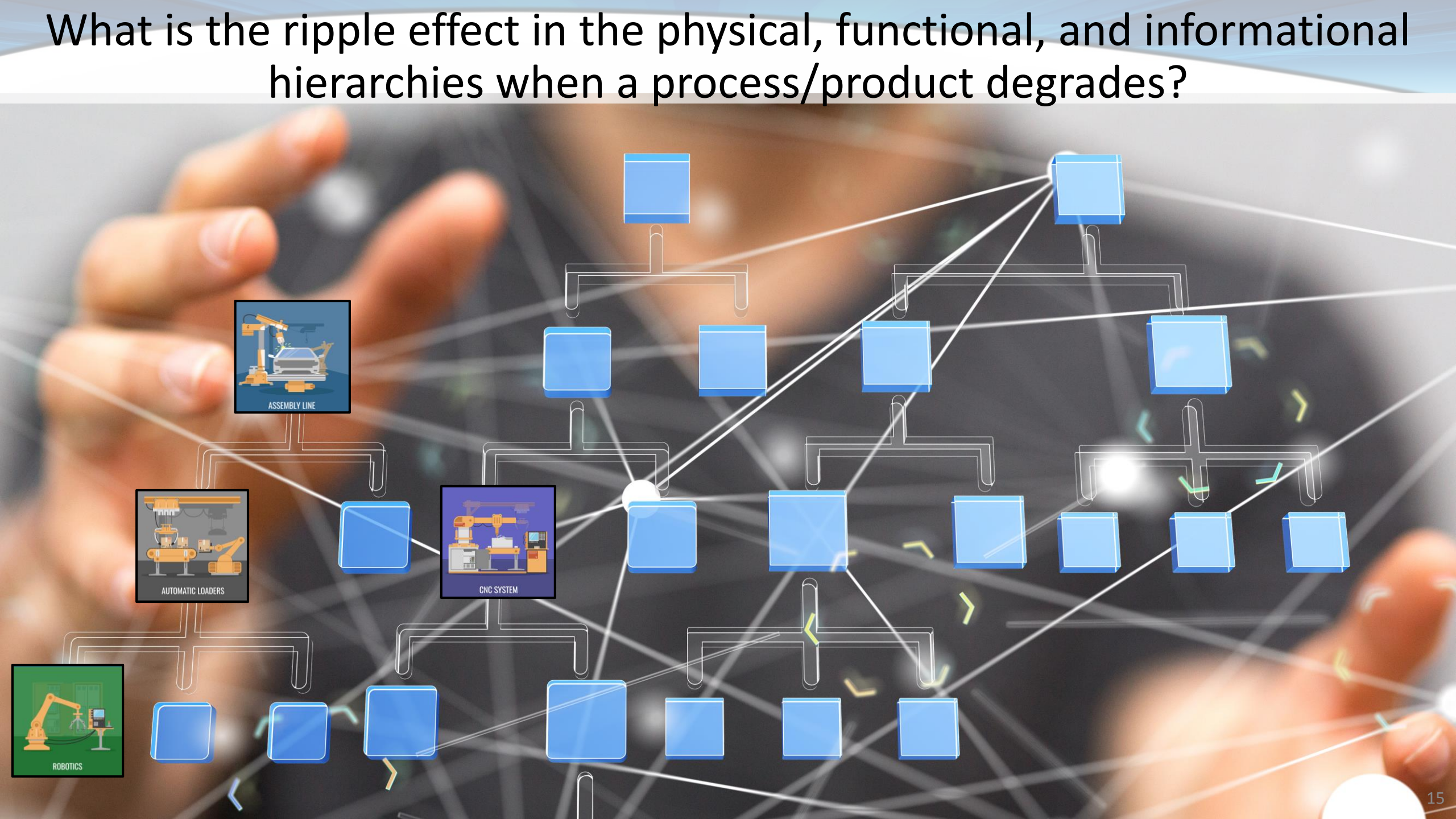




TCP deviations: 7-D system measured vs. calculated deviations from controller actual joint positions minus target joint positions

Reference data set URL:
https://www.nist.gov/el/intelligent-systems-division-73500/cognition-and-collaboration-systems/degradation-measurement

What is the ripple effect in the physical, functional, and informational hierarchies when a process/product degrades?



