NIST Advanced Manufacturing Series 100-21

2018 NIST/OAGi Workshop: Enabling Composable Service-Oriented Manufacturing Systems

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National Institute of
Standards and Technology
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Abstract

This report summarizes the results from the 2018 NIST/OAGi Workshop: Enabling Composable Service-Oriented Manufacturing Systems, which was held at the National Institute of Standards and Technology campus in Gaithersburg, MD, on April 23-24, 2018. This was the fourth in this series of workshops begun in 2015 to foster a shared vision of a new Smart Manufacturing (SM) platform to support Composable Service-Oriented Manufacturing (SOM) systems. The purpose of the workshop series is to identify and discuss challenges in advancing the vision within the context of open cloud service platforms for Smart Manufacturing systems. Like the previous workshop reports, the document gives (1) summaries of presentations on Smart Manufacturing and the theme of Composable Service-Oriented Manufacturing systems, (2) summaries of the six breakout sessions, each providing a unique perspective on the theme, and (3) the key findings from the workshop.

Acknowledgements

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Keywords

Smart Manufacturing, Service-Oriented Manufacturing, Standards Development, Digital Manufacturing, Reference Models, Life-Cycle Management, Industrie 4.0, Cyber-Physical Production Systems, Message Standards, Systems Characterization, Reference Architecture, Service Marketplaces, Ontologies

Acronyms

API – Application Programming Interface

ASME – American Society of Mechanical Engineers

ASTM – ASTM International (formerly the American Society for Testing and Materials)

BPCCS – Business Process Cataloging and Classification System

CAD – Computer-Aided Design

CAE – Computer-Aided Engineering

CPMS – Cyber-Physical Manufacturing Services

DMDII – Digital Manufacturing and Design Innovation Institute

ERP – Enterprise Resource Planning

IEC – International Electrotechnical Commission

IEEE – Institute of Electrical and Electronics Engineers

IoT – Internet of Things

IIoT – Industrial Internet of Things

IOF – Industrial Ontologies Foundry

ISA – The International Society of Automation

ISO – International Organization for Standardization

IT – Information Technology

LCM – Life-Cycle Management

LCM SOI – Life-Cycle Management Service-Oriented Integration

MESA – Manufacturing Enterprise Solutions Association

MQTT – Message Queuing Telemetry Transport

MBMSD – Model-Based Messaging Standards Development

MSLCM – Messaging Standards Life-Cycle Management

NIST – National Institute of Standards and Technology

OAGi – Open Applications Group Incorporated

OAGIS – Open Applications Group Integration Specification

OBO – Open Biomedical Ontologies

OEM – Original Equipment Manufacturer

OLE – Object Linking and Embedding

OPC – OLE for Process Control

OPC UA – OPC Unified Architecture

R&D – Research and Development

RM – Reference Model

RM LCM – Reference Model Life-Cycle Management

ROI – Return-On-Investment

SDO – Standards Development Organization

SM – Smart Manufacturing

SMASM – Smart Manufacturing Apps and Services Marketplaces

SME – Small- to Medium-sized Enterprise

SMRM – Smart Manufacturing Reference Model

SMS – Smart Manufacturing Systems

SMSC – Smart Manufacturing Systems Characterization

SOA – Service-Oriented Architecture

SOM – Service-Oriented Manufacturing

TC – Technical Committee

Executive Summary

The National Institute of Standards and Technology (NIST) hosted *2018 NIST/OAGi Workshop: Enabling Composable Service-Oriented Manufacturing Systems* at its Gaithersburg, MD, campus on April 23-24, 2018. Over 100 experts from industry, government, national laboratories, and academia participated. This was the fourth in a new series of workshops begun in 2015 to foster a shared vision of a new Smart Manufacturing (SM) platform that will support Composable Service-Oriented Manufacturing (SOM) systems. The objectives of the workshop were to (1) help in creation of a roadmap for research in this nascent field; (2) inform future technical work; and (3) offer information to industry, government agencies, and other stakeholders focused on manufacturing systems integration.

The main premise of the workshop is that a revolutionary convergence of several technological advances such as enhanced networking, adaptive automation, cloud services, and data analytics will be applied to existing manufacturing operations to create Smart Manufacturing systems. Significantly, the systems of the future will be available through on-demand composition of focused apps or services. Such apps or services are cyber-physical applications focused on a single function, as opposed to large, monolithic, multi-functional applications. Manufacturers will access these as on-demand downloadable components or cloud services using a pay-as-you-go model which promises to lower barriers and reduce cost significantly.

However, as the variety of apps, services, and systems available through this new SM development model proliferate, so do the risks associated with using, managing, and integrating them. One way to reduce the risks is to ensure that there is an ecosystem of capable standards and technologies that enable the composition of these apps, services, and systems within a new SM platform.

The workshop participants continued to explore the needed technical foundation for the ecosystem of standards and technologies as well as the SM platform. In addition to the five working sessions from the previous year, the workshop added a new session on Data Analytics. These sessions are:

- **Smart Manufacturing (SM) Model-Based Message Standards Development (MBMSD)** focused on innovative modeling methods and tools for efficient development, use, and maintenance of message standards, which are key to scalable service-oriented integration.
- **SM Systems Characterization (SMSC)** focused on technical means and measurement methods that can be used to assess an organization’s manufacturing systems for readiness, capabilities, and maturity level in their plans to implement smart manufacturing.
- **Smart Manufacturing Reference Model and Reference Architecture (SMRMA)** focused on developing reference models and architecture to support integration of diverse machines and software vendors’ applications, enabling smart manufacturing capabilities.
- **Smart Manufacturing Apps and Services Marketplaces (SMASM)** focused on the need for precise vocabularies, technologies, and interface standards for equipment and resources to allow apps and services interoperability, and market infrastructure and governance.
- **Industrial Ontology Foundry (IOF)** focused on exploring value and feasibility of standardization of concepts and relations describing the intended meanings within the industrial domain in a manner that enables computer reasoning and improves reasoning across data sources.
- **Data Analytics (DA)** focused on both technical and interface obstacles associated with manufacturers using cloud-based, data-analytics (DA) services.

As a theme this year, the workshop focused on the fast-changing landscape of technologies and standards impacting Composable Service-Oriented Manufacturing (SOM) systems. The main findings from the workshop include the following:

- **New promising technical capabilities continue to emerge**. Each session identified and discussed new technologies & standards, which the participants believe to be essential to their respective R&D areas.
- **Issues with adoption and integration of the technical capabilities are challenging**. As in the previous years, it is clear from the session discussions that adoption and inclusion of new technical capabilities within the manufacturing enterprise often carry prohibitive integration cost tags.
- **Industry-wide mobilization is needed to address the tough issues.** Because of the complexity and costs associated with adoption and integration of new technological capabilities, it is necessary to involve industrial communities to both develop and agree on industry-wide implementation approaches and standards. In addition, these complexities require that the industry stakeholders organize themselves and act efficiently.
- **Industry-wide road-maps should be developed to address the tough issues.** For the industry stakeholders to organize themselves in an optimal fashion, there is a clear need for developing and maintaining industry-wide R&D road-maps.

The workshop maintained coverage of the areas from the previous workshop and added the new Data Analytics area. The overall directions for the workshop and the sessions remained on course from the previous year.

The ultimate governance goal of the workshop series is to support the community to drive specific R&D projects to contribute to the vision of Composable SOM apps/services and systems. Future events, such as this series, are hoped to enable execution of collaborative R&D efforts with high probability of success.

1 Introduction

This report documents the fourth workshop in the workshop series on the topic of Composable Service-Oriented Manufacturing (SOM) systems. Here we give a summary of a longer motivation for Composable SOM systems[1], followed by a description of the workshop and the report itself.

1.1 Background: Composable Service-Oriented Manufacturing (SOM) Systems

The pursuit of Smart Manufacturing (SM) and exploration of Service-Oriented Manufacturing (SOM) to enable SM continues to be of great interest to industry. The vision for SOM is that future cyber-physical systems will be available in small "apps" or "services" and assembled or re-configured economically to execute complex workflow processes. These small apps have been called "microservices" that perform specific business, technical, or operational services, and which are linked together by other applications or workflows.

However, using the existing approaches has resulted in SOM systems that are costly to manage. Changes to these SOM systems to meet dynamic and complex workflow-process requirements currently demand laborious, manual processes to adapt, or re-configure their component services.

Advances in integration approaches are needed for the vision of SOM-based SM to materialize. That, however, requires new capabilities, including (1) SOM services life-cycle management and (2) SOM ecosystems life-cycle management. The former includes requirements analysis, design, behavior analysis, provisioning, deployment, discovery, use, and decommissioning of services. The latter includes services composition, design of service ecosystem operations, and optimization of service ecosystem execution.

On the other hand, manufacturers are concerned about time and cost of using these new capabilities. That includes efficiencies of (1) searching for and discovering relevant manufacturing services, (2) integrating them in an interoperable way, and (3) re-configuring them to meet changing requirements. We refer to systems capable of efficiently addressing these concerns as Composable SOM Systems.

Achieving such Composable SOM Systems requires new technologies. A key part missing from existing technologies is methods that provide for (1) precise management of reference domain semantics and (2) reliable interpretation of context-specific domain information. Hereafter, we name these methods Reference Models Life-Cycle Management (RM LCM) methods. Without them, there will be no basis for Composable SOM systems.

Significant scientific and engineering work is needed for achieving RM LCM. Measurement science, including a testbed to support hypothesis testing and experimentation, is needed to establish basis for standards representations of manufacturing information and knowledge-bases. Formalization of these representations will build on results from logic and rule-based knowledge systems; taxonomy/ontology development; knowledge, taxonomy, and ontology management systems; category theory; and other areas.

Standards will be critical to move research results from the testbed into industrial use. They will enable the needed interoperability and provide guidelines for development and implementation of new technologies. Standards cover terminology, definitions, methodologies, metrics, specifications, testing, and other issues.

[1] Nenad Ivezic, Boonserm Kulvatunyou, Dennis Brandl, Hyunbo Cho, Yan Lu, David Noller, Jim Davis, Thorsten Wuest, Farhad Ameri, William Bernstein. NIST/OAGi Workshop: Drilling down on Smart Manufacturing -- Enabling Composable Apps. Available at http://nvlpubs.nist.gov/nistpubs/ams/NIST.AMS.100-8.pdf

In summary, the underlying hypothesis for this workshop and the workshop series is that measurement science, information standards, and technology advancements are needed to deliver RM LCM methods that are necessary to enable *Composable SOM Systems*, and the vision of *SOM-based Smart Manufacturing.*

1.2 Workshop Motivation and Objectives

The National Institute of Standards and Technology (NIST) hosted the *2018 NIST/OAGi Workshop: Enabling Composable Service-Oriented Manufacturing Systems* at its Gaithersburg, MD, campus on April 23-24, 2018. The event brought over 100 participants from industry, government, national laboratories, and academia to identify measurement science, standards, technology challenges, and research and development (R&D) needs for the vision of Composable SOM systems. The objectives were to:

- Serve as a building block for creation of a roadmap for research, by developing information on:
  - Goals for Composable SOM systems viewed from multiple perspectives;
  - Capability gaps preventing the goals of Composable SOM systems;
  - Technologies required to address the capability gaps;
  - Future measurement- and standards-related challenges for Composable SOM systems;
  - Research and development needed to address the challenges.
- Inform future NIST technical programs and strategic planning.
- Offer valuable information to government agencies and stakeholders focused on the challenging area of systems integration within manufacturing environments.

1.3 Workshop Technical Sessions

1.3.1 How were session topics selected?

An earlier workshop identified standards and technology R&D issues[2] that prevent reaching our vision. The 2016 workshop started to address these issues through five separate breakout sessions. This year, we extended the coverage with an additional session. The following is a summary of the sessions.

1.3.2 Session descriptions

This report is based on workshop discussions within six technical sessions, each taking a separate perspective on developing and adopting new technologies and standards to achieve Composable SOM Systems. Common to their differing perspectives is that they explore knowledge-based modeling approaches to achieve reference model life-cycle management (RM LCM) methods. The knowledge-based modeling allows capture and sharing of both structured and unstructured descriptions and specifications of manufacturing systems, processes, and products in computer-processable forms. The computer-processable representations capture information, know-how, guidance, and standards that enable Composable SOM systems. The sessions were:

- **Smart Manufacturing (SM) Model-Based Message Standards Development (MBMSD) Methods** explored novel knowledge-model-based methods for conveying intended usage – both customization and context – for messages used by SOM Systems. This novel approach to specification is used to support new message standards life-cycle-management (MSLCM) capabilities.

- **Smart Manufacturing Systems Characterization (SMSC) Methods** investigated knowledge-model-based characterizations of the manufacturers' maturity and technologies' capabilities to implement composable

[2] Nenad Ivezic, Boonserm Kulvatunyou, Yan Lu, Yunsu Lee, Jaehun Lee, Albert W. Jones, Simon P. Frechette. OAGi/NIST Workshop on Open Cloud Architecture for Smart Manufacturing. Available at https://dx.doi.org/10.6028/NIST.IR.8124.

applications and SM systems. These novel methods will be utilized to support reasoning about the composability of these technologies within Smart Manufacturing Systems based on their interface designs.

- **Smart Manufacturing Reference Models and Architecture** (**SMRMA**) brought together standards developers, technology providers, and manufacturers to discuss reference models and architecture of ICT-enabled smart manufacturing systems. In addition to briefing the existing development efforts on smart manufacturing reference models and reference architectures, the participants explored the feasibility of service-oriented-architecture and how knowledge models could be used to specify services registration, discovery, orchestration, and data interchange for service-oriented manufacturing systems.

- **Smart Manufacturing Apps and Services Marketplaces (SMASM)** explored knowledge-model-based definitions of multiple aspects of SOM systems, apps, and marketplaces. These novel models will be utilized to support the identification and analysis of current technological and other challenges, as well as requirements from the stakeholders of Composable SOM Systems.

- **Industrial Ontology Foundry (IOF)** investigated new knowledge-model-based approaches to develop a collaborative framework and platform for submitting, validating, and sharing ontologies for the industrial and manufacturing domains. In this way, the knowledge will be captured and refined to facilitate smart manufacturing practices and resources.

- **Data Analytics (DA)** focused on both technical and interface obstacles associated with manufacturers using cloud-based DA services including matching specific, manufacturing problems to specific DA solution algorithms; and estimating uncertainties associated with using these algorithms.

1.3.3 Sessions charge

The workshop participants were given charge to discuss and report on the topics in their respective breakout sessions to support structured presentation of roadmap material for future road-mapping activity.

1.4 Workshop Report Organization

The ideas presented in this report reflect the different perspectives on the topic of Composable SOM Systems given by the workshop attendees. As such, they can, at best, be viewed as a representative sampling of the entire industry. We envision follow-on workshops in this series to refine the research roadmap material for Composable SOM Systems presented in this report. The organization of the report is as follows. Section 2 summarizes plenary presentations of the first day. Sections 3-8 represent the main content of the report and describe results of each breakout session. Section 9 offers conclusions of the workshop. Appendices provide additional information from sessions, including definitions of key terms describing Composable SOM Systems and presentation material from the first day of the workshop approved for publication by the authors.

2 Day 1 – Opening Plenary Presentations

2.1 Overview

The first day of the workshop was a plenary session dedicated to (1) presentations from industry, academia, and government describing key efforts to advance state of art and practice in Smart Manufacturing and (2) presentation by session chairs to describe updates and plans for breakout sessions.

2.2 Agenda

The table summarizes the activities of the first day.

Time	Title
9:00	Intro & Welcome (Serm Kulvatunyou, Nenad Ivezic, Simon Frechette)
9:15	Keynote I – (Mike Molnar, NIST)
9:55	Keynote II – Lessons Learned from I4.0 at Land O' Lakes (Mark Short, Land O' Lakes)
10:35	Break
10:50	Marketplace Session Update (Thorsten Wuest – WVU & Soundar Kumara – PSU Keynote III -- Smart and Advanced Manufacturing Innovation in DOE, Sudarsan Rachuri, DOE
11:20	Presentation I - Smart Factory IT Promotion for SME and Standardization in Korea (Prof. DongHag Choi), KATS)
12:00	Reference Architecture Session Update (Yan Lu - NIST, David Noller - IBM) + Presentation (Prof. Cheng)
12:30	Lunch
2:00	Presentation II - Smart Factory: Manufacturing Execution Optimization (Leyuan Shi – U. of Wisconsin)
2:40	Smart factory experience in a Korean SME (Hyunbo Cho – POSTECH, Sang Ki Choi & Young Zoo Kim – ShinShinSa)
3:10	MBMSD Session Update (Serm Kulvatunyou - NIST, Nenad Ivezic - NIST, and Scott Nieman - LoL)
3:30	Break
4:00	SMS Characterization Session Update (Kym Wehrle - DMDII, Michael Brundage - NIST)
4:30	IOF state of play (Jim Wilson - OAGi, Michael Gruninger - U Toronto)
5:00	Data Analytics Session Update (Al Jones-NIST, Willawan Onkham - UPS)
5:30	Adjourn

2.3 Presentation Summaries

Keynote I: Manufacturing USA & DMDII (Mike Molnar, NIST)

This keynote discussed a national effort to raise the innovation potential of nationwide manufacturing capacities and consisted of three parts. First was an overview of Manufacturing USA – the national network for manufacturing innovation. The second described operation of one of the institutes in the network – the Digital Manufacturing and Design Innovation Institute (DMDII). The third summarized the status of the network today.

Keynote II: Lessons Learned from I4.0 at Land O' Lakes (Mark Short, Land O’ Lakes)

This keynote described the mission of the Data-to-Value programmatic effort within Land O’ Lakes’ journey to achieve its Industry 4.0 (I4.0) vision. The mission is to enable a culture of data-driven decision making balanced with business expertise and intuition. The desired outcome is to unleash the power of analytics by collaborating with the Business and IT operating units of the company to identify opportunity, focus efforts, and deliver value in support of Land O’ Lakes’ broader growth objectives.

Marketplace Session Update (Thorsten Wuest – WVU & Soundar Kumara – PSU)

In this session update, the potential and status of smart manufacturing apps and service marketplaces were discussed. The aim of the session was to work towards a shared, secure, open-access infrastructure rich in functionality for easier systems integration and composability to be able to drive technological capability beyond just products by integrating services on standards, uncertainty quantification, benchmarking, performance-use metrics, systems modeling, and many more. A special focus of this year's workshop was on current technological and other challenges, interoperability and security issues, as well as requirements from the stakeholders' (e.g., designers', providers', and users') perspectives.

Keynote III: Smart and Advanced Manufacturing Innovation in DOE (Sudarsan Rachuri, DOE)

The keynote described some of the on-going activities in the Advanced Manufacturing Office (AMO) of Energy Efficiency and Renewable Energy at the Department of Energy (DOE). It discussed the AMO from the point of view of its three strategies of (1) Technical Assistance, (2) R&D Consortia, and (3) R&D Projects. Technical Assistance is driving a corporate culture of continuous improvement and wide-scale adoption of proven technologies to reduce energy use in the industrial sector. Shared R&D Consortia offers affordable access to physical and virtual tools, and expertise, to foster innovation and adoption of promising technologies. Research and Development Projects supports innovative manufacturing processes and next-generation materials. Current barriers and opportunities were discussed along with details of several on-going activities.

Presentation I: Smart Factory IT Promotion for SME and Standardization in Korea (Prof. Dong-Hag Choi, KATS)

The presentation discussed on-going developments in Korea, including an adoption of Industry 4.0, manufacturing innovation strategy, the Smart Factory Foundation effort, and a number of case studies from these efforts.

Reference Architecture Session Update (Yan Lu – NIST & David Noller – IBM)

This session update discussed requirements on production plants, supply chains, and logistic systems to be flexible in design and reconfigurable "on the fly" to respond quickly to customer needs, production uncertainty, and market changes. Service-Oriented Architecture (SOA) is a promising approach to achieving such manufacturing agility. It has proven effective for business process adaption and – especially when combined with emerging Internet of Things (IoT) technology and the concept of cyber-physical production systems – is expected to similarly revolutionize real-time manufacturing. This session aimed to bring standards developers, technology providers, and manufacturers together to discuss impacts of ICT technologies on the emerging manufacturing systems architecture.

Presentation II: Smart Factory: Manufacturing Execution Optimization (Prof. Leyuan Shi, University of Wisconsin)

Many manufacturing firms use aggregated data to provide scheduling/decision solutions for handling their daily operations. Given the nature of shop floors operating in real time, these average-based scheduling systems cannot be fully executed since unexpected events such as rush orders, design changes, machine breakdowns, defective parts, and delivery delays, etc., are almost inevitable. Currently, shop floors respond to unexpected events via manual rescheduling or by spreadsheet, which leads to poor predictability and visibility of performance, slow response to uncertainties and market changes, and low efficiency of their production and supply chain systems.

In this talk, Manufacturing Execution Optimization (MEO) technologies developed by Dr. Shi and her team were presented. MEO will enable the production system to be smart. By establishing top-floor to shop-floor communication in real time, manufacturing firms will be able to significantly improve their production and supply chain efficiency while responding to changes and disturbances in the most time-optimal manner. The presentation also briefly reviewed the history of software in Manufacturing and recent trends in software development outside of Manufacturing to propose a new model for Industry 4.0. An example covering Scheduling & Planning optimization was presented.

Smart Factory Experience in a Korean SME (Prof. Hyunbo Cho, POSTECH; Sang Ki Choi & Young Zoo Kim, ShinShinSa)

This presentation discussed experiences of a Korean small-or-medium (SME) manufacturing. ShinShinSa is a globally operating company that produces and supplies major press forming and assemblies for its products. The company has small-to-large press machines and a variety of high-tech production machines, inspection equipment for quality assurance, and facilities to manufacture and maintain molds.

Model-Based Message Standards Session Update (Serm Kulvatunyou & Nenad Ivezic – NIST; Scott Nieman – Land O' Lakes)

The session update discussed the objective of seeking to advance the methodology for messaging standards (e.g., OAGIS) development and usage. The vision of the group is to develop model-driven methods and tools that drive more effective and easier-to-use message standards. Latest developments, such as business process context-based usage and life-cycle management of messaging standards were discussed.

Characterization Session Update (Kym Wehrle – DMDII, Michael Brundage – NIST)

Harmonization of digital assessment tools is needed to accelerate the adoption of digital technologies within the industrial base and Department of Defense. A number of organizations are funding projects to better understand their current digital state and the implications of adopting digital technology within their operations. This session update explored the activities required to harmonize common digital technology principals, approaches, and tools to ultimately strengthen U.S. manufacturing competitiveness.

Industrial Ontologies Foundry (Jim Wilson – OAGi, Michael Gruninger – University of Toronto)

The session update focused on the formation of an Industrial Ontologies Foundry (IOF), a new effort for converging existing semantic representations from the industrial and manufacturing domain. The primary purpose of the IOF is to develop a collaborative framework and platform for supporting development, submitting, validating, and sharing of ontologies for the industrial and manufacturing domains. In this way, knowledge can be captured in a common semantic form and shared to facilitate smart manufacturing and optimize other industrial practices and uses of resources along the lifecycle of a manufactured product. This year's session reviewed the structure of this new organization, what we've learned from an initial proof-of-concept effort, and the principles and processes that should be used by the IOF to deliver value to the manufacturing industry.

Data Analytics Session Update (Albert Jones – NIST & Willawan Onkham -- UPS)

This session update focused on both technical and interface obstacles associated with manufacturers using cloud-based DA services. The session discussed solutions to four such problems. The first involves matching specific manufacturing problems to specific DA solution algorithms. For example, what kinds of manufacturing problems are best solved using neural networks and how can we choose an appropriate algorithm for the available data. The second involves estimating uncertainties associated with using those algorithms, software implementations of the algorithms, and any exogenous factors impacting the results. The third involves extending the existing predictive model markup language (PMML) to include standardized guidelines for helping manufacturers create the models and training data needed to use PMML. The fourth topic involves measuring the accuracy of DA models in the real-world of manufacturing. It is impossible to build a completely error-free DA model. This is true regardless of (1) the amount, type, and quality of the input data and (2) the complexity of the manufacturing. It goes without saying, that the ability to measure that accuracy is critical.

3 Model-based message standards development

3.1 Overview

More automation is needed to increase integration efficiency, agility, and resilience of manufacturing enterprises. High-quality message standards and their development and usage methods within service-oriented manufacturing systems are essential to the automation. This, however, requires new tools and methods for specification of service requirements and capabilities.

This session reviewed on-going work to revolutionize the way message standards are collaboratively developed and used. New model-based architecture and systems engineering approaches were explored. These approaches are expected to create reference models and analysis and synthesis tools to serve as a basis of requirements and capability specification for manufacturing services. Such reference models and associated tools allow syntax-independent and business-process-first standards development and usage to become a reality. The new models and tools reduce manufacturing applications integration risk and costs to software providers and manufacturer users, promote standards adoption, and lead to more efficient and automated integrations.

The current progress within the OAGi Semantic Refinement Method and Tool (SRT) Working Group and OAGi Smart Manufacturing (SM) WG was presented. Recent use-case scenarios across the two efforts have been reviewed. In addition, the OAGi Small and Medium Enterprises Working Group activities were reviewed. The meeting objective was to arrive at a focused set of requirements for the three working groups to address over the next six months to one year, as well as beyond.

3.2 Agenda

Time	Title
9:00	Introductions
9:15	Smart Manufacturing Requirements: Smart Mfg. WG update
9:45	Small & Medium Enterprises Requirements: SME WG update
10:15	Contextualization Needs: BPCCS status & update
10:45	Break
11:15	Semantic Refinement Tool (SRT) status & update
12:00	Discussion
12:30	Lunch
2:00	Next steps for MBMSD
3:30	Session Ends

3.3 Participants

Name	Organization
Boonserm Kulvatunyou	NIST
Nenad Ivezic	NIST
Scott Nieman	Land O’ Lakes
Marija Jankovic	University of Macedonia, Greece

Miroslav Ljubicic	Glovo, Spain
Jim Wilson	OAGi
Jin Bo	ETRI, Korea
Jaime Wightman	Lockheed Martin
Jianwu Wang	UMBC
Mike Rowell	Oracle
Simon Frechette	NIST
Nikola Stojanovic	Individual

3.4 Highlights

Session highlights include the following:

- Manufacturing data integration models have changed radically with the introduction of the Industrial Internet of Things (IIoT). While, traditionally, manufacturing integration models represented bottom-up hierarchical data integration, with IIoT integrated into manufacturing information systems, real-time (streaming) data at lower layers can be integrated directly to higher layers or clouds, which can be accessed by all layers.
- An ongoing challenge is the lack of standards guiding integration of IIoT data directly into the business layer and how to fuse business information with IIoT data.
- There is lack of standards guidance on representing IIoT data and integrating the data with business-level messages.
- There is an ongoing effort to combine OAGi and MIMOSA standards to address this lack of standards and guidance. OAGi is an industry consortium dedicated to reducing the cost of integration by developing inter-operable, cross-functional, cross-industry, data-model-driven, and extensible standards to meet the challenge of a rapidly-changing global digital economy. MIMOSA is an industry association dedicated to developing and encouraging the adoption of open, supplier-neutral, standards enabling physical asset lifecycle management spanning manufacturing, fleet, and facilities environments.
- There is an ongoing effort at OAGi to advance manufacturing applications integration capability at Small and Medium Enterprises (SMEs).
- The intent behind the SME-focused effort is to describe a plan for an ‘SME Starter Pack’ and its OAGIS standard deliverables, to analyze benefits and costs of the ‘SME Starter Pack’ plan, and to develop an initial SME Starter Pack Proof-of-Concept.
- Business Process Classification and Cataloguing System (BPCCS) was prototyped for OAGIS business scenario documentation by adding business process context definition and keeping the definition with BPMN business process models corresponding to OAGIS scenarios.
- The role of the NIST-developed Semantic Refinement Tool (SRT) is to provide a common methodology, to establish a shared data architecture, and to allow collaboration among developers and users of message standards.
- SRT is used today in the agriculture sector to create integration artifacts to achieve greater efficiencies in message standards development. Efficiency gains have been reported also in the aerospace sector.
- There are on-going advanced SRT enhancement efforts, such as generation of JSON schemas.

