Spinning a Standards-Based Digital Thread for Smart Manufacturing

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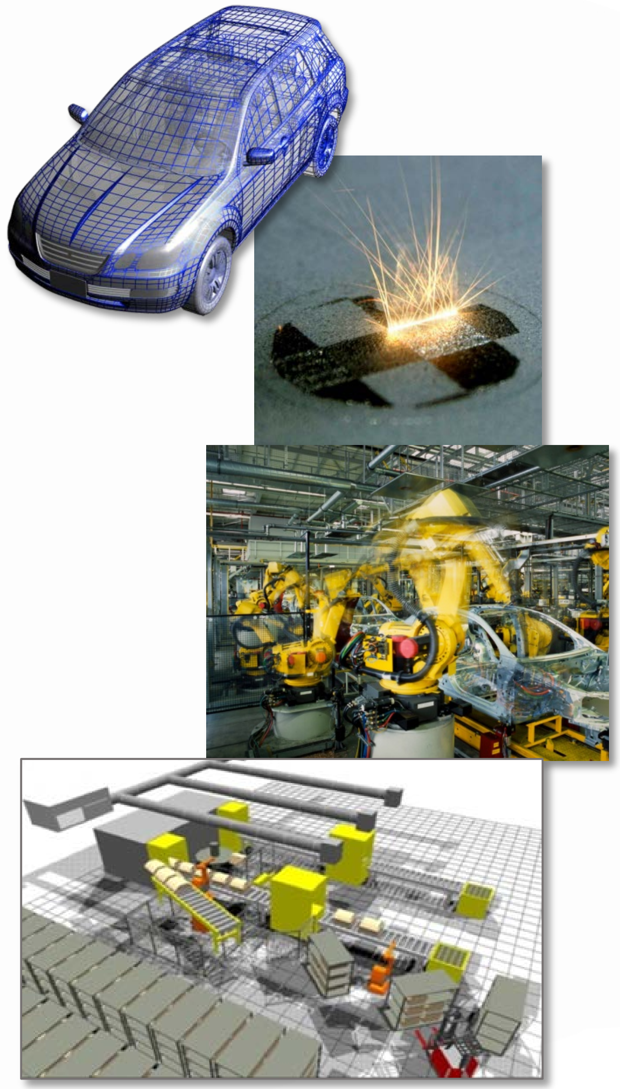


Outline

- NIST and Manufacturing
- Economics of the Digital Thread
- Standards for the Digital Thread
- NIST Digital Thread for Smart Manufacturing Project
- Summary

NIST and Manufacturing

NIST and Manufacturing

"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

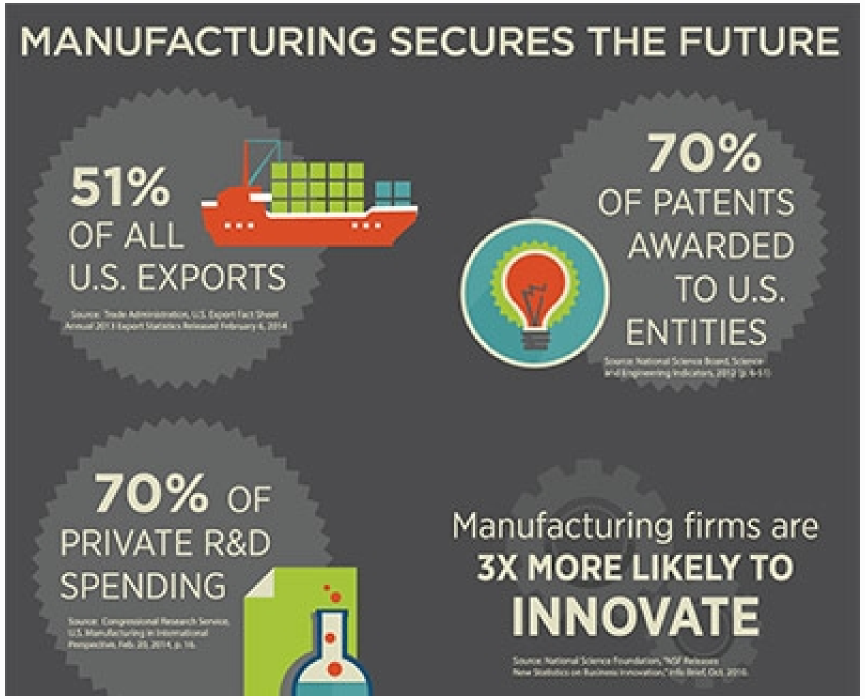
NIST Mission: To promote U.S. innovation and industrial competitiveness by advancing **measurement science**, **standards**, and **technology** in ways that enhance economic security and improve our quality of life.