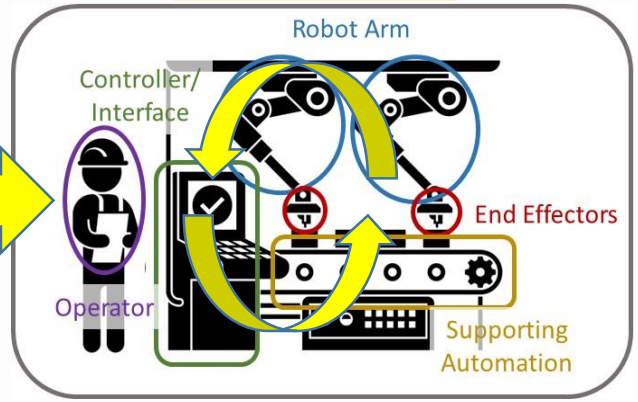
Is there a cost-effective, methodical approach to guide manufacturers through the PHM design and deployment process when you don't know all of the failure modes?

How do you **verify** and **validate** such an approach?

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?

Steps 1, 2, 3



START

Physical and Task Decomposition,
Process and Task Metric ID with Relationships

Step 4

LIKELIHOOD \ IMPACT	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med Hi	High	High
Likely	Low	Low Med	Medium	Med Hi	High
Possible	Low	Low Med	Medium	Med Hi	Med Hi
Unlikely	Low	Low Med	Low Med	Medium	Med Hi
Very Unlikely	Low	Low	Low Med	Medium	Medium

Risk Identification

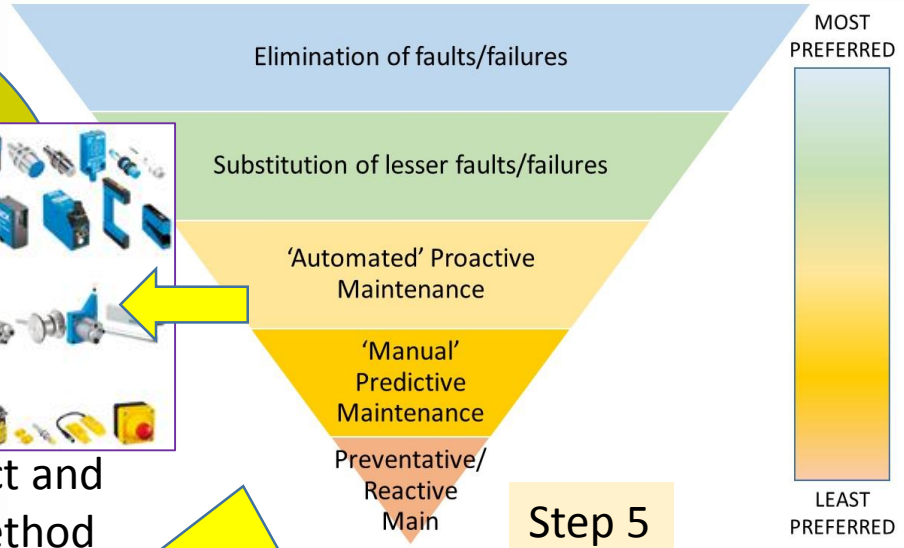
Data to Collect and
Collection Method

Step 6

Physical Element Metric ID,
Relationship Mapping and Quantification

Steps 7, 8

END



Risk Reduction

Step 5

Next Steps…

- Updating our research efforts to better reflect changing needs of industry
- Further development of test methods and performance metrics
- Strategic collaborations with industry to pilot test methods to get and give feedback
- Greater understanding of common configurations
- **ATTEND Friday's ASME's Standards Meeting**