3.5 Conclusion

The following table summarizes the identified issues and opportunities and respective submitters. The items represent a focused set of requirements for the OAGi Semantic Refinement Tool and Smart Manufacturing groups to address within the next six months to one year, and later.

Item #	Issue/Opportunity	Submitter
1	Support to generate B2MML using JSON Schema	Dennis Brandl
2	User stories/use cases explaining Smart Manufacturing needs	Nikola Stojanovic
3	Define Smart Manufacturing architecture to analyze user stories/use cases	Nikola Stojanovic
4	Increase usability of BPCCS tool	Marija Jankovic, Thomas Knothe
5	Enable BPMN model introspection in BPM tools (e.g., BPCCS, Trisotech tools)	Scott Nieman
6	BPCCS tool functionality enhancement: advanced search, cross-referencing classification schemas, context reasoning	Marija Jankovic
7	BPCCS validation	Marija Jankovic
8	SRT-BPCCS Integration	Scott Nieman
9	Opportunity to apply BPCCS to Modular shop-floor IT (R&D)	Marija Jankovic
10	Represent BPCCS meta-model using ebRIM metamodel profile	Nikola Stojanovic

4 Smart Manufacturing Systems Characterization

4.1 Overview

This session explored the activities required to harmonize common digital technology principals, approaches, and tools to ultimately strengthen U.S. manufacturing competitiveness.

Harmonization of digital assessment tools is needed to accelerate the adoption of digital technologies within the industrial base and Department of Defense. A number of organizations are funding projects to better understand their current digital state and the implications of adopting digital technology within their operations.

The objective of the workshop was to:

1. Review and gather feedback on current and developing assessment tools and the driving organizations behind the development and facilitation of the assessments
2. Identify users of the assessments and define end-user objectives of the tools to refine and inform digital assessment harmonization road mapping efforts
3. Identify requirements of the digital assessment harmonization output (e.g., digital taxonomy of organizations and assessments, interactive web-based tool, etc.).

Given the wide range of assessments available, the workshop determined how various assessments were interrelated. The participants discussed the variability between the tools and the challenges of implementing. The uncertainty in determining which tool to use and the amount of resources being dedicated by various organizations in creating new maturity models was also addressed.

4.2 Agenda

Time	Title
9:00	Welcome & Overview of the Day
9:30	Review and gather feedback on current development of assessment tools
10:00	Inform digital assessment harmonization road mapping: use case identification
10:45	Inform digital assessment harmonization road mapping: Use case + Assessment Gap Analysis
12:30	Lunch
2:00	Identify requirements of the digital assessment harmonization output
3:30	Joint Session and Panel Discussion

4.3 Participants

Name	Organization
Michael Brundage	NIST
Quanri Li	NIST
Kym Wehrle	DMDII
Roy Whittenburg	MBD360 LLC
Sangsu Choi	IGI, LLC
Hyunbo Cho	POSTTECH

4.4 Highlights

The session highlights include:

- Current maturity models do not consider impact of business factors. More Return on Investment (ROI) studies are needed.
- A need exists for an unbiased accreditation process for assessments.
- Current maturity models need to be classified by the purpose of the assessment.
- There is a gap in the interoperability of the current assessments. Studies are needed on how much they overlap.
- Future assessments should incorporate actionable outcomes in the form of dashboards and measurable metrics.
- Ownership of various assessments should be clear. The roles of organizations that integrate new technologies/standards into the assessments versus the organizations that disseminate/execute the assessments need to be clearly defined.
- The sources of data need to be defined. Are the data sources automated? Who owns the data? How is the data classified? These questions need to be answered in future assessments.
- Assessments should be classified based on output: checklists, report based, prioritized assessment list, taxonomy of assessments and resources, web-based tools.

4.5 Conclusion

The following table summarizes the needs and priorities for assessment options in smart manufacturing.

output	Rank	Weight
Action based recommendations (improvement plan, wizard function)	1	22
ROI/Business case for recommendations (high/low risk profiles for activities)	2	21
Must provide rational of output (the why behind the recommendation)	3	16
Best practice for each level of maturity	4	11
Diagnostic tool that adapts to business	5	10
Centeral location for all assessments	5	10
Web-based interative portal	7	9
Plug in tools to assessment for an "auto" assessment	8	5
Outline that provides high level first and allows one to drill down into details	8	5
Adaptable by domain/industry	10	4
Need to take multiple inputs prior to aggregation data	11	3
scalability	11	3
Identify lead times, est. costs of capability implementation, how capabitlities build upon one another	13	1
Cloud-based tool/mobile tool	14	0
Web interface w/ interview + admin features	14	0
Rate assessments for comprehension	14	0
Underlying logic so you can interrelate assessment outputs	14	0

5 Smart Manufacturing Reference Model and Reference Architecture

5.1 Overview

Future manufacturing must become “smart” – capable of agilely adapting to a wide variety of changing conditions. This requires production plants, supply chains, and logistic systems to be flexible in design and reconfigurable “on the fly” to respond quickly to customer needs, production uncertainty, and market changes. Service-Oriented Architecture (SOA) provides a promising approach to achieving such manufacturing agility. It has proven effective for business process adaption and – especially when combined with emerging Internet of Things (IoT) technology and the concept of cyber-physical production systems – is expected to similarly revolutionize real-time manufacturing.

This session brought standards developers, technology providers, and manufacturers together to discuss impacts of information and communication technologies (ICT) on the emerging manufacturing system architecture. More specifically, we would like to explore how SOA can help integrate IoT, digital factory, and cloud computing technologies into modern manufacturing environments and enable manufacturing systems to respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs.

The envisioned outcomes of this break-out session were the surveys of existing smart manufacturing reference models and reference architectures from industry and SDOs and a feasibility analysis of applying SOA to integrate shop-floor automation systems with enterprise software systems in smart manufacturing environments. Challenges were identified for implementing SOA-based smart manufacturing systems and standards in support of such implementations.

5.2 Agenda

Time	Topic
9:00-9:20	Review and discussion of the previous workshop results and developments since
9:20-9:45	Lot-Size of One: The Role of Open-Architecture Products and Services
9:45-10:10	The Smart Manufacturing Platform-AMCoT and its Automated Construction Scheme of Cloud Manufacturing Services
10:10-10:35	A Study on Utilizing Maturity Model for Finding Suitable Manufacturing Services
10:35-10:50	Condition-based Production Control for Cyber-Physical Manufacturing Systems
10:50-11:15	The Open Process Automation™ Forum Technical Reference Model
11:15-11:40	An Optimization framework for "Production as A Service" and Agent based Manufacturing
11:40-12:05	
12:05-12:30	Decentralized Service Oriented Manufacturing System – The Machine’s Point of View
12:30-1:30	
1:30-3:30	Discussions for SOASM
3:30	Session Closed

5.3 Participants

Name	Organization
Yan Lu	NIST
Mohsen Moghaddam	Purdue University
Hung	Chinese Culture University, Taiwan
Kiyotaka Takahashi	Hitachi
Dennis Brandl	BR&L Consulting
Kira Barton	University of Michigan
Feng Ju	Arizona State University
Binil Starly	North Carolina State University

5.4 Highlights

The session highlights include the following:

- The goal of service-oriented architecture for smart manufacturing (SOASM) is to realize adaptive factory, agile/collaborative manufacturing, mass customization/individualization, and enable a secure manufacturing environment.
- The benefits of SOASM include**:** improved OEE, fast SME entrance into market, reduced cost, and improved quality.
- Current manufacturing systems, where diverse applications exist, and endless spreadsheets are used for information exchange, are not designed for SOA.
- There are overlaps among the functionality of the applications but there is a lack of modular design of the functions.
- Enterprise-level SOA applications are prevalent in practice, while micro-service architecture is emerging for enterprise integration.
- Huge gaps exist between big OEM and SME capabilities to adopt SOA integration.
- Full adoption of SOA in manufacturing will first be achieved at higher smart-manufacturing function levels, such as ERP and MOM.
- Existing SOA-based smart-manufacturing-enabling standards include ISA 95/88/106, OPC UA, RESTful, SOAP, MQTT, AQMP, DPWS, MTConnect, ISO/IEC JT1 SOA architecture, IEEE/IEC TSN, ZVEI MTP, NAMUR, OPAF TRM, OAGIS, MESA B2MML, BPMN.
- Other enabling technologies include: IoT/edge computing, microservices, multi-agent systems, block chain, JSON scheme, 5G, Integration platform, ESB, AI and machine learning, AVM, PHM, Cloud computing, autonomous robot, AGV, and 3D printing.
- There is ongoing standards work that includes I4.0 Component and List of properties standards within IEC TC65.

5.5 Conclusion

The following tables summarize the capability gaps for service-oriented manufacturing systems and the technical solutions and the top prioritized action items. The items represent a focused set of requirements for the development of SOASM.

Capability Gaps for SOASM

1. Reference model for SOASM
2. Service capability modeling; description and integration language (for composition)
3. Capacity and performance characterization and measurement, including aggregation
4. Manufacturing service requests should indicate nonfunctional requirements: for example, response time, carbon emission, safety, and security
5. How to define service interfaces – message modeling, API: manual vs automatic invocation
6. Service registry and semantic modeling
7. Service-oriented system verification and validation
8. How to encapsulate the existing applications/functions in services

Technical Solutions

1. Start with more use scenarios at different levels
2. Start with activity models (e.g., ISA 95) and taxonomies (e.g., eCl@ss)
3. Application context modeling
4. Define list of properties of manufacturing systems
5. Start with Web service interface standards for interface and registry definition and capture dynamic information later
6. Learn the approach of real time bidding from IT industry (Google)
7. Quality of Service Verification & Validation (QoS V&V) – refer to networking technology

Tool decisions:

1. Reduced-scale testbeds
2. Cloud-based platform

Priority Actions

1. Collect use scenarios at different levels
2. Work with ISA 95, etc., on defining Level 2 and 4 activity models
3. Survey existing taxonomy from eCl@ss and list of properties to support service modeling
4. Standard service (common service types) agonistic to application
5. Service type extended to vertical sectors
6. How to quantify service capability - Data-driven capability quantification (extrapolation, transfer learning)

6 Smart Manufacturing Applications and Services Marketplaces

6.1 Overview

With the proliferation of devices that establish high degrees of connectivity, data collection, and data analysis capabilities, we can see "Smart Manufacturing Architectures" becoming popular. "Smart" has become a common term preceding everything that deals with advancements in the field. It is necessary and timely to think about how hardware (sensor and communication equipment and manufacturing equipment), modeling, analytics, and software will work together in a seamless manner and advance smart manufacturing. With the focus of "architecture" and "applications in the context of market places", this workshop brings together academicians, industrial practitioners, and government representatives to address the foundational issues. We aim to bring together these experts from different regions (North America, Europe, Asia) and/or backgrounds (e.g., Industrial Internet, Industry 4.0, Intelligent Manufacturing Systems) who will present their (and their communities') understanding of enabling architectures in a Smart Manufacturing scenario.

Modern manufacturing industry is investing in new technologies such as Internet of Things (IoT), big data analytics, cloud computing, and cybersecurity to cope with system complexity and dynamics, increase information visibility, improve production performance, and gain competitive advantage in the global market. This advancement is rapidly bringing the new generation of smart manufacturing, i.e., a new cyber-physical system tightly integrating the manufacturing enterprise in the physical world with the virtual enterprise in the cyber space and interfacing with society. It is increasingly a consensus that operational technology & information technology (OT/IT) integration through robust architectural guidance is an essential aspect of successfully implementing smart manufacturing in the manufacturing enterprise. Realizing the full potential of cyber-physical social systems depends to a great extent on the development of new methodologies in the Internet of Manufacturing Things (IoMT) for data-enabled engineering innovations and integrating it with dynamic social needs. Given the proliferation of manufacturing innovation institutes at the national level and each having its focus, it is important in the evolving context to clearly specify the architectural aspects of the future enterprises – starting from society needs to strategic decision-making of manufacturing organizations.

It is necessary for all players in the manufacturing domain from academia, government, and industry to clearly lay out the foundations of computing infrastructures for future smart manufacturing. Needs (social and industrial) keep changing. How can manufacturing organizations use these changes and resulting new requirements? How can these new requirements propagate through manufacturing organizations? To answer these questions, it is becoming increasingly clear that we need a robust architectural design. Is it enough to have the cloud, IoT, and analytics as services? Are there architectures that go beyond these (and if so, which ones and how do they differentiate themselves from one another?)? What will be applications in the context of marketplaces and where (at what level) are they placed within the architecture? What are the right questions to ask? What will be the direction of the right answers?

We aim to establish a clear roadmap of what a smart manufacturing architecture will look like, with a specific focus on

a. levels/perspectives (e.g., data-driven) in manufacturing and translating them into architecture levels,
b. models for capturing and processing data, modeling, and analytics.

Ultimately, we hope that this provides the architectural foundations for a future factory seamlessly interfacing with robots, machines, and humans. Aside from this objective, we hope to discuss the current landscape of enabling architectures for several of the popular (international) variations of Smart Manufacturing, namely, Industry 4.0, Smart Manufacturing, Industrial Internet, IIoT, Intelligent Manufacturing, CPS/CPPS, etc. We hope to achieve a better understanding of the differences in enabling architectures (if any), including the individual perspectives they are built upon (e.g., Data centric, Hardware centric, etc.).

6.2 Agenda

Time	Title
9:00	Introductions
9:15	Clean Energy Smart Manufacturing Innovation Institute (CESMII) Smart Manufacturing Marketplace Architecture (*Craig Dory, CESMII / Rensselaer Polytechnic Institute*)
9:45	Edge Computing Methods for Smart Manufacturing Apps (*Sagar Kamarthi, Northeastern University)*
10:15	Automated Planning-based SM applications (*John Jung-Woon Yoo, Bradley University*)
10:45	Decision Guidance Systems & Service Networks: A marketplace to connect innovative product ideas with (SME) manufacturing capacity (*Alex Brodsky, George Mason University*)
11:15	Discussions
11:45	Lunch
13:00	Smart Sensors and their implementation in smart manufacturing (SM) systems (*Satish Bukkapatnam, Texas A&M)*
13:30	Parallel Computing and Network Modeling for Efficient Condition-Monitoring Apps in SM Market Place (*Hui Yang, Penn State University*)
14:00	Holistic Approach to Machine Tool Data Analytics (*Thorsten Wuest, West Virginia University*)
14:30	Discussions
3:30	Session Ends

6.3 Participants

Name	Organization
Soundar Kumara	Penn State University
Thorsten Wuest	West Virginia University
Craig Dory	CESMII
Sagar Kamarthi	Northeastern University
John Yoo	Bradley University
Alex Brodsky	George Mason University
Satish Buklapatnam	Texas A&M
Hui Yang,	Penn State University
Rachael Sexton	NIST

6.4 Highlights

The session highlights included the following:

- One result is that in our session a data driven perspective is taken in almost all presentations. The Smart Manufacturing app examples were mainly focused on extracting and analyzing data, be it on the edge, in the cloud, or elsewhere.
- Three main themes were discussed across all contributions: Composable Applications, Different (architecture) Levels; and No Higher Level Insights. In the following, these three themes are elaborated in more detail.
- ***Composable Applications*** facilitate workflows and utilization of different levels of data analytics and manufacturing resources
    - New CESMII architecture was presented (a big step forward)
    - Apps in the marketplace included those published by 3rd party providers, users (or such), and marketplace/platform-integrated ones (e.g., visualization)
    - Possibility to compose workflows of various apps and provide those to others who face similar challenges
- ***Different (Architecture) Levels*** come into play when talking about apps in the smart manufacturing environment, machine vs system level, cloud vs. edge, etc.
    - Smart sensors using SM wrappers addressing some of the interoperability issues
    - System level: example - use power profile to compare manufacturing machine tools
    - Questions that arose included: What happens when analytics are performed on the edge and only the results are transferred in cloud - this basically reduces the ability for further in-depth analytics (which brings me to my next point)
- How can 'black boxes' in apps / analytics services be overcome? A heavily discussed challenge was how the current models often provide a result that is correct but does not provide any ***higher-level insights*** that improve understanding of the system
    - Another discussion on that topic circled around using decision guidance systems

6.5 Conclusion

In conclusion, the interest in and development of Smart Manufacturing Apps and Services Marketplaces continues to increase. This year marks an important step with the presentation of the CESMII marketplace architecture as a reference for the future development. Going forward, we envision this workshop moving its main focus from development aspects to analysis, comparison, and critique of existing marketplaces, as well as deep-dives into specific issues on theoretical and applied levels. These issues may include the effective and efficient composition of multiple apps and services, (semi-)automated negotiations, and collaborator identifications. It can be safely stated, that despite the fact that the first marketplaces are starting operation, there are several interesting research issues, theoretical and practical, that still deserve our attention.

7 Industrial Ontologies Foundry (IOF) - *Creating Semantic Content for Industry*

7.1 Overview

This session focused on the Industrial Ontologies Foundry (IOF), an emerging effort for converging and extending existing semantic representations from the industrial and manufacturing domains. The primary purpose of the IOF is to develop a collaborative framework and platform supporting development, submission, evaluation, validation, and sharing of ontologies for the industrial and manufacturing domains. In this way, knowledge can be captured in a common semantic form and shared to facilitate smart manufacturing and other industrial practices and resources along the lifecycle of a manufactured product.

This was the third workshop held for the IOF. After the first workshop, held at NIST in December 2016, a community of manufacturing end users, software vendors, and researchers formed to pursue the IOF idea. The resulting organization now has a charter, website, and an organizational structure including a Governance Board and Technical Oversight Board. A pilot effort (aka proof-of-concept) is also underway to explore a top-down approach to defining the top 20 notions identified through a survey of the membership. This effort will be used to test and evolve approaches to formalize manufacturing knowledge that will be canonized as principles and practices of the organization. The pilot effort has also identified various common-interest areas that are expected to lead to the formation of Domain Boards focused around manufacturing subdomains or groupings of related manufacturing notions.

The nascent state for the IOF provided the context for this third IOF workshop. However, the workshop was not a working session focused on making decisions, but rather was focused on exchange of information that could inform decisions and directions for the IOF going forward. Sessions in this workshop fell into the following categories:

- Use cases employing semantic technologies in industry
- Introductory summaries of related efforts and new participants
- Case studies that employed a top down approach to manufacturing ontology development
- A report from the Top-Down thread of the IOF community's proof-of-concept
- Tools to support the IOF and uses of its content

7.2 Agenda

Time	Title
8:30	Keynote – Model-Based for Manufacturing in Airbus (*Fernando Mas, Airbus Senior Expert - remote*)
9:10	Overview of IOF Session (*Evan Wallace, NIST*)
9:20	Standards for smart manufacturing: using ontologies to landscape standards into knowledge graphs (*Irlan Grangel-González, Fraunhofer IAIS*)
10:05	Use Case: End of Life Processing (*Richard Sharpe, Loughborough University*)
10:35	ST4SE - Semantic Technologies for Systems Engineering (*Dr. Todd Schneider, Engineering Semantics*)
10:45	Development of Ontology based decision support system for Manufacturing Process Planning (*Dusan Sormaz [presenter], Professor, Arkopaul Sarkar, PhD Student; Department of Industrial and Systems Engineering Ohio University*)
10:55	Towards a Unified Database for the Norwegian Manufacturing Research Laboratory (*Oleksandr Semeniuta, Norwegian University of Science and Technology*)
11:10	The Product Life Cycle Ontologies and the IOF: Cases, Lessons, and Best Practices (*J. Neil Otte, Department of Philosophy, University at Buffalo (SUNY)*)

11:50	Using BFO to categorize and define IOF proof-of-concept terms (Top-down approach) (*Hyunmin Cheong, Research Scientist, Autodesk*)
12:30	Lunch
1:30	Modular Ontologies for Engineering Design and Decision Making (*Thomas Hagedorn, UMass Amherst*)
2:00	Using Ontology for Model-driven User Experience (*Sam Chance, Managing Director of Solution Engineering; Cambridge Semantics*)
2:20	Tools and Infrastructure for continuous integration: FIBO case study (*Dean Allemang, Working Ontologist, LLC; EDM council - remote*)
3:00	Mobi: A Shared Collaboration Environment for Semantic Content (*Stephen Kahmann, Technical Lead, Special Programs; Inovex Corp.*)
3:30	Session Closed

7.3 Participants

Name	Organization
Farhad Ameri	Texas State University
Sam Chance	Cambridge Semantics
Hyunmin Cheong	Autodesk
Tim Finin	University of Maryland, Baltimore County
Paul Goodall	Loughborough University
Michael Gruninger	University of Toronto
Mark Gryparis	Lockheed Martin
Thomas Hagedorn	UMass Amherst
Kevin Mark Himka	Boeing Company
Stephen Kahmann	iNovex Information Systems
Dimitris Kyritsis	EPFL
Pom Jin Lee	Korea Institute for Advancement of Technology
J. Neil Otte	University at Buffalo
Ian Phillips	Lockheed Martin
Todd Schneider	Engineering Semantics
Oleksandr Semeniuta	NTNU
Richard Sharpe	Loughborough University
Dr. Dusan Sormaz	Ohio University
Dr. Toshiya Teramae	Hitachi LTD.
Evan Wallace	NIST
Roy Whittenburg	MBD360 LLC
Jim Wilson	OAGi

7.4 Highlights

This session highlighted:

- areas of interest and requirements from industry such as mediation between models and services (e.g., from Airbus and Loughborough University),
- extensive prior work such as the Common Core and CHAMP ontologies that could be leveraged for IOF content,
- work ontologizing manufacturing standards that enable the agility of Industry 4.0,
- capabilities of tools available for creating, managing ontology content, and exploiting it for insight, and
- methods, successes, and challenges in managing parallel development and evolution of ontologies in FIBO, a similar effort to IOF for the financial sector.

Additionally, Neil Otte proposed adopting BFO as the upper ontology, the Common Core Ontologies (CCO) as Middle ontologies for IOF, and the product life cycle ontology as a starting point for mid-level ontologies. He also proposed adoption of a set of best practices from this experience. This workshop was not organized to make such decisions, so no action was taken on these proposals. The ontologies mentioned are available at: https://github.com/NCOR-US/CHAMP . His proposal is in Appendix B of this document.

7.5 Conclusion

Presentations and participation at this workshop indicated that there is significant industry interest in ontology-based solutions for managing the volume and variety of data in manufacturing industries (particularly in those involved in designing and building complex electromechanical products, such as the aerospace industry). While there is a great deal to do to create semantic models to support such needs, there are similar efforts that have already made this journey in other communities such as biology (OBO Foundry) and finance (FIBO). The IOF community can leverage what those other efforts have learned in terms of methodology, practices, and tooling to speed up our effort in the industrial space. Furthermore, there is a healthy subcommunity already working on ontologies for manufacturing and other engineering-intensive domains that has been participating in the IOF since the first workshop in December 2016. The next step for the IOF group is to hold a face-to-face meeting to decide its priorities, which methodology, practices, and tooling to adopt, and on what schedule. By the end of this workshop, IOF leadership had already begun planning such a meeting for mid-summer 2018.

8 Data Analytics

8.1 Overview

Enhancement of data analytics capabilities is the urgent key strategic issue for large corporations. Few organizations can make effective use of data analytics, while the majority is still figuring out the best approach to synthesize the big data to allow the C-suite to make better-informed decisions. Recently, artificial intelligence (AI) has become the primary goal of data analytics implementations; however, it is well established only in large and sophisticated firms that have support from both senior leaders and information technology systems. This session focused on both technical and interface obstacles associated with manufacturers using cloud-based, data-analytics services.

8.2 Agenda

Time	Title
9:00	Introductions
9:15	Data Analytics: Transforming UPS for Today and Tomorrow
9:45	Discussion
3:00	Session Ends

8.3 Participants

Name	Organization
Albert Jones	NIST
Wilawan Onkham	UPS

8.4 Highlights

There are several challenges for development and deployment of analytical schemes in manufacturing, such as using cloud-based, data-analytics (DA) services. For example, UPS collects massive data from its customers – information about approximately 16 million packages daily. In the vision of CEO David Abney, UPS wants to harness big data to support business decisions. The smart global logistics network initiative was developed as one of strategic investments for technology advancement. It is at higher levels of automation and integration than the current technology. However, the biggest challenge is to fill the gap between what UPS wants to be and what it currently has especially in terms of quality, nature, and dimension of data; computation time; and urgency of task. Four challenges of data analytics are illustrated below.

The first problem involves matching specific manufacturing problems to specific DA solution algorithms. For example, what kinds of manufacturing problems are best solved using neural networks and how can we choose an appropriate algorithm for the available data? One of alternative solutions is to develop a dynamic heuristic process to select the best algorithm for a particular data set using either model accuracy or error as criteria.

The second issue involves estimating uncertainties associated with using those algorithms, data quality, software implementations of the algorithms, and any exogenous factors impacting the results. Currently there is no standard nor measurement to indicate the level of data quality or cleanliness and, importantly, how to know when to stop cleaning or manipulating the data before ingesting it to a model-development process.

The third issue involves extending the existing predictive model markup language (PMML) to include standardized guidelines for helping manufacturers create the models and training data needed to use PMML. PMML is the leading standard for statistical and data-mining models. Currently, PMML is supported by over 20 vendors and organizations. With PMML, it is easy to develop a model on one system using one application and deploy the same model on another system using a completely different application. PMML provides a way for analytic applications to describe and exchange predictive models produced by data mining and machine-learning algorithms.

The fourth topic involves measuring the accuracy of data-analytics models in the real-world of manufacturing. Typically, the percentage of errors or R-square are common measurements of predictive models. These measurements are reasonable when there is enough of historical data to train and test the predictive model. In some business cases, we may have only a few weeks of historical data and the business requirement is to predict the future for the next weeks. It will be very difficult to have a validation period preventing model over-fitting problems and model accuracy may be below acceptable limits. Statistically, this predictive model cannot explain a trend or seasonality pattern of such data set. This means that it is impossible to build a completely error-free DA model. This is true regardless of (1) the amount, type, and quality of the input data and (2) the complexity of the manufacturing process. The ability to measure that model accuracy is critical. Indeed, we need knowledge and experience to come up with appropriate solutions.

8.5 Conclusion

In conclusion, advancing the data analytics capabilities is a critical course of action for organizations to gain market competitiveness. However, it is very difficult to judge what is an optimal approach. This issue also depends on the vision of senior leaders and flexibility of the organizational structure to prevent wasting money without adding any value to the organization or for its customers.

9 Summary

This document reported on the *2018 NIST/OAGi Workshop: Enabling Composable Service-Oriented Manufacturing Systems*, which is fourth in a series of workshops begun in 2015 to foster a shared vision of a new Smart Manufacturing (SM) platform that will support Composable Service-Oriented Manufacturing (SOM) systems. The workshops explore the needed technical foundation for achieving the vision. The following are main findings from the workshop and next steps proposed for the workshop series.

9.1 Key Findings

9.1.1 Extensive New Technical Capabilities Are Needed for Composable SOM

Realizing the vision of Composable Service-Oriented Manufacturing (SOM) requires many advances in underlying technologies to build more capable systems-integration approaches. The focus of the workshop and the community is on (1) providing new reference model life-cycle management (RM LCM) capabilities and (2) using those capabilities to build required new technologies.