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

Why Manufacturing Matters

- $2.1T in value added to the U.S. economy
- **Highest multiplier effect** (3.6) of any economic sector
- 12.3 million manufacturing workers in the United States, accounting for **9 percent of the workforce**
- In addition, manufacturing supports an estimated **18.5 million jobs** in the United States—about one in six private-sector jobs
- **Output per hour** for all workers in the manufacturing sector has increased by more than **2.5 times** since 1987



NIST MEP infographic www.nist.gov/mep/why-manufacturing-matters

Manufacturing is a key driver of productivity growth, innovation, and trade

www.nam.org/Newsroom/Top-20-Facts-About-Manufacturing/

Economics of the Digital Thread

Economic Analysis of Technology Infrastructure Needs for Advanced Manufacturing

- Objective – Determine technology infrastructure needs to support advanced manufacturing.
  - NIST conducts such studies regularly to help inform NIST's strategic planning and current/future investments.
- Method – Conduct qualitative and quantitative investigation of the barriers to adoption of smart manufacturing technologies and processes, with a focus on the underlying technology infrastructure.
  - identify current and emerging trends related to smart manufacturing;
  - identify technology infrastructure needs to support the development and adoption of smart manufacturing technology;
  - document the challenges and barriers that inhibit the development of technology infrastructure;
  - estimate the economic impact of meeting these technology infrastructure needs; and
  - assess potential roles for NIST in meeting technology infrastructure needs and realizing economic benefits.


Economic Analysis of Technology Infrastructure Needs for Advanced Manufacturing

Smart Manufacturing

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RTI INTERNATIONAL

Economic benefits of meeting technology infrastructure needs for smart manufacturing are $57.4 billion per year.

Gallaher, M. P., Oliver, Z. T., Rieth, K. T., and O'Connor, A. C., 2016. Economic analysis of technology infrastructure needs for advanced manufacturing: Smart manufacturing. Report NIST GCR 16-007, RTI International.

Study Take-Aways for the Digital Thread

- Managing digital data streams through models ($8.922 M/year)

  What: CAD models, material characteristics, simulation models of part creation, plant layout

  Needs: High-fidelity process models, physical model representation for flexible objects, data standardization, standard and simpler equipment interfaces to facilitate consistent data entry, standard terminology for automated part costing

- Seamless transmission of digital information ($10,310 M/year)

  What: seamless sensor integration, interoperability between platforms, secure data transmission (wired, wireless)

  Needs: Secure data transmission; secure cloud computing and data sharing; standard communication protocols; retrofitable, plug-and-play data communications systems; data interoperability of 3D model parameters and product manufacturing information

- Efficient communication of information to decision makers ($7,717 M/year)

  What: easy-to-interpret, comprehensive interfaces, accessible from any location

  Needs: Common taxonomy across platforms and disciplines, standards in interface design for manufacturing equipment

Gallaher, M. P., Oliver, Z. T., Reth, K. T., and O’Connor, A. C., 2016. Economic analysis of technology infrastructure needs for advanced manufacturing: Smart manufacturing. Report NIST GCR 16-007, RTI International.

Standards for the Digital Thread

Types of Standards

Process	ISO-9000	ISO 27001	ISO 50001	CMMI
Semantic Models	ISA 95	STEP	QIF	MTConnect
Transport Syntax	OPC/UA	MQTT	AMQP	
Communication	TCP/IP	UDP	RS-422	XBee
Security	DES	SSL	TLS	KERBEROS

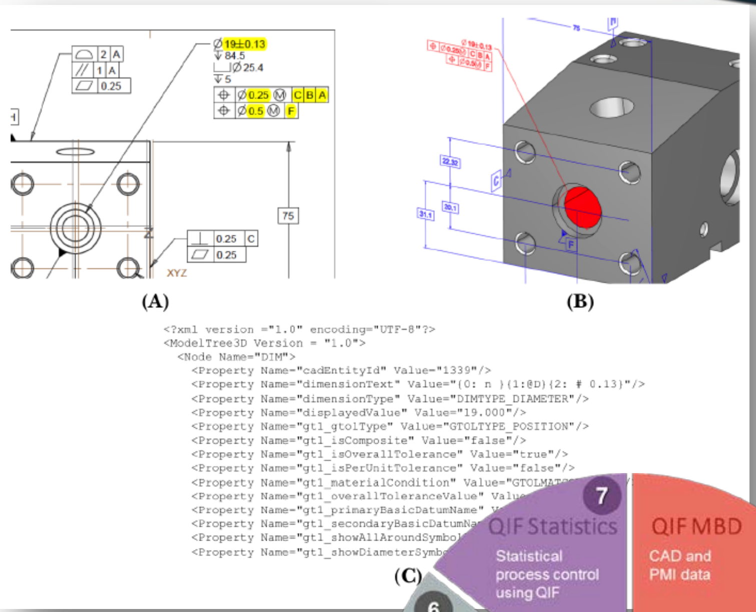
Will Sobel, AVM Task 3: Standards Development and Promulgation,
NIST MBE Summit, April 13, 2016, Gaithersburg, MD

Challenges for Industrial Data Standards

- No ”one model to rule them all.” Choose best standards in domain.
- We need semantically rich data standards with context.
  - Context varies based on lifecycle phase (e.g., design, manufacturing, quality)
  - Context varies based on the level of interaction with data (e.g., systems, operations, enterprises)
- We need a normalized method for contextualizing data at different points of the lifecycle
- We need identifiers that persist across domains
- Move out of the weeds of a domain and think about inputs and outputs at the boundary of the domain
- Forget about the data format and think about what is being represented in the data