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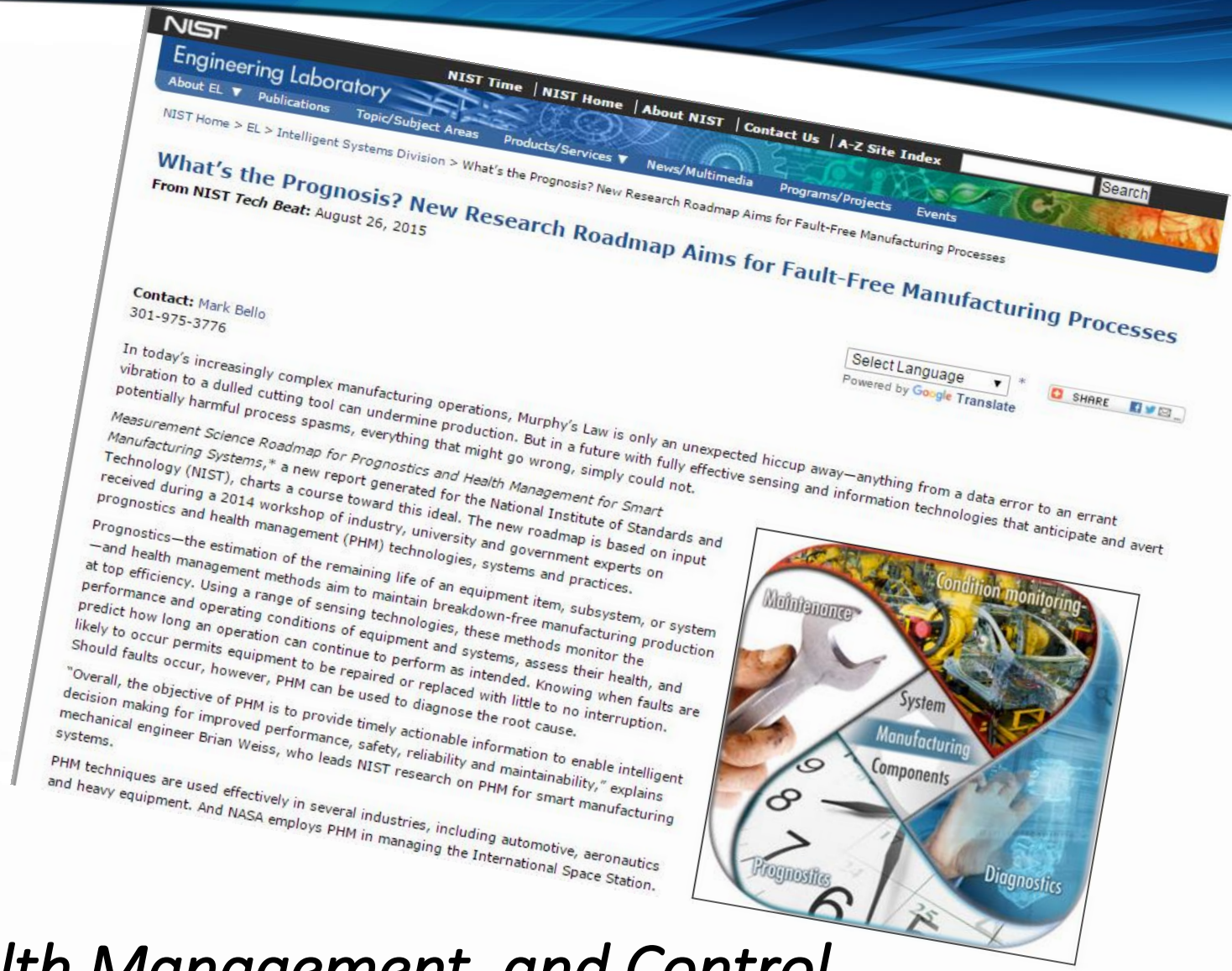

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What's the Prognosis? New Research Roadmap Aims for Fault-Free Manufacturing Processes

From NIST Tech Beat: August 26, 2015

Contact: Mark Bello
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In today's increasingly complex manufacturing operations, Murphy's Law is only an unexpected hiccup away—anything from a data error to an errant vibration to a dulled cutting tool can undermine production. But in a future with fully effective sensing and information technologies that anticipate and avert potentially harmful process spasms, everything that might go wrong, simply could not.

Measurement Science Roadmap for Prognostics and Health Management for Smart Manufacturing Systems,* a new report generated for the National Institute of Standards and Technology (NIST), charts a course toward this ideal. The new roadmap is based on input received during a 2014 workshop of industry, university and government experts on prognostics and health management (PHM) technologies, systems and practices.

Prognostics—the estimation of the remaining life of an equipment item, subsystem, or system—and health management methods aim to maintain breakdown-free manufacturing production at top efficiency. Using a range of sensing technologies, these methods monitor the performance and operating conditions of equipment and systems, assess their health, and predict how long an operation can continue to perform as intended. Knowing when faults are likely to occur permits equipment to be repaired or replaced with little to no interruption. Should faults occur, however, PHM can be used to diagnose the root cause.

"Overall, the objective of PHM is to provide timely actionable information to enable intelligent decision making for improved performance, safety, reliability and maintainability," explains mechanical engineer Brian Weiss, who leads NIST research on PHM for smart manufacturing systems.

PHM techniques are used effectively in several industries, including automotive, aeronautics and heavy equipment. And NASA employs PHM in managing the International Space Station.

Prognostics, Health Management, and Control

www.nist.gov/el/isd/ks/phmc.cfm