Each breakout session, within its respective area of interest, discussed advances in RM LCM capabilities for the new technologies. Common to the sessions' differing perspectives is that all sessions focused on developing knowledge-based modeling approaches to achieve RM LCM methods. This focus is in line with developing needed capabilities to communicate and act on information in context-specific ways without failures in interpretation and without costly mediation help, re-interpretation, or manual intervention. These capabilities are then utilized to allow new models, methods, and tools to play a key role in enabling Composable SOM systems by supporting interoperable integration, search for and discovery of relevant manufacturing services, and configuration and reconfiguration of these services. In summary, the following is how the five breakout sessions help develop knowledge-model-based RM LCM capabilities to enable advances towards Composable SOM Systems:

- **Smart Manufacturing (SM) Model-Based Messaging Standards Development (MBMSD) Methods** provides knowledge-model-based specification for conveying customization and context information for manufacturing services within SOM Systems, which will be used to advance message standards life-cycle-management (MSLCM) capabilities.
- **Smart Manufacturing Systems Characterization (SMSC) Methods** develops knowledge-model-based characterizations of both the manufacturers' requirements and the technologies' capabilities, which will be used to support reasoning about the composability of these technologies within SM systems based on their interface designs.
- **Smart Manufacturing Reference Models and Architecture (SMRMA)** provides knowledge-model-based specifications for conveying information about data interchange, systems integration, and data fusion, enabling development of (1) a Smart Manufacturing Reference Architecture and (2) information standards and system interfaces, which are needed to allow disparate services/systems to exchange, understand, and exploit information flows.
- **Smart Manufacturing (SM) Apps and Services Marketplaces (SMASM)** explores knowledge-model-based definitions of multiple aspects of SOM systems, apps, and marketplaces, which will be used to support the identification and analysis of current technological and other challenges as well as requirements from the stakeholders for Composable SOM Systems.
- **Industrial Ontology Foundry** investigates new knowledge-model-based approaches to develop a collaborative framework and platform for submitting, validating, and sharing ontologies for the industrial and manufacturing domains. In this way, the new approaches will be used to facilitate smart manufacturing practices and resources in Composable SOM Systems.

- **Data Analytics (DA)** explores both technical and interface obstacles associated with manufacturers using cloud-based, data-analytics (DA) services. The issues explored are knowledge-intensive and include matching specific manufacturing problems to specific DA solution algorithms, and estimating uncertainties associated with using these algorithms.

9.1.2 R&D Road-mapping is a Needed Resource in Developing Composable SOM

This workshop report provides descriptions of the goals, missing capabilities, proposed technology characteristics, and action items in six working areas, based on the participants' discussions in the corresponding breakout sessions. This material is intended to enable a future R&D road-mapping effort. Future workshops may refresh the material as needed.

The road-mapping material can be used by the stakeholder community to plan and direct development of new technologies and by SDOs to develop the standards needed to integrate those technologies into Composable Service-Oriented Manufacturing systems. Stakeholders are expected to make use of this and future workshop reports to update and align their R&D programs relevant to Composable Service-Oriented Manufacturing systems.

9.2 Next Steps: R&D Projects to Enable Industrial Impacts

As in the previous year's workshop, it is recognized that the ultimate governance goal of the workshop series is to support the community to drive specific R&D projects to contribute to the vision of Composable SOM apps/services and systems. The many topics discussed in the workshop represent a wealth of information that can be used to prioritize and initiate new R&D projects in industry, academia, and government R&D programs.

Future workshops are expected to provide a vehicle to help the community drive towards this governance goal. It is hoped that future events such as the workshop series will enhance the maturity and enable execution of collaborative R&D efforts with high probability of success. Along with the R&D focus, future workshops need to pay close attention to potential impact of the R&D efforts.

Appendix A – Key Terms

- **Composable Service-Oriented Manufacturing (SOM) –** High-value SOM approaches with the core capability to efficiently search for and discover relevant manufacturing services, integrate services in interoperable ways, and configure and re-configure these services to meet changing requirements.
- **Knowledge-based Modeling** – Modeling of information, functions, processes, organizations, and other aspects of man-made systems that allows capture and sharing of both structured and unstructured information as well as specifications of manufacturing systems, processes, and products in computer-processable forms. The computer-processable representations capture information, know-how, guidance, heuristics, and standards that enable reasoning necessary for realizing Composable SOM systems.
- **Reference Models Life-Cycle Management (RM LCM) Methods** – A critical part required by new technologies to achieve Composable SOM. The methods address the activities ranging from creation, to adaptation, to use of reference models. These methods play essential roles in achieving precise management of reference semantics for the domain and reliable interpretation of context-specific domain information required by Composable SOM Systems. Techniques used in the LCM methods need to support high-level abstractions, separation of concerns, and loose coupling. They may use declarative approaches, including information- and knowledge-based models, rule-based systems, and taxonomy- or ontology-based systems.
- **Service-Oriented Manufacturing (SOM) Systems** – Manufacturing systems paradigm influenced by the service-oriented views of computing and information systems where manufacturing capabilities and resources are provided as services within a distributed, open ecosystem of service providers and consumers who use these services in assembling their systems.
- **Smart Manufacturing Systems (SMS)** – New generation of advanced manufacturing systems enabled by the convergence of information and communication technologies with emerging physical technologies to influence more efficient, automated, programmable, and flexible forms of manufacturing that meet changing consumer demands, market conditions, and supply chain capacities.
- **SOM Life-Cycle Management (LCM) Capabilities** – Capabilities of SOM Systems that include both (1) the SOM services life-cycle management (including requirements analysis, design, analysis, provisioning, deployment, discovery, use, and decommissioning of services) and (2) the SOM ecosystems life-cycle management (including SOM services composition, design of SOM ecosystems operations, and, optimization of SOM ecosystem services execution).

Appendix B – Neil Otte's proposals for the IOF

THE PRODUCT LIFE CYCLE ONTOLOGIES AND THE IOF: CASES, LESSONS, BEST PRACTICES

J. Neil Otte, neilotte@gmail.com

[Handout]

PROPOSAL

The IOF ought to officially adopt Basic Formal Ontology as an upper-level ontology and the Common Core Ontologies as mid-level ontologies. Then, the IOF should begin with the Product Life Cycle Ontologies, and revise, extend, and replace them as needed.

Common Core Ontologies (CCO) is a suite of mid-level ontologies, including ontologies of:

- Agents
- Artifacts
- Currency Units
- Events
- Extended Relations
- Geospatial
- Information Entities
- Modality
- Qualities
- Time
- Units of Measure

BFO-conformant, good documentation, widely-used, more polished than many OBO Foundry ontologies, and relevant to the domain of industry.

The Product Life Cycle (PLC) Ontologies is a suite of mid-level ontologies, including ontologies of:

- Commercial Entities
- Design
- Manufacturing Processes
- Maintenance
- Product Life Cycle
- Testing Processes
- Machines and Tools

Pros: BFO and CCO-conformant, and appropriate to the scope of the IOF. Presently, there is work underway to add to it an ontology for material properties.
Cons: Still a work in progress

CONSIDERATIONS IN FAVOR OF THE ABOVE

- BFO and the CCO are widely used, well-documented, and highly successful ontologies.
- Adopting BFO will bring in the resources of the National Center for Ontological Research.
- The PLC ontologies will provide users with clear examples of how their ontologies may be re-factored to be conformant with BFO.
- The governance of the PLC ontologies is available starting June 1, 2018.
- BFO has been approved as ISO/IEC standard 21838-2
- BFO is available in both OWL and CL (CLIF and FOL) formats

Resources:
All ontologies discussed here, along with these slides and this handout, are available at: https://github.com/NCOR-US/CHAMP. The National Center for Ontological Research website and wiki are here: https://ubwp.buffalo.edu/ncor/ and http://ncorwiki.buffalo.edu/index.php/Main_Page

Side Two: Cases, Lessons, and Best Practices

1. The True Path Rule applies to asserted classes only. Use defined classes for convenience and to aid in conforming to the rule.

   Ex. Product = 'Artifact and bearer of some Product Role.'

2. When building reference ontologies, avoid creating many relations that double the semantic work being done by classes. Example:

   Bad: 'Product has_product_function some Product Function.'
   Better: 'Product bearer_of some Function.'

3. Processes should be represented by classes, not relations.

4. Every class should receive an Aristotelian, or genus-species form, definition to be placed in a class annotation, and a separate annotation should list the term editor who is responsible for creating it.

5. If necessary, allow cheats and short cuts in application ontologies. Reference ontologies require representing what is true of reality, not what is expedient.

6. Creating hierarchies for artifact types is hard. Don't forget to represent artifact functions, artifact manufacturers, past uses of artifacts belonging to the same product line, etc. This will aid querying for artifacts even in the absence of a well-built taxonomy of artifact types.

7. A service is a process. When you sign a service agreement, you don't buy a service. You buy the claim on someone else to provide the service, and the seller acquires an obligation to provide that service upon request. Both the claim and the obligation may be represented with roles.

8. The completeness of your ontology doesn't rest with whether or not someone's preferred term is available in it, but rather, with whether or not your ontology can express the same meaning in an alternative vocabulary.

9. In class labels, use prefixes and sortal noun phrases. Examples:

   Bad: Water
   Good: Portion of Water
   Bad: Work
   Good: Process of Work

10. Certain terms like 'color' can refer both to a disposition (e.g. the power to induce others to have a certain qualitative experience) and the quality that is the base of the disposition (e.g. the surface grain structure responsible for reflecting light away from an object). When necessary, represent both

11. Never confuse information with the entities the information is about. '5 centimeters' is not a length; rather, it is a measurement that is about a length

Appendix C – Presentation Materials from Day 1 of the Workshop

This appendix contains presentation material from the first day of the workshop approved for publication by the authors.

ManufacturingUSA

Manufacturing USA and DMDII

NIST/OAGi Workshop: Enabling Composable Service-Oriented Manufacturing Systems

April 23, 2018

Mike Molnar
Advanced Manufacturing National Program Office

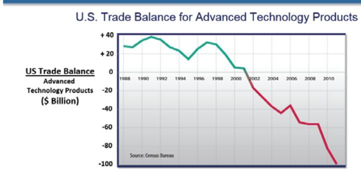
An interagency team building partnerships
with U.S. Industry and Academia

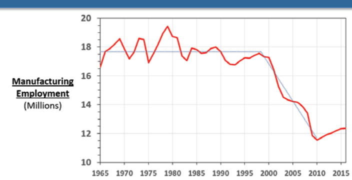
USDA

Agenda

- Manufacturing USA Overview
- How an Institute Works – DMDII
- Network Today / Closure

Manufacturing USA





President's Council of Advisors on Science and Technology
Advanced Manufacturing Partnership - 2011-2012
Advanced Manufacturing Partnership 2.0 - 2013-2014

Revitalize American Manufacturing and Innovation Act
118 bipartisan co-sponsors!
signed into law December 16, 2014

MFG USA

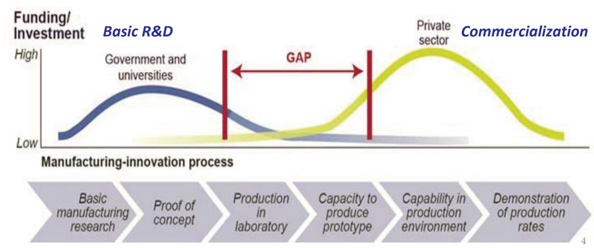
National Network for Manufacturing Innovation

Enhancing American Competitiveness by
- Manufacturing technology
- Education & Workforce Development

PCAST: Manufacturing USA Institutes Addressing the "Scale-up" Gap

Focus: *address market failure of insufficient industry R&D in the "missing middle" or "industrial commons" to de-risk promising new technologies*

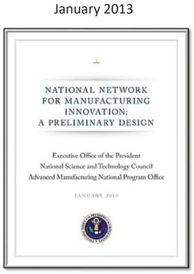
Approach: *bring private sector investment back to the gap*

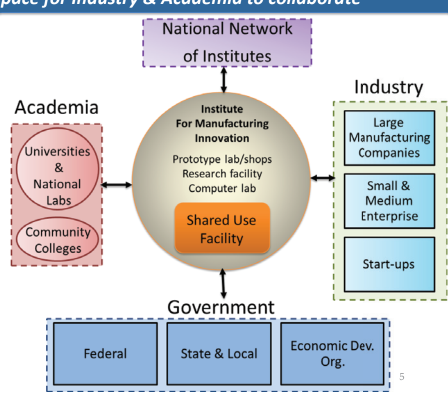


The Institute Design

Creating the space for Industry & Academia to collaborate

Institute Framework
Design published
January 2013





Agenda

- Manufacturing USA Overview
- **How an Institute Works – DMDII**
- Network Today / Closure

Institute Example: Digital Manufacturing and Design Integration

UI LABS/DMDII Facility, Chicago IL
GRAND OPENING MAY 2015

Agency sponsor: DOD
Startup funding: $70M public, $110M co-investment
94,000 square feet - digital manufacturing lab, instructional and collaboration space

1) Each Institute has a clear mission based on a critical Industry need

DMDII exists to transform American manufacturing competitiveness by accelerating the development and adoption of digital technology across the manufacturing enterprise

DMDII

2) Each Institute creates value for industry participation and funding

A Workshops

Topic-focused sessions where partners engage in solution oriented discussions to drive projects and investments

B Factory Floor

Creating an experiential manufacturing environment to demo, test & prove a wide variety of DM&D technologies

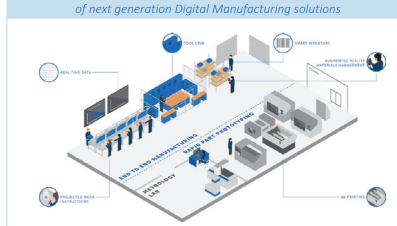
C PROJECTS

Applying the DMDII workshop and technical outcomes into real world applications

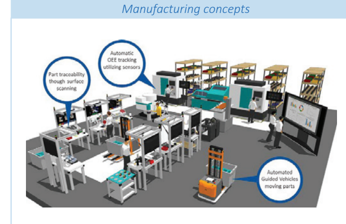
DMDII

3) Each Institute creates an effective collaboration space for pre-competitive applied R&D

Future Factory Platform
A neutral space for experimentation, testing, development and validation of next generation Digital Manufacturing solutions



Digital Capability Center
A dedicated training environment to teach core Digital Manufacturing concepts



DMDII

4) Each Institute is operated by an industry-led consortium

Aerospace & defense	Lockheed Martin, GE, Boeing, Rolls-Royce, Northrop Grumman
Industrial equipment	John Deere, Caterpillar, ITW
CPG	StanleyBlack&Decker, Duracell
Chemicals & agriculture	Dow
Automotive	faurecia
Pharma & medical products	Johnson & Johnson
High tech & telecom	Siemens, Microsoft, Autodesk
Services	McKinsey & Company

Small to Mid-sized Manufacturers
Ferralloy, Green Dynamics, Atlas, WPC Wrightwood

High growth Startups + Technology Providers
ARIS, UPSKILL, SCOPE, SupplyDynamics

Universities + Community Colleges
Northwestern University, Georgia Tech Research Institute, Illinois, Michigan

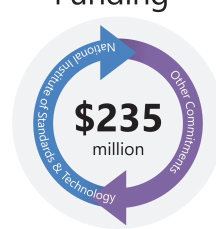
NSF, NASA, ONR, United States Coast Guard, US Army Corps of Engineers, DARPA

DMDII

5) Federal start-up funding for each Institute must catalyze at least 100% co-investment

Funding

$70,000,000
Digital Manufacturing Innovation Institute
DMDII



$165,000,000
Other Commitments

DMDII is funded by a five year $70,000,000 cooperative agreement from the federal government and leverages >$180,000,000 in other commitments.

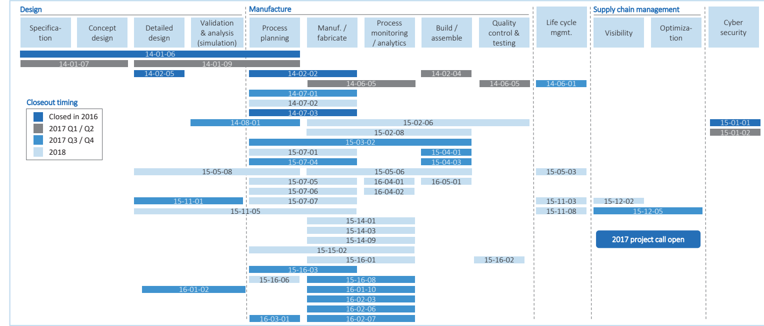
DMDII

6) Each Institute works on the industry priorities and big challenges only solvable by collaboration

	THEME	OBJECTIVES*
Design	**Move Manufacturing to the Left** Inform conceptualization and design phases with relevant, data-driven insights from across the entire product lifecycle. Ultimately part and product-related data of all kinds should move bidirectionally across the digital thread from concept to end-of-life.	• Pilot: "Day in the life of CAD" • Workshop/project: Real-time CAD feedback • Transitions: facilitate select project commercialization
Future Factory	**Integrate, Reduce-to-Practice to Drive ROI** Connect the dots of digital manufacturing, discover the remaining impediments to adoption and work through them. Integrate portfolio project outcomes plus emerging commercial technologies in DMDII's Future Factory sandbox as well as in a digital twin pilot involving a member manufacturer's operational environment.	• Pilot: Factory digital twin in member operations • Workshop: Sensor ROI & Marketplace • Integrations: 17+ projects & 3rd party solutions
Supply Chain	**Deliver Promise of Digital Thread & Digital Twin** Connect previous MBD/MBE/Digital Twin work with new project calls, workshops and pilots to build on the aggregate learnings. The proposed initiatives strive to reduce the technology to practice with pragmatic solutions that are inspired by real-world constraints represented through pilots and member feedback.	• Pilot: Supply chain design and digital twin • Workshop/playbook: Pragmatic model-based-definition • Workshop/pilot: Blockchain for supply chain use cases
Cyber Security	**Protect America's Growing Digital Manufacturing Advantage** Digital Manufacturing tech increases the sector's attack surface and simultaneously makes it an even more attractive target as the U.S. builds competitive economic advantage. A key focus is cyber-hardening small-to-medium-sized manufacturers (SMMs), which represent 90%+ of U.S. manufactured GDP.	• Cyber Security Hub: Work with DoD to establish** • SW Tool: SMM cyber assessment & mitigation • Training program: SMM cyber security basics**

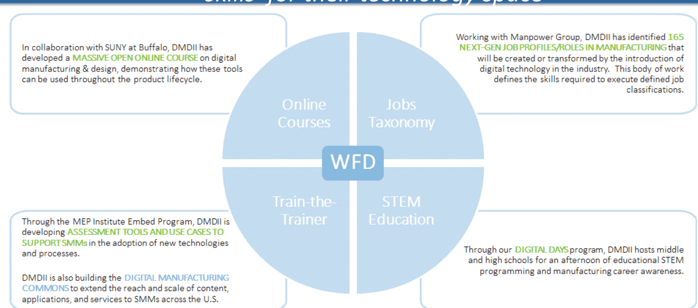
DMDII

7) Each Institute manages a balanced portfolio of real projects for industry



DMDII

8) Each Institute addresses the skills gap on education and workforce skills for their technology space



The future of WFD at DMDII is expected a mix of experiential, in-person training and scalable online services

DMDII

Agenda

- Manufacturing USA Overview
- How an Institute Works – DMDII
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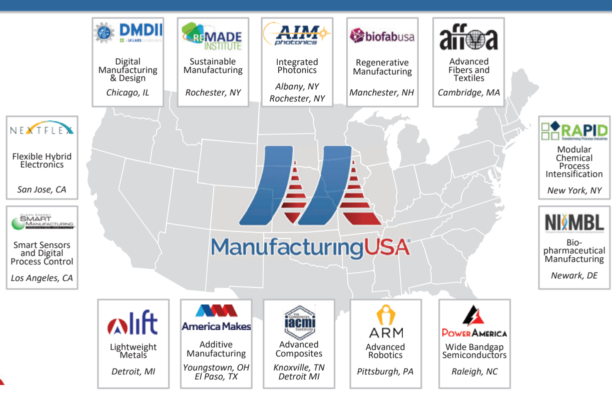
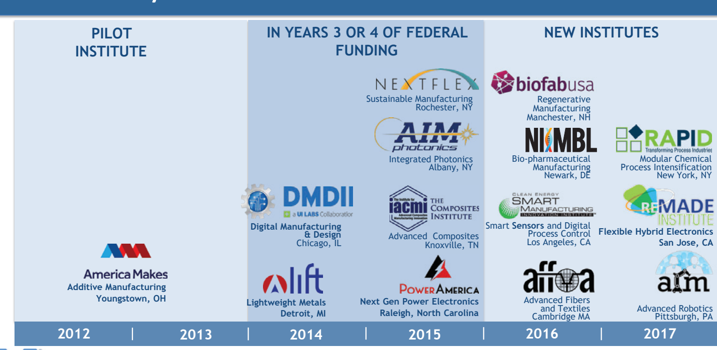
Manufacturing USA Today



Today a Network of Fourteen Institutes



Unique Institute Charters spanning a range of technologies

Electronics	Materials	Bio-Manufacturing	Energy Usage / Environmental Impact	Digital Automation
AIM photonics – Integrated Photonics – Albany, NY Rochester, NY	lift – Lightweight Metals – Detroit, MI	biofabusa – Regenerative Manufacturing – Manchester, NH	RAPID – Modular Chemical Process Intensification – New York, NY	DMDII – Digital Manufacturing & Design – Chicago, IL
NextFlex – Flexible Hybrid Electronics – San Jose, CA	iacmi – Advanced Composites – Knoxville, TN	NIIMBL – Bio-pharmaceutical Manufacturing – Newark, DE	Smart Manufacturing – Smart Sensors and Digital Process Control – Los Angeles, CA	America Makes – Additive Manufacturing – Youngstown, OH
PowerAmerica – Wide Bandgap Semiconductors – Raleigh, NC	affoa – Advanced Fibers and Textiles – Cambridge MA		REMADE Institute – Sustainable Manufacturing – Rochester, NY	arm – Advanced Robotics – Pittsburgh, PA

Together we are Securing America's Future

Making an Impact

- 14 innovation institutes develop new manufacturing techniques
  - decrease manufacturing costs; scale up; share equipment; develop standards; ensure cybersecurity for manufacturing; provide access to expertise; ensure industry leadership
- ~300 collaborative R&D projects
- 200,000 people trained in advanced manufacturing
- 1 billon federal investment matched by over $2 billion non-federal funds

All tables, figures, and photos in this document were produced by the Advanced Manufacturing National Program Office Interagency Working Team, unless otherwise noted.

Thank you!

MFG USA

Visit: www.ManufacturingUSA.com
Follow: @mfgUSA

Clean Energy Smart Manufacturing Innovation Institute

Dr. Sudarsan Rachuri

Advanced Manufacturing Office

www.manufacturing.energy.gov

sudarsan.rachuri@hq.doe.gov

OUTLINE

- EERE/AMO and Manufacturing USA Overview
- Current Barriers and Opportunities
- Goals and focus of CESMII
- Smart Manufacturing
  - Data Analytics, Reference Model and Testbed
  - CESMII Roadmap
- Potential Collaboration Topics
- Q&A

But before we begin-

So what is smart manufacturing?
To put simple create new, additional jobs in the U.S.

Smart way to improve efficiency, productivity – energy, material, and competitiveness

But I could not resist an alphabetical soup
SM = IoT+CPS+AI (ML)

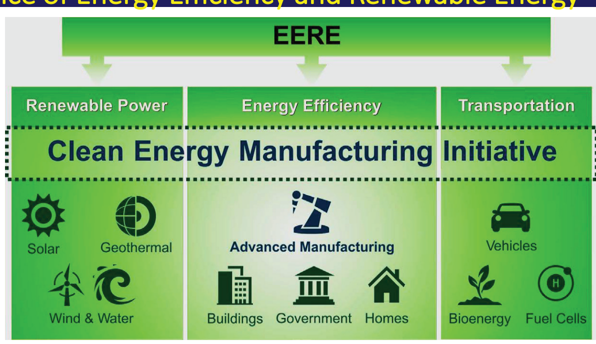
DEFINING SMART MANUFACTURING

Smart Manufacturing is the **business**, **technology**, **infrastructure**, and **workforce** practice of optimizing enterprise operations

- though the use of secure engineered systems that integrate operational and informational technologies (OT/IT) and drive manufacturing toward plug-and-play and shared use of physical operations.

In essence, SM enables the **right information** and **right technology** to be available at the **right time** and in the **right form** to the **right people**, powering smart decision-making within factories and across networked value chains.

Advanced Manufacturing Office of Energy Efficiency and Renewable Energy



Collaboration toward:
Common goal to collectively increase U.S. manufacturing competitiveness

Coordination for:
- Reduction of duplication
- Translation of best practices
- Codifying universal models

AMO: Three complimentary strategies

Technical Assistance: Direct engagement with Industry

Driving a corporate culture of continuous improvement and wide scale adoption of proven technologies, such as CHP, to reduce energy use in the industrial sector

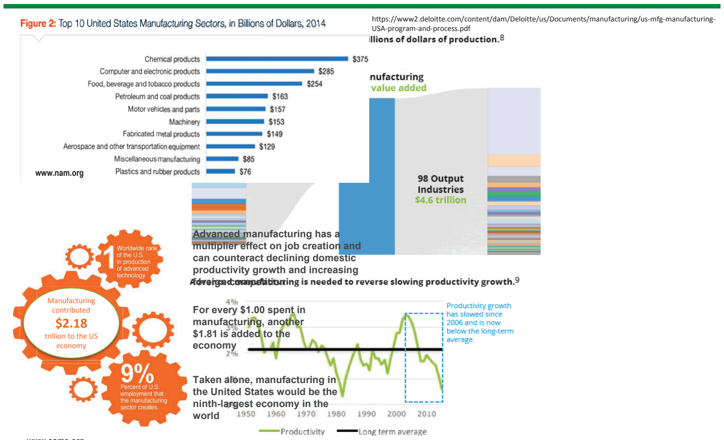
R&D Consortia: Public-Private consortia model

Shared R&D Consortia offer affordable access to physical and virtual tools, and expertise, to foster innovation and adoption of promising technologies

R&D Projects: Bridging the innovation gap

Research and Development Projects to support innovative manufacturing processes and next-generation materials

Manufacturing is vital for US economy



www.asme.org http://www.nam.org/Newsroom/Facts-About-Manufacturing/

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

But there is US R&D Investment Gap

TOTAL U.S. R&D (2009) $400 BILLION

RESEARCH		DEVELOPMENT	
FEDERAL R&D $125B		INDUSTRIAL R&D $275B	
FEDERAL LABS UNIVERSITIES NOT-FOR-PROFITS	U.S. INNOVATION GAP	INDUSTRY	
BASIC RESEARCH	TRANSLATIONAL R&D	APPLIED R&D	PRE-PRODUCTION
DISCOVERY-INNOVATION	RADICAL INNOVATION	NEW PRODUCTS	
		INCREMENTAL INNOVATION	IMPROVED PRODUCTS
BASIC RESEARCH $76B		APPLIED R&D $71B	DEVELOPMENT $253B

SBIR/STTR PHASE 1 AND 2: ~2.5B

Credit: Sridhar Kota, The Role of Innovation and manufacturing R&D

ReMaking America Paperback – July 10, 2013
Edited by Richard McCormack

Dr. Sudarsan Rachuri AMO/EERE/DOE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Manufacturing USA Program Address these issues

MFG USA

Vision: U.S. global leadership in advanced manufacturing

Mission: Connecting people, ideas, and technology to solve industry-relevant advanced manufacturing challenges, thereby enhancing industrial competitiveness and economic growth, and strengthening our national security.