Standards Examples

- 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.
- ANSI Quality Information Framework (QIF) standard
  - Streamlines the **flow of quality information** across the complete product-quality lifecycle.
- MTConnect
  - MTConnect streams data from running machines, controls, sensors, making **shop data** available in XML format for real-time data analysis.
- OMG Systems Modeling Language (SysML)
  - Extending SysML to enable integration of systems modeling and analysis



Digital Thread Project Results

Lifecycle Information Framework and Technology

FROM INFORMATION SILOS…

Design

Analysis

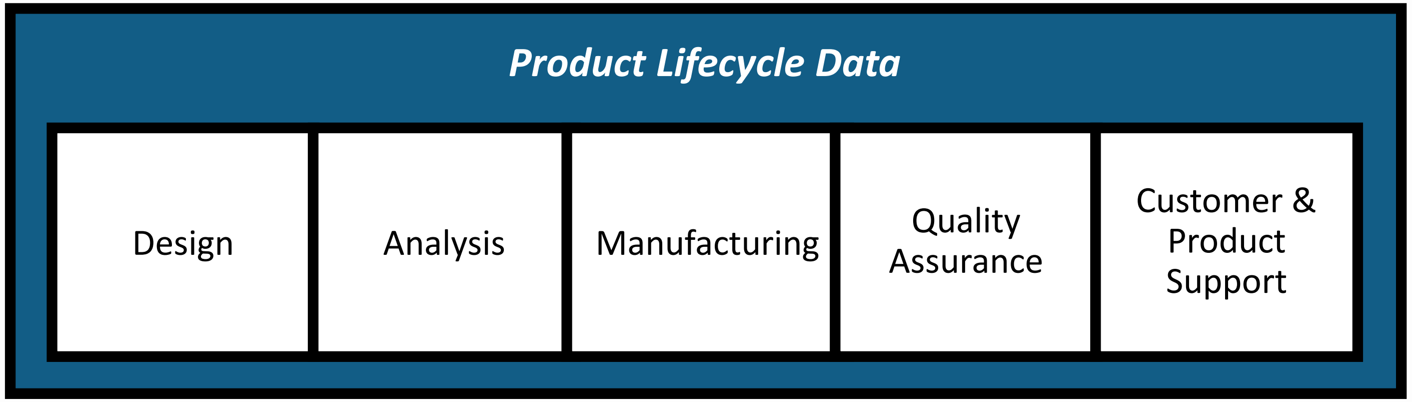
Manufacturing

Quality Assurance

Customer & Product Support

Hedberg Jr, T., Barnard Feeney, A., Helu, M., & Camelio, J. A. (2017). Towards a Lifecycle Information Framework and Technology in Manufacturing. *Journal of Computing and Information Science in Engineering, 17*(2), 021010-021010-021013. doi:10.1115/1.4034132

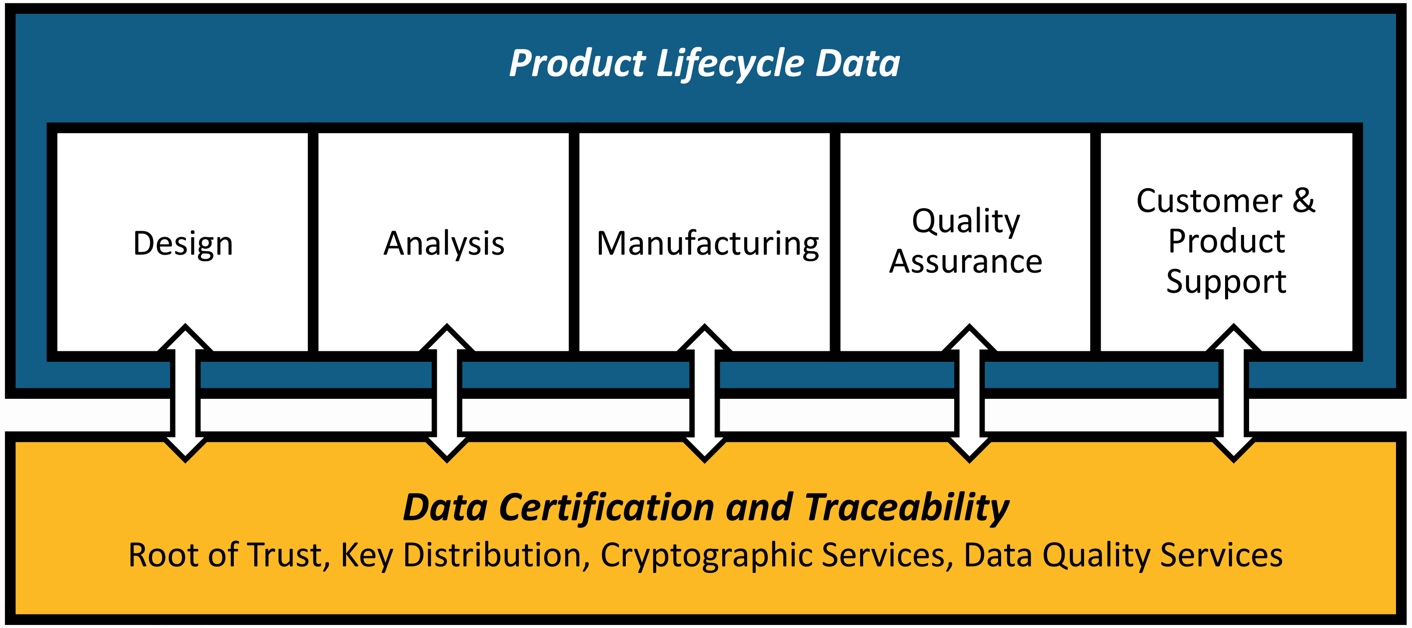
Lifecycle Information Framework and Technology



