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

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Global Product Data Interoperability Summit, Tempe Arizona

20 September 2017

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

Supplemental graphics used in this presentation were provided by PRESENTERMEDIA

Who am I?

- Education
  - **Purdue University**, *B.S., Aeronautical and Astronautical Engineering*, Dec. 2005, concentration on Design and Dynamics & Control
  - **The Pennsylvania State University**, *M.S., Engineering Management*, Aug. 2014, concentration on Systems Engineering
  - **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

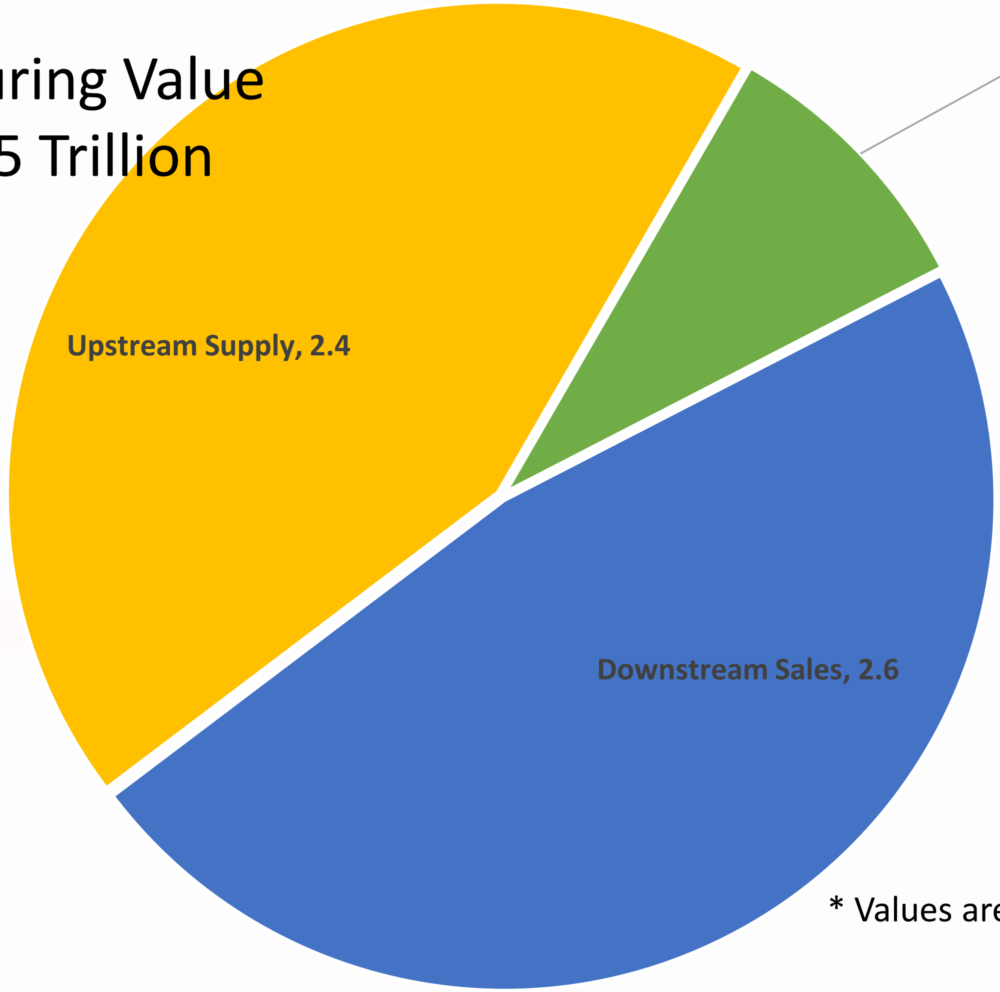
- Economy of manufacturing in the United States
- Industry problems and needs in the context of interoperability
- Recommendations and solutions for ushering in the future of Interoperability Innovation

Manufacturing Economy

It’s rising and bigger than you think!

Manufacturing is ⅓ of the U.S. Economy

Total Manufacturing Value Chain of ~$5.5 Trillion



* Values are in Trillion USD ($)

MAPI Foundation. (2017, Accessed: 2017-08-21). Myth-Busting American Manufacturing. Retrieved from http://www.webcitation.org/6t5IoctUk

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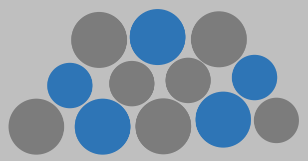
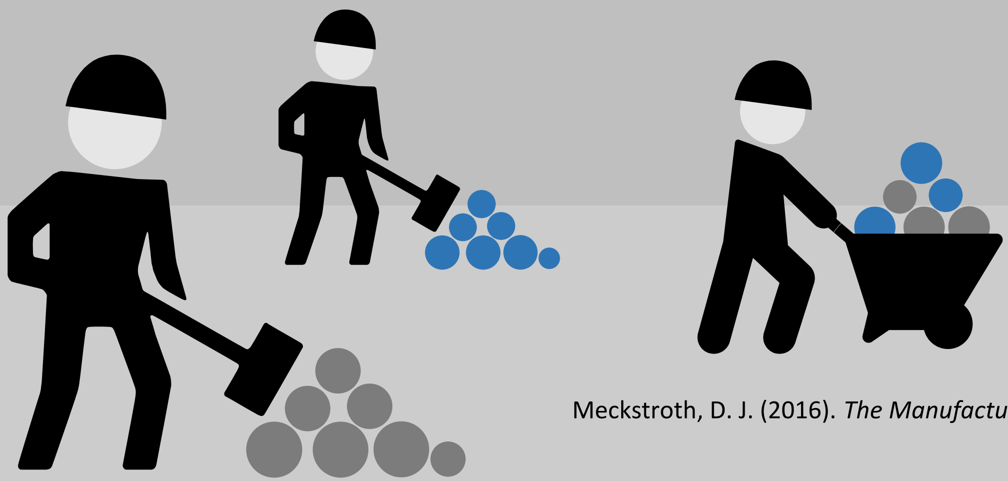
Upstream Supply

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

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





Meckstroth, D. J. (2016). *The Manufacturing Value Chain is Much Bigger Than you Think!* (PA-165). Retrieved from MAPI Foundation, Arlington VA: http://www.webcitation.org/6t5IjO4ba.

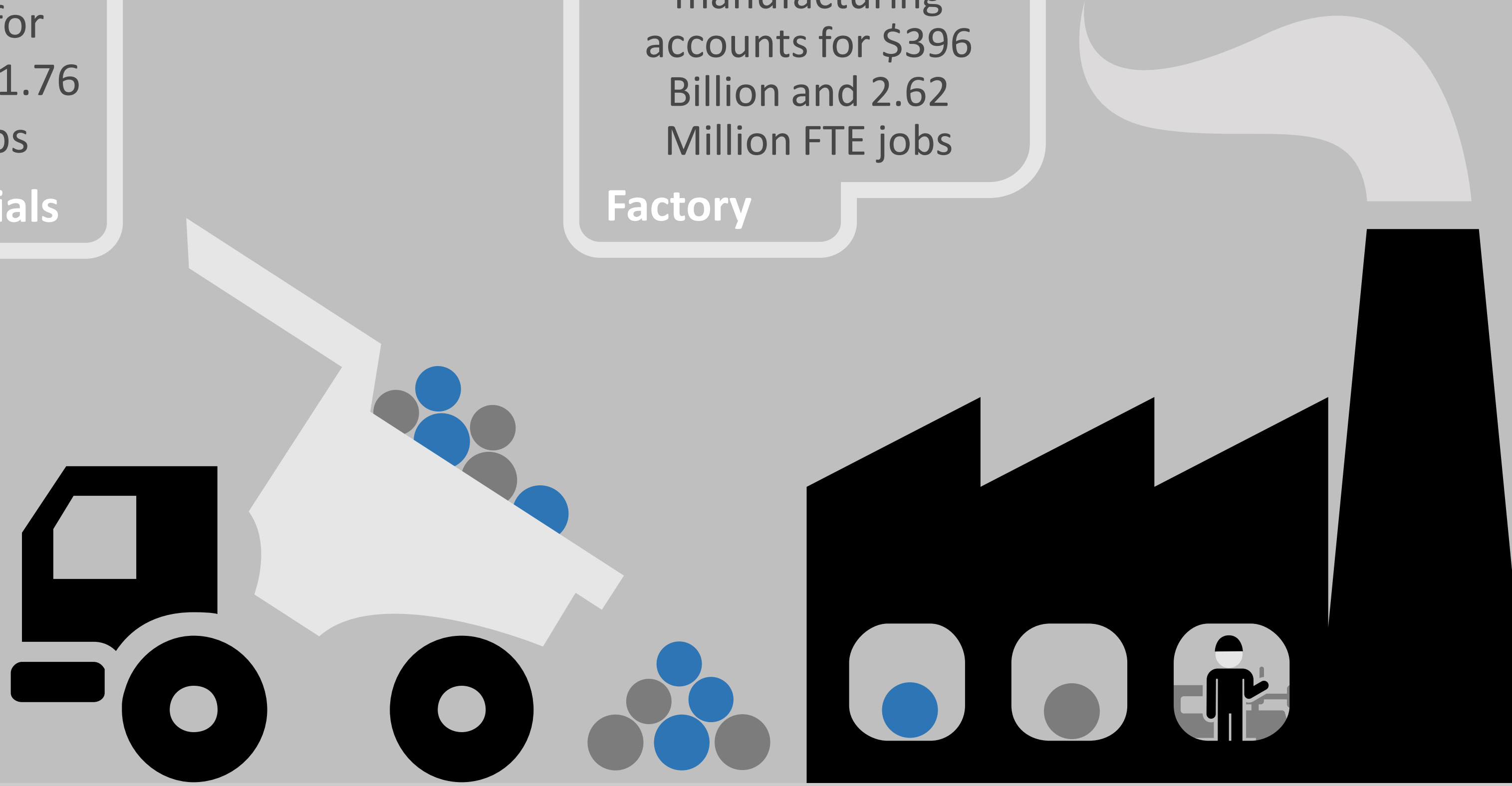
Torpey, E. (2014, Accessed: 2017-08-21). Got skills? Think manufacturing. Retrieved from http://www.webcitation.org/6t7hUZNag