Goal 1: Increase Competitiveness

Goal 2: Facilitate Technology Transition	Goal 3: Accelerate the Manufacturing Workforce	Goal 4: Ensure Stable and Sustainable Infrastructure

www.manufacturing.gov
www.manufactuingusa.com

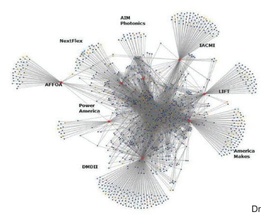
Credits: Dr. Frank Gayle, AMNPO, NIST

Dr. Sudarsan Rachuri AMO/EERE/DOE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

and we are making good progress | Manufacturing USA

- $600 million federal investment
- >$1.3 billion matched by non-federal
- 14 active institutes
- 1,600 members
- >300 technology development projects
    - *Members include two-thirds of Fortune 50 U.S. manufacturers*
    - *8 out of the 10 top-ranked research and engineering universities.*



Manufacturing USA , A Third-Party Evaluation of Program Design and Progress, Deloitte Study , Jan 2017

Institutes are achieving high degrees of network connectivity and strong member recruitment, reaching respective "tipping points" that drive towards success.

Dr. Sudarsan Rachuri AMO/EERE/DOE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

OUTLINE

- **EERE/AMO and Manufacturing USA Overview**
- **Current Barriers and Opportunities**
- **Goals and focus of CESMII**
- **Smart Manufacturing**
    - **Data Analytics, Reference Model and Testbed**
    - **CESMII Roadmap**
- **Potential Collaboration Topics**
- **Q&A**

Dr. Sudarsan Rachuri AMO/EERE/DOE

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But there are barriers according to McKinsey Analysis

Manufacturers need to overcome major implementation barriers, of which some are more relevant for advanced players

Top 5 barriers mentioned by manufacturers with no/limited progress in Industry 4.0

- **Difficulty in coordinating actions** across different organizational units
- **Lack of courage** to push through radical transformation
- **Lack of necessary talent**, e.g., data scientists
- **Concerns about cybersecurity** when working with third-party providers
- **Lack of a clear business case** that justifies investments in the underlying IT architecture

+

Additional top barriers mentioned by more advanced manufacturers

- **Concerns about data ownership** when working with third-party providers
- **Uncertainty about in- vs. outsourcing** and lack of knowledge about providers
- **Challenges with integrating** data from disparate sources in order to enable Industry 4.0 applications

Level of progress in Industry 4.0

SOURCE: McKinsey Industry 4.0 Global Expert Survey 2016

Industry 4.0 after the initial hype Where manufacturers are finding value and how they can best capture it, Mckinsey Global Institute

Dr. Sudarsan Rachuri AMO/EERE/DOE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

There is a slow and uneven progress in capturing value from data

There has been uneven progress in capturing value from data and analytics

	Potential impact: 2011 research	Value captured %	Major barriers
Location-based data	• $100 billion+ revenues for service providers • Up to $700 billion value to end users	50–60	• Penetration of GPS-enabled smartphones globally
US retail[1]	• 60%+ increase in net margin • 0.5–1.0% annual productivity growth	30–40	• Lack of analytical talent • Siloed data within companies
Manufacturing[2]	• Up to 50% lower product development cost • Up to 25% lower operating cost • Up to 30% gross margin increase	20–30	• Siloed data in legacy IT systems • Leadership skeptical of impact
EU public sector[3]	• ~€250 billion value per year • ~0.5% annual productivity growth	10–20	• Lack of analytical talent • Siloed data within different agencies
US health care	• $300 billion value per year • ~0.7% annual productivity growth	10–20	• Need to demonstrate clinical utility to gain acceptance • Interoperability and data sharing

1 Similar observations hold true for the EU retail sector.
2 Manufacturing levers divided by functional application.
3 Similar observations hold true for other high-income country governments.

SOURCE: Expert interviews; McKinsey Global Institute analysis

Credits: Mckinsey Global Institute

..and there is this question – Does companies gets credit for long-term investments in R&D?

The answers you get are:

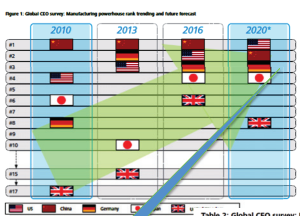
- resulting knowledge might walk out the door, as employees join other firms or start their own,
- you can acquire firms who have the needed technology.

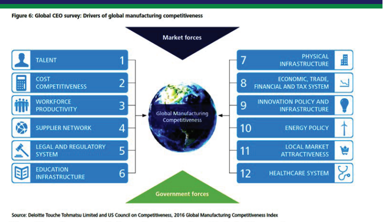
- If everyone followed that logic, however, there'd be little innovation to walk out the door or to acquire!
- Fortunately, neither of these concerns is warranted according to Sarah Williamson, why companies, investors, and the nation will be better off if companies make long-term investments in R&D.

There's No Good Alternative to Investing in R&D, Anne Marie Knott, HBR, April 17, 2018

Sarah Williamson is the CEO of FCLTGlobal

But we have great opportunity for US Competitiveness and global leadership





Opportunities for CESMII

Table 2: Global CEO survey: Ranking of future importance of advanced manufacturing technologies by executives

Advanced Manufacturing Technologies	US	China	Europe
Predictive analytics	1	1	4
Smart, connected products (IoT)	2	7	2
Advanced materials	3	4	5
Smart factories (IoT)	4	2	1
Digital design, simulation, and integration	[illegible]	5	3
High performance computing	6	3	7
Advanced robotics	7	8	6
Additive manufacturing (3D printing)	8	11	9
Open-source design/Direct customer input	9	10	10
Augmented reality (to improve quality, training, expert knowledge)	10	6	8
Augmented reality (to increase customer service & experience)	11	9	11

Source: Deloitte Touche Tohmatsu Limited and US Council on Competitiveness, 2016 Global Manufacturing Competitiveness Index

From - https://www2.deloitte.com/global/en/pages/manufacturing/articles/global-manufacturing-competitiveness-index.html

Two major opportunities
1) Smart Manufacturing Contribution to Energy Productivity Goal 2030

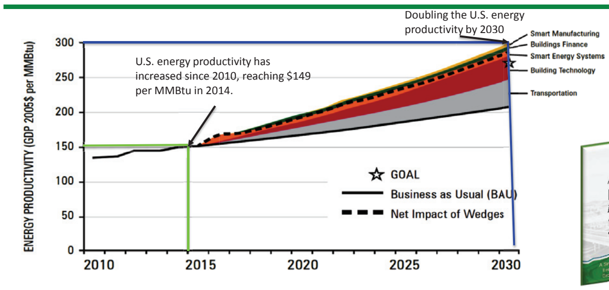
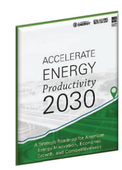


Figure 7. Projected Energy Productivity Benefits to 2030



http://www.energy2030.org/

$$\text{Energy productivity} = \frac{1}{\text{energy intensity}} = \frac{\text{annual GDP}}{\text{annual total primary energy use}}$$

i.e., the economic value created per unit of energy used

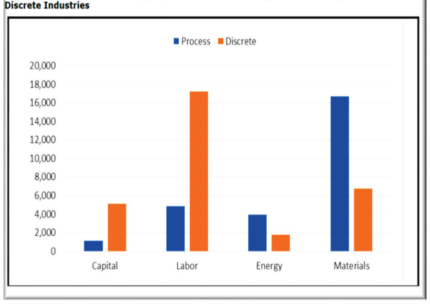
Increasing energy productivity can be achieved by either growing GDP at a faster rate than energy use or reducing the growth rate of energy use to a rate of growth less than GDP growth.

Two major opportunities
2) Economic Impacts of technology infrastructure to support Smart Manufacturing

Report findings:
Total economic impacts estimated to be ~ $57.4 billion per year and would accrue over multiple years.

- *Discrete parts manufacturing ~ $30.8 billion*
- *Process manufacturing ~ $26.6 billion.*

Figure ES-2. Annual Cost Savings by Factors of Production (millions of USD) for Process and Discrete Industries



https://dx.doi.org/10.6028/NIST.GCR.16-007

https://www.rti.org/impact/economic-analysis-technology-infrastructure-advanced-manufacturing

OUTLINE

- **EERE/AMO and Manufacturing USA Overview**
- **Current Barriers and Opportunities**
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- **Smart Manufacturing**
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  - **CESMII Roadmap**
- **Potential Collaboration Topics**
- **Q&A**

CESMII Vision: Smart Manufacturing is manufacturing in 2030

MISSION

Radically accelerate the development and adoption of advanced sensors, controls, platforms, and models for U.S. manufacturing through integrated, industry-led Smart Manufacturing (SM) technical, business, and educational methodologies.

OBJECTIVES

To enhance U.S. manufacturing productivity, global competitiveness, and reinvestment, leading to significantly:

- ↑ energy productivity
- ↑ economic performance
- ↑ CESMII sustainability
- ↑ workforce capacity

GOALS

15% improvement in energy efficiency in first-of-a-kind demonstrations at manufacturing plants or major processes within 5 years

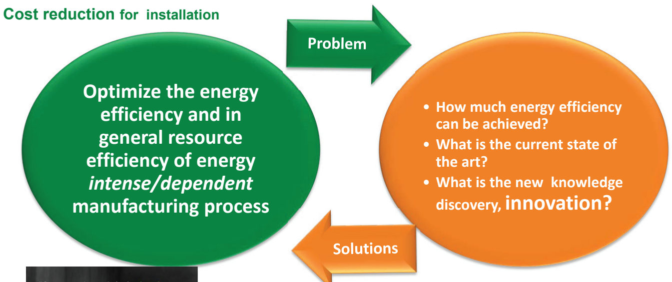
50% reduction in cost and time to deploy SM in existing processes within 5 years

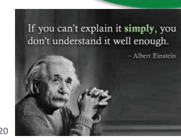
Significant industry adoption of SM technology within 5 years

Sustainable portfolio of business, technology, research and development, and workforce development activities that directly replaces initial Federal funding within 6 years

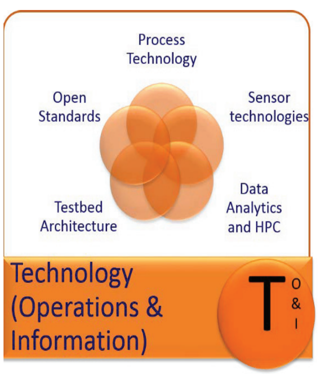
50% improvement in energy productivity within 10 years

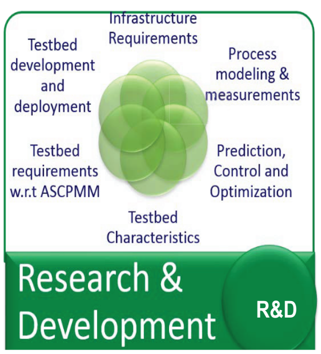
So what are the Goals and Focus of the Institute?



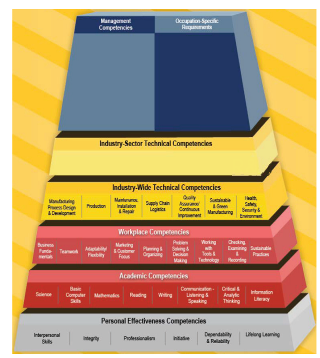


Let us look at CESMII Focus





Let us look at CESMII Focus –Workforce Development and Education



http://www.careeronestop.org/CompetencyModel/competencymodels/advanced-manufacturing.aspx

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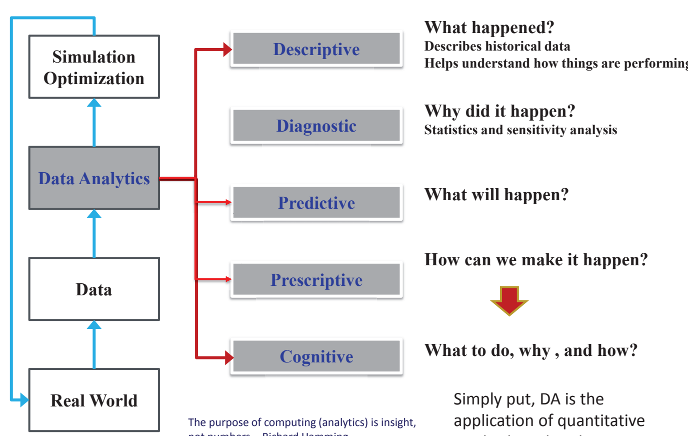
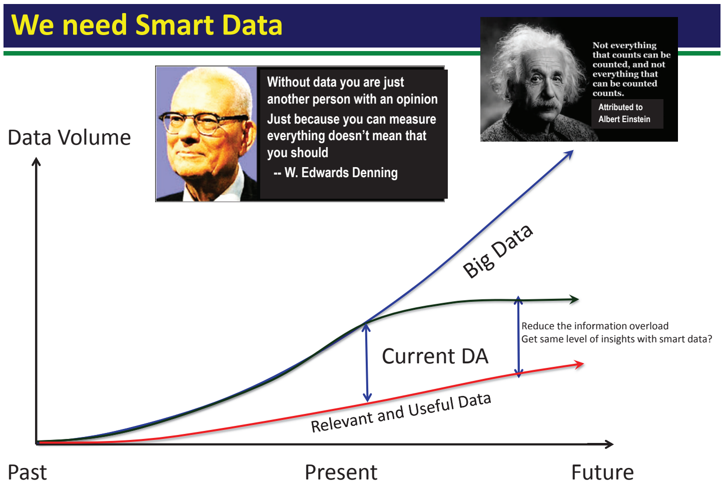
What is Data Analytics ?



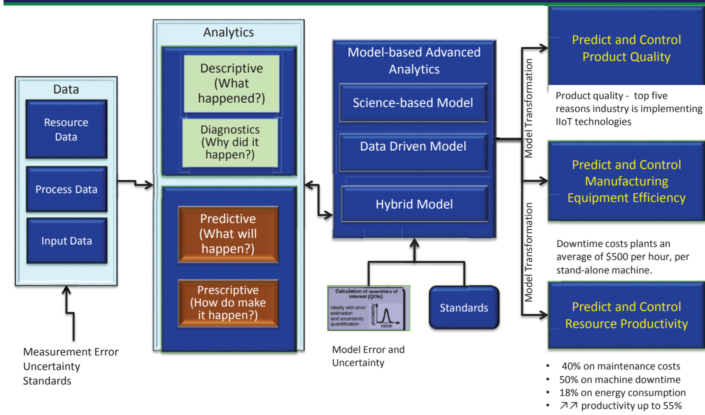
The purpose of computing (analytics) is insight, not numbers. - Richard Hamming

Simply put, DA is the application of quantitative methods and tools to turn data into insight and action

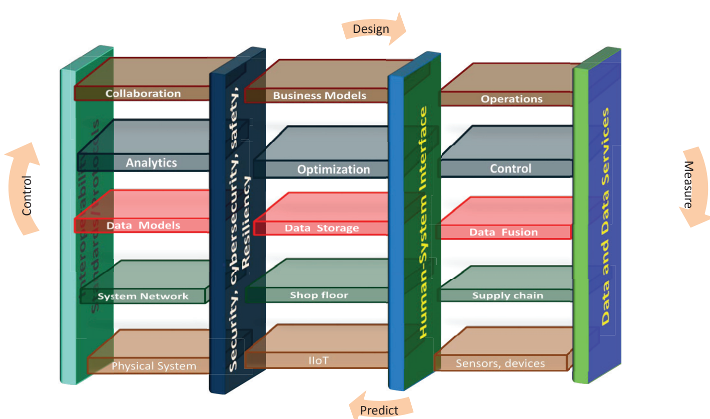
We need Smart Data



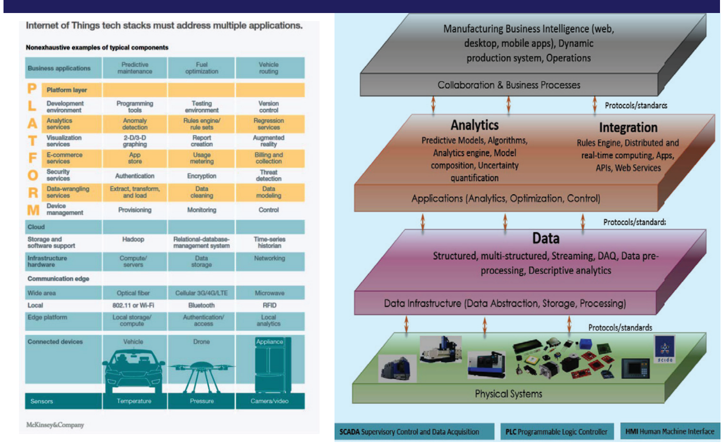
We need a good Model-based Advanced Analytics



Smart Manufacturing Reference Architecture



What are the Layers of Smart Manufacturing Technologies ?



We need a Testbed Framework

Levels*	Data What	Motivation Why	Function How	Network Where	Time When	People Who
Machine Level						
Process Level						
Shop floor level						
Plant Level						
Extended Enterprise Level (Including supply network)						
Deployed Testbed						

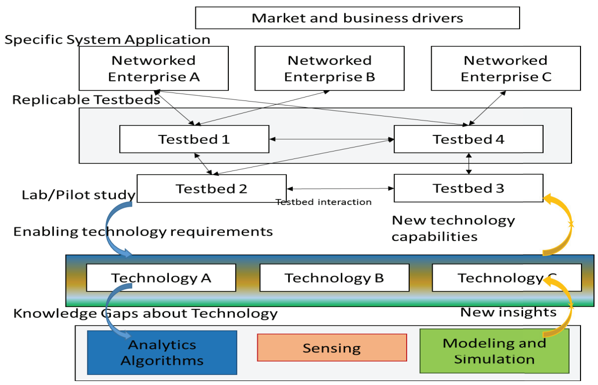
*Testbed Architecture cell level description with respect to testbed characteristics and requirements could be based on Zachman Framework

Based on the Testbed Framework let us look at OT&IT Integration

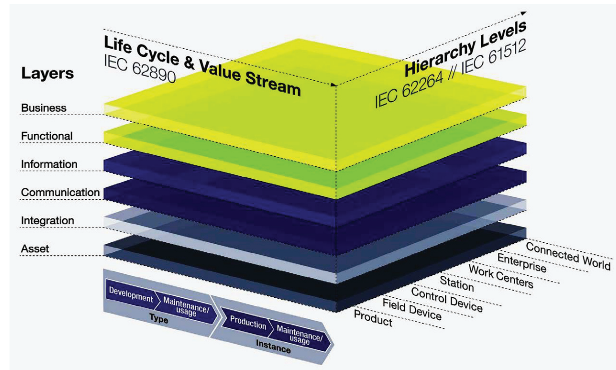
IT / OT	IIoT					PCO	MS&A	Data analytics	HPC
	Sensors Actuators	M2M	ICS	CPS	Security				
Petroleum refining									
Chemicals									
Metals manufacturing									
Food and beverage									
Glass									
Pulp and paper									
Defense and Aerospace									
Discrete manufacturing									
Microelectronics									
Additive Manufacturing									
Other Applications									

What is the strategy for Testbed for Smart Manufacturing?

Concept of testbed for Smart Manufacturing Systems Integration

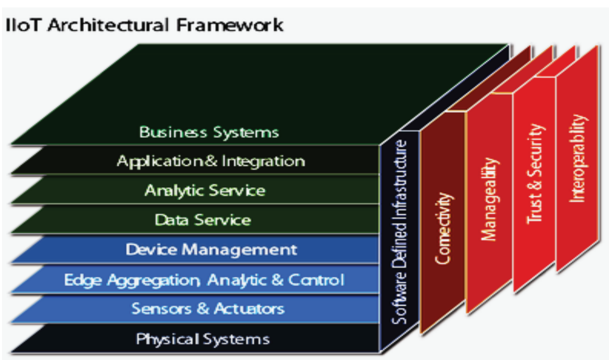


Let us look at similar efforts
Reference Architecture Model Industry 4.0



RAMI 4.0 (DIN SPEC 91345:2016-04 Standard)

Let us look at similar efforts
Industrial Internet Reference Architecture



The Industrial Internet Reference Architecture (IIRA) is a standards-based open architecture defined by the Industrial Internet Consortium (IIC). Based on ISO/IEC/IEEE 42010:2011 Systems and software engineering -- Architecture description

industrial internet CONSORTIUM

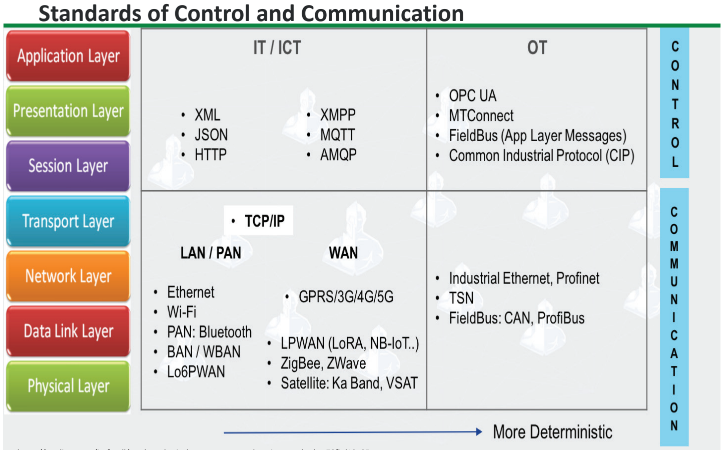
Let us look at similar efforts
IoT and IIoT

IoT	IIoT
Revolution	Evolution
Things	Data
Ad hoc connectivity	Structured connectivity
Important –but not critical	Mission critical • Analytics • Security • Data integrity • Response times
User serviced	User + OEM + Vendor serviced
New • Devices • Standards	Existing • Devices • Standards
Proprietary Solutions	Defined Standards

- Data Access
  - Performance
  - Profiles
  - Proxies
- Uptime
  - Diagnostics
  - Fault Tolerance
  - Security
- Openness
  - Open Standard
  - Multi-vendor

http://www.totallyintegratedautomation.com/2016/03/profinet-fits-iiot-industrie-4-0/

Let us look at similar efforts
Standards of Control and Communication



https://medium.com/iotforall/a-cyber-physical-systems-approach-to-iot-standards-e78fbd12e95

© The Cerebrus Group

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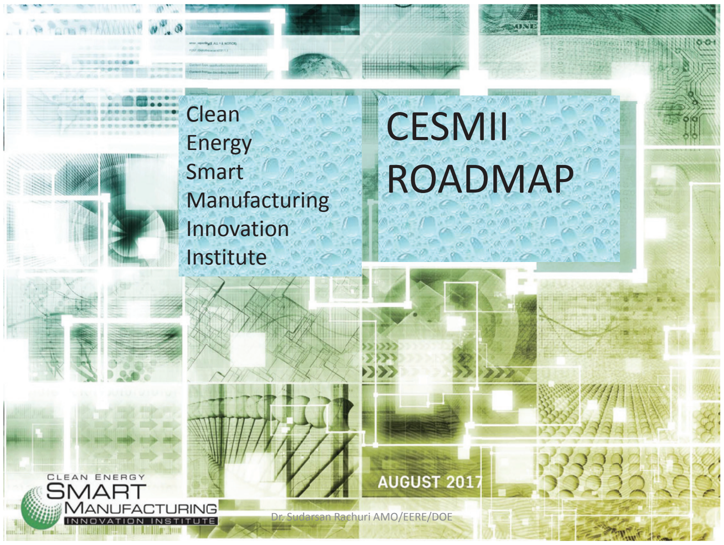


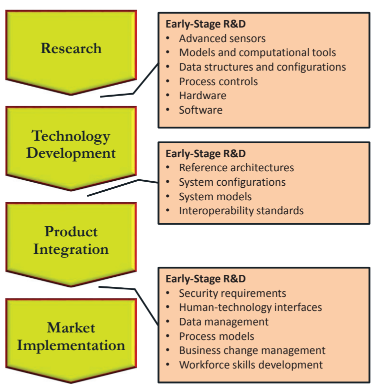
CESMII Roadmap Objectives

- **Start up the Institute** and continue to build the **world's best SM network,** providing:
  - Objective information on SM technologies
  - R&D portfolio that only an Institute can address
  - Consultation, assessment, and SM Platform access
  - Cross-industry information and studies
  - Training
- Cross-link **CESMII Regional Manufacturing Centers** (RMCs)
- Launch first call for **CESMII projects**
- Set up for **CESMII Roadmapping 2018–2022 process**

DEFINING CESMII'S R&D PORTFOLIO

- Facilitate implementation of new manufacturing solutions and OT-IT integration
- **Accelerate early-stage R&D** in ways no company or industry can do alone.

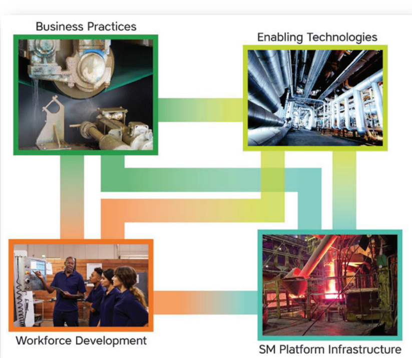
The CESMII R&D Portfolio will simultaneously **address knowledge gaps and advance innovation in SM technology, processes, and workforce**.



Key Items for Successful Projects and Proposals

A. Define the actual manufacturing problem
B. Identify R&D Challenges, Opportunities, Knowledge Gaps
C. Explain Quantitative and qualitative methods to be used
D. Discuss Data management methods
E. Explain the Use of Machine learning in a Smart-Paradigm
F. Identify Sensor-computing interfaces
G. Use of Smart Manufacturing Reference Architecture & Platform
H. Describe Data-driven and Hybrid models
I. Explain Model V&V UQ
J. Identify Knowledge gaps, Reusable Components for Testbeds

CESMII ROADMAP STRUCTURE



The CESMII Roadmap: 2017–2018 includes the following content:

- Strategic Objectives — the desired outcomes of CESMII activity
- R&D Portfolio — priority needs for collaborative R&D projects, studies, and assessments (not include for Workforce Development)
- Near-Term Action Plan — a timeline of activities for the next year

Optimize manufacturing and increase energy productivity

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Some Opportunities

ASTM INTERNATIONAL
Helping our world work better

New ASTM Journal

Smart and Sustainable Manufacturing Systems

Call for Papers

Submit your paper and advance the measurement science, standards and protocols, and tools needed to design, analyze, and control smart manufacturing systems based on a cyber-physical infrastructure for digital manufacturing.

Relevant Topics Include

- Information and domain specific modeling, semantics and architecture for manufacturing systems
- Cyber-physical infrastructure for design, analysis and control of smart manufacturing systems
- Model-based systems engineering and machine-to-machine communications
- Multi-layer networks and control
- Life cycle engineering and sustainability
- Supply chain modeling for smart manufacturing
- Real-time data analytics for predictive modeling for manufacturing system performance
- Uncertainty quantification and propagation including verification and validation
- Manufacturing process (continuous and discrete) characterization for sustainable manufacturing
- Material information modeling across the product life cycle
- Resiliency and recovery of smart manufacturing systems and supply chains
- Cloud computing and manufacturing services
- Digital manufacturing
- Digital thread for additive manufacturing

We welcome research papers, industry case studies and application papers, survey papers, and technical notes. We advocate for papers that have strong theoretical content and demonstrate manufacturing industry applications.

For more information contact Alyssa Conaway
aconaway@astm.org | tel +1.610.832.9620 | www.astm.org/SSMS

Objectives

This journal fosters transdisciplinary research that crosses the boundaries of information science, systems engineering and engineering design, manufacturing, and product life cycle with a focus on how to make manufacturing systems smarter and sustainable.