…TO LINKED DATA…

Hedberg Jr, T., Barnard Feeney, A., Helu, M., & Camelio, J. A. (2017). Towards a Lifecycle Information Framework and Technology in Manufacturing. *Journal of Computing and Information Science in Engineering, 17*(2), 021010-021010-021013. doi:10.1115/1.4034132

Lifecycle Information Framework and Technology

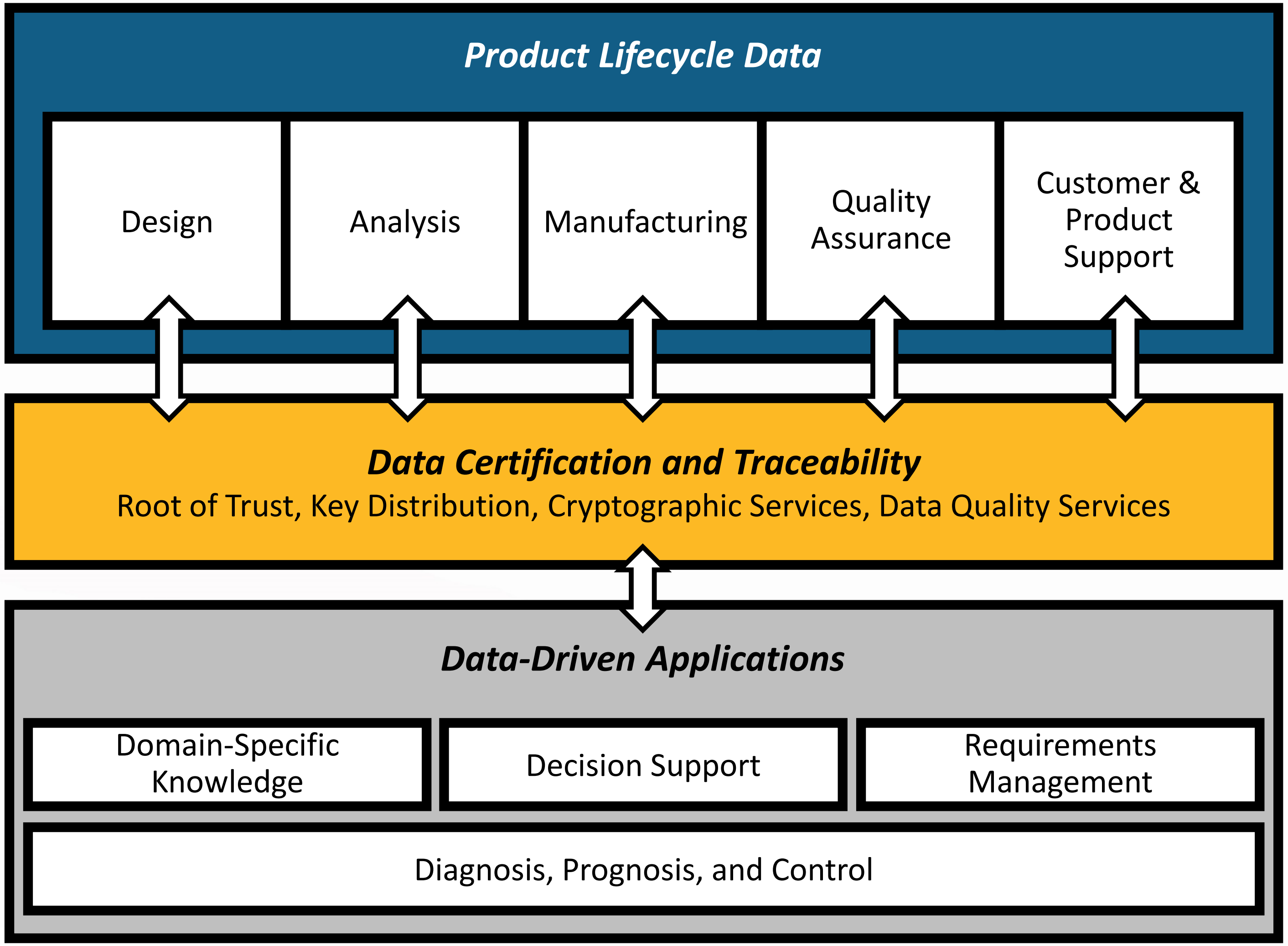


…WITH BUILT IN TRUST AND TRACEABILITY…

Hedberg Jr, T., Barnard Feeney, A., Helu, M., & Camelio, J. A. (2017). Towards a Lifecycle Information Framework and Technology in Manufacturing. *Journal of Computing and Information Science in Engineering, 17*(2), 021010-021010-021013. doi:10.1115/1.4034132

Lifecycle Information Framework and Technology

…FOR DRIVING APPLICATIONS WITH DATA!



