Smart Manufacturing: The Practice of Real Time Data and Manufacturing Intelligence

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Smart Manufacturing
Simply Stated

The Operational Business and Technology Practice of radically increasing the application of real-time data throughout the manufacturing enterprise and changing the operational structure

The right data in the right form, the right people with the right knowledge, the right technology and the right operations, whenever and wherever needed throughout the manufacturing ‘enterprise’
Smart Manufacturing
A Term of Practice

• Enterprise integration to realize untapped market, productivity and performance opportunities

• Real-time Data and Modeling to qualify materials, parts, properties, assemblies and drive real-time precision

• Operational Practices (A Vocabulary of Practices: intensification, virtualization, modularization, qualification and optimization) to achieve value in an increasingly customized product space with accelerated demand dynamics
Manufacturing Vertical
- Static physical facilities
- Legacy operations
- Always operating
- Need to qualify moving product
- IP in product & operations
- Highly compartmentalized
- Highly heterogeneous
- High risk profile

Secure I, P and SaaS

Data & Device Integration & Orchestration

Smart Factory Manufacturing Analytics

Smart Enterprise Manufacturing Integration

Collaborative Innovation & Practice

Converting Data to Information

Converting Information to Knowledge

Converting Knowledge to Manufacturing Intelligence

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What is the CESMII?
CESMII
A National Network of Capability
Headquartered in LA

Northwest
California
Northeast
Southeast
Gulf Coast

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Precision, Productivity, Product Space
Energy a Material Cost

REVENUE, GROWTH & REINVESTMENT

CESMII’s goals:
• Double energy productivity in US manufacturing every 10 years
• Halve the cost of deploying SM systems relative to state of the art in 5 years
• Increase the SM workforce in US multi-fold in 10 years
• Double the SM technology supply chain rate of increase in value and participation
• Reduce U.S. energy use in 10 years while increasing manufacturing competitiveness

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Let's Consider Some Examples
“Field to Fork”
OEM Collaborative & Network-Based, Smart Manufacturing

Connected Supply Chain
- Agile
- Demand Driven
- Raw Material to Finished Product

Safe Production
- Improved safety
- Fewer incidents
- More user friendly

Energy Efficient
- Lower emissions
- Less energy used
- Green manufacturing

Sustainable Production
- Higher value products
- Data for decision making
- Product Lifecycle Management

Optimization
- Asset Utility/Zero Downtime
- Quality/Zero Defects
- Reliable results

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Supply Side Management
Chain of Custody

Elevator – Weekly Study

South Annex

North Annex

Steel Annex

Product
- No Sample
- Unknown Dirty Oats
- Known Dirty Oats
- Unknown Pre-Clean
- Known Pre-Clean
- Unknown GF Oats
- Known GF Oats
- Risk Analysis Req.
- Non-Usable Oats
- By-Product
- Pre-Sized Oats
- MT/Out of Service

© 2017 General Mills
First Steam Methane Reformer Furnace
*Port Arthur, TX*

- Already efficient
- Distributed sensing
- Distributed actuation (96 burners)
- High fidelity model & reduced order models

**Praxair**

Intensification through Measurement & Operational Integration

- Simple Model
- HPC Model
- Burner Controls
- Metrics

- Reduction of wasted energy
- Halve capital cost
- Dynamic energy management

Extend to 20 U.S. SMRs

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Business Virtual Enterprise & Distributed Asset Modularization

Enterprise thinking: virtual enterprise model that incorporates physical assets as components to execute production.