Editor-in-Chief

Dr. Sudarsan Rachuri
Federal Program Officer
Advanced Manufacturing Office
EERE, Dept. of Energy, Washington, DC, USA
email: ssms.journal@astm.org

"The science behind the standard [has] to be explained so that people can have trust in the standard. This journal was conceived to fill that gap and also to have an intersection of manufacturing science, information science and data science with focus on industry application."
Dr. Sudarsan Rachuri

http://www.astm.org/SSMS

V&V
Verification and Validation in Computational Modeling and Simulation

NEW OPPORTUNITY

Development of ASME Verification and Validation (V&V) Standards for Advanced Manufacturing

The ASME V&V standards committee is exploring the formation of a new committee to develop verification and validation protocols for computational modeling in advanced manufacturing.

This effort reflects a growing interest among various stakeholders from industry, government, and academia in V&V and UQ as a vehicle to help advance new manufacturing technologies and methods, and the need for standard procedures in this area. Specific areas of focus are currently being identified and prioritized, such as process characterization and efficiency, materials and material properties, hierarchical processing in manufacturing, and big data analytics for smart manufacturing. The new committee will also foster research collaborations with National Network for Manufacturing Innovation institutes, other scientific societies (e.g., ASTM, IEEE) and industry.

ASME is currently soliciting subject matter experts and affected stakeholders to help support this effort, and influence the prioritization of topics to be addressed.

Benefits to Participants of Standards Participation

By participating, you can influence the quality and direction of the standards of your chosen field, and reap personal and professional rewards, such as:
- Networking with the foremost technical experts in your field.
- Awareness of technical issues, and standards and best practices in your industry.
- Broader understanding of other segments of your industry worldwide.
- In some instances, fulfilling the requirements for professional development.

The initial founding members of this new committee include research experts from industry, academia, government, and industry consortia.

Benefits to Supporting Organizations and the Public

Organizations realize direct and indirect benefits when they support employees' membership in ASME Standards & Certification activities, such as:
- Organization's perspective considered in standards development and requirements.
- Enhancement of participating employees' understanding of relevant standards.
- Access to opportunities for shared participation in research and development.

How to participate

Participation is simple. You need to submit an ASME Codes and Standards Personnel Form and ASME Codes and Standards Participation Acknowledgement Form. **Please contact Marian Heller (HellerME@asme.org, +1.212.591.8514) and she will help you with the process.**

FAQs about Standards and Certification
http://tinyurl.com/ostdeen

General information on participation in Standards committee
http://tinyurl.com/plvggme

Codes & Standards

ASME
The American Society of Mechanical Engineers (ASME)

https://cstools.asme.org/csconnect/CommitteePages.cfm?Committee=101978604

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Q&A ???

Sudarsan.Rachuri@hq.doe.gov

Advanced Manufacturing Office (AMO) Multi-Year Program Plan For Fiscal Years 2017 Through 2021

https://energy.gov/eere/amo/downloads/advanced-manufacturing-office-amo-multi-year-program-plan-fiscal-years-2017

Dr. Sudarsan Rachuri
AMO/EERE/DOE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

2018 The NIST & OAGi Workshop, Gaithersburg

Smart Factory Promotion and Standardization in Korea

(Results, Reference Model, Future)

2018. 4. 23

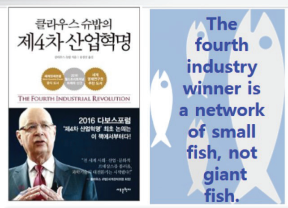
Dong-Hag Choi
Smart Manufacturing
National Standards Coordinator
NSC 국가표준코디네이터 NATIONAL STANDARD COORDINATOR
Korean Agency for Technology and Standards

Contents

1 World Crisis and Industry 4.0
2 Manufacturing Innovation Strategy
3 Smart Factory Promotion
4 Smart Factory Cluster Projects
5 Standardization in Korea

Current Crisis in the World

Industrie 4.0 & Trends in the World



Industry Domain
- Digitization (data)
- Automation (robot)
- Connectivity (platform)
- Customization (apps)
- Industrial convergence
- Resource constraint

New economic phenomenon
- Digital economy
- Sharing economy
- Freelance economy
- Platform economy
- Re-cycling economy
- Re-shoring

4th Industrial Revolution ➜ Convergence & Smart & Speed

Breakthrough technologies (ex: IoT, Big data, AI)

Innovative products & service mkts. (ex: smart home, autonomous vehicles, etc.)

- Smart automation(Hyper-connected)
- Mass Personalization(Superintelligence)
- Speed competition(Small & Fast)

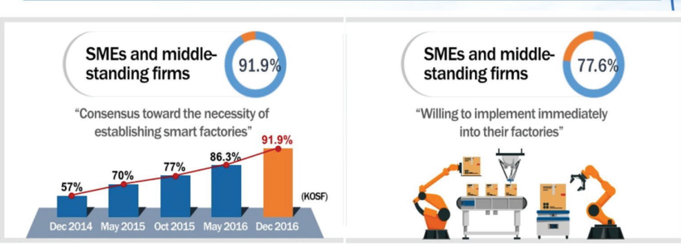
" In the new world, it is not the big fish which eats the small fish, it's the fast fish which eats the slow fish (Klaus Schwab, Chairman of WEF)"

New industrial policy direction : "Manufacturing Innovation Strategy"

NSC 국가표준코디네이터 NATIONAL STANDARD COORDINATOR

Industrie 4.0 & Trends in Korea

Korea Smart Factory Implementation



- Increased needs of Implementation Technologies for multinational corporations and middle standing firms in Korea
- Increasing ICT Industry (IIoS, IIoT, CPPS, Cloud, Big Data, 3D Printing, AR/VR/MR, AI) for Smart Factories in Korea

NSC 국가표준코디네이터 NATIONAL STANDARD COORDINATOR

Manufacturing Innovation Strategy in Korea

- SMEs participate in the smart factory program voluntarily
- Government and Companies collaborate supporting SME to go SMART
- Government Guides Three-Track Approaches

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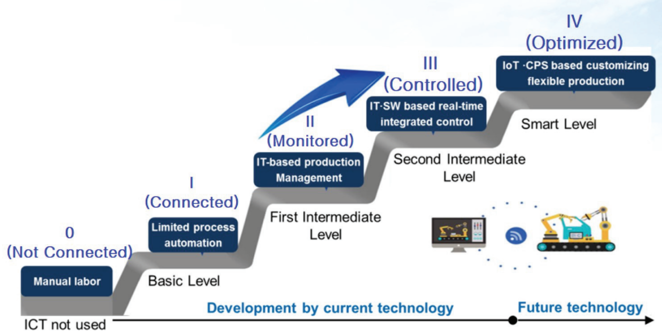
System Implementation Promotion

- Gov. and Co. Collaborate in order to Support SMEs to Go Smart



Korea Smart Factory Foundation(KOSF)

『The Main Organization for Smart Factory Related Activities in Korea』

Transformation & Diffusion
- Smart Factory Transformation for SMEs
- Diffusion of Idea and Technology

Basis Technology
- Representative Factory
- Demo Factory
- Testbed & Usecase

Standard·Manpower
- Standard Development, Certification
- Manpower, Education and Training

Technology Planning
- Adoption of Advanced Solutions and Technologies (A-ICBM*)

* A-ICBM: AI, IoT, Cloud, Bigdata, Mobile)

Result of Smart Factory Promotion

Average of the result from 2,800 Companies ('16E)

스마트공장 추진 성과

생산성	불량률	원가	납기 준수율
30% 향상 Productivity	45% 감소 Defect	15% 절감 Cost	16% 단축 Delivery

('15) 1,240
('17) 5,003
('22) 20,000

매출액 증가 및 기업 신뢰도 향상
* 스마트공장 구축 완료 2,800개사('17.12월) 대상

Revenue
Credibility
Reliability

Case 1 – MES for Vacuum Heat Treatment

Saehan Vacuum Heat Treatment Co (http://heattreatment.co.kr/):
1. First year saving of electricity cost exceeded initial investment($50,000)
2. Reduction of defects by 67%

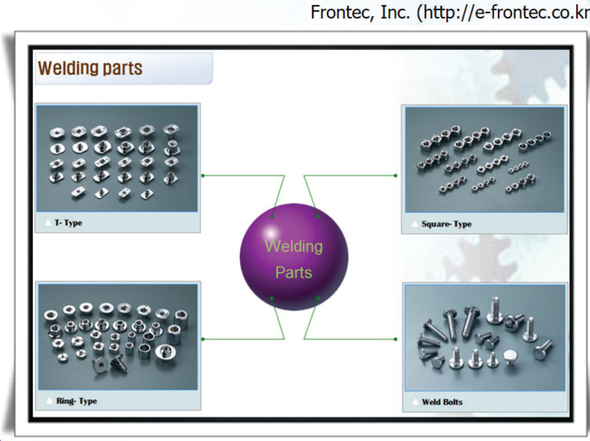
SSMMS: SHVHT Smart Manufacturing Management System

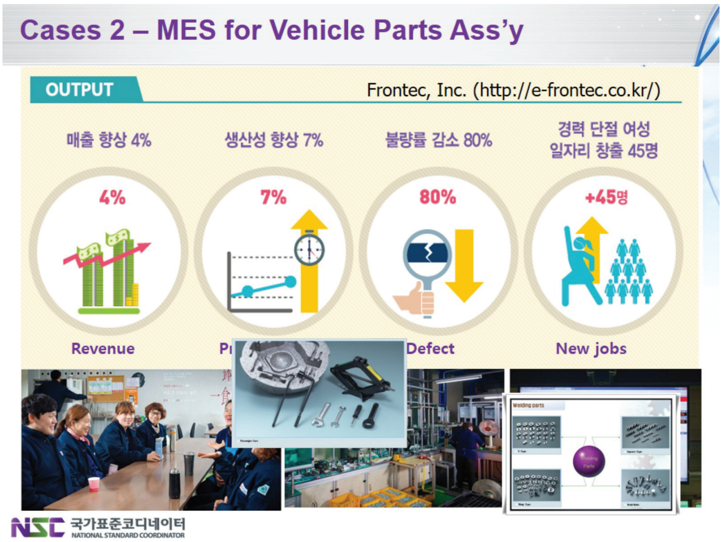
Cases 2 – MES for Vehicle Parts Ass'y

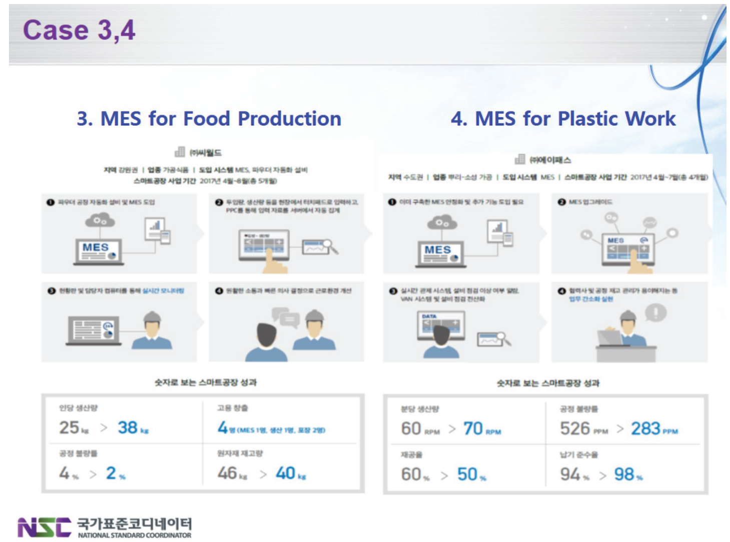
Frontec, Inc. (http://e-frontec.co.kr/)

Cases 2 – MES for Vehicle Parts Ass'y

Frontec, Inc. (http://e-frontec.co.kr/)

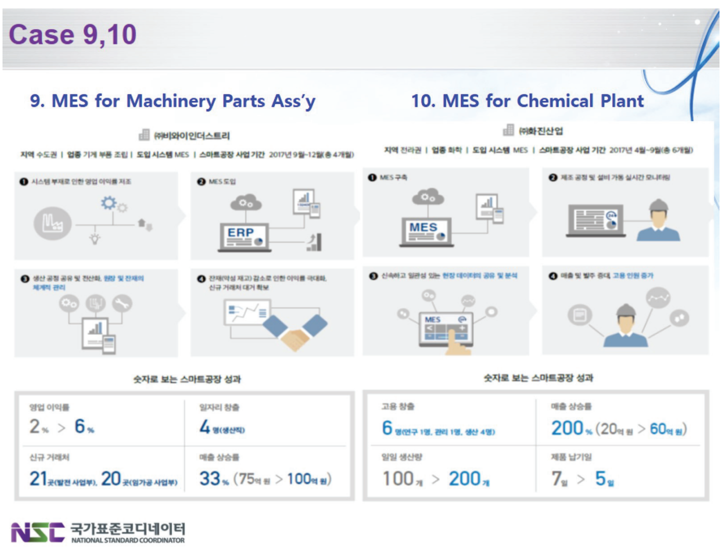


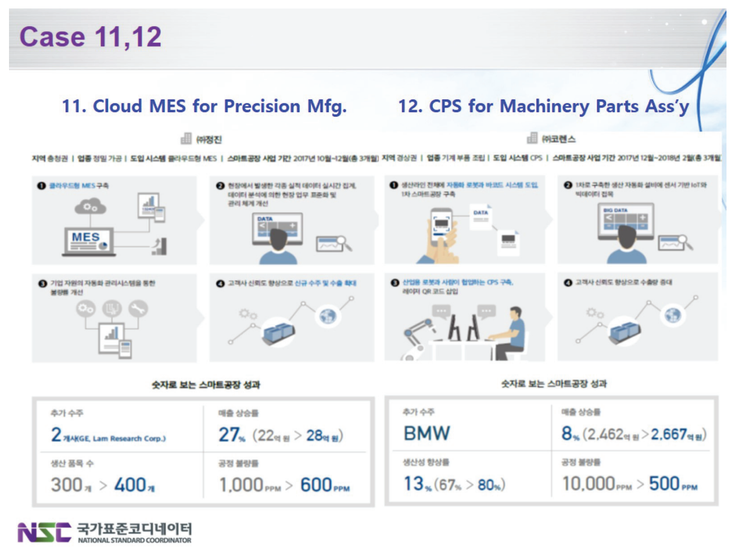

Cases 2 – MES for Vehicle Parts Ass'y
OUTPUT
Frontec, Inc. (http://e-frontec.co.kr/)
매출 향상 4%
생산성 향상 7%
불량률 감소 80%
경력 단절 여성
일자리 창출 45명
4%
7%
80%
+45명
Revenue
Defect
New jobs
국가표준코디네이터
NATIONAL STANDARD COORDINATOR


Case 3,4
3. MES for Food Production
4. MES for Plastic Work
숫자로 보는 스마트공장 성과
25 > 38
4
4 > 2
46 > 40
60 > 70
526 > 283
60 > 50
94 > 98
국가표준코디네이터
NATIONAL STANDARD COORDINATOR


Case 5,6
5. MES for Electronic Parts Ass'y
6. MES for Machinery Parts Ass'y
숫자로 보는 스마트공장 성과
70 > 92
1,900 > 1,300
85 > 96
45 > 65
3
2,000 > 500
18,684 > 17,542
4 > 3
국가표준코디네이터
NATIONAL STANDARD COORDINATOR


Case 7,8
7. MES for Precision Manufacturing
8. MES for Surface Treatment
숫자로 보는 스마트공장 성과
0.45 > 0.3
60 > 30
32 > 28
15~20
5.95 > 2.12
76.3 > 88.9
국가표준코디네이터
NATIONAL STANDARD COORDINATOR


Case 9,10
9. MES for Machinery Parts Ass'y
10. MES for Chemical Plant
숫자로 보는 스마트공장 성과
2 > 6
4
6
100 > 200
7 > 5
국가표준코디네이터
NATIONAL STANDARD COORDINATOR


Case 11,12
11. Cloud MES for Precision Mfg.
12. CPS for Machinery Parts Ass'y
숫자로 보는 스마트공장 성과
2
27
300 > 400
1,000 > 600
BMW
13
10,000 > 500
국가표준코디네이터
NATIONAL STANDARD COORDINATOR

Case 13,14

13. ERP for Plastic Work

14. PLM for Mold

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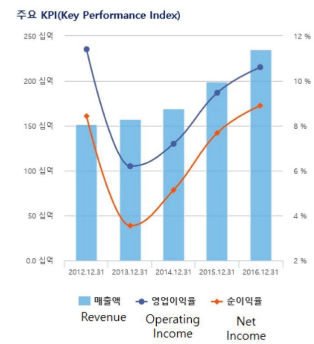
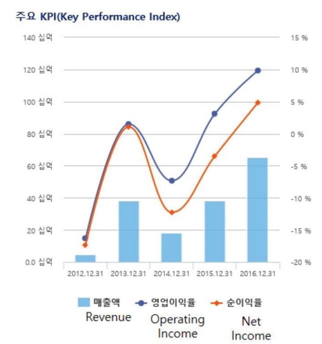
Case 15,16

15. (주)연우 - Cosmetic
www.yonwoo.kr



16. 디에스글로벌㈜ Inspection
www.dsglobal.biz



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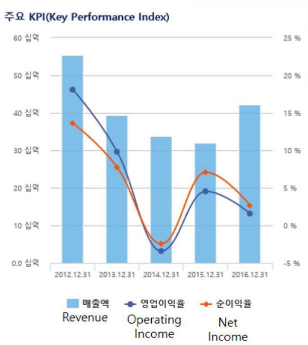
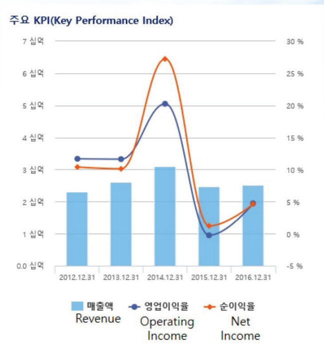
Case 17, 18

17. 미르기술 Inspection
www.mirtech.com



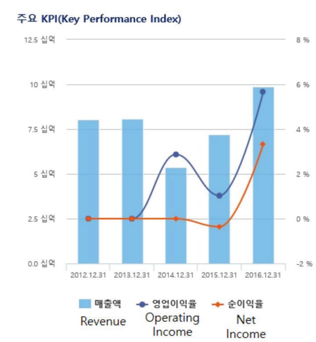
18. 새한열처리 Heat treatment
www.heattreatment.co.kr



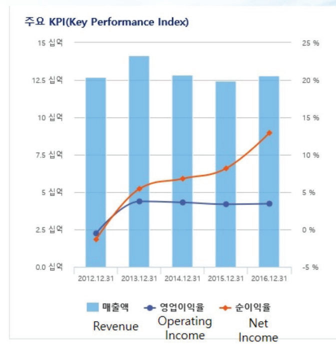
국가표준코디네이터 NATIONAL STANDARD COORDINATOR

Case 19,20

19. 에이엔텍 Semicon. EQ.
www.mirtech.com



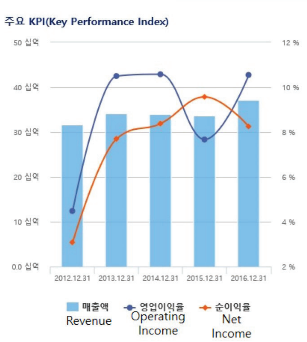
20. 유남전기, Copper Parts
www.yneco.com



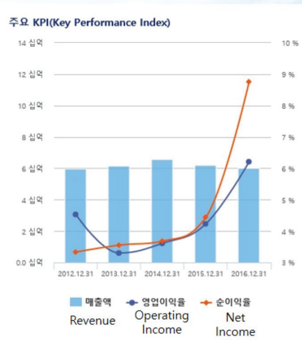
국가표준코디네이터 NATIONAL STANDARD COORDINATOR

Case 21,22

21. 프럼파스트, Plumb
www.plumbfast.co.kr



22. 한국나노텍, Painting
www.paintb.modoo.at



국가표준코디네이터 NATIONAL STANDARD COORDINATOR

Smart solution providers behind the scene

This study analyses the opportunities and challenges of international cooperation in the field of Industrie 4.0. It is based on more than 150 interviews and discussions with experts from Germany, China, Japan, South Korea, the UK and the US. The latter five countries are set to become important future suppliers of Industrie 4.0 solutions and are therefore potentially attractive cooperation partners for Germany.

(p6, Executive Summary, 'Industrie 4.0 in a Global Context', Acatech 2015)

South Korea, important future suppliers of Industrie 4.0 Solutions

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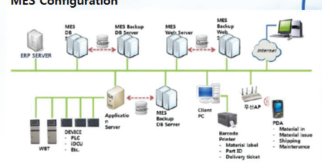
Smart solution providers behind the scene(1)

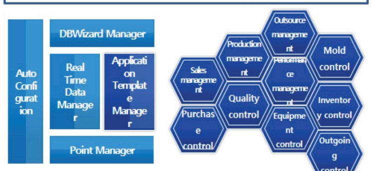
MES Solution (DABOM - MES)

- It integrates 4M (Man, Machine, Material, Method) information of production resources with M2M technology of wired and wireless sensor.
- Applies Web service standard MES application technology to enable real-time central management of multiple plants scattered around the global.

MES Configuration



References

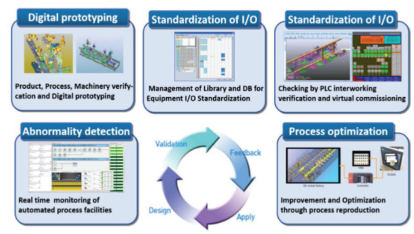


Smart solution providers behind the scene(2)

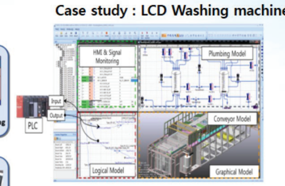
CPS Solution (UDM Platform - CPS)

- This CPS platform could support strategic decision making solution by connecting all the information on vertically & horizontally integrated horizons verifying, sharing and analyzing cyber-physical models & data.

System Components



Case study : LCD Washing machine



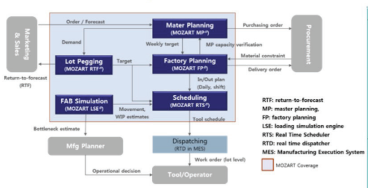
References

Smart solution providers behind the scene(3)

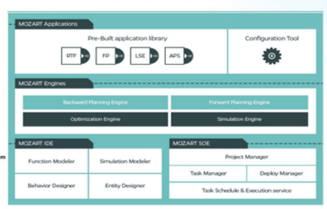
APS Solution (MOZART - APS)

- Integrated planning and scheduling solutions for smart operation management of semiconductor and display industries
- Achievement : Keeping the level of accuracy by more than 95% and reducing the cycle time by 20 to 30%

Scope



APS Architecture



References

Cooperating Organizations for KOSF

Participants: KCCI, KITECH 한국생산기술연구원, KETI 전자부품연구원, SAMSUNG, HYUNDAI, KATS Korean Agency for Technology and Standards, kpc 한국생산성본부, SBC 중소기업진흥공단, KOSMIA 한국스마트제조산업협회, 창조경제혁신센터, KBIZ 중소기업중앙회, KSA Korean Standards Association

Government: Ministry of Trade, Industry and Energy; Ministry of SMEs and Startups; Korean Agency for Technology and Standards

Supporters: SAMSUNG, HYUNDAI, posco, HYUNDAI HEAVY INDUSTRIES CO.,LTD., LG, DOOSAN, SK, kt, Hanwha, LOTTE, HYOSUNG

Smart Factory Cluster Projects

Objective of Smart Factory Cluster

- Developing the advanced smart factory reference model for leading the smart Innovation in the industrial complex.

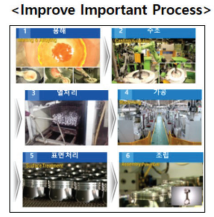
Six Projects

- Developing the Representative Smart Factory
  - * Best practice system for SMEs which high-tech Smart manufacturing technologies are concentrated.
- Developing the Demo Smart Factory
  - * Test-Bed center for smart manufacturing technology and system .
- Smart Communication Infra
  - * Big-data center for manufacturing information analysis, cloud service for factories, IoT standard
- Smart Factory Propagation in Banwol·Sihwa industrial complex
- Learning Program for Factory Workers
- Tour Program of Representative and Demo Smart Factory

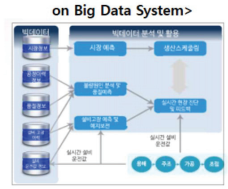
Representative Smart Factory

- **"Best Practice" for SMEs**
- **Establish Smart Factory Construction Standard on Root Industry(casting, welding, heat/surface treatment), laying the foundation of technology localization**
- **Two more Representative Smart Factories are going on development**

<Improve Important Process>



<Intelligent Operation based on Big Data System>

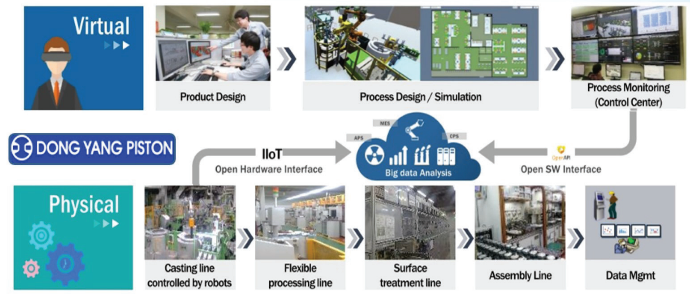


<Digital Synchronization>

SMIC(Smart Manufacturing Innovation Center)

Smart Factory Cluster Projects - Demo Factory

	Before (March 2016)	After (Present)
Automation	- Limited automation only for specific production	- Implement an automated infrastructure to support multi-product and flexible production
Digitalization	- Separated operation for digitalized design and real-time process monitoring - Partially production control automation	- Connecting virtual and physical production based on the IoT·CPS Intelligent control and automation based on the Big data



Smart Factory Cluster Projects - Demo Factory

Propose direction of 4th industrial revolution (Lighthouse Project)

- Suggest direction how to upgrade the domestic manufacturing industry
- Suggest the application plan considering global and industrial standards (de-facto)
  - » Propose application plans of the IEC/ISO, Industry 4.0 and IIC standards and their linkage

Establish the global smart factory reference model (Reference Testbed)

- Develop the testbed using 8 smart manufacturing technologies
- Operate interoperability certification lab based on the standards
  - » Environments for technical tests (linked with international certification test)

1	Big Data	5	Cloud
2	CPS	6	Robots
3	IoT	7	3D Printing
4	Smart Sensor	8	AR/VR

Implementation of Demo Smart Factory by connecting between 'virtual manufacturing' and 'physical manufacturing'

Optimization of productivity | Reduction of defects | Optimization of automation

Demo Factory – Interoperability

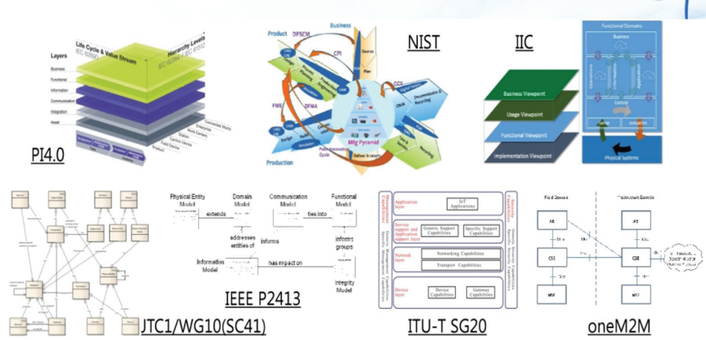
Development of standardized interoperability certification test device and operational environment

- Build environment for interoperability test based on smart factory standards like OPC-UA, AML, oneM2M…
- Interoperability test through participation of 12 local companies

