Engineering a $100B Paradigm Shift: Economic and System Drivers to Interoperability Innovation

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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

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Who am I?

• Education
  • **Purdue University**, B.S., *Aeronautical and Astronautical Engineering*, Dec. 2005, concentration on Design and Dynamics & Control
  • **Virginia Polytechnic Institute and State University**, *Ph.D. Candidate*, Industrial and Systems Engineering

• Current NIST Role
  • Project Manager of the Digital Thread for Smart Manufacturing project in the Smart Manufacturing Operations Planning and Control program
  • Co-Leader of the Smart Manufacturing Systems Test Bed

• Industry Roles
  • Voting Member of the American Society of Mechanical Engineers (ASME) Y14.37, Y14.41, and Y14.41.1 subcommittees from the ASME Y14 suite of standards
  • Co-Chair and Americas Lead for the Visualization Working Group for LOTAR International
Bottom Line Up Front (B.L.U.F.)

**Cyber-physical** infrastructures enabled by **linked-data** and **system-thinking** would save the U.S. manufacturing $100 Billion annually.
Presentation Overview

• Economy of manufacturing in the United States

• Industry problems and needs in the context of interoperability

• Recommendations and solutions for ushering in the future of Interoperability Innovation
Manufacturing Economy

It’s rising and bigger than you think!
Manufacturing is $\frac{1}{3}$ of the U.S. Economy

Total Manufacturing Value Chain of ~$5.5$ Trillion

- Downstream Sales, 2.6
- Upstream Supply, 2.4
- Sales to Non-Manufacturing Supply Chains, 0.5

* Values are in Trillion USD ($)

Mining and raw material processing accounts for $431 Billion in Value-Add

1.27 Million FTE jobs are attributed to mining and raw material processing


Wholesale and Retail trade account for $281 Billion and 1.76 Million FTE jobs

Pre-production manufacturing accounts for $396 Billion and 2.62 Million FTE jobs

In total, Supply Chain domestic industry production provides a $2.4 Trillion value-add spread across all industries of the economy


Production manufacturing adds $1.057 Trillion in value to the economy.

Production manufacturing provides demand for 6.15 Million FTE jobs.


Wholesale Distribution

Wholesale distribution adds $496 Million of value and 2.83 Million FTE jobs to the economy


Transportation

Provides $58 Billion value-add and 446,000 FTE jobs


Retail distribution add $719 Million of value and 12.11 Million FTE jobs to the economy.


Professional and support services related to manufacturing add $252 Billion of value and 1.94 Million FTE jobs to the economy.


Multiplier Effect

Value Add

$3.60 of value-add in the economy for every $1 of manufacturing value

Jobs

For each FTE manufacturing job, 3.4 FTE jobs are created in non-manufacturing sectors

U.S. GDP

Manufacturing final demand accounts for 34% of U.S. GDP

Exports

59% of Manufacturing demand is attributed to exports


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Productivity Growth

Interoperability Problems and Needs

A different perspective than the status quo
“We have reached the fundamental limits of what our [tools] and processes can handle”

Dr. William C. Regli
Past Acting Director, Defense Sciences Office (DSO), Defense Advanced Research Projects Agency (DARPA)
Data and System Interoperability

• Models are simply representations of products, but considered the authoritative sources

• Point-to-Point interoperability is not enough

• Engineering thought processes are applied to data and systems instead of data-science thought processes
Data and System Interoperability

• Need connected systems and linked-data federated across enterprises

• Less than 37% of the US Public understands data analytics, but US Manufacturing Executives rank “predictive analytics” as the most important future technology ¹

• Enhanced sensing and monitoring, seamless transmission of digital information, and advances in analyzing data and trends would save manufactures $30 Billion annually ²

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Viewpoints Interoperability

- Context varies based on the phase of the lifecycle (e.g., design, manufacturing, quality)

- Context varies based on the level of interaction with data (e.g., systems, operations, enterprises)

- Shape / specification is not enough, behavior and context required too, but all three must be agile and dynamic
Viewpoints Interoperability

• Stop thinking about data interoperability, think domain interoperability

• Need a normalized method for contextualizing data at different points of the lifecycle

• Forget about the data format and think about the “thing” being represented in the data

• Move out of the weeds of your domain and think about inputs and outputs at the boundary of your domain

• Who needs what information when and who is generating the it?
Product Lifecycle Management (PLM)

- PLM conflated with PDM, MES, ERP
- PLM sold as a tool
- PLM taught as a methodology
- First rule of PLM... “customization”
- Business-driven PLM instead of PLM-driven business
Product Lifecycle Management (PLM)

• Customization: Stop it!