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

Materials

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

Factory



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

Meckstroth, D. J. (2016). *The Manufacturing Value Chain is Much Bigger Than you Think!* (PA-165). Retrieved from MAPI Foundation, Arlington VA: http://www.webcitation.org/6t5IjO4ba.

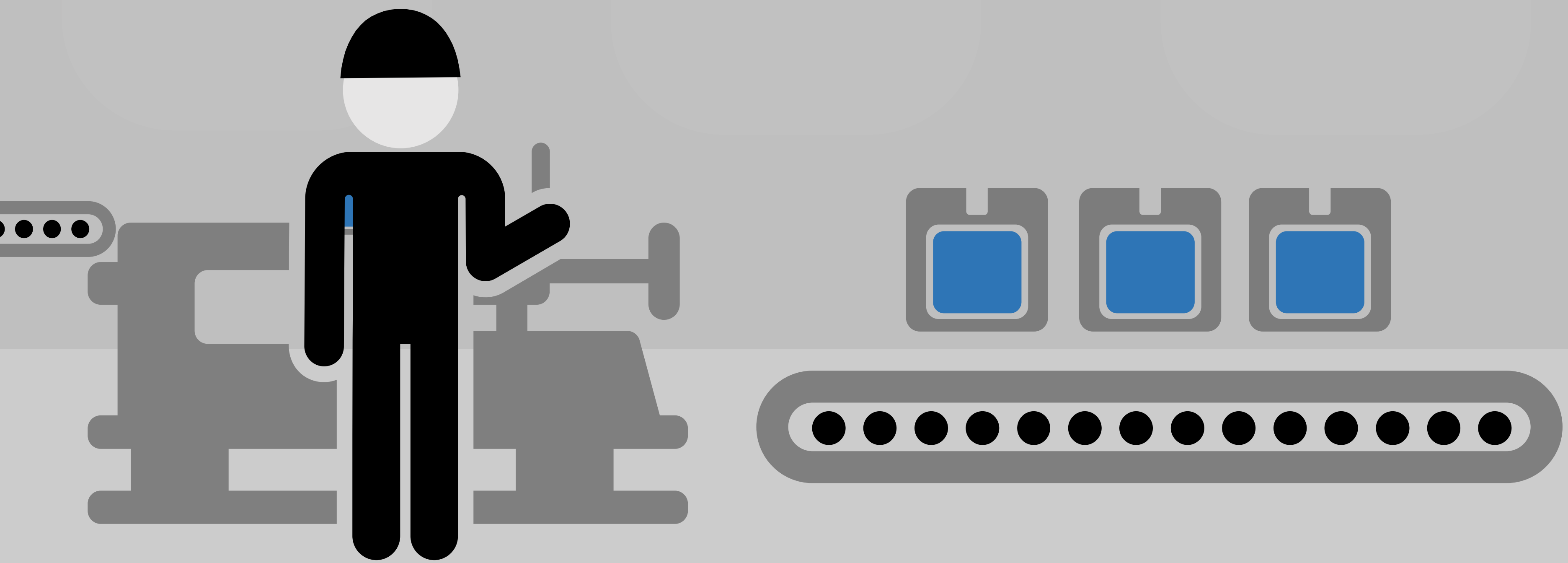
Torpey, E. (2014, Accessed: 2017-08-21). Got skills? Think manufacturing. Retrieved from http://www.webcitation.org/6t7hUZNag

Production manufacturing adds $1.057 Trillion in value to the economy

Production

Production manufacturing provides demand for 6.15 Million FTE jobs

Production Line



Meckstroth, D. J. (2016). *The Manufacturing Value Chain is Much Bigger Than you Think!* (PA-165). Retrieved from MAPI Foundation, Arlington VA: http://www.webcitation.org/6t5IjO4ba.

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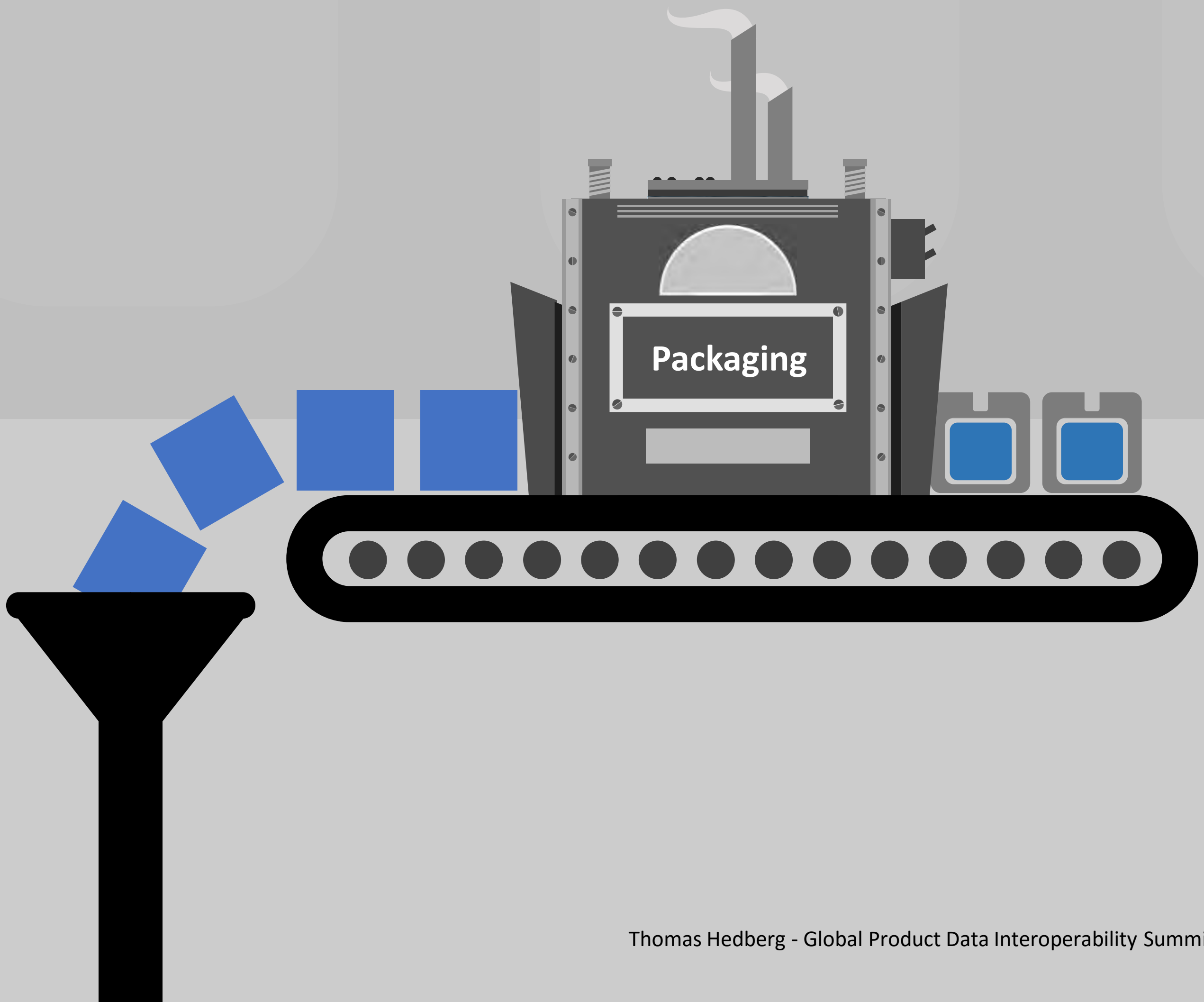
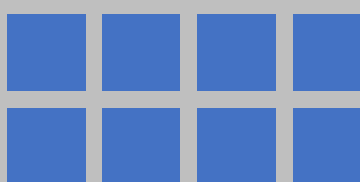
Downstream Sales