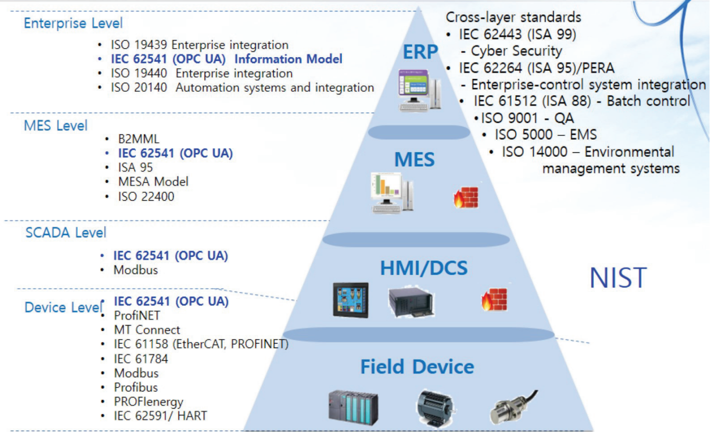
- Apply global smart factory standards (Germany, USA) and collaborate technically
- Develop a reference model to evaluate major smart factory standardized technologies
- Encourage the participation of solution companies to increase competitiveness in manufacturing

National Standards Coordinator KATS

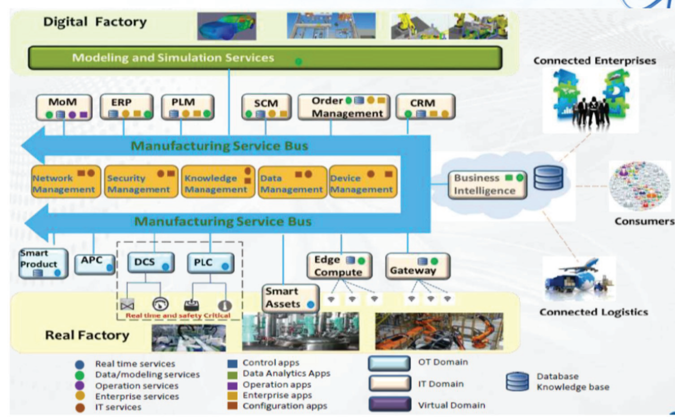
Smart Manufacturing Reference Models



Enterprise/Control System Integration Standards



NIST Manufacturing Transformation



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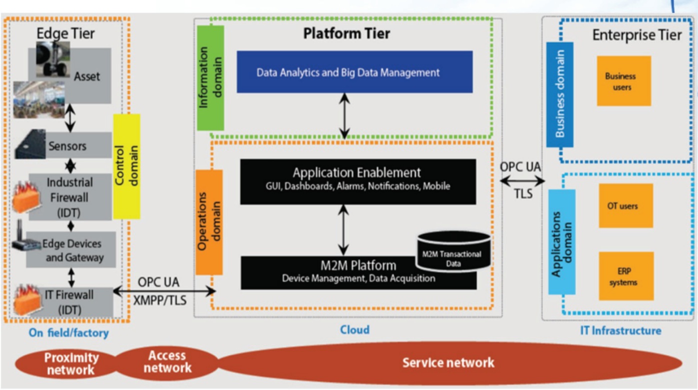
IIRA Structure

IIRA 3-Tier Architecture



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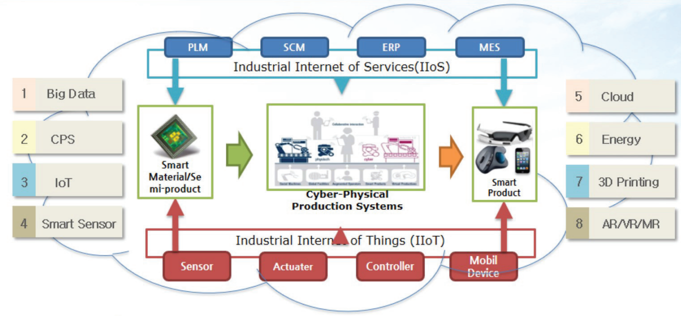
Smart Manufacturing 8 Technology & 12 Industry

12 New Industry	① Electricity and autonomous car ② Smart Ship ③ IOT appliance ④ Robot ⑤ Bio−Health ⑥ Aviation · Drones ⑦ Premium consumer goods ⑧ Energy new industry ⑨ Advanced materials ⑩AR·VR ⑪ Next generation display ⑫ Next generation semiconductor



Smart Mfg. Ecosystem	Cloud based (IIoT, IIoS, CPPS)➔Smart 4M1E➔Smart Plug & Working Platform

*Ref. 2017 Smart Factory Technical Roadmap / 2017 Smart Factory Standardization R&D Roadmap / Smart Manufacturing National Standards Coordinator

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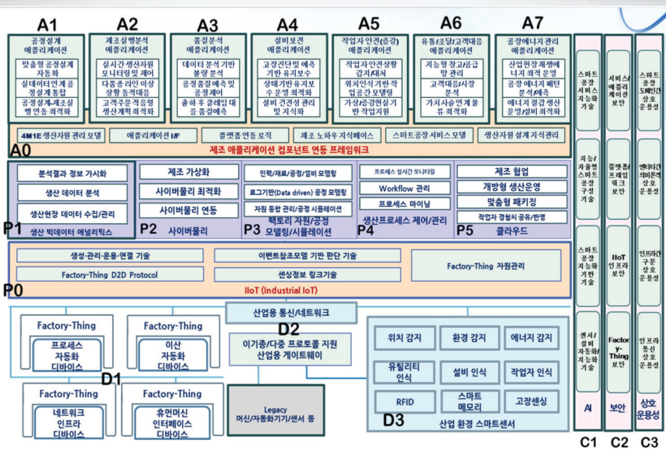
Smart Manufacturing System Components MAP



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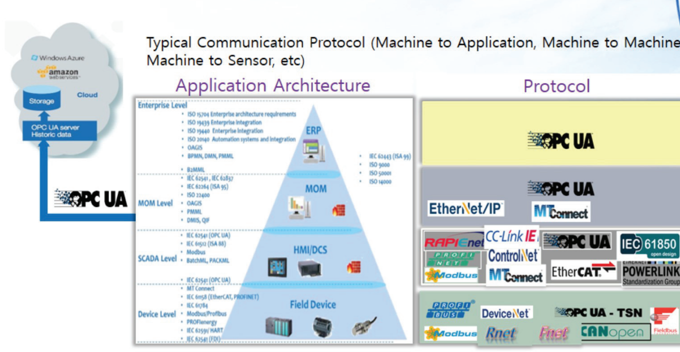
Industrial Communication Protocol 1

NIST

Typical Communication Protocol (Machine to Application, Machine to Machine, Machine to Sensor, etc)



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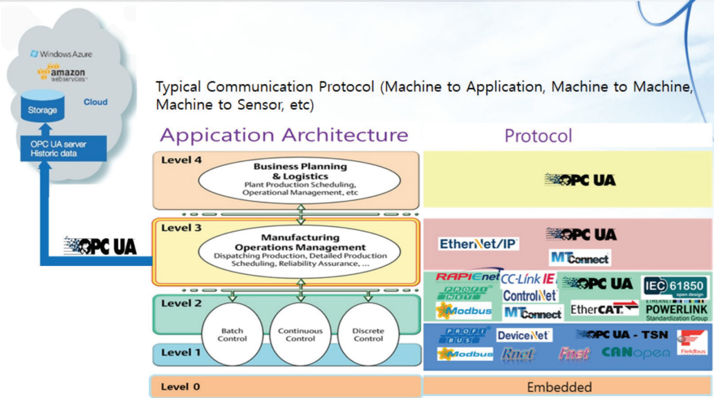
Industrial Communication Protocol 2

ISA-95 Arch.

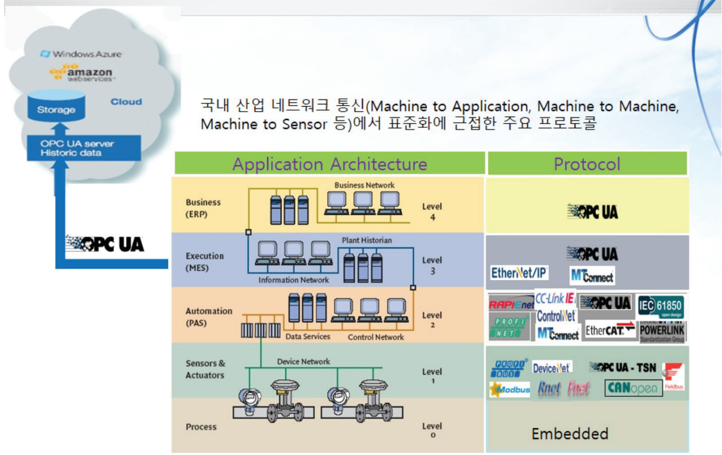
Typical Communication Protocol (Machine to Application, Machine to Machine, Machine to Sensor, etc)



Industrial Communication Protocol 3

ISA-95 Process

국내 산업 네트워크 통신(Machine to Application, Machine to Machine, Machine to Sensor 등)에서 표준화에 근접한 주요 프로토콜



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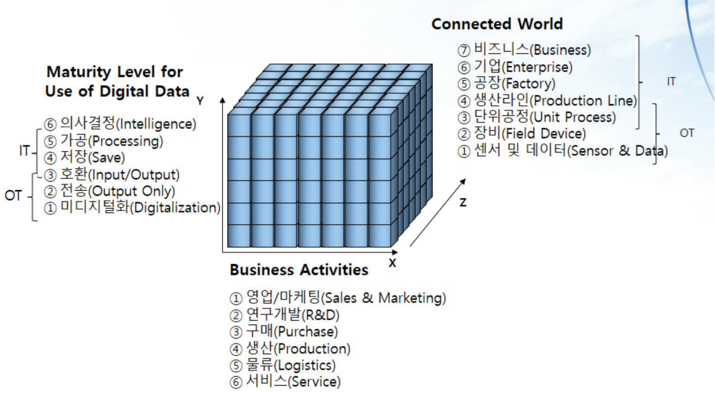
Model Structure

Standard



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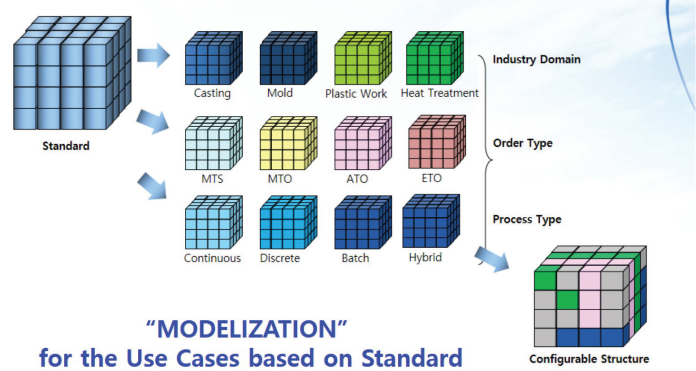
Modelization & Use cases

Extended & Advanced



"MODELIZATION"
for the Use Cases based on Standard

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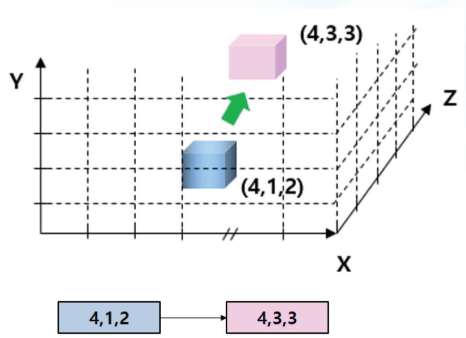
Model & Use cases

Self Diagnosis & Action Plan



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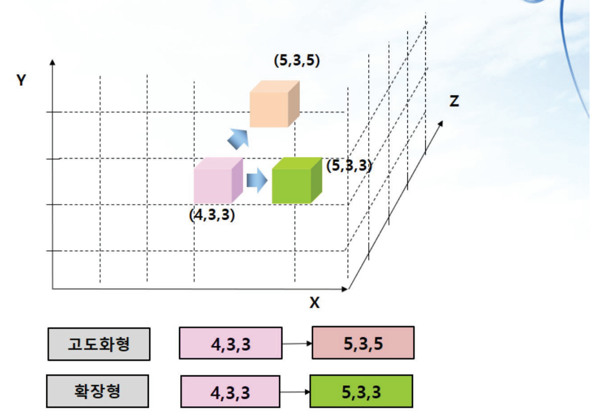
Model & Use cases

Extended and Advanced Model



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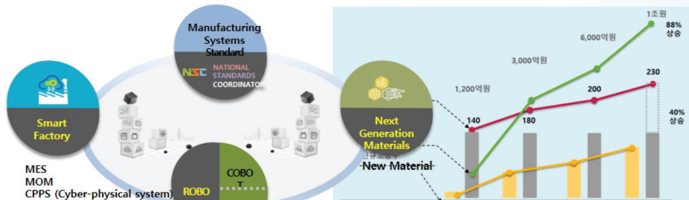
Use Case - Standardization for SHINSHINSA (on going)

[Issue]
Press Factories have Same Problem

[Before]
6 persons, 15 sec/each, 2,000pcs/day

[After]
1 person, 10 sec/each, 2000pcs/day

- LG Electronics
  - Purchasing Team,
  - Mutual Growth Team,
  - Institute of Production and Technology
- SHINSHINSA
- POSTECH
- Partner#1, #2, #3
- National Standards Coordinator KATS



구 분	(2018)년 (기술개발 전년)	(2019)년 (개발종료 해당년)	(2020)년 (개발종료 후 1년)	(2021)년 (개발종료 후 2년)
신규고용(명)	10	50	70	100
상시고용(명)	130	130	130	130

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Smart Manufacturing NSC KATS

KATS

(Korea Agency for Technology and Standards)

Promote Industrial Competitiveness

Improve Standard of Living

Intelligent Infrastructure

[redacted]

Standardization
- KS establishment & Certification
- National Standardization Plan
- ISO/IEC National Body

Conformity Assessment
- KOLAS , KAS, KAB

Product Safety
- Electric Appliances
- Consumer Product
- Children's Product

Metrology
- Control Legal Metrology

TBT
- TBT Affairs for WTO and FTA

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Thanks

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National Standards Coordinator
Korea Agency for Technology and Standards

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KATS 국가기술표준원
KOSMIA 한국스마트제조산업협회

Introduction to Intelligent Manufacturing Research Center (iMRC)

Fan-Tien Cheng
National Cheng Kung University

April 23, 2018

iMRC Mission Statement

- **Improving production efficiency and yield rate is a worldwide goal**
  - To stay competitive in a globalizing world economy, applying information and communications technology (ICT) to improve manufacturing efficiency and yield is the common practice of the manufacturing industry around the world. Germany's Industry 4.0 is one of the examples.
- **Smart Machinery Industry Program**
  - Taiwan Government promotes "**Smart Machinery Industry Program**" to provide more intelligent manufacturing options.
- **iMRC's** mission is to **realize the goal of manufacturing zero-defect products.**
  - To cooperate with the "**Smart Machinery Industry Program,**" iMRC integrates the researches from interdisciplinary and inter-university collaboration. **iMRC provides various kinds of intelligent manufacturing services on the cloud based on the Advanced Manufacturing Cloud of Things (AMCoT) framework so as to develop a comprehensive intelligent manufacturing cloud service system**. iMRC is dedicated to equipping the production lines of various industries with the intelligent manufacturing capabilities, so that the manufacturers are able to produce **Zero-Defect products as well as high efficiency and high flexibility machine tools.** **(Intelligent manufacturing capabilities includes single-machine intelligence, production-line intelligence, and fab-wide intelligence.)**

The Importance of Quality and the Visions of Industry 4.1

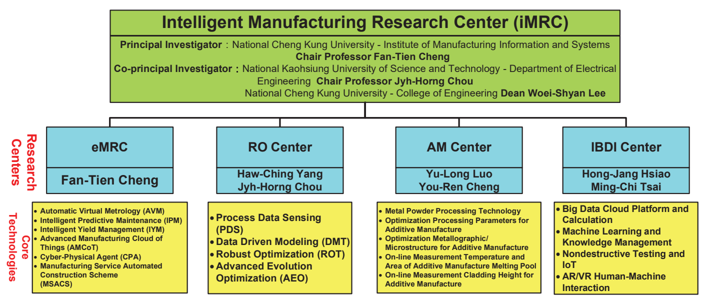
- **Industry 4.0 values productivity, but overlooked the importance of quality**
  - Industry 4.0 stresses highly on improving the productivity of production lines, but with less emphasis on quality. This makes it impossible for the factories to achieve the goal of zero defects. The key reason is the lack of an affordable and practical **online real-time total inspection system.**
- **Samsung Note 7 battery defects causing over 24 billion USD of loss**
  - Take the flaws of the Samsung Note 7 cellphone battery production process for example, **while demanding high productivity from the production line, the quality of the products is relatively neglected**. According to the estimation of Bloomberg, Samsung lost 2 billion USD of revenue and the market value of its stock depreciated about 22 billion USD.
- **Zero Defects and the Visions of Industry 4.1**
  - From the example mentioned above can we understand that it's important not to overlook the quality of products while pursuing productivity. By integrating the technologies such as **Automatic Virtual Metrology (AVM), Intelligent Predictive Maintenance (IPM), Intelligent Yield Management (IYM), and Advanced Manufacturing Cloud of Things (AMCoT) into the industry 4.0 platform, the goal of zero defects can be achieved.** This is defined as "**Industry 4.1**" by professor Fan-Tien Cheng. **The intelligent manufacturing system developed by iMRC can realize the visions of Industry 4.1.**

332 IEEE ROBOTICS AND AUTOMATION LETTERS, VOL. 1, NO. 1, JANUARY 2016

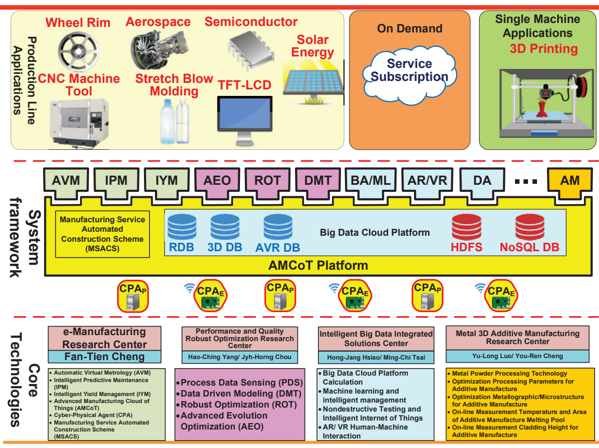
Industry 4.1 for Wheel Machining Automation

Fan-Tien Cheng, *Fellow, IEEE*, Hao Tieng, *Student Member, IEEE*, Haw-Ching Yang, *Member, IEEE*, Min-Hsiung Hung, *Senior Member, IEEE*, Yu-Chuan Lin, *Student Member, IEEE*, Chun-Fan Wei, and Zih-Yan Shieh

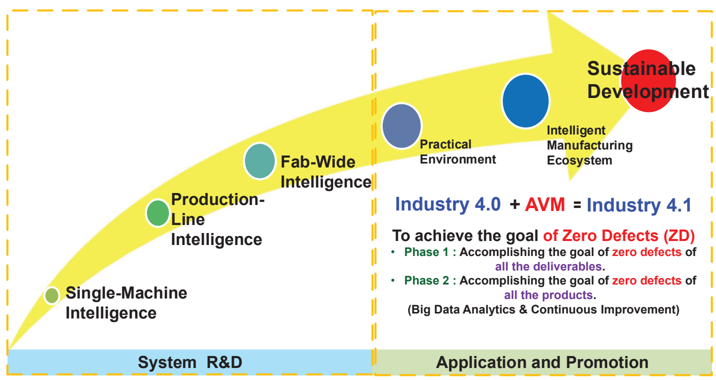
Research Teams and Members



Intelligent Manufacturing System Framework



iMRC Technology Roadmap



Missions of iMRC

- Our Intelligent Manufacturing Research Center is dedicated to assist various Manufacturing Industries to realize the visions of Industry 4.1.

- Phase 1：Accomplishing the goal of having zero defects of all the deliverables.
- Phase 2：Accomplishing the goal of having zero defects of all the products.
  (Big Data Analytics & Continuous Improvement)

全自動虛擬量測

Automatic Virtual Metrology (AVM)

Abstract

Abstract

- Virtual Metrology (VM) is a method to conjecture manufacturing quality of a process tool based on data sensed from the process tool when physical metrology is not available to achieve the goal of total inspection.
- In other words, VM can turn the offline sampling inspection with metrology delay into online and real-time total inspection.
- The Automatic Virtual Metrology (AVM) system developed by our team has been applied to high-tech industries such as semiconductor, TFT-LCD, and solar-cell industries. Recently, the AVM system has also been deployed in the traditional machine-tool and aerospace industries such as Wheel Manufacturing Automation and Engine-Case Manufacturing.

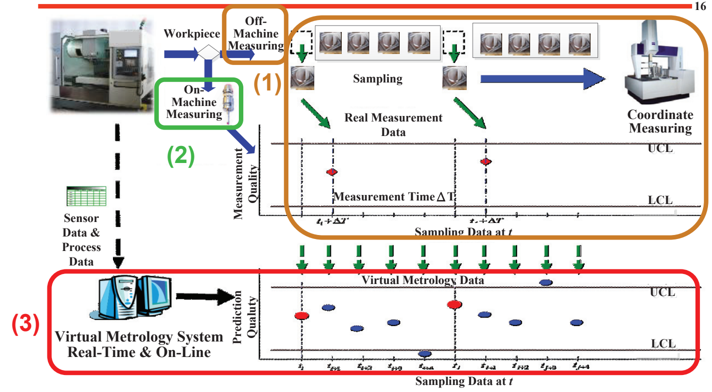
Industrial Requirements for Total Inspection

Industrial Requirements and Expectations to Total Inspection

- To save the costs, the industries adopt sampling inspection to conduct quality monitoring in the present stage, but this cannot achieve comprehensive quality control.
- To economically reach the goal of total inspection, the development of virtual metrology (VM) technology is required.

VM Definition

Virtual Metrology (VM) for Machine Tools



- VM can convert sampling inspections with metrology delay into real-time and on-line total inspection.

AVM Demonstrations

Live Demo of AVM for CNC Precision Machining
(At the 2012 Taiwan International Machine Tool Exhibition, 福裕)

AVM Demo for CNC Precision Machining
(October 20, 2015 at ITRI, 工研院)

AVM Demo for Engine-Case Manufacturing
(April 14, 2016 at AIDC, 漢翔)

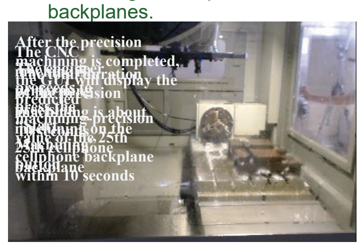
AVM Demo for Cordless-Grease-Gun Manufacturing
(December 26, 2017 at FFG, 友嘉)

AVM Demo for Stretch PET Blow Molding Machine
(January 18, 2018 at Chumpower, 銓寶)

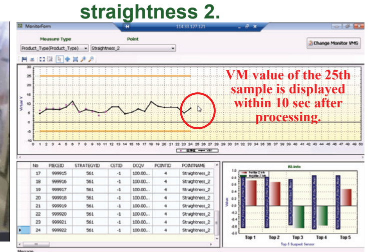
AVM Demo for CD of Photo Process
(February 1, 2018 at ASE, 日月光)

Live Demo of AVM for CNC Precision Machining
(At the 2012 Taiwan International Machine Tool Exhibition)

- Video showing the precision machining on cellphone backplanes.
- GUI displaying real-time and online VM values of straightness 2.

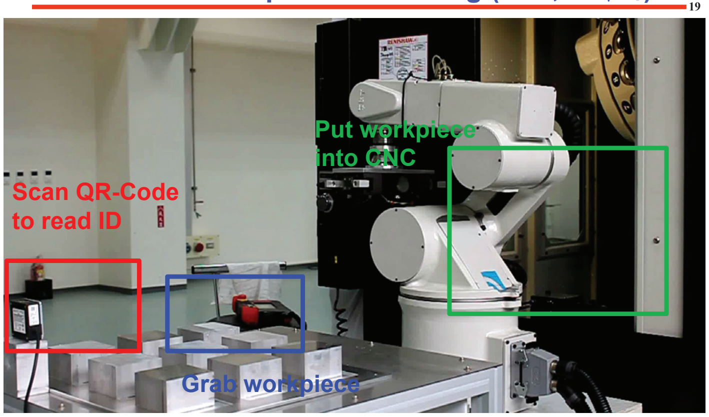


(The CNC tool was located in a machine tool factory in Taichung)

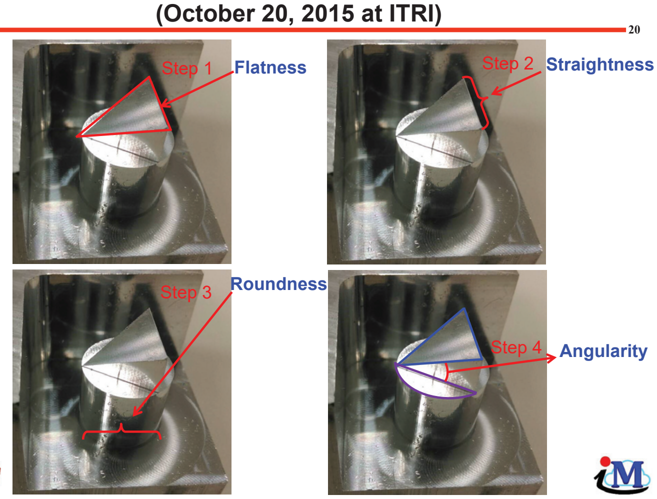


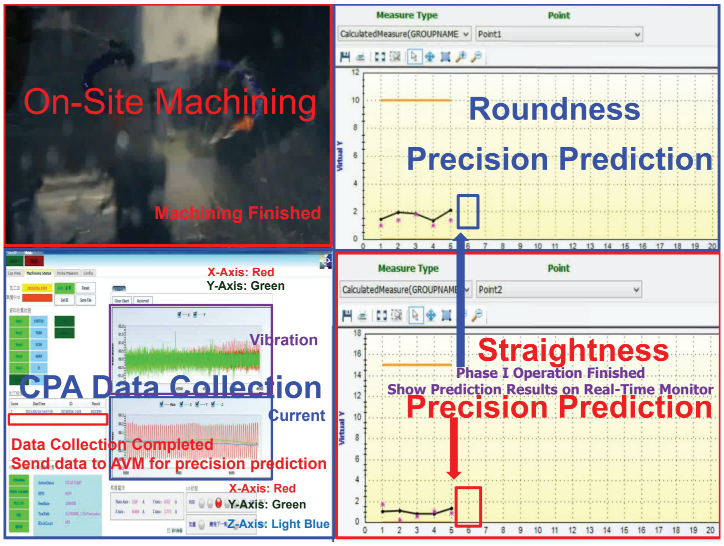
(The GUI was shown at the Exhibition Hall in Taipei)

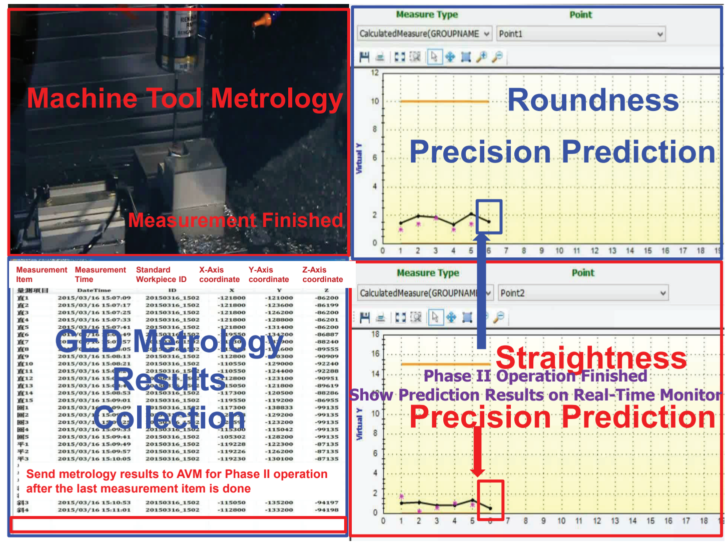
Applying AVM to Standard-Workpiece Machining (ITRI,工研院)