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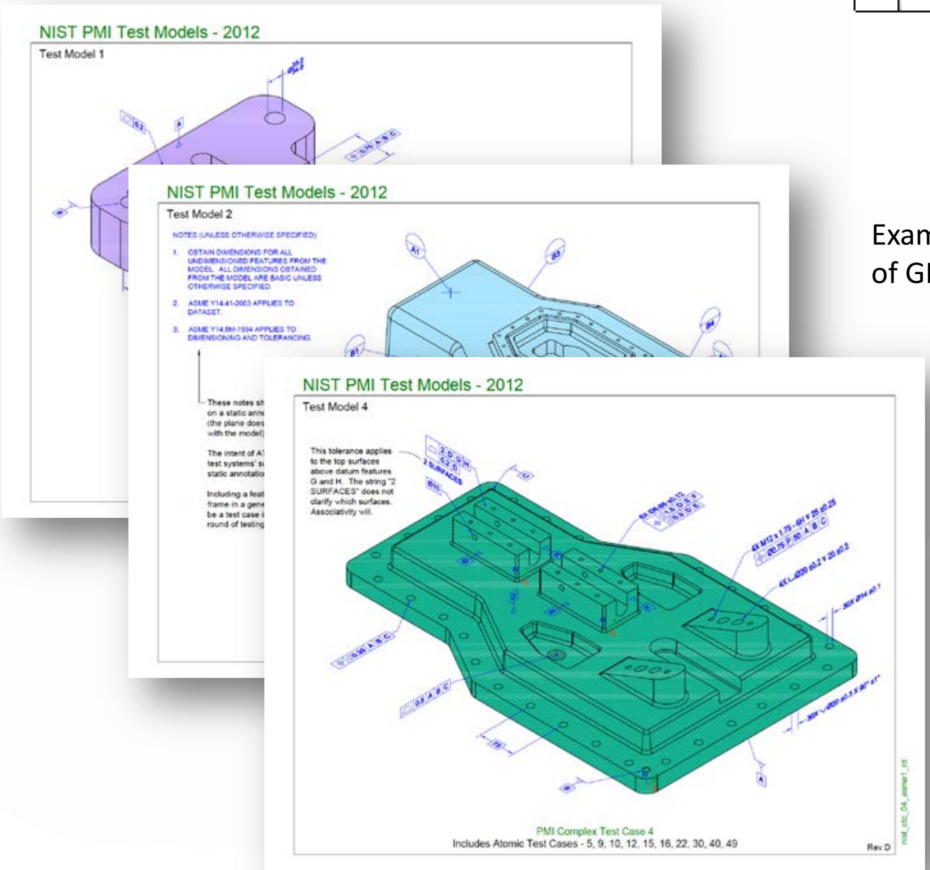
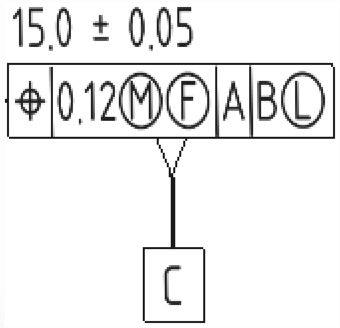
PMI Validation and Conformance Testing





Example presentation of GD&T annotation

Overview of CAD Capabilities

	CAD A	CAD B	CAD C	CAD D
No Limitations	85%	74%	69%	67%
Presentation Limitations only	2%	10%	18%	14%
Representation Limitations	13%	16%	13%	19%
Representation Level	87%	84%	87%	81%

- Supporting PMI standards implementation in CAD
- Verified and validated representation of PMI concepts in CAD models
- https://go.usa.gov/mGVm
- NIST STEP File Analyzer https://go.usa.gov/yccx

International TechneGroup

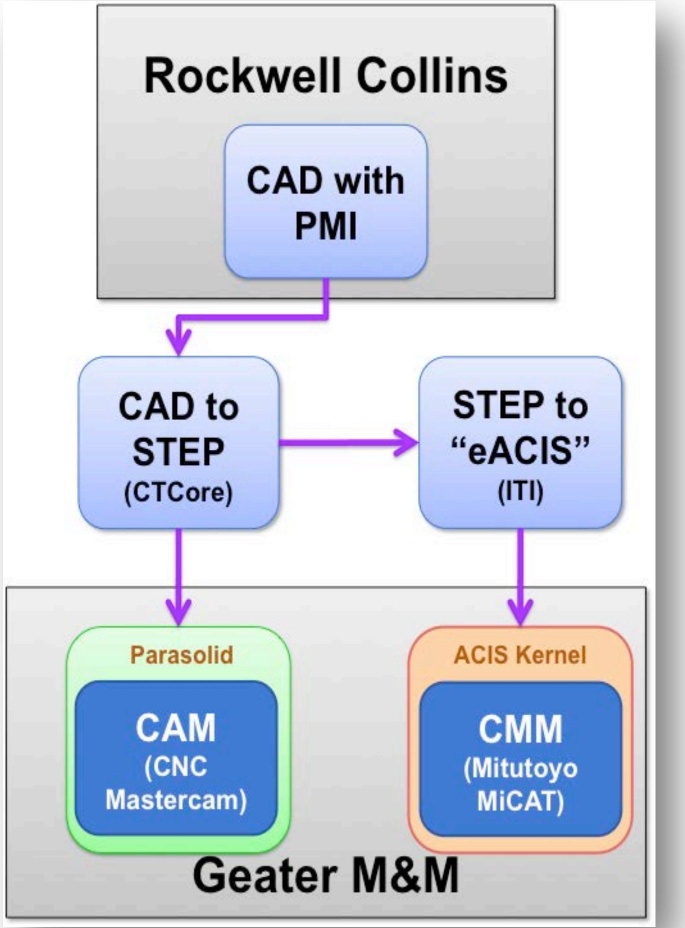
Design to Manufacturing and Inspection

- Proof-of-Concept demonstrator for standards-based transport of PMI downstream to manufacturing and First Article Inspections