Wholesale Distribution

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



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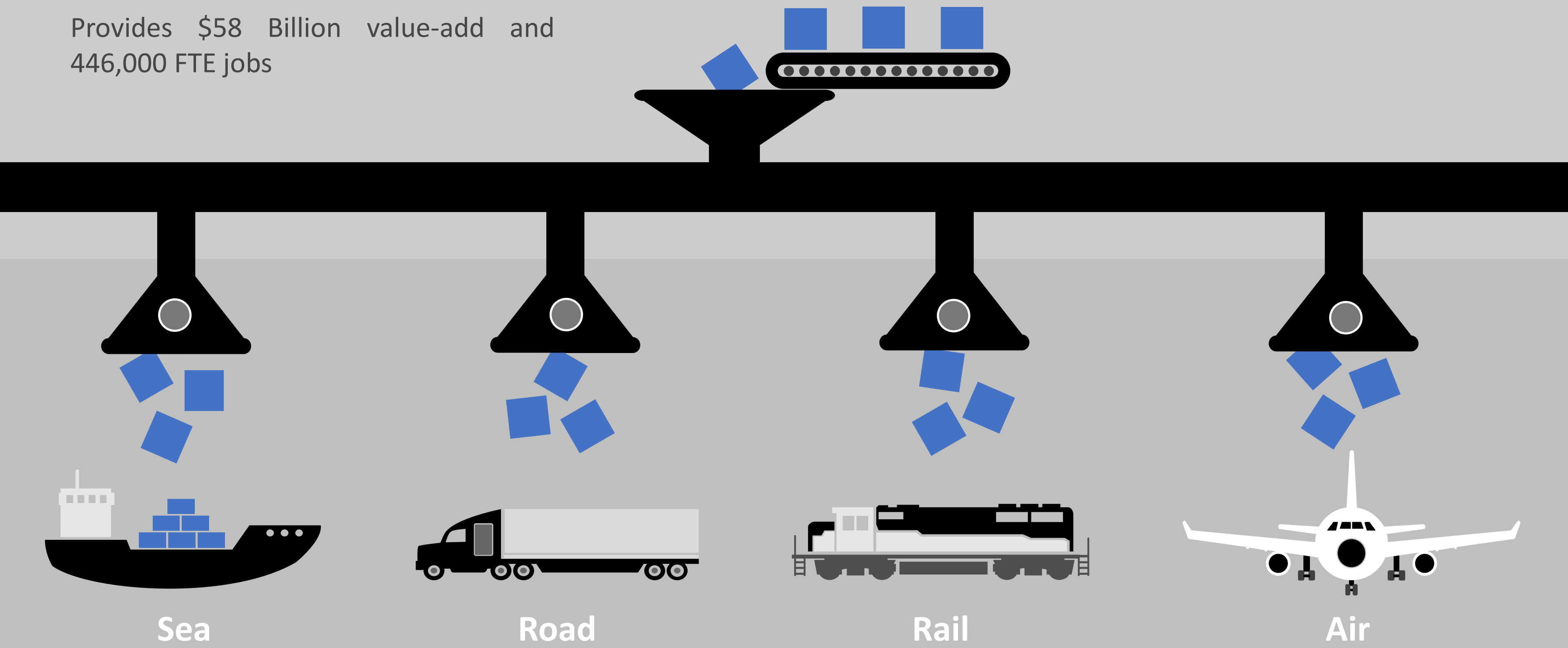
Torpey, E. (2014, Accessed: 2017-08-21). Got skills? Think manufacturing. Retrieved from http://www.webcitation.org/6t7hUZNag

Transportation

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



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

Distribution

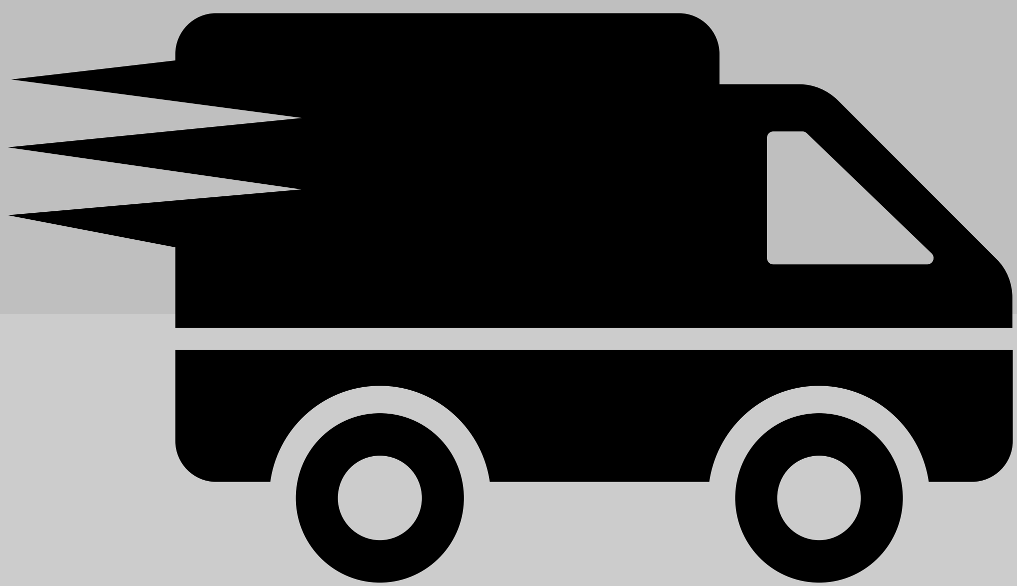
Meckstroth, D. J. (2016). *The Manufacturing Value Chain is Much Bigger Than you Think!* (PA-165). Retrieved from MAPI Foundation, Arlington VA: http://www.webcitation.org/6t5IjO4ba.

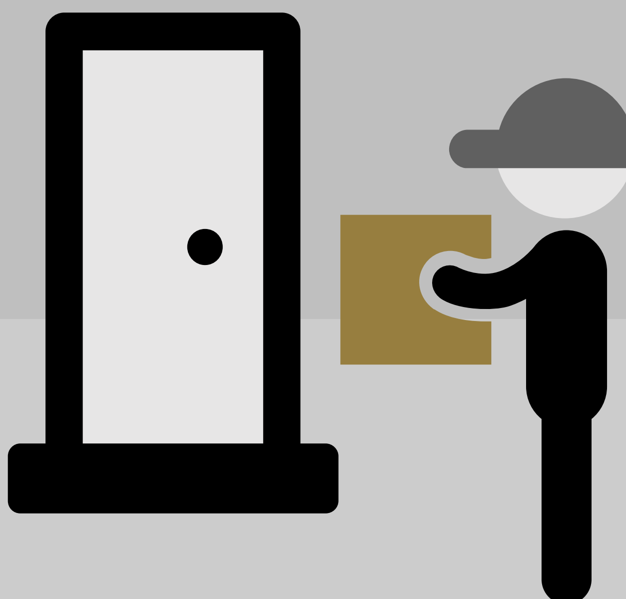
Torpey, E. (2014, Accessed: 2017-08-21). Got skills? Think manufacturing. Retrieved from http://www.webcitation.org/6t7hUZNag

Services

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

Support





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Multiplier Effect

Value Add

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

Jobs

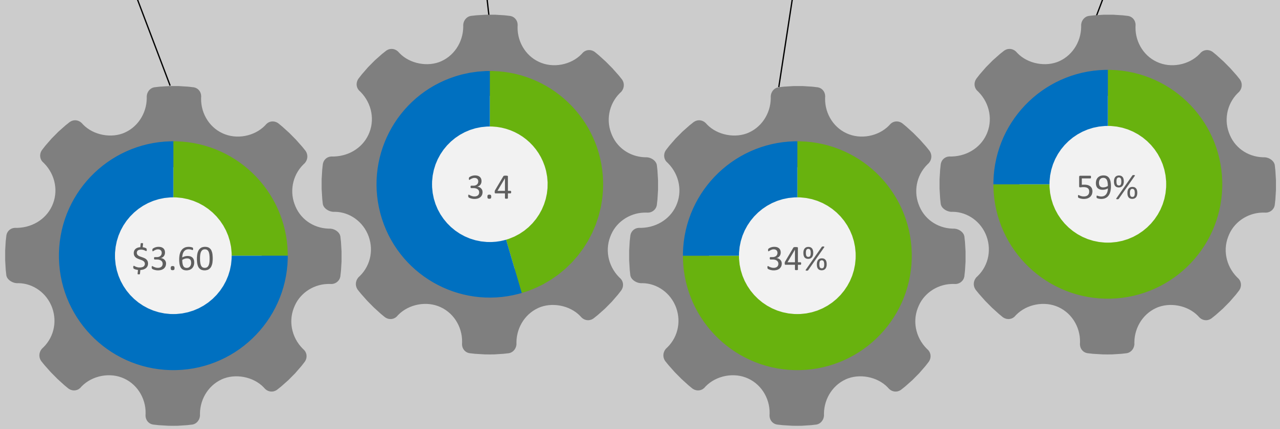
For each FTE manufacturing job, 3.4 FTE jobs are created in non-manufacturing sectors