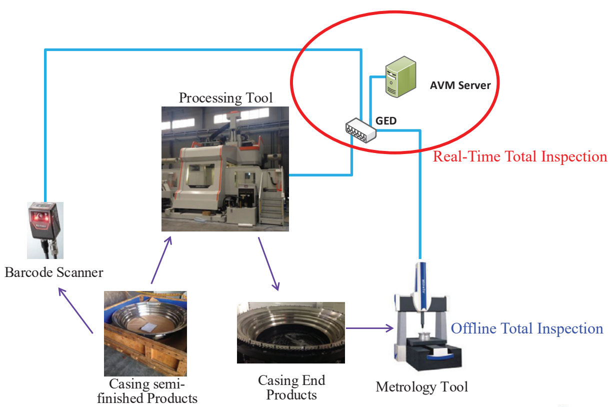
AVM Demo for Standard-Workpiece Machining
(October 20, 2015 at ITRI)





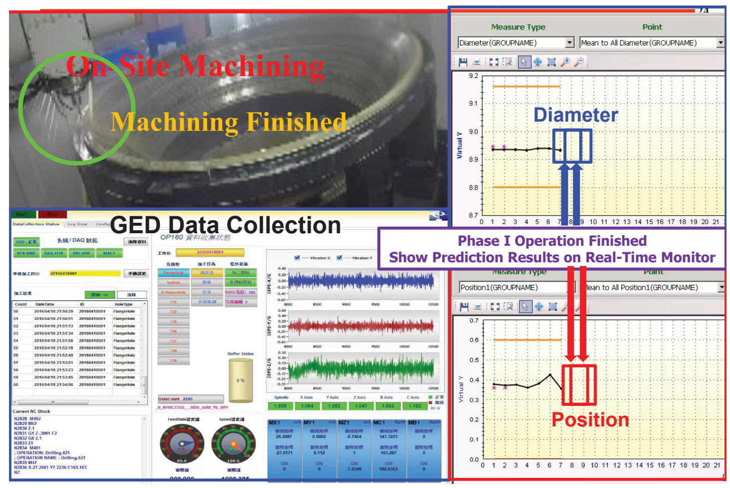


Applying AVM to Engine-Case Machining (AIDC, 漢翔)

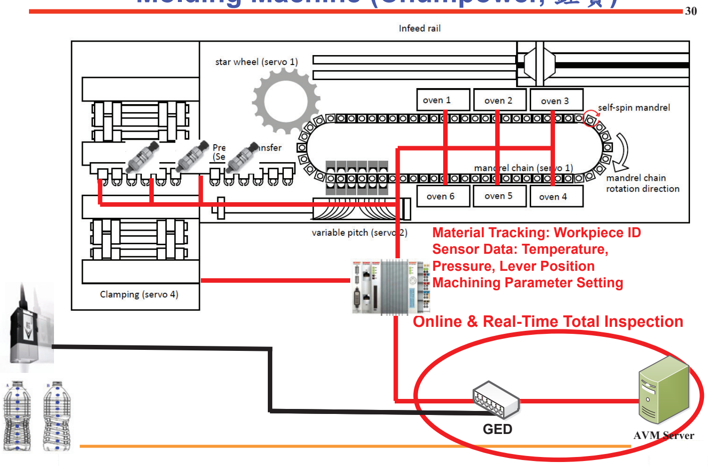


AVM for Engine-Case Manufacturing

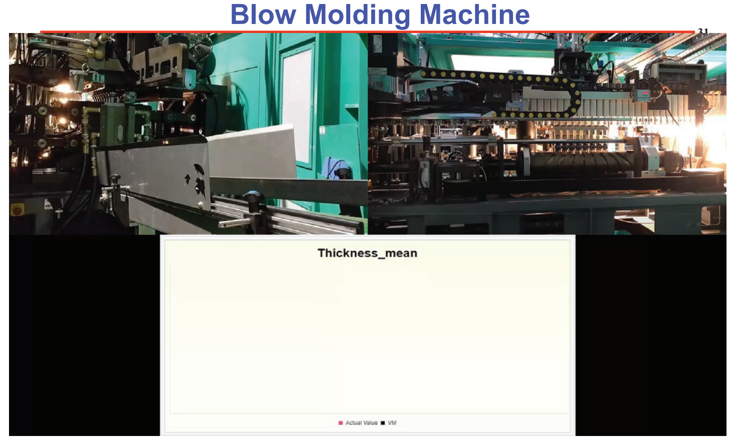
(April 14, 2016 at AIDC, 漢翔)



AVM Demo for Stretch PET Blow Molding Machine (Chumpower, 銓寶)

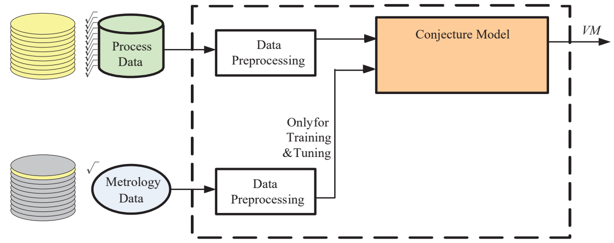


Live AVM Demo for Stretch PET Blow Molding Machine



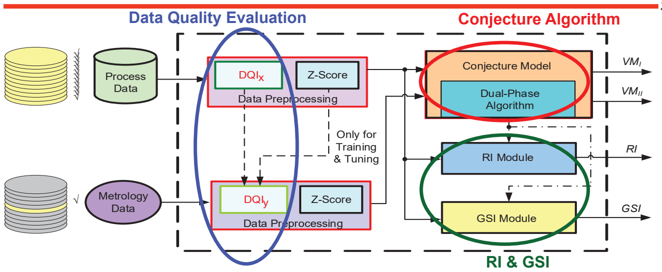
Introduction to AVM Technology

Traditional VM Scheme



- Traditional VM values are provided without the reliance indexes (RIs) so users don't know whether VM values are reliable or not. This phenomenon is attributed to the so-called applicability/manufacturability problem of VM.
- Promptness and accuracy of traditional VM may not be achieved simultaneously. When promptness is emphasized, accuracy is poor; and when accuracy is emphasized, promptness cannot be achieved.
- The traditional VM scheme is not able to perform on-line and real-time quality evaluation of process-and-metrology data collected. As such, abnormalities in process data or metrology data cannot be excluded and will be added to the model tuning or re-training processes, resulting in deteriorated VM accuracy.

Automatic Virtual Metrology (AVM) Scheme



- The AVM system generates the accompanying reliance index (RI) of each VM_I and VM_{II}. Users can check the reliability of the VM prediction via its corresponding RI value.
- Promptness and accuracy can both be taken into consideration in the dual-phase algorithm. Phase I emphasizes promptness to immediately calculate and output the Phase-I VM value (VM_I); Phase II improves accuracy to re-calculate (with the newly refreshed VM models) and output the Phase-II VM values (VM_{II}).
- The AVM system can ensure the quality of process data and actual metrology data on-line and real-time, thus the quality of the outputted VM values can be further assured.

Benefits of Implementing AVM

Benefits of Implementing AVM

- Reduce the cost of purchase (of metrology equipment)
- Reduce cycle time
- Achieve real-time and workpiece-to-workpiece quality total inspection
- Assist to realize the baseline predictive maintenance (BPM)
- Achieve the state of "turning offline sampling inspection with metrology delay into online and real-time total inspection" to meet the standard of yield management big data analysis of Industry 4.0
- Reach the state of Zero Defects of all products

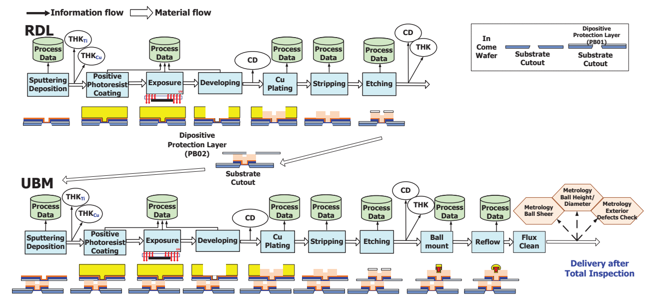
Companies or Organizations that have technology transferred and/or deployed AVM related Patents or Technologies

- Semiconductor Industry: TSMC (台積電), UMC (聯電), ASE (日月光)
- TFT-LCD Industry: AUO (友達), Innolux (群創), CPT (華映)
- Photovoltaic Industry: Motech (茂迪)
- Machine Tool Industry: FEMCO (遠東機械), 友嘉 (FFG)
- Aerospace Industry: AIDC (漢翔)
- Stretch Blow Molding Machine Industry: Chum Power (銓寶)
- Carbon Fiber Industry: Formosa Plastics Cooperation (台塑)
- Organizations: ITRI (工研院) (Machine Tool Technology Center工具機科技中心 & Big Data Technology Center巨資中心) , MIRDC (金工中心)

先進製造物聯雲

Advanced Manufacturing Cloud of Things (AMCoT)

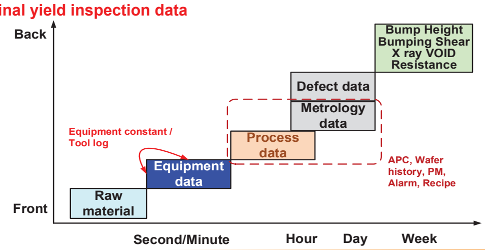
Take Bumping Process for Illustration



RDL: Re-distribution Layer
UBM: Under Bump Metallurgy

Bumping Process Data Types

- Bumping process goes through the above production steps and will generate various types of data in the final yield rate inspection, and these data range from per second (e.g., tool log) to per week (e.g., yield inspection):
  - Different raw material data
  - Tool data (such as tool log: when to change components, or when to stop the tool, etc.)
  - Production data (such as process, maintenance, alarms, recipe, etc.)
  - **Metrology data** and defect data
  - **Final yield inspection data**



Advanced Manufacturing Cloud of Things (AMCoT)

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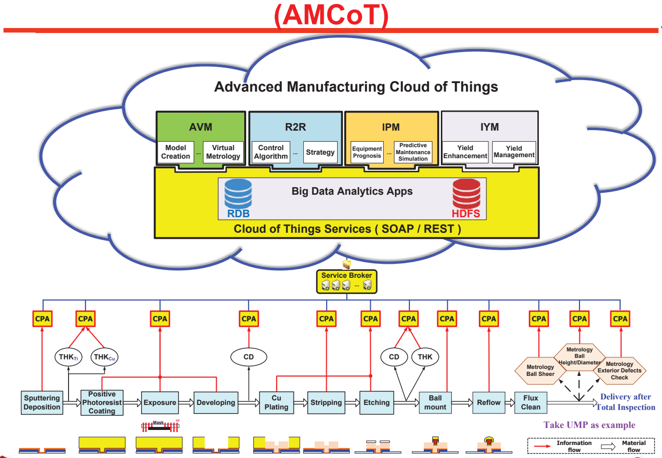
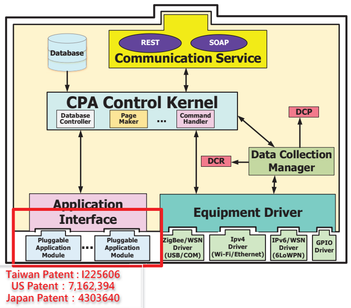


Cyber-Physical Agent (CPA)

An IoT Device

Features of CPA

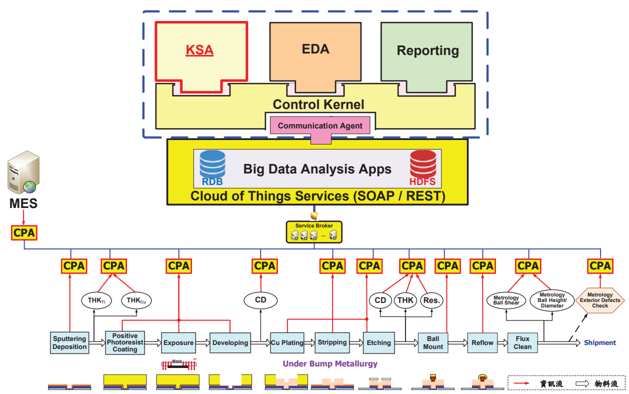
- Data Collection and Communication
  - **Data Collection from all the physical objects is the fundamental feature of CPA.**
  - **Horizontal & Vertical Communications for integrations among physical objects, cyber systems, and human operators can enable reporting and decision making of CPS.**
- Identification
  - **All physical objects in WIPs should be uniquely identifiable.**
  - **CPA should know where the object is and what the object does at any time.**
- Smart Applications
  - **Various Smart Applications can be implemented as pluggable application modules and plugged into CPA.**



CPA Architecture

Cloud-based
Intelligent Yield Management (IYM) System

Intelligent Yield Management (IYM) System Framework



Yield and Cost Changes in Product Development Cycle

- Yields(blue line) will gradually **rise up in the ramp-up phase**, and then keep steady in the mass-production phase. On the contrary, product cost (red line) will decrease as the phases proceed.
- Company's competitiveness would be effectively **enhanced if the blue/red solid lines could be improved into their corresponding segmented lines.**

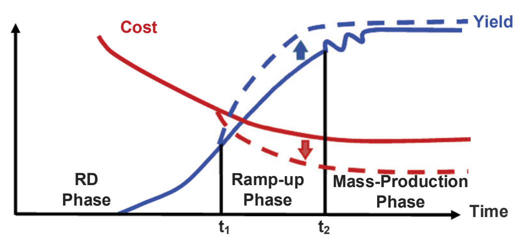
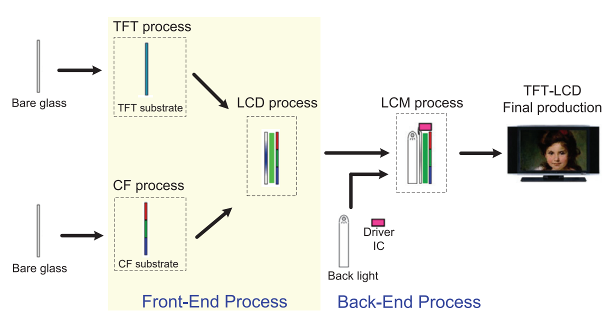


Fig. 1. Yield and cost changes in product development cycle.

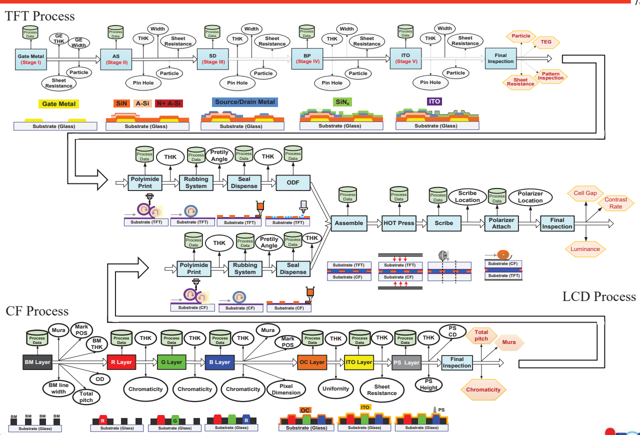
Key-variable Search Algorithms (KSA)
of IYM for Finding the Root Causes of Yield Losses

Process Flow of TFT-LCD Manufacturing

- The TFT-LCD manufacturing flow consists of four processes: TFT, CF (color filter), LCD, and LCM (liquid crystal module).

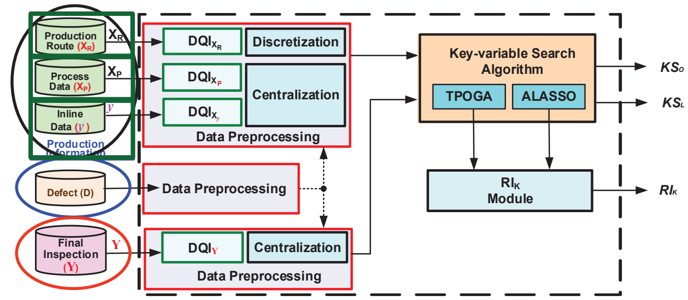


TFT-LCD Front-End Process

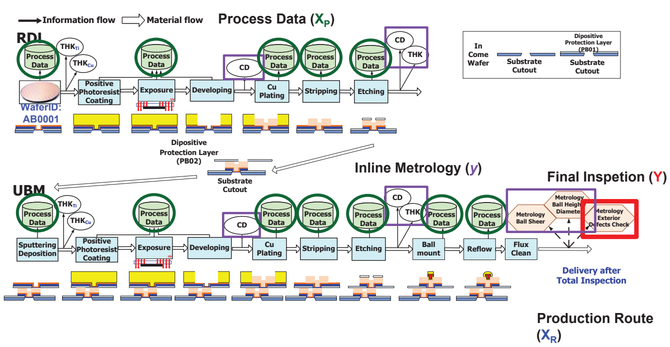


KSA Scheme (2/2)

- Input data of the KSA scheme can be sorted into three types:
  - Production Information
  - Defect
  - Final Inspection
- Production information includes: **1. Production route (X_R), 2. Process data (X_P), and 3. In-line metrology values which may contain real metrology (y) or Virtual Metrology ($\hat{y}$) values.**



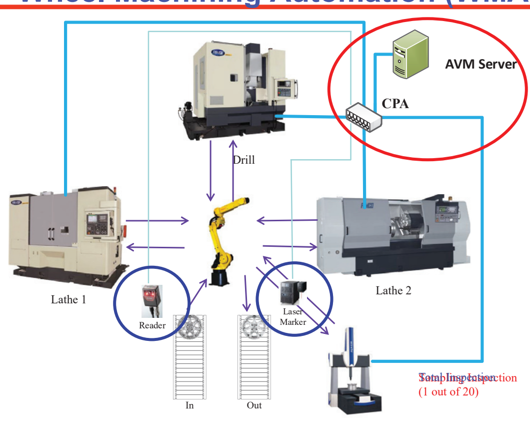
Input Data of KSA
Take Bumping Process for Illustration



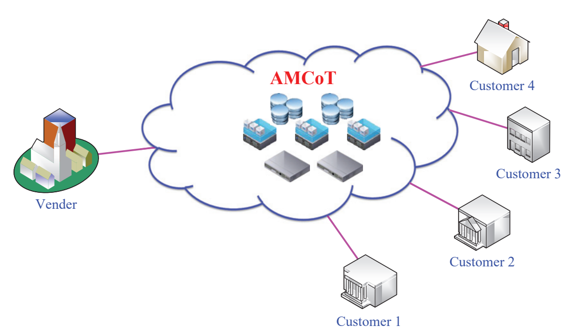
AMCoT for Smart Machinery

Machinery Cloud (機械雲)

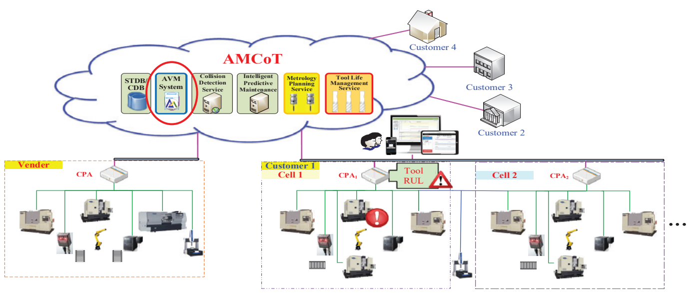
Applying AVM to the Total Inspection of Wheel Machining Automation (WMA)



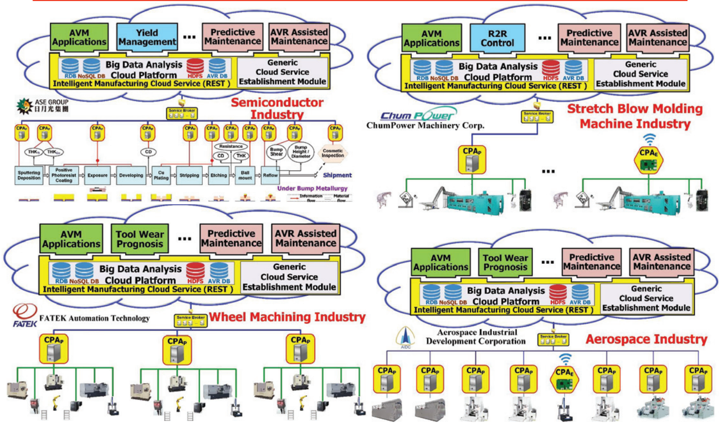
Application Diagram of AMCoT



Integrating WMA's Vender and Customers into AMCoT

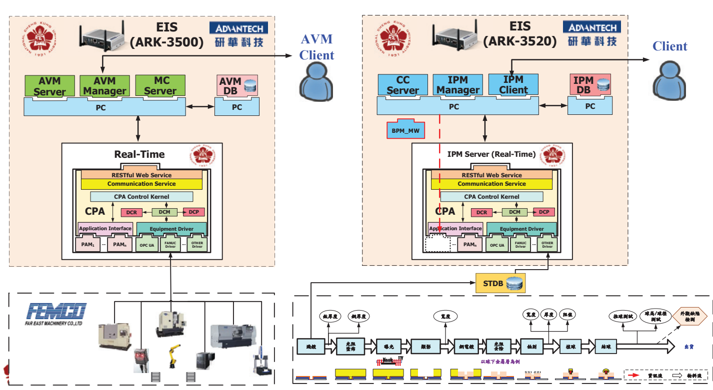


AMCoT Application Scenarios



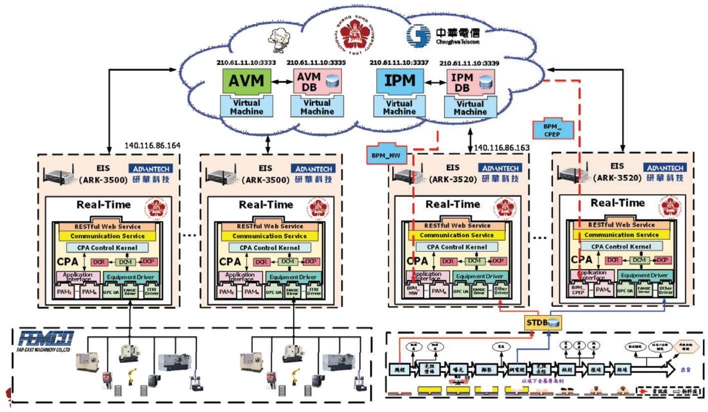
Server-based – AVM & IPM Deployments

Server-based AVM, AVM DB, IPM, and IPM DB are deployed respectively onto two ADVANTECH's EIS IPC。

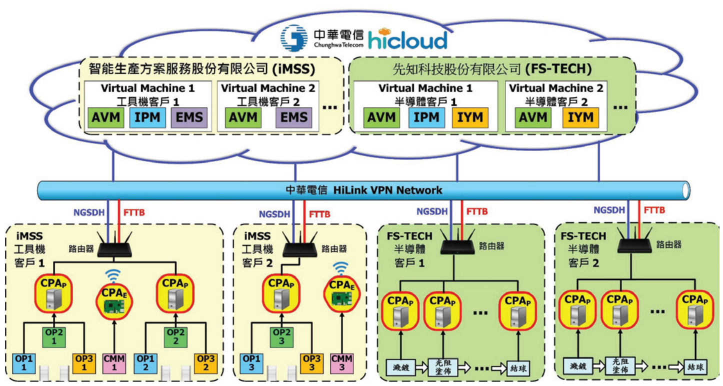


Cloud-based – AVM & IPM Deployments

Four virtual machines including AVM, AVM DB, IPM, and IPM DB are deployed onto the hicloud.



Intelligent Machinery Cloud (智慧機械雲)



Smart Factory: Manufacturing Execution Optimization

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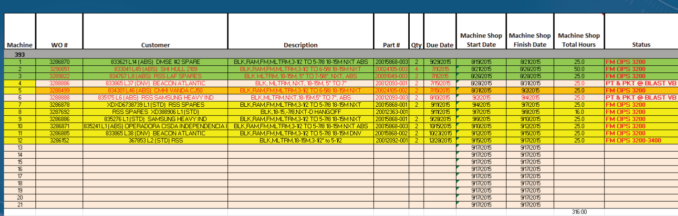
APRIL 23, 2018

Outline

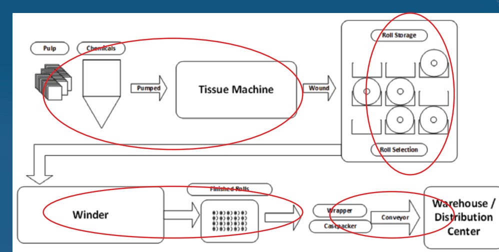
- Introduction
- Manufacturing Execution Optimization
- A Case Study
- Consumable software in Manufacturing

Shop-floor Management

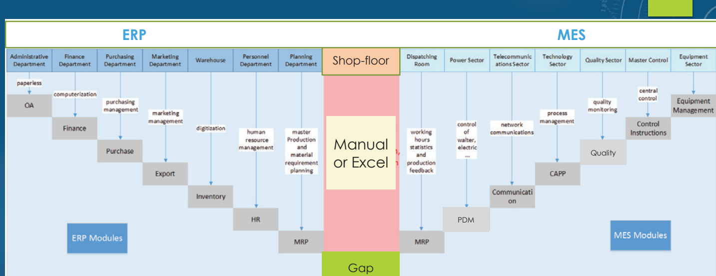
- Transition from "knee-jerk" manual spreadsheet scheduling
  - No validation to schedule changes
  - 15 mins spent per operation to change formatting and calculations



Flow-Shop Real-time Optimization

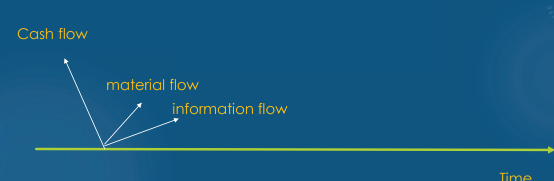


Lost of capacity by 10-15%



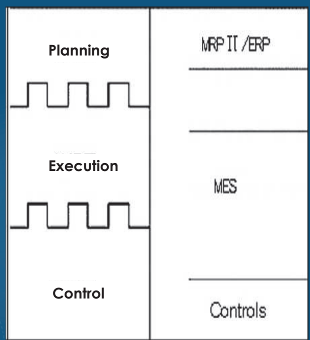
Execution is not optimized

ERP Summary



ERP got the numbers right
Timing related decisions are almost useless
Why?

