Smart Manufacturing and the Steel Casting Industry

Paul H. Cohen
Edward P. Fitts Department of Industrial and Systems Engineering
North Carolina State University

Steel Founders’ Society of America
Spring Leadership Meeting

March 4, 2016
On behalf of…

SMLC
Smart Manufacturing Leadership Coalition
a 501c6 non-profit organization

Denise Swink
CEO

https://www.smartmanufacturingcoalition.org/
First Paperless Design in the Aeronautical Industry
Industrial Revolution Waves

Inflection Points from 18th to the 21st Century

Wave 1.0
Mechanization of Processes; First Industrial Loom

Wave 2.0
Division of Labor and Mass Production; Electrical Energy

Wave 3.0
Logic Controllers; LAN; Databases

Wave 4.0
Intelligent Machines; Cloud Computing; Real-Time Computation

End of 18th Century | Start of 20th Century | Start of 1970’s | Since 2011
Data Generated by Manufacturing

Manufacturing generates more data than any other sector of the economy.

**Annual Data in Petabytes Stored by Sector, 2010**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Petabytes Stored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
<td>1812</td>
</tr>
<tr>
<td>Government</td>
<td>911</td>
</tr>
<tr>
<td>Banking</td>
<td>773</td>
</tr>
<tr>
<td>Media</td>
<td>776</td>
</tr>
<tr>
<td>Retail</td>
<td>424</td>
</tr>
<tr>
<td>Investment</td>
<td>336</td>
</tr>
<tr>
<td>Healthcare</td>
<td>375</td>
</tr>
<tr>
<td>Education</td>
<td>275</td>
</tr>
<tr>
<td>Utilities</td>
<td>207</td>
</tr>
</tbody>
</table>

IDC; McKinsey Global Institute
DIGITAL MATURITY BY INDUSTRY

How does SME respond to Investing in Software, Hardware and Talent Acquisition

*DIGITAL INTENSITY*

*TRANSFORMATION MANAGEMENT INTENSITY*

- Fashionistas
  - Travel & Hospitality
  - Telecom
- Digirati
  - High Technology
  - Retail
  - Banking
- Conservatives
  - Consumer Packaged Goods
  - Manufacturing
  - Insurance
- Beginners
  - Pharmaceuticals
  - Agriculture
  - Manufacturing

MIT Center for Digital Business, 2014
Merging Physical with the Digital World

Digital Factories – Data goes back and forth between digital and the physical world.

The robots demonstrate state-of-the-art door assembly. The monitors above the model show how communication can work in a self-organizing production system of the future.

Digitalization of Manufacturing, Siemens, 2014
From Punch Cards and Tape.....

Punched Tape

Magnetic Tape
....to the Industrial Internet
From Factory Floor to Enterprise Level Communication

Peter Evans, Marco Annunziata, Pushing Boundaries of Minds and Machines, GE Industrial Internet, 2012
The Cybermanufacturing Systems (CM) Program supports fundamental research to enable the evolution of a wide range of network-accessed manufacturing services that:

- employ applications (or “apps”) that reside in the “cloud” and plug into an expansible, interactive architecture;
- are broadly accessible, guarantee reliable execution and have capabilities that are transparent to users; and
- are accessible at low cost to innovators and entrepreneurs, including both users and providers.

Cyber-Physical Systems Program
Digital Design and Manufacturing Innovation Institute (DOD)

What is Digital Manufacturing and Design?
By capturing data at every stage of the production process—and by deploying specially-designed software and other digital tools—manufacturers can efficiently share and revise their digital designs.

The Technology
Digital manufacturing and design is the ability to connect different parts of the manufacturing life-cycle through data, and to utilize that information to make smarter, more efficient business decisions.
What is Smart Manufacturing (DOE)?

• Advanced networked systems that combine sensors, data, models, and algorithms to improve efficiency, process flows, and product quality across interconnected new and legacy equipment – highly interoperable, smart systems for manufacturing.

http://energy.gov/sites/prod/files/2015/02/f20/smart_mfg_industry_day_johnson.pdf
Visionary Goals
Based on AMP work team report

• Seamless interoperation of manufacturing automation equipment from different vendors allowing plug-and-play configurations
• Energy use and waste streams per unit output from manufacturing plants are reduced by 20% to 50%
• Deployment cost of sensors fall by an order of magnitude
• Real-time optimization and control to adapt to changes in feedstock, market demands and plant performance

http://energy.gov/sites/prod/files/2015/02/f20/smart_mfg_industry_day_johnson.pdf
Essential Technologies & Key Features

• Affordable Industrial Data Collection & Management System
  – Resilient Wireless Sensors, Low Cost Networked Sensors
  – Noninvasive Real-time Measurement Solutions

• Standardized IT Platform
  – Data Interoperability
  – Multi-scale Dynamic Modeling & Simulation

• Enterprise Wide Integration: Business Systems, Manufacturing Plants & Suppliers
  – Open Standards
  – Standard Interface
  – Process Models
Greater than the Sum of its Parts

SMLC is building the nation’s first Open Smart Manufacturing Platform for collaborative industrial-networked information applications through at-scale demonstrations.