U.S. GDP

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

Exports

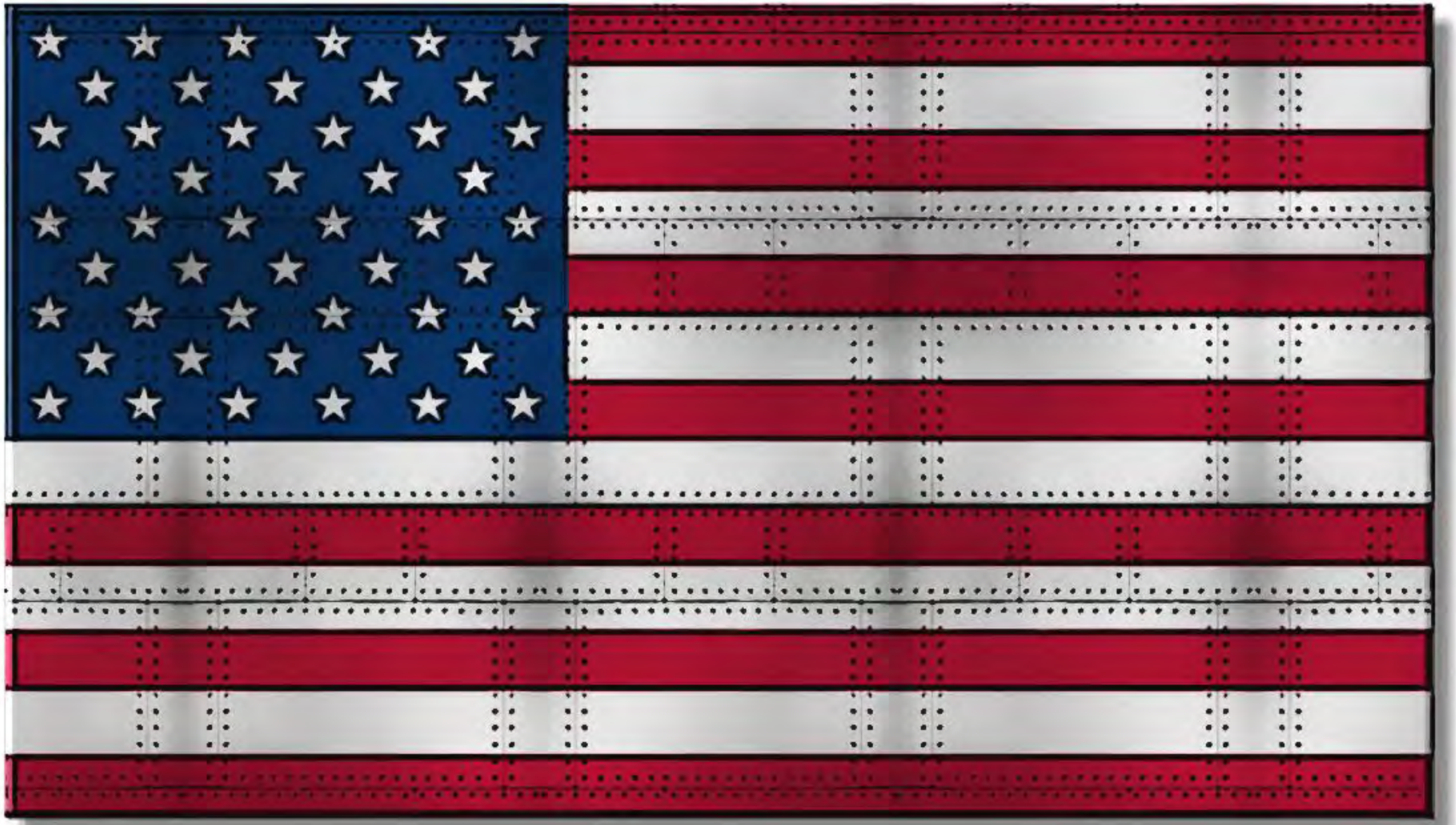
59% of Manufacturing demand is attributed to exports



Meckstroth, D. J. (2017, Accessed: 2017-08-21). A New Model for Manufacturing's Multiplier Effect. Retrieved from http://www.webcitation.org/6t5lw6KtP

Giffi, C., Rodriguez, M. D., & Mondal, S. (2017). *A look ahead: How modern manufacturers can create positive perceptions with the US public*. Retrieved from Washington DC: http://www.webcitation.org/6t5Jrgh83

Productivity Growth



MAPI Foundation. (2015, Accessed: 2017-08-21). Facts About Modern Manufacturing. Retrieved from http://www.webcitation.org/6t5JUs9ye

Interoperability Problems and Needs

A different perspective than the status quo

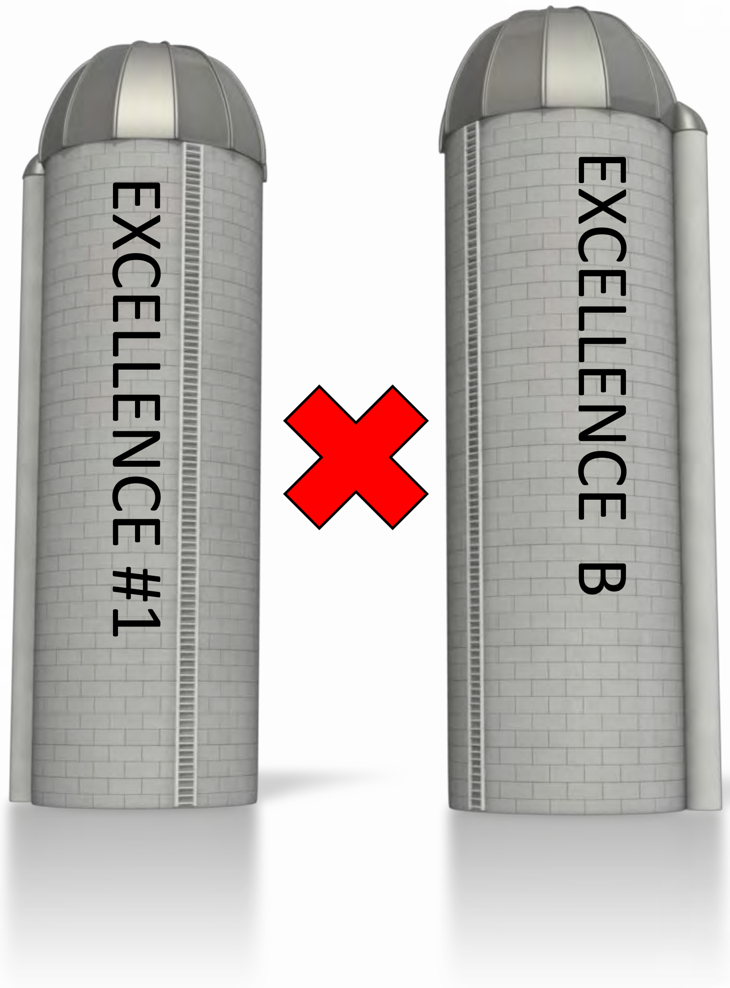
“We have reached the fundamental limits of what our [tools] and processes can handle”

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

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

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]

1. Giffi, C., Rodriguez, M. D., & Mondal, S. (2017). *A look ahead: How modern manufacturers can create positive perceptions with the US public*. Retrieved from Washington DC: http://www.webcitation.org/6t5Jrgh83
2. Anderson, G. (2016). *The Economic Impact of Technology Infrastructure for Smart Manufacturing* (NIST Economic Analysis Briefs 4). Retrieved from Gaithersburg MD: http://nvlpubs.nist.gov/nistpubs/eab/NIST.EAB.4.pdf

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

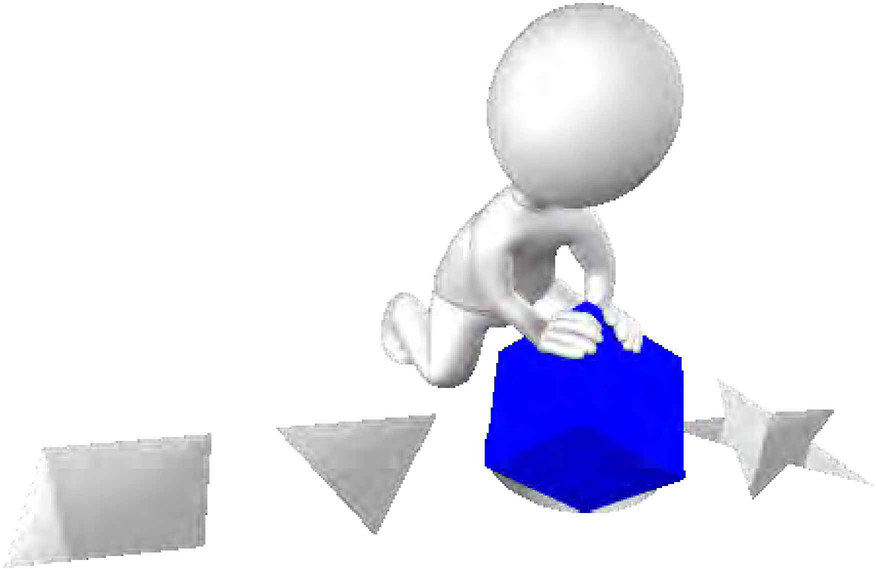
- If you cannot trust your customers and supply chain, then why are you doing business with them?
- Digital signatures and certificates: Trust, but verify!
- Authentication, authorization, and traceability are three pillars of trust that protect intellectual property