- Reduced and/or eliminate recreation of part design data, reduce risk of error introduction downstream

- https://go.usa.gov/xnc3v

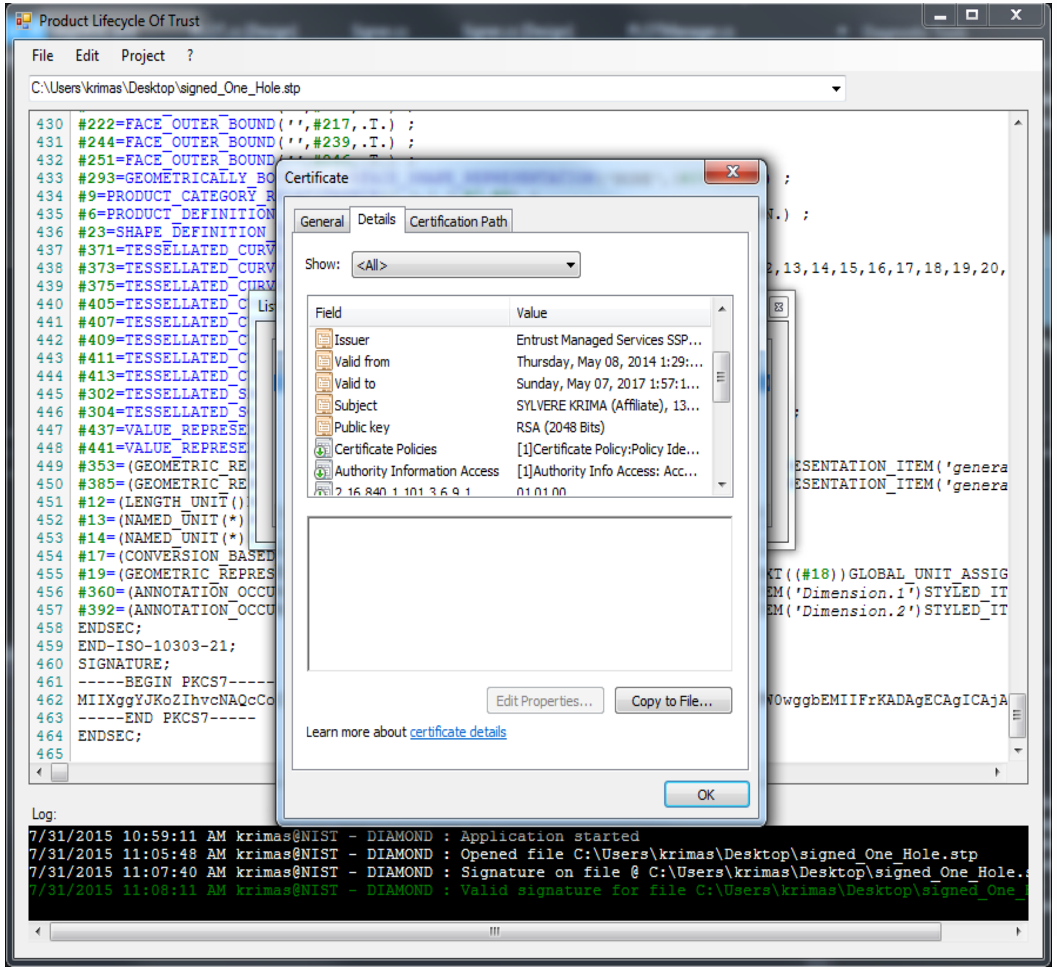
- Report: https://go.usa.gov/xnc3f



Trainer, A., Hedberg Jr, T., Barnard Feeney, A., Fischer, K., & Rosche, P. (2016). *Gaps Analysis of Integrating Product Design, Manufacturing, and Quality Data in the Supply Chain using Model-Based Definition.* 2016 MSEC, Blacksburg, VA