SMLC envisions a 21st century SM enterprise (from suppliers, OEMs, and companies to supply chains) that is fully integrated, knowledge-enabled, and model rich. Such visibility across the enterprise (internal and external) would radically improve the ability to inform decisions and drive action.

The Open Smart Manufacturing Platform and Marketplace enables manufacturing companies of all sizes to gain easy, affordable access to modeling and analytical technologies that can be tailored to meet cross-industry business-case objectives without having to retrofit existing systems.
The Fundamental Challenge Today

• We rely on core systems as a business driver, but every system requires its own architecture.

• Core systems are usually built to provide a specific purpose or capability.

• The industry needs an **open infrastructure** that can stitch disparate systems and seams together to create innovative solutions.

• These point solutions are crying out for a way to connect, collaborate and interoperate to achieve a comprehensive approach to manufacturing.
Why an *Open* Smart Manufacturing Platform?

- Smart Manufacturing adoption is challenging due to lack of awareness, risks and ROI barriers.
- **Open Smart Manufacturing Platform** is needed to provide a highly accessible, industry-driven, enabling infrastructure that is missing today.
- Importantly, through its open architecture design, the platform will **interface with commercial and open source technologies** providing endless opportunities for innovation, sustainability and competitiveness to all manufacturing stakeholders.
- This infrastructure will provide real-time, data based application development, deployment, performance, and reuse implemented in “as needed services” accessible through the cloud.
- **Open architecture**: vendor agnostic standards based integration and ability to interface with commercial and open source platform technologies.
Why an *Open* Smart Manufacturing Platform?

- **Open access**: low cost access to Smart Manufacturing Platform technologies

- **Open Marketplace**: open access (for contributors and users) to composable, market-driven commercial and open source application libraries inclusive of deployment, data management, modeling and analytics and metrics applications and associated non proprietary deployment data, certifications, and services

- **Flexible, Affordable, and Accessible**

- **Through its open, vendor agnostic architecture**, *small, medium, and large companies* across the entire manufacturing value chain can benefit.

- The Smart Manufacturing Platform integrates components manufacturers use to customize decision orchestration and management systems. Designed to interface with both legacy and modernized systems. This functionality significantly reduces the risks and costs required to adopt new manufacturing technology and solutions.
Building Infrastructure
Powering Smart Decisions

Enterprise Business System

Enterprise Optimization & Sustainable Production
- Higher value products
- Improved quality
- Zero downtime
- Increased equipment life/utilization

Agile Demand-Driven Supply Chains
- Higher product availability
- No inventory
- Product lifecycle management

Sustainable

Agile, demand-driven

Plantwide

Production

Optimization

Supply Chains

Energy, Sustainability, EH&S
- Improved safety
- Reduced energy and emissions
- Highly sustainable

Suppliers

Factory

Distributor Center

Customer

OEM Machine Builders

© SMLC, Inc. All Rights Reserved.
Clean Energy Smart Manufacturing Innovation Institute

A Cyber Physical Network of Regional Smart Manufacturing Centers (RSMC) actionably linked through the open SM Platform and Marketplace.
Steel Casting

Elements of Smart Manufacturing

- Access Data Historian
- Process control
- Production and quality control
- Supply chain
- Minimize energy
- Link mills
- Link to suppliers
- Informed decision-making across enterprise
Specifications and Performance

Selected Specifications

- Composition Limits and Tolerances
- Dimensions, Weight and Tolerances
- Properties and Performance
- Surface Integrity and Roughness
- Internal Integrity, Soundness
- Testing Methods and Procedures

Machinability

- Composition and micro-structure can dramatically impact machinability
  - Tool life
  - Finish
  - Power
  - Chip type

https://www.sfsa.org/
Adaptive Control

Intelligent Adaptive Fixtures
- DMDI Project
  - Product Development & Analysis, LLC (lead)
  - Arizona State University
  - Steel Founders’ Society of America
- Fixture system adapts to piece to piece dimensional variability to reduce manual set-up time, reduce scrap and rework.

Machining Process
- A component of a smart manufacturing system
- Issues
  - No open architecture controllers
  - What do I do with all the data?
  - Cannot access signals in controller
    - Emergence of MT Connect
    - “Point solutions”; not generic
  - No data to test algorithms
    - NIST program
Required Skills are Expanding

- **CAD/CAM/PLM**
  - Digital Design, Analysis and Simulation Tools; BOM Management

- **Sensors/Controls**
  - Sensor Hardware; Control Algorithms; Communication Standards; Factory Integration; Embedded Systems

- **Cloud Computing**
  - SQL/NoSQL; HDFS, MapReduce; Hive; Pig;

- **Machine Learning**
  - Big Data Manipulation; Statistical Tools; Data Mining; Forecasting; Decision Making

- **Process Intelligence**
  - Identifying KPI/KSI; Building Dashboards; Predictive Maintenance; Process Optimization

- **Data Visualization**
  - Charts and Infographics; Data Representation and Transformation

- **Sensors/Controls**
  - Sensor Hardware; Control Algorithms; Communication Standards; Factory Integration; Embedded Systems
Wave 4.0 is Turning Into a Tsunami!

Digitize to Survive

Why big data should become smart data

General Electric

Siemens

The Connected Enterprise

End-to-end Intel IoT Platform

Rockwell Automation

Intel