Technologies vs. Standards

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

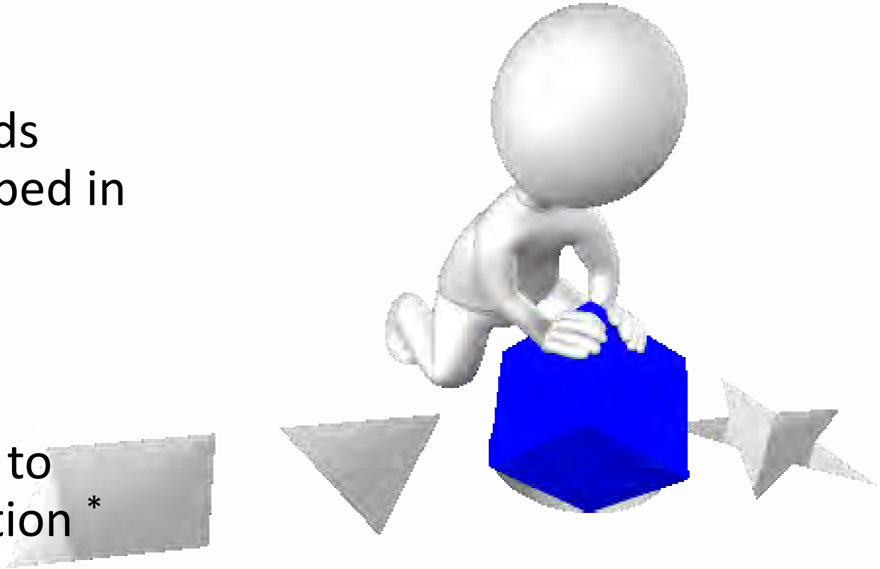
- No open geometric modeling kernels developed with standards-based information models

- 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 *

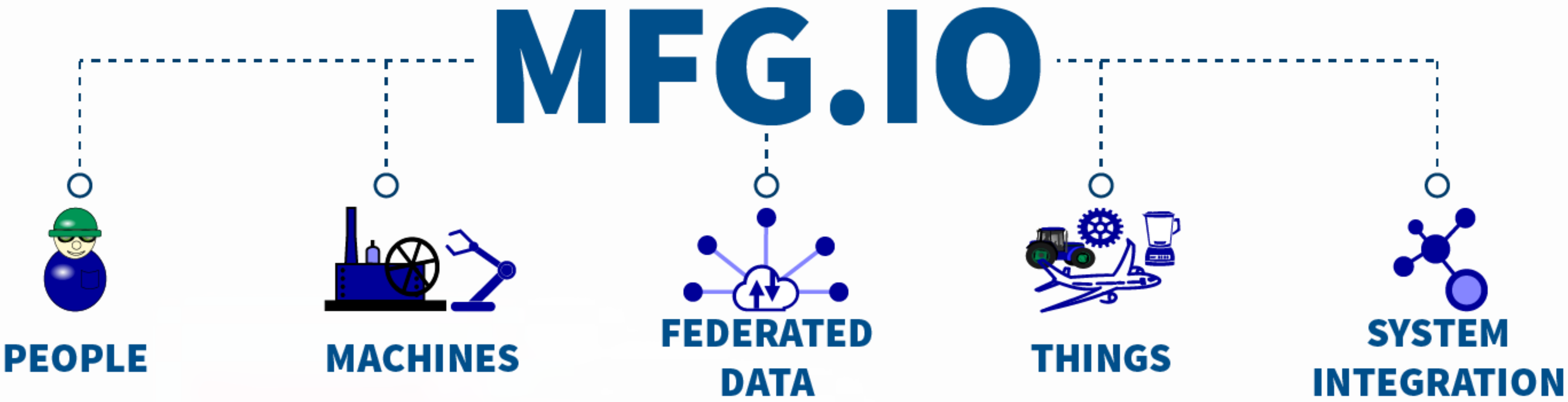


* Anderson, G. (2016). *The Economic Impact of Technology Infrastructure for Advanced Manufacturing: An Overview* (NIST Economic Analysis Briefs 1). Retrieved from Gaithersburg MD: http://nvlpubs.nist.gov/nistpubs/eab/NIST.EAB.1.pdf

Recommendations for Interoperability Innovation

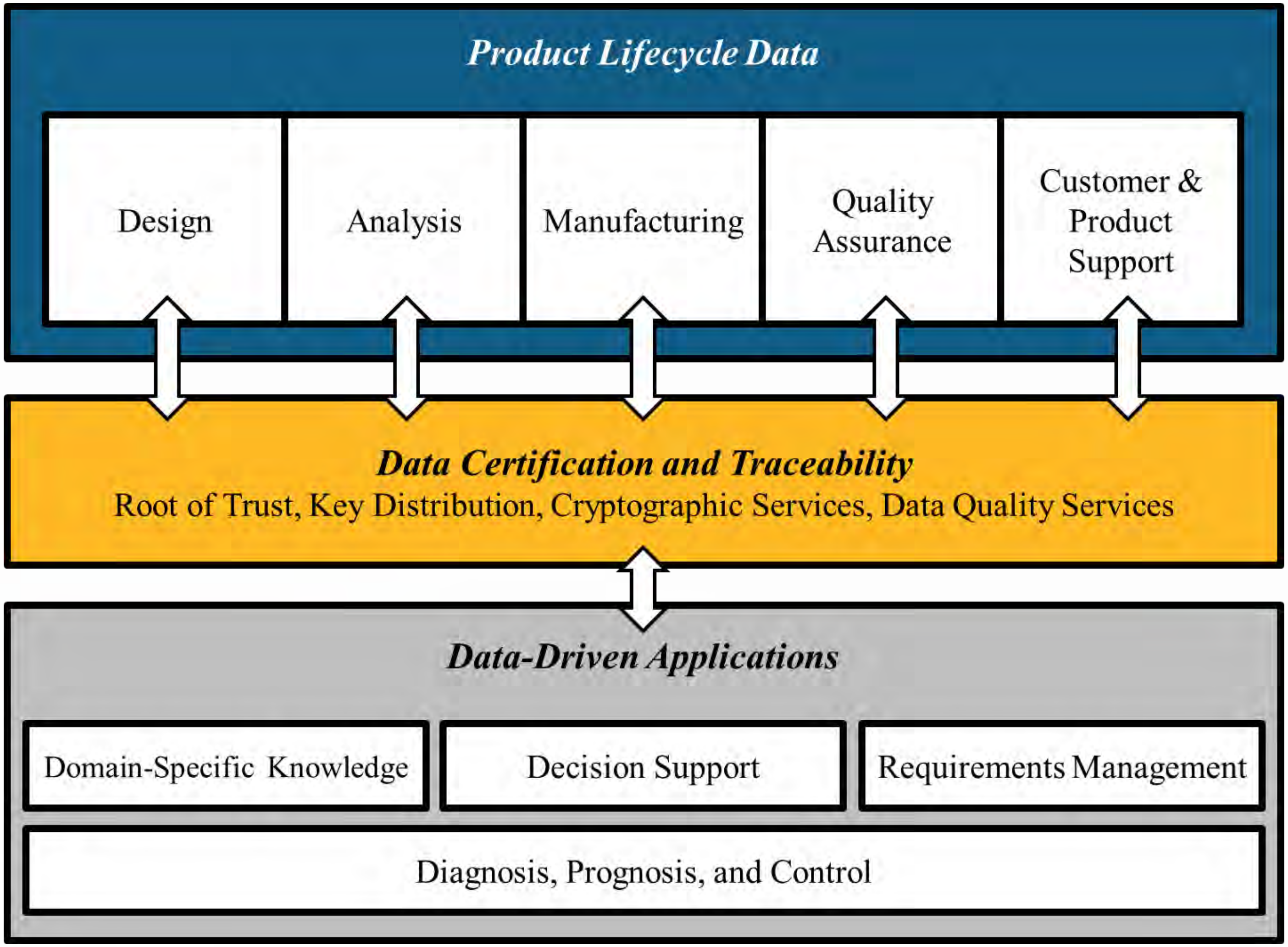
It’s time for a new core of the paradigm