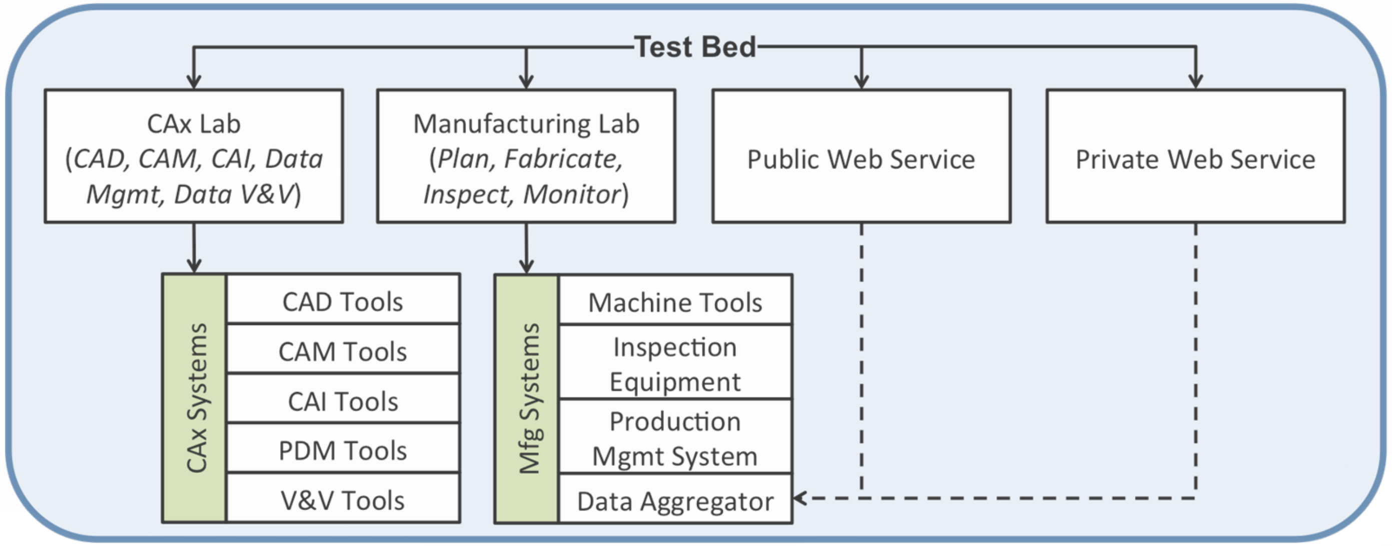
Digital Manufacturing Certificate Toolkit

- Toolkit includes a User Interface and API for Reading, Writing, and Verifying digital signatures in models
- Supports G-Code (ISO 6983), QIF 2.0, PDF/PRC, and STEP P21 formats
- Toolkit and source code available at: https://github.com/usnistgov/DT4SM



NIST Smart Manufacturing Systems Test Bed

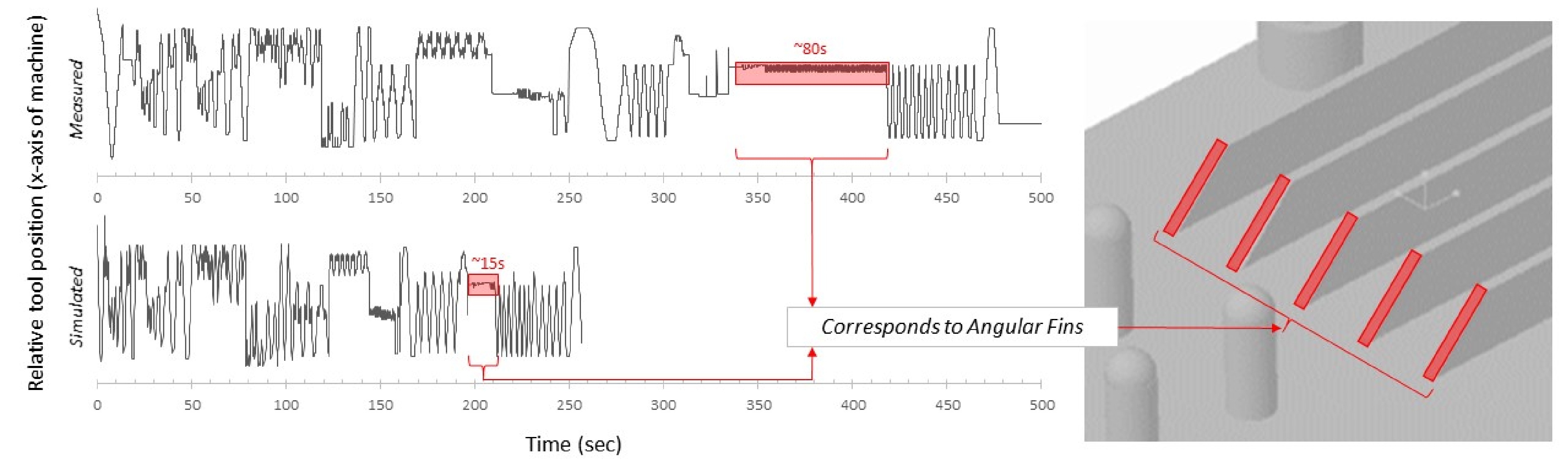
- Reference architecture and implementation
- Rich source of data for fundamental research (TDPs with native CAD, STEP, MTConnect, QIF)
- Physical infrastructure for standards and technology development
- Demonstration test cases for education
- https://go.usa.gov/xnqJr
- Report: https://go.usa.gov/xncc3