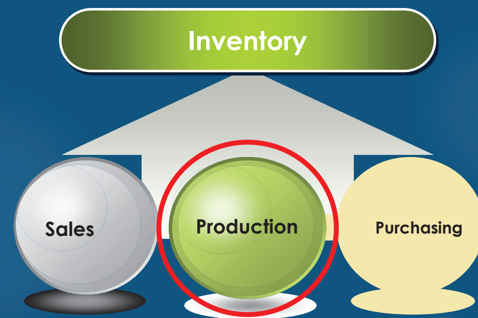
MES: Manufacturing Execution Systems



Planning and scheduling is based on MRP or APS technologies

Keep tracking time related activities

SCM—Use Inventory to deal with uncertainty



Outline

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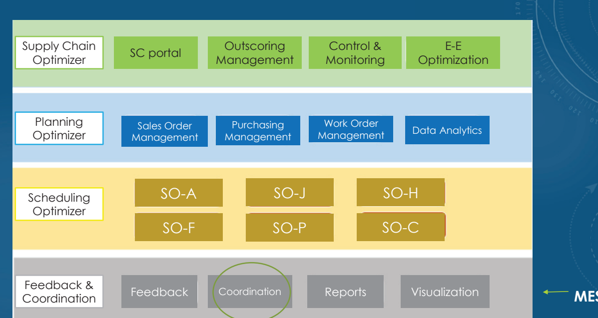
Manufacturing Execution Optimization

- A set of digital tools for enterprise system analysis, design, planning, scheduling, optimization, and improvement (based on Nested Partitions optimization framework)
- Highly configurable & scalable
- Full visibility to production outcomes
- Provide a common platform within Factory for information sharing and exchange
- Supports data-driven decision making in real time

Benefits of MEO

- Greatly improve on-time delivery rate
- Reduce MCT (Manufacturing Critical-Path Time) significantly
- Maximization of facility capacity
- Reduced Overhead count
- Be flexible to changing circumstances and know the impacts ahead of time

MEO Architecture



Scheduling Modules

Job Shop
- little Item repetition, no BOM
- Focus on machine scheduling

Assembly
- Labor-dependent Operation Duration
- Simultaneous Operations
- Various precedence constraints

Specialized
- Heat treatment
- Fabrication
- Paint
- Service

Planning Coordination

- Released Schedule used as starting point (link with scheduling ◆)
- Plans remaining Released Work Orders
- Plans Unreleased Work Orders
- Determines release and completion date
- Balances utilizations and due date performance by **simulating** releases, available hours, or earliest start dates ◆

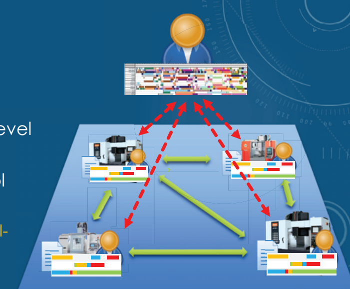
Simulation Optimization Problems

Production Control

- Uses information from ERP
  - FG inventory, WIP inventory w/ released schedule
  - raw inventory w/ released plan
- Assigns supply to demand
- Determines if Sales Order Due Dates can be met
- Minimizes MCT (Manufacturing Critical-Path Time)
  - Total time required to deliver final products
  - Identifying critical Work Orders (shifting) ◆◆

Scheduling-Planning-Control

- Start from shop-floor: the source of variability
- Link local areas together to create coordination
- Bottom-Up visibility to the impact on top-level demand
- Top-down prediction to results and control over top-level demand
- Response to changes and disturbances in real-time



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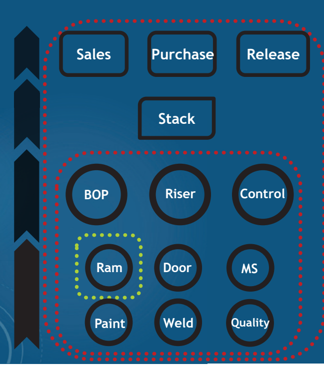
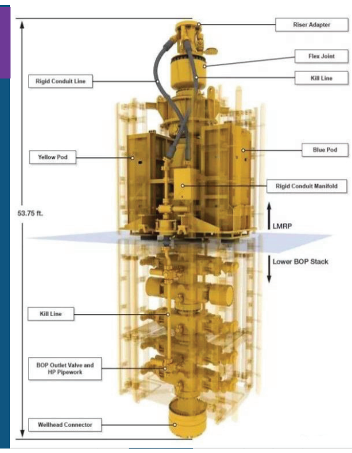
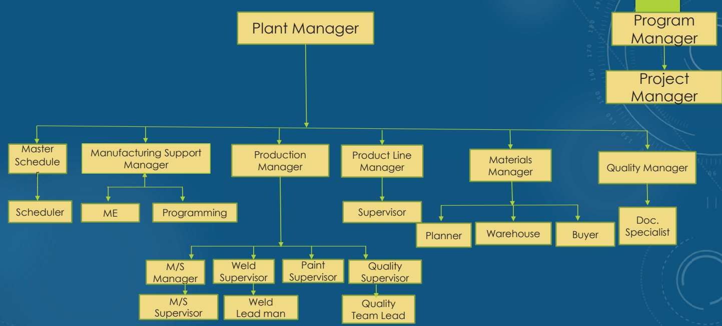
Case Study







Every one who is related to production communicates on the MEO platform

Results

Performance	Before	After	Change
On time delivery rate	30%	85%	↑183%
Capacity Utilization	36%	48%	↑33%
Machine shop Utilization	46%	80%	↑74%
Inventory turnover	25%	53%	↑112%
Number of Schedulers	23	1	↓95%

Saving more than 10 million dollars per year!

Comment from the User

- "The utilization of the MEO is driving us to improve our discipline and causing a **culture change**"

Real-time Simulation Optimization

22

Save 8-10%!

Outline

- Introduction
- Manufacturing Execution Optimization
- A Case Study
- Consumable software in Manufacturing

HISTORY

ERP

LEGACY MONOLITHS → ISOLATED MODULES ······▶ MICRO SERVICES

LEGACY MONOLITHS	ISOLATED MODULES	MICRO SERVICES
One system does everything Custom-built	Collection of systems Function-specific systems Isolated	Function-specific services Integrated custom front-end

MRP

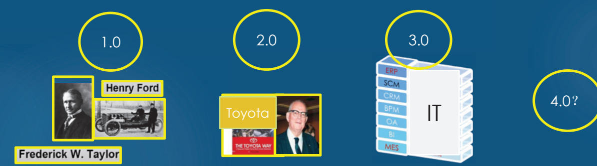
Micro-services encapsulate niche experience and knowledge allowing customers to avoid reinvention and focus on customization within their organization

Nested API

- Using nested layers comprised of solvers and simulation engines
- Decentralized but real-time coordinated with each functional entity
- Deploy sophisticated technology in an accessible format
- Focus on utilizing capabilities instead of building capabilities

Cyber-Physical Production Systems

Production Revolution



Thank You!

engineering laboratory

Standard-based Semantic Integration, Past, Present, and Future

Composable Service-Oriented Manufacturing Systems Workshop

Serm Kulvatunyou, Ph.D.
Systems Integration Division
National Institute of Standards and Technology, USA
&
Scott Nieman
Land O'Lakes

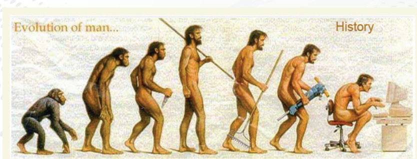
April 23, 2018

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

Objective

- A perspective on history
- R&D activities we are engaging
- Future directions

NIST



HISTORY OF INTEGRATIONS

NIST

Evolution

Pre-Internet: POTS/X.25/T1	Public Internet	Smart Device / Mobile
Stone Age	Bronze Age	Iron Age
Mainframe Cobol Copybook Tape Punch cards Early PC Files Disk EDI VAN NetWare Vs. TCP/IP	Web Servers HTTP HTML Web Services /XML ebXML SOAP RDF	Mobile Apps HTTP REST JSON JSON Schema BPMN Ontologies

NIST

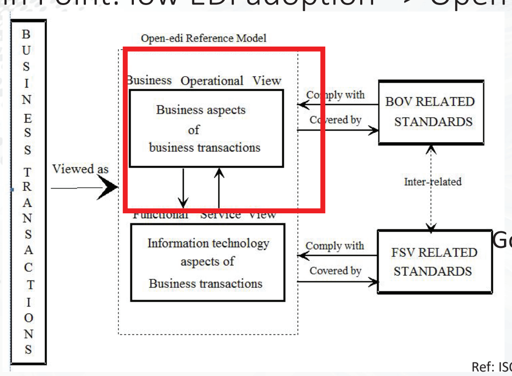
Stone Age (pre-Internet)

Data Exchange Standards	Forms of Specifications	Exchange Formats
--	Cobol Copybook	Fixed position 80 column Tagged data
X12 / EDIFACT	Data Dictionary, Text or Word documents, SEF	Tagged, Text file with varying delimiters, enumerated code lists
STEP	EXPRESS	STEP file exchange format, SDAI

Technology Highlights	Technologies
Transfer technologies	File Import/Export, EDI VAN, Email, ETL, CORBA
Storage technologies	File-based DB, RDBMS

NIST

Pain Point: low EDI adoption => Open EDI



Golden Age?

Ref: ISO/IEC 14462

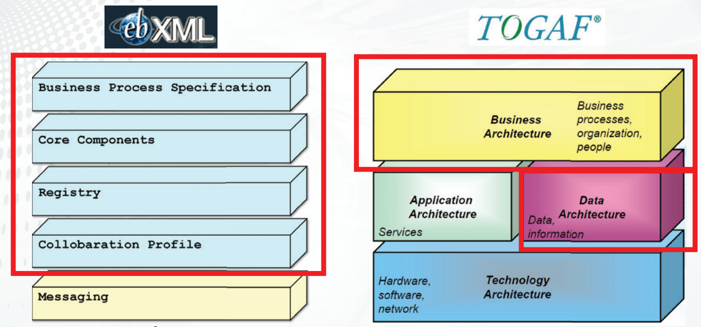
NIST

Bronze Age (Public Internet)

Data Exchange Standards	Forms of Specifications	Exchange Formats
STEP	EXPRESS	EXPRESS-XML
OAGIS	DTD, XML Schema	XML, JSON
MTConnect	XML Schema	XML
OPC UA	XML Schema	Binary, XML
ISO 15926	XML Schema, **OWL**	XML, OWL/RDF, JSON-LD

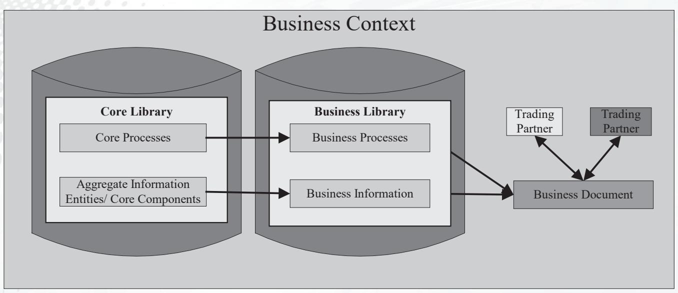
Technology Highlights	Technologies
Transfer technologies	Message-oriented Middleware, EDIINT with AS1 and AS2, RMI-IIOP, Web Services (SOAP, WSDL, BPEL, ebXML), Enterprise Service Bus (ESB), REST (Swagger, ODATA),
Storage technologies	NoSQL

Pain Point: Need better Business Requirements



Ref: ISO 15000 Series

How do we provide context to the data?

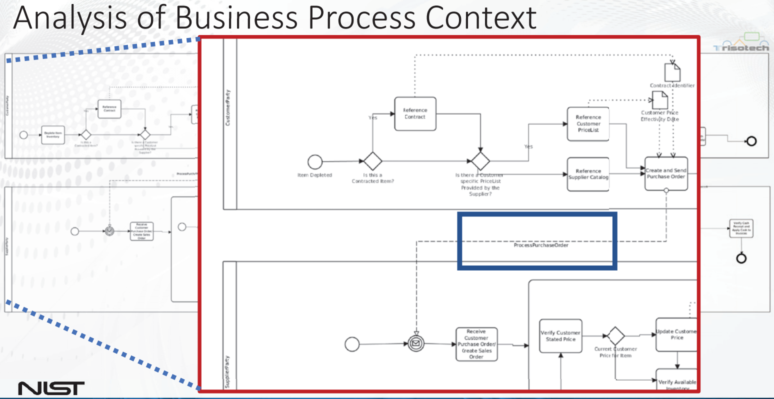


Iron Age (Past Few Years and Forward)

Data Exchange Standards	Forms of Specifications	Exchange Formats
STEP	SysML => EXPRESS, OWL, XML Schema, etc.	EXPRESS, XML, OWL/RDF
OAGIS	CCTS RDB => XML Schema, JSON Schema, OWL, etc.	XML, JSON, RDF, JSON-LD, Protobuf, etc.
OPC UA	UML => XML Schema, OWL, etc.	XML, RDF, JSON-LD, etc.
IOF	OWL	OWL/RDF

Technology Highlights	Technologies
Transfer technologies	Cloud-based integration tools, Data Streaming Protocol, Swagger and ODATA for REST
Storage technologies	Graph DBs, Relational-to-Graph (Ontology-Based Data Access)

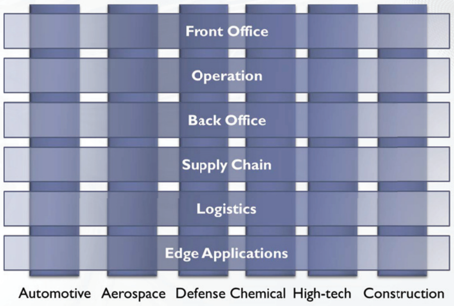
Analysis of Business Process Context



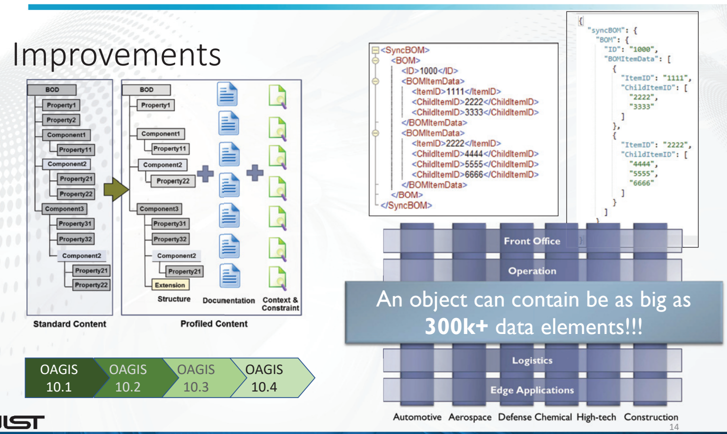
OAGIS Model-Based Vision

What is OAGIS?

- Open Applications Group Integration Specifications (OAGIS)
- Since 1994
- 100+ Business Objects
- 1100+ Messages (BOD)

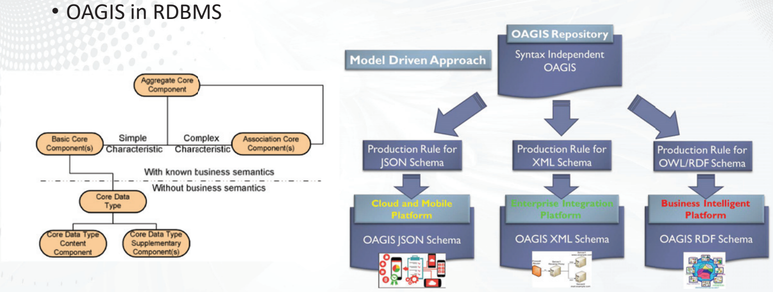


Improvements



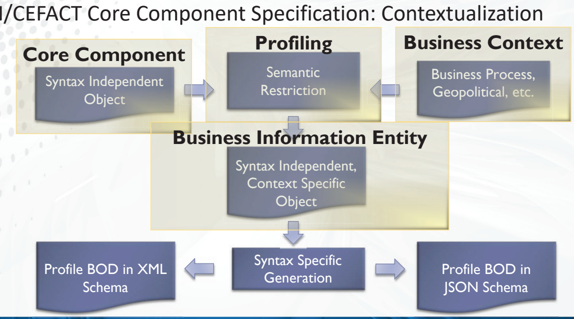
Approach: Syntax Independent Standard

- UN/CEFACT Core Component Specification: Meta-model
- OAGIS in RDBMS

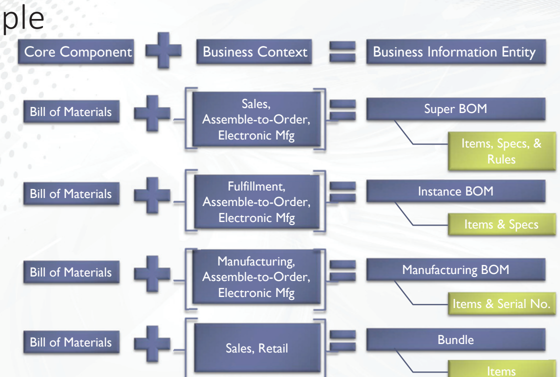


Approach: Message Profiling based on Business Context

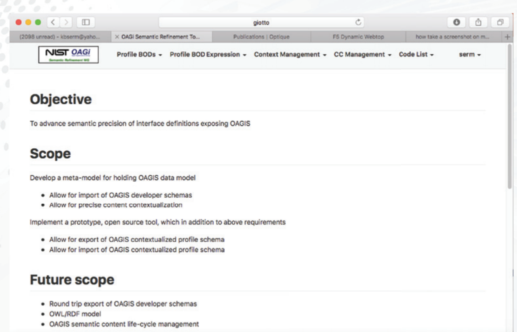
- UN/CEFACT Core Component Specification: Contextualization



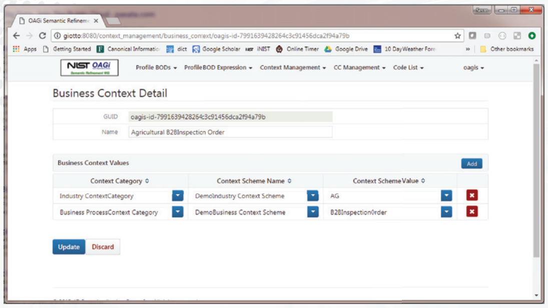
Example



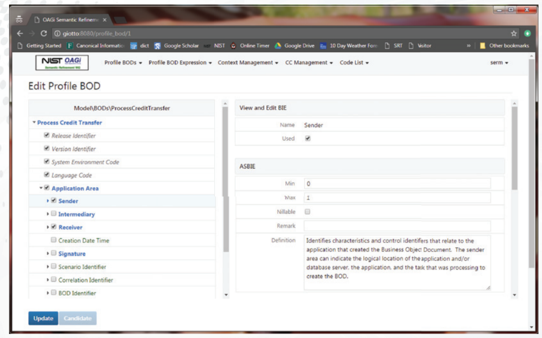
Result: NIST/OAGi Semantic Refinement Tool (SRT)



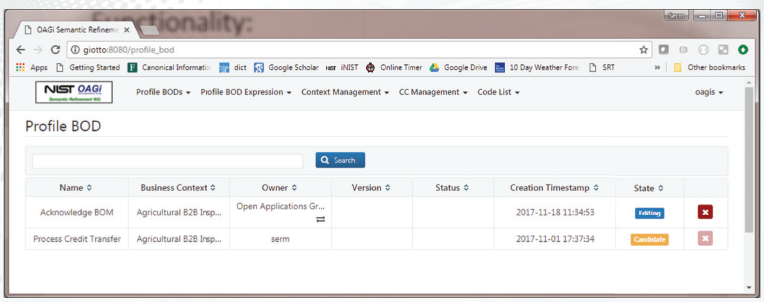
Functionality: Business Context Management



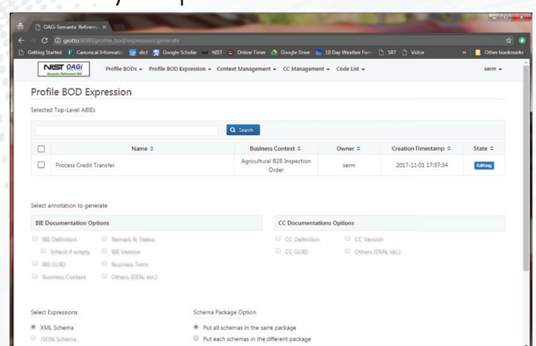
Functionality: Object Profiling



Functionality: Profiled Object Life Cycle Management

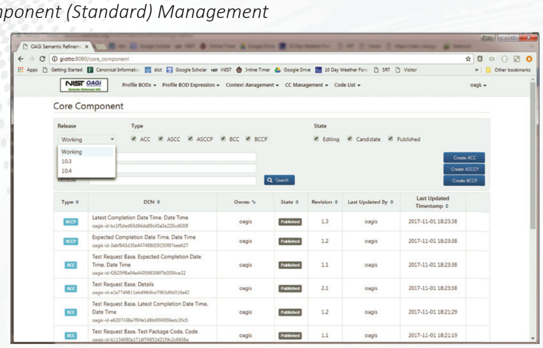


Functionality: Expression Generation



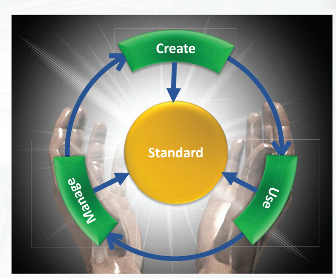
Functionality: New Standard Life Cycle Management

Core Component (Standard) Management



Roadmap

- JSON Schema, REST API
- Automatic profiled object upgrade
- Semantic-based search
- Multi-tenant
- Standard evolution
  - Standards usage harmonization
  - Standards harmonization (mapping tool)
  - Release & change management
- Integration with the business process management

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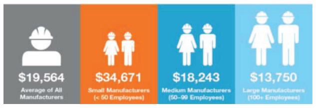
An increase in regulations and compliance costs are pushing organizations to find new ways to optimize their operations

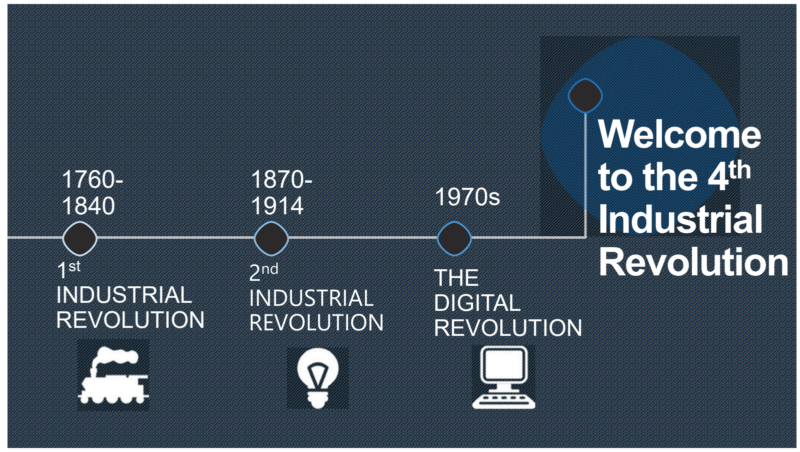
Regulatory compliance costs per employee per year for manufacturers, 2012 (in 2014 Dollars)



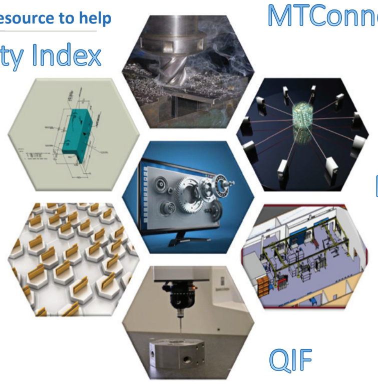
Major regulations promulgated by Presidential Administration, Manufacturing

President	Years in Office	Total Major Regulations	Average Major Regulations Per Year
Clinton	1993-2000	69	9
Bush	2001-2008	55	7
Obama	2009-2013*	82*	16*

The introduction of emerging technologies coupled with organizations looking for new ways to optimize their operations is introducing a complex landscape with many questions on where to start and how to operationalize the solutions



With a surge in tools and resource to help



Multiple technology shockwaves are impacting the manufacturing sector simultaneously

***The speed and scope of the technological shockwave currently gathering momentum is unprecedented* - PwC**

- Digital human behavior
- Artificial intelligence (AI)
- Internet of Things (IoT)
- Robotics
- Augmented reality & virtual reality
- Additive manufacturing

Harmonization of digital assessment tools is needed to accelerate the adoption of digital technologies within the industrial base and Department of Defense

A number of organizations are funding projects to understand their current digital state and the implications of adopting digital technology within their operations

Assessment Title	Purpose	Assessment Owner
Digital Capabilities Assessment	Identifies an organizations "digital state" and additional capabilities required to be a completely digitally enabled factory	IMEC
MOM Capability Maturity Model	Determines the level of an organization's capability to have mature, robust and repeatable manufacturing operations	MESA International
Model-based Enterprise (MBE) Capabilities Index	Identifies essential steps that, when implemented, could maximize integrated manufacturing deliverables	DoD (U.S. Army/ MANTECH)
Digital Enterprise Maturity Assessment	Assess an organization's digital enterprise maturity at a high level with assessment criteria in systems engineering, product definition, data management, production planning and manufacturing, quality, and enterprise collaboration	Boeing

Complications

- Unclear **how the assessments interrelate** to one another
- There is **variability between tools** which makes the **application of recommendations difficult** to implement
- Uncertainty in **understanding which tool to leverage** for specific use cases
- Lots of **resources are being exhausted** among many stakeholders to develop tools to help organizations understand the implications of adopting digital technologies and quantify the impact of adoption

Manufacturers want to make sense of the digital noise

DMDII lead breakout session: Workshop Objectives

- The **objective** of this workshop is to:
  1. Review and gather feedback on **current and developing assessment tools** and the driving organizations behind the development and facilitation of the assessments
  2. Identify users of the assessments and define end-user objectives of the tools to refine and **inform digital assessment harmonization road mapping** efforts
  3. **Identify requirements of the digital assessment harmonization output** (e.g. digital taxonomy of organizations + assessments, interactive web-based tool, etc.)
- These objectives will be achieved through a series of interactive discussions and presentations

DMDII a UI LABS Collaboration

Thank you!!

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Industrial Ontologies Foundry
State of Play

Jim Wilson and Michael Gruninger • 2018-04-23

IOF's Primary Goal

The IOF's primary goal is to create a suite of open and principles-based ontologies, from which other domain-dependent or application ontologies can be derived in a modular fashion, remaining non-proprietary and non-implementation-specific, so they can be reused in any number of industrial domains or manufacturing specializations.

Other IOF Goals

- Provide principles and best practices by which quality ontologies can be developed that will support interoperability for industrial domains
- Institute a governance mechanism to maintain and promulgate the goals and principles
- Provide an organizational framework and governance processes that ensure conformance to principles and best practices for development, sharing, maintenance, evolution, and documentation of IOF ontologies

Just Getting Started

- First meeting December 2016
- About 70 current participants
- Governance Board established and working
- Technical Oversight Board established and working
- Top-Down Working Group established and working

Governance Board Members

- Barry Smith, SUNY Buffalo
- Fernando Mas, Airbus
- Nicola Guarino, The National Research Council (Italy)
- Serm Kulvatunyou, NIST
- Chris Will, Dassault
- Michael Gruninger, University of Toronto
- Jim Wilson, OAGi

Governance Board Activities

- IOF Membership Policies and Procedures: nearly compete
- IOF Working Group Policies and Procedures: just getting started
- IOF Legal Establishment: starting soon
  - Funding
  - Secretariat services
  - Marketing and communications

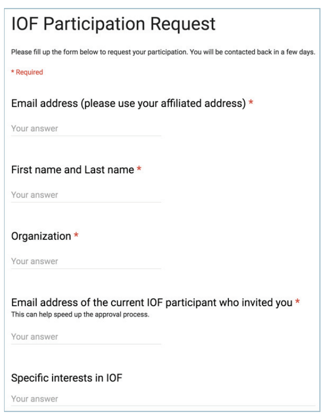
Website

http://IndustrialOntologies.org

redirects to
https://sites.google.com/view/IndustrialOntologies

Join

Join


IOF Participation Request

Please fill up the form below to request your participation. You will be contacted back in a few days.

* Required

Email address (please use your affiliated address) *

Your answer

First name and Last name *

Your answer

Organization *

Your answer

Email address of the current IOF participant who invited you *
This can help speed up the approval process.

Your answer

Specific interests in IOF

Your answer