Announcing…

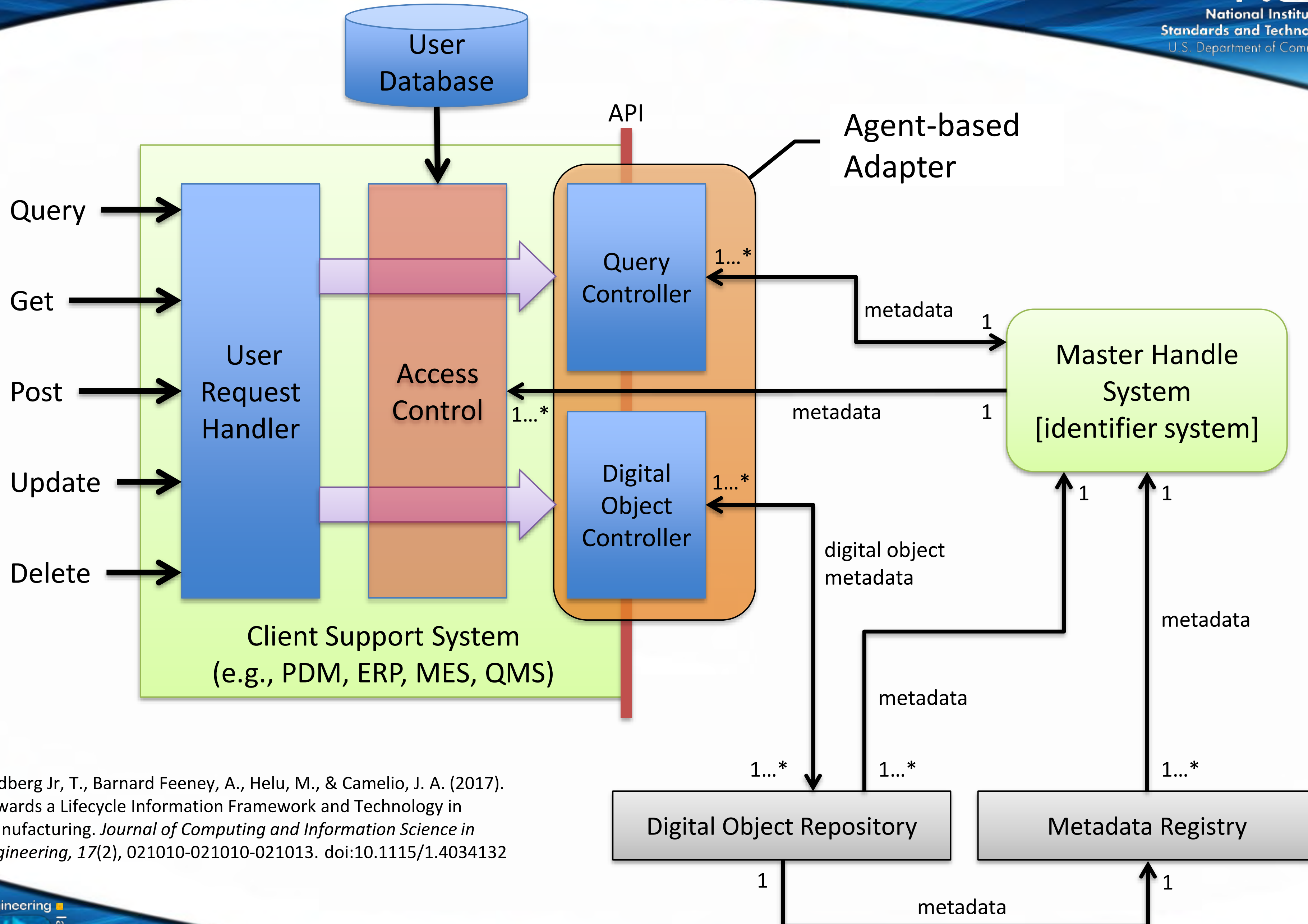


Manufacturing Handles: Spinning the Digital Thread of Connected Enterprises

Lifecycle Information Framework and Technology



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



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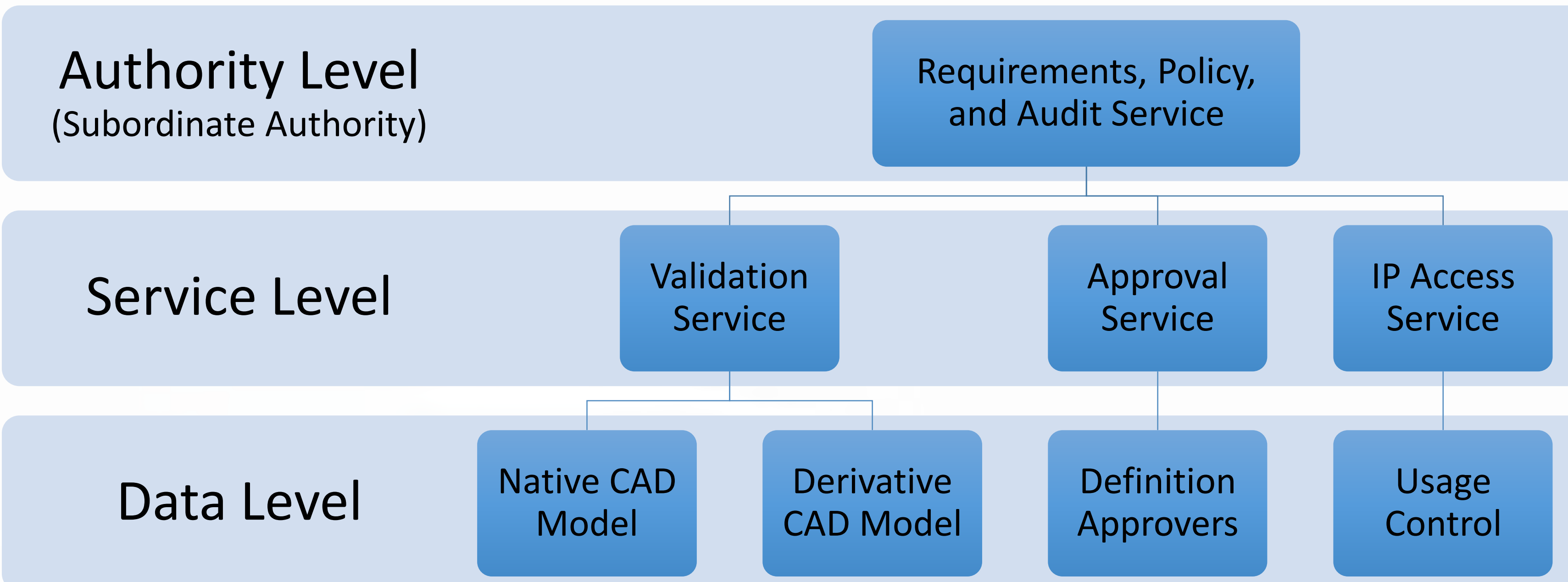
Trustworthiness in Certificates and Blockchain

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)**



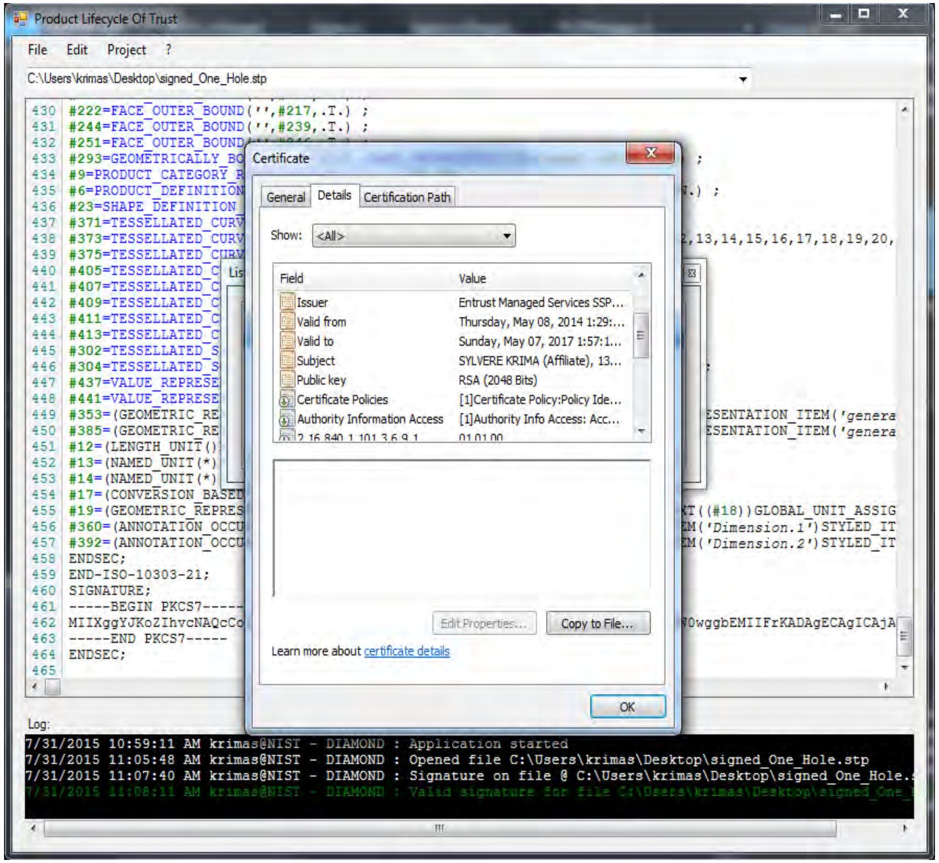
Public Working Group on Blockchain for Manufacturing is Forming Now!