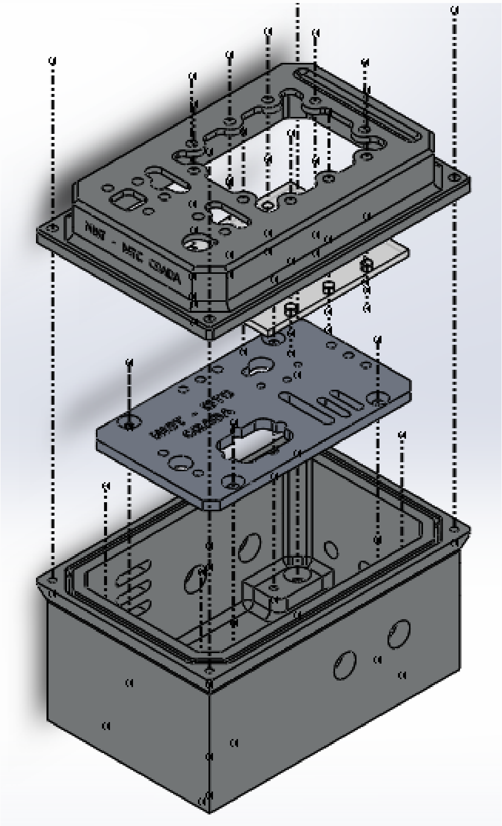
Monitoring Manufacturing Systems

- Simulated cycle time for feature was 15 seconds, but measured cycle time was 80 seconds. Feed rate mismatch affects production schedule
- Determine root cause of feed mismatch and remedy production scheduling issues
- Integrate multiple data sources (STEP, NC Code, MTConnect, QIF) from systems across the product lifecycle to determine causation using data analytics
- Report: https://go.usa.gov/xnccB

VIMANA



NIST-MTC Collaboration



Test assembly produced for data integration experiment.

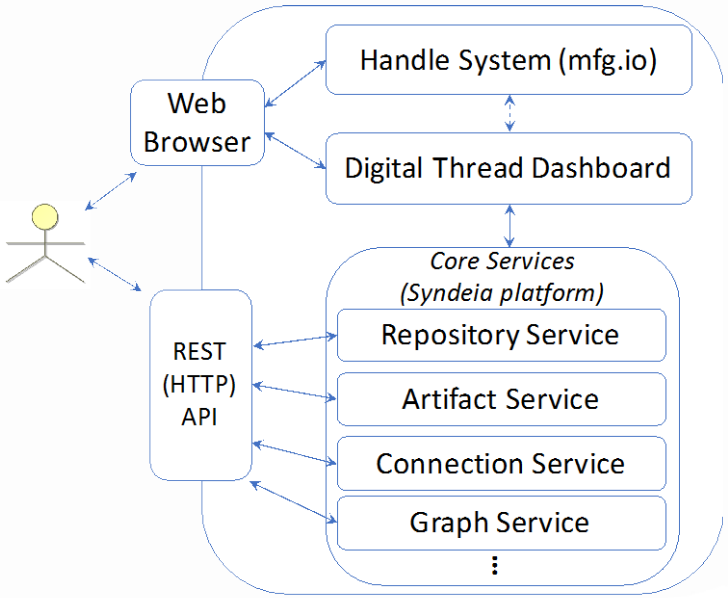
- Contract design house (NIST) and OEM (MTC) relationship.
- The assembly was jointly designed, manufactured at NIST, inspected by both parties. MTConnect and QIF data was collected and analyzed.
- Data interoperability issues exist. Manual data manipulation was required.
- Persistent IDs are required to make all data traceable to the authority CAD model through all process steps.
- Paper forthcoming

mtc
Manufacturing Technology Centre

Current work: System Lifecycle Handler

Requirements

- Identify artifacts and relationships in the digital thread
- Provide a unique global identifier system for the digital thread
- Provide a multiple-step resolver system for global identifiers
- Common handler system for global identifiers
- Search and query artifacts/versions in the digital thread
- Build a digital thread by establishing connections between artifacts
- Traceability, impact analysis, and continuous validation and integration of the digital thread
- Provide visualization /graph queries on the digital thread
- Expose the digital thread as an API



intercax

Summary

- Novel smart manufacturing technology infrastructure would save manufacturers $57.4 billion annually.
  - Conservative - methodology accounts for impact in a single year, but benefits would persist
- Barriers to innovation increase cost of R&D, disincentivize private investment, and magnify role of public institutions.
  - Potential adopters, uncertain of ROI, are unwilling to pay for novel features, which diminishes incentive to invest in the technologies.
  - Trusted third-party standards and performance data let adopters know what they are buying at various cost points
- Overcoming critical technical barriers may require investments in public-private manufacturing consortia.
  - We need open platforms and marketplaces where small players can innovate
  - Developing and disseminating technology infrastructure to support those platforms will require investments in both consortia and technology-extension services.
- Small enterprises face significant barriers to adoption of smart manufacturing technology.
  - Novel technology infrastructure that decreased the cost of software and implementation would increase adoption among SMEs,
  - Providing the technology infrastructure for cloud-based smart manufacturing, e.g., could make big data storage and analytics more accessible for SMEs.
- Technology infrastructure needs are vast and often interrelated
  - Unbalanced investment, closing some technical gaps while leaving other needs unmet, would likely fail to fully realize economic impact.
- Important areas where public sector can help: data analysis, cyber security, human capital, and interoperability of systems, machines, and other data streams.

Thank you!

https://go.usa.gov/xnqwy

Publication Search: https://go.usa.gov/xnc2e

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