• One system is not better than another system. One platform is not better than another platform. The best is in what you have already invested!

• Need standard methods for mapping the representations from one system to another in distributed and federated environments
Trustworthiness and Interoperability

- Inherent distrust between operating units and among supply chain
- Traceability Interoperability
- Authentication, authorization, traceability vs. intellectual property rights
Trustworthiness and Interoperability

- If you cannot trust your customers and supply chain, then why are you doing business with them?

- Digital signatures and certificates: Trust, but verify!

- Authentication, authorization, and traceability are three pillars of trust that protect intellectual property
Technologies vs. Standards

• Proprietary technologies and specifications are being pushed to standards without a transfer of technology rights.

• No open geometric modeling kernels developed with standards-based information models.

• Technology investment and adoption is based on short-term cost / benefit analysis.
Technologies vs. Standards

• Support the new ASME MBE Standards Committee (Fred Constantino, ConstantinoF@asme.org)

• The United States needs an open-standards supported geometry kernel that is developed in the U.S. and/or international standards community

• Evidence shows proprietary standards fail to address the underlying barriers to innovation*

• Consortia can address critical interoperability issues, Need more public-private partnerships*

Recommendations for Interoperability Innovation

It’s time for a new core of the paradigm
Announcing...

MFG.IO

Manufacturing Handles: Spinning the Digital Thread of Connected Enterprises

PEOPLE
MACHINES
FEDERATED DATA
THINGS
SYSTEM INTEGRATION

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Lifecycle Information Framework and Technology

Trustworthiness in Certificates and Blockchain

Leveraging X.509 Private Key Infrastructure and Privilege Management Infrastructure, coupled with Blockchain, as an all-in-one solution

A system based on **Authorization** with embedded **Authentication**.  
(what the data is)  
(how the data can be used)

<table>
<thead>
<tr>
<th>Authority Level (Subordinate Authority)</th>
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<tbody>
<tr>
<td>Requirements, Policy, and Audit Service</td>
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<th>Service Level</th>
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<td>Validation Service</td>
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<td>Approval Service</td>
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<td>IP Access Service</td>
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<th>Data Level</th>
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<tr>
<td>Native CAD Model</td>
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<td>Derivative CAD Model</td>
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<tr>
<td>Definition Approvers</td>
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<td>Usage Control</td>
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Public Working Group on Blockchain for Manufacturing is Forming Now!
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
Generating a Cyber-Physical Graph

https://dx.doi.org/10.1115/1.4034132


Physical.Person


Physical.Machine

Cyber.Data.Stream

Cyber.Data.Model.Design

Monitors

*Append "?noredirect" to end of HTTPS-URI to see meta-data*
INNOVATION IS...

...MOVING FROM INFORMATION SILOS...

...TO LINKED DATA...

...WITH BUILT IN TRUST AND TRACEABILITY...

...DRIVING APPLICATIONS!

Stay tuned for public demonstrations throughout Fiscal Year 2018
In summary...
Conservatively, $100 Billion annual savings is available to industry through the adoption of open-standards, model-based methods and advanced manufacturing.
Think Differently...

Seize the opportunity to invert the paradigm and create a foundation for a multi-viewpoint, federated enterprise supported by domain-specific knowledge.
Questions?

Thank you for your kind attention!

Thomas Hedberg
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Digital Thread: https://go.usa.gov/xNP8x
SMS Test Bed: https://smstestbed.nist.gov
My Publications: https://go.usa.gov/xNP8R

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Backup

Help!
Data Collection and Aggregation

- Design
  - CAX
  - As Designed
- Fabrication
  - CAM/NC Code
  - As Planned
- Inspection
  - MTConnect
  - As Executed
  - OIF
  - Dynamic Scheduling & Process Control
  - As Measured

Monitoring + Diagnosis + Prognosis

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NIST Smart Mfg. Systems Test Bed

Goals:

- Reference architecture and implementation
- Rich source of data for fundamental research
- Physical infrastructure for standards and technology development
- Demonstration test cases for education

http://smstestbed.nist.gov
4-Tier Architecture

• Designed as a four-tier architecture

• Implemented across three networks

• Provides segregated access to internal and external clients