Digital Manufacturing Certificate Toolkit

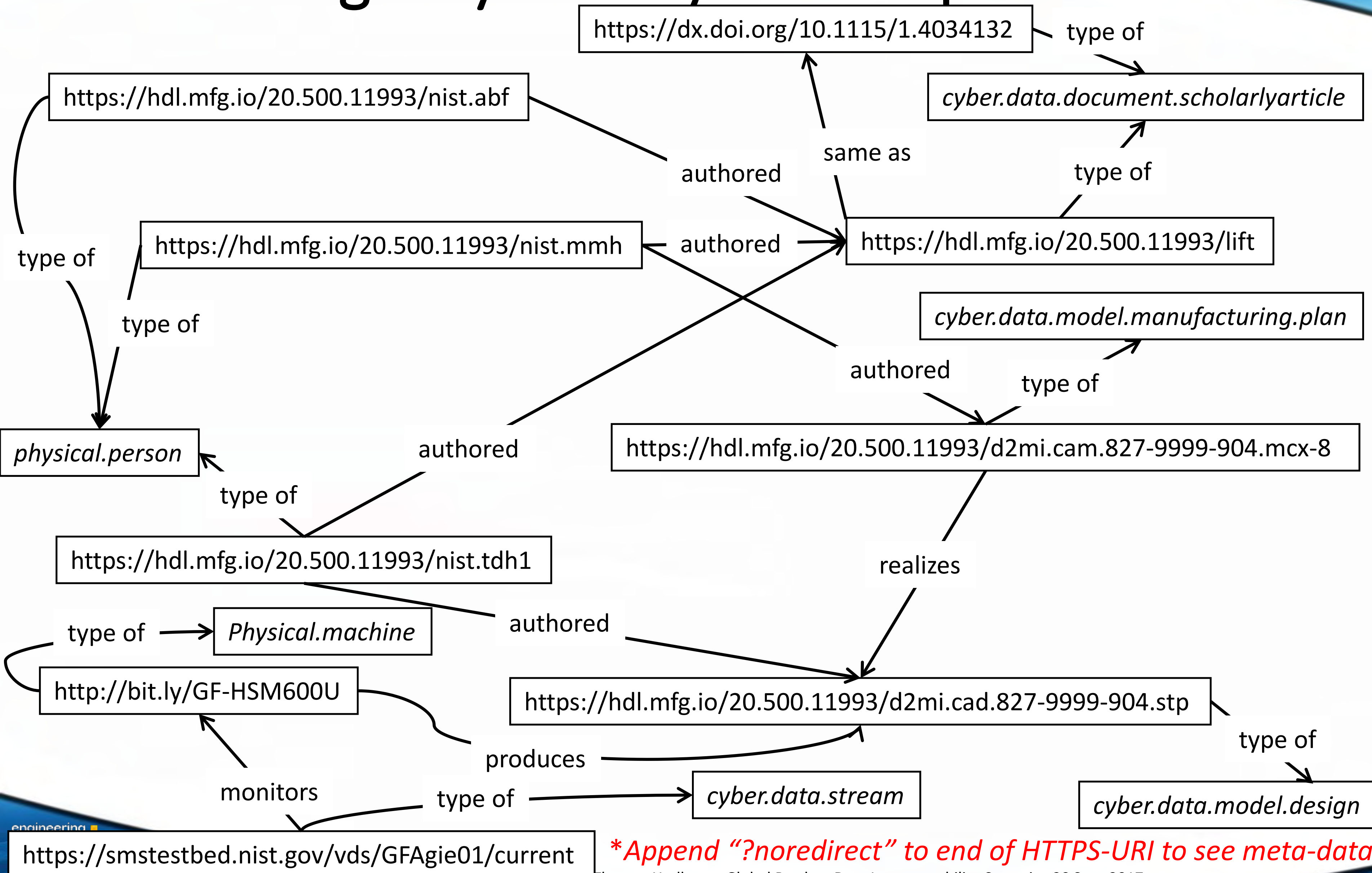
- Toolkit includes a User Interface and API for Reading, Writing, and Verifying digital signatures in models

- 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



**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!

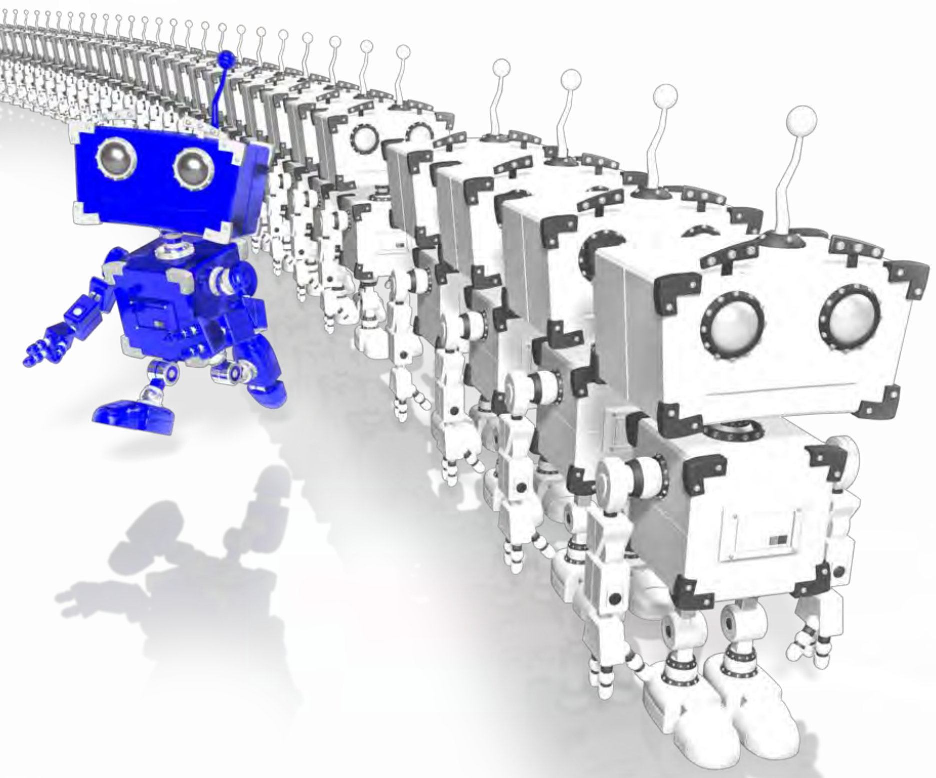
Stay tuned for public demonstrations throughout Fiscal Year 2018

In summary…

Economic Value Add…

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


POWER IS IN YOUR HANDS
DEMANDS SUCCESS
SUCCESS
VS
FAILURE
DEMANDS SUCCESS

Questions?

Thank you for your kind attention!