Customers
Production on Demand

Production and Delivery

Port Arthur TX
2nd Location

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Integrated line management of part precision, materials/metallurgical properties, dynamic part movement, defect reduction, energy management.
Corning – modularize (integrate) upstream supplier
LA & Orange County – small metals, food & apparel utility demand-response/renewables
Pfizer – micro reactors for product customization qualification
Alcoa – real-time optimization of sheet & plate manufacturing flow paths
Over 90% manufacturing in SME’s
Vocabulary of SM Practice

Modularization, Intensification Virtualization & Optimization with Sensors, Controls, Platforms & Modeling

SM Value propositions

– Intensification
– Production on demand
– Customization and value add in the trade space
– Supply side management and chain of custody
– Portable continuous miniaturization
– Distributed modularization & ecosystems
– Business virtualization & asset modularization
– Modularization and scaling flexibility
The Analogy with Health Care

SMLC
Smart Manufacturing Cloud Platform

- New sensors to “see”
- Data input
- Actionable manufacturing data anytime,
- Data aggregation
- High fidelity modeling
- Value chain/Supply Chain KPI
- Smart grid/ecosystem
- Business systems, ERP, cost accounting

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Operational Space of Seams, Time, Data & Action
Sweet Spot for Operational Modularization & Intensification
Machines – People - Materials Dynamic Manufacturing Ecosystem

Data/Design

Training

Analysis/Evaluation

Systems Integration & Engineering

Validation

In Service

Control & Automation

Time – days/hours

Multiple Pass
Variability Reduction
Supply Chain Performance

Macro

Time – hours/minutes

Event Variability/
Tradeoff Adjustment; Dynamic
Performance; Integrated Metrics

Meso

Time – minutes/μseconds

Tolerance & Resilience
Qualification;
ICME, High Fidelity
Precision

Micro

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Smart Manufacturing Practice and Reusability
End-to-End Systems
Advanced Sensing Controls Platforms &
Modeling (ASCPM)
What Got Us Here Won’t Get Us There

Value Creation

Business Applications

Core Functions

Core Systems

Data Input

General Mills Eco System of STUFF
One-off, Proprietary, On Premise Will not Get Us There This is not secure
Span Heterogeneous Environment
On-premise – Off Premise – On Premise
Maintain State

On Premise
Edge Data
Compute

SM
Platform
Data
Structure

Contextualized Data Steps
Data Assets
Data Model
Data Config

Modeling & Analytics Steps
Modeling Provider Product 1
Data Config
Analytics Provider Product 2

Data Compute
Data Model
Data Config

Don’t Reinvent Discretize and Reuse
Security at Business Granularity

Visualization

Enterprise Workflow

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Spin Up Multiple Projects
Reuse Data & Application Configurations

Contextualized Data Steps

On Premise Edge Data Compute

SM Platform Data Structure

Data Assets Data Model

Data Config Oats Data Config Dairy Data Config xxx

Workflow Analytics2 Modeling1 Visualization EMS

Access to data from Application Container
Public/Private Key Trust relationship

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Systems Infrastructure for Smart Manufacturing Practice
Collaboration & Business Processes

Application: Analytics, Optimization, Control

Data Infrastructure: Abstraction, Storage, Processing

System Network: Shop floor – Supply Chain, Integration

Physical System: “Things” of IoT – Machines, Sensors, Actuators, Devices

Inoperability Standards and Protocols

Security, Cybersecurity, Safety, Resiliency

Human-System Interface

Data and Data Services

Reference Architecture & Practice Thinking

Sudarsan Rachuri
Open Architecture – Vendor Agnostic
Open Access – low cost & easy to use
Open Market Place – composable software libraries & data
Open Market Place - Innovation
Trusted Data Broker

Data Valuation
Collective vs. Proprietary

Build a Business Model

Smart

Collective Manufacturing Intelligence
Converting Knowledge to Manufacturing Intelligence
Converting Information to Knowledge
Converting Data to Information

IoT

Collaborative Innovation & Practice
Smart Enterprise Manufacturing Integration
Smart Factory Manufacturing Analytics
Data & Device Integration & Orchestration
Secure Data Highways
Secure I, P and SaaS

Practice Valuation
Collective vs. Proprietary

Big Data

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Build a Rich Marketplace

Reusable Configurations
Core Deployment Services