Thomas Hedberg
thomas.hedberg@nist.gov

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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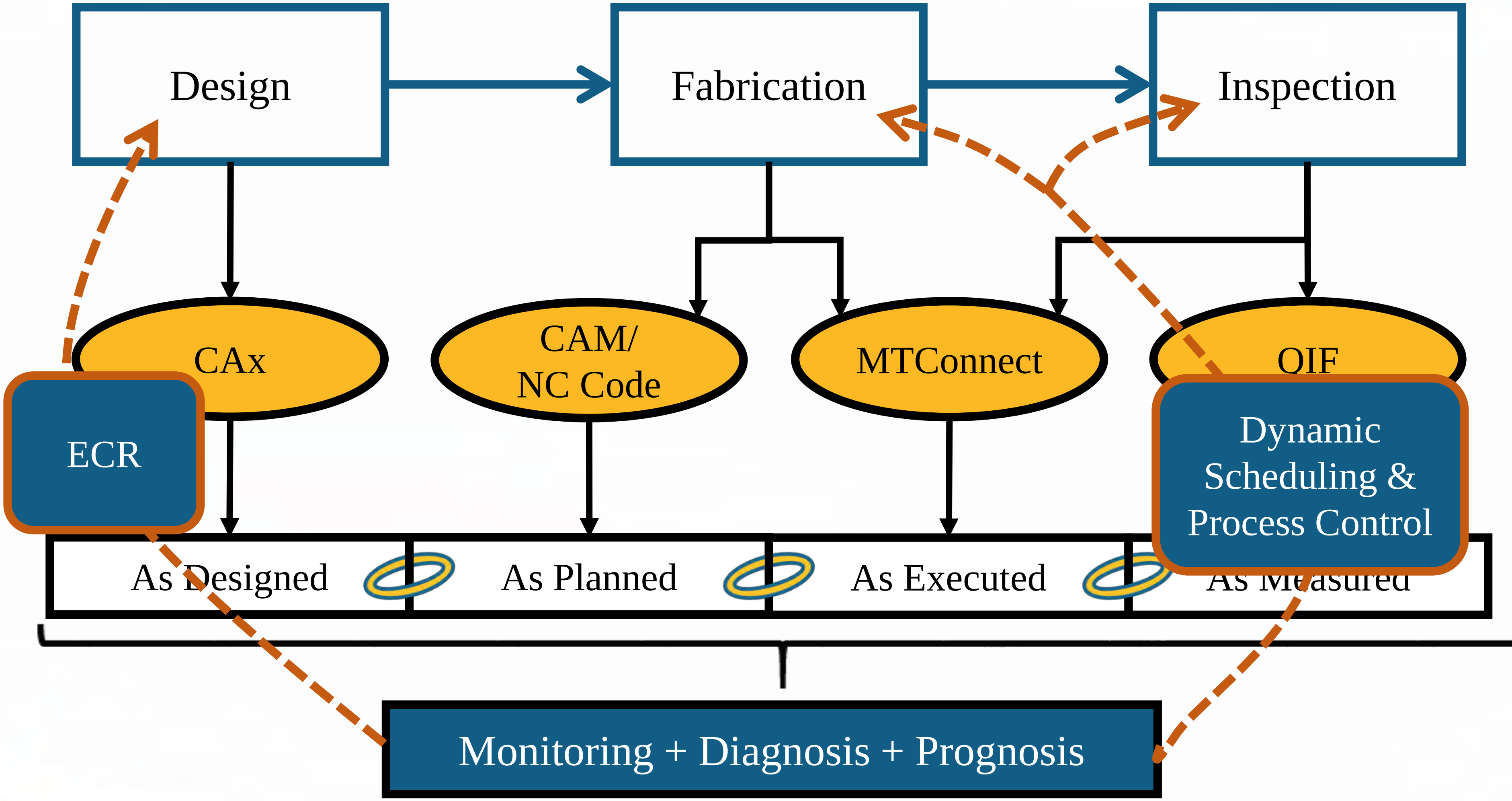
Backup

Help!

Data Collection and Aggregation

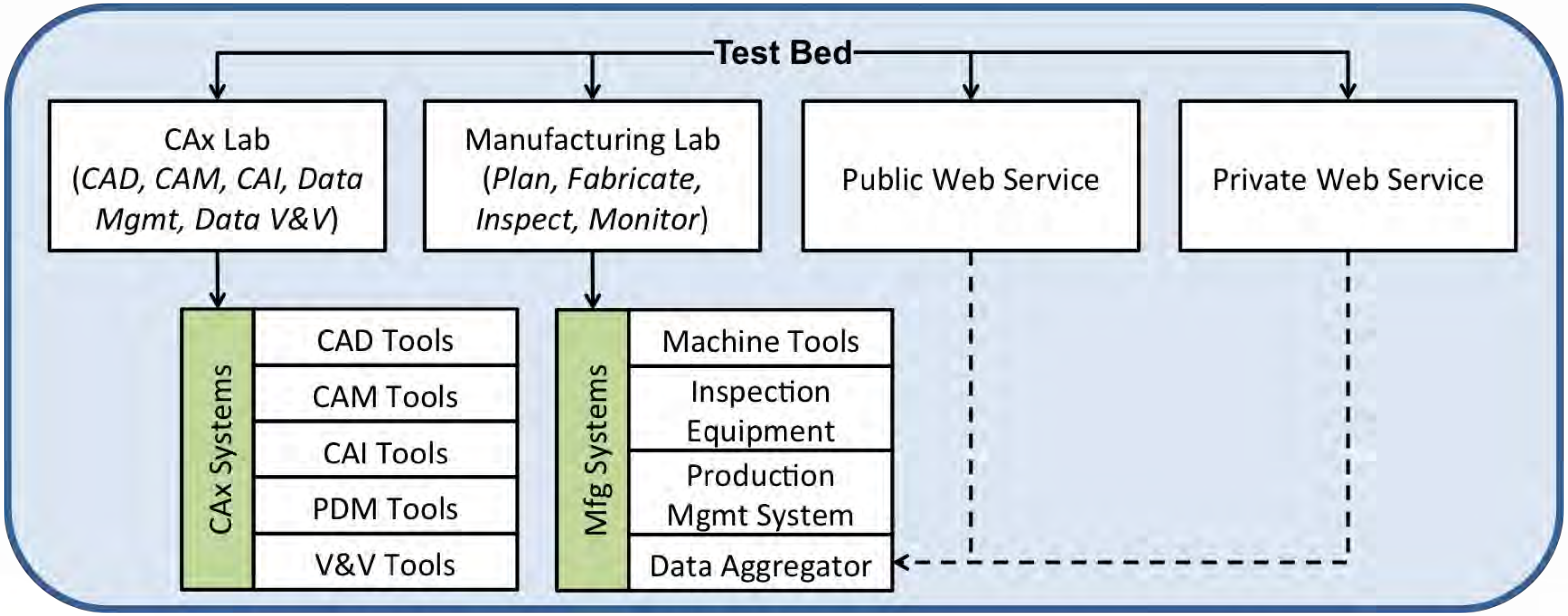


NIST Smart Mfg. Systems Test Bed

National Institute of Standards and Technology
U.S. Department of Commerce

Goals:

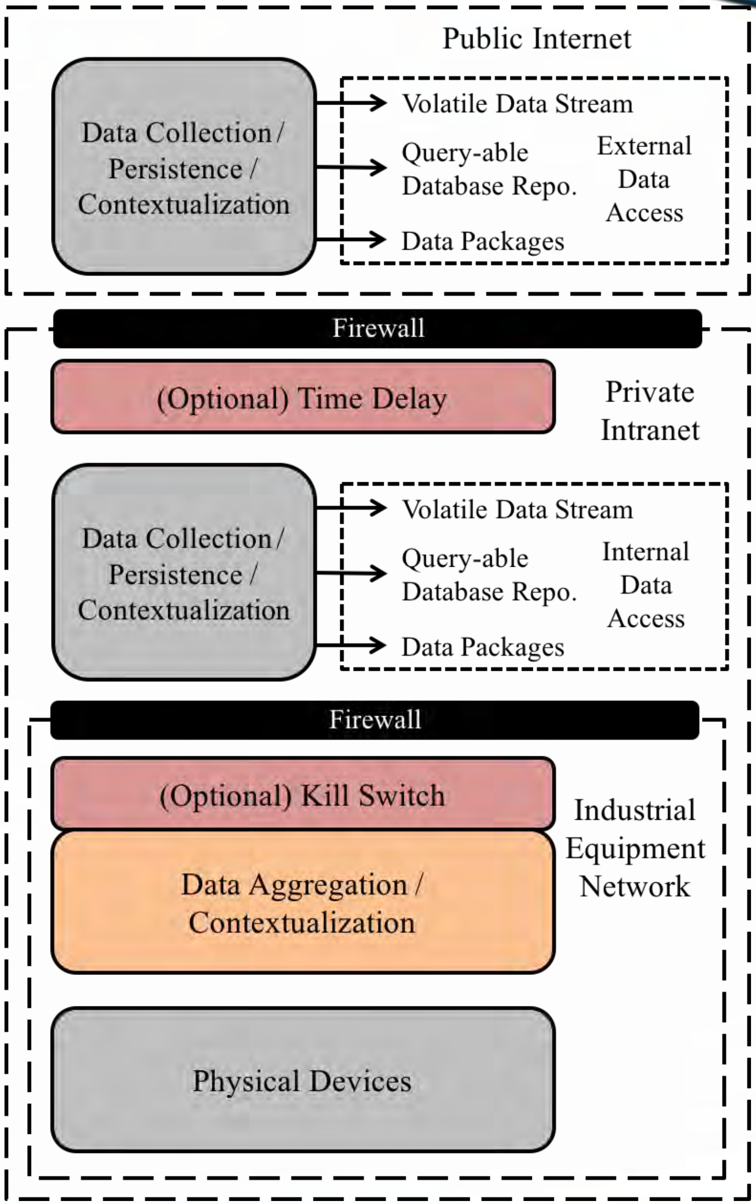
- Reference architecture and implementation
- Rich source of data for fundamental research
- Physical infrastructure for standards and technology development
- Demonstration test cases for education



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



Helu, M., Hedberg Jr, T., & Barnard Feeney, A. (In Press). Reference architecture to integrate heterogeneous manufacturing systems for the digital thread. *CIRP Journal of Manufacturing Science and Technology*. doi:10.1016/j.cirpj.2017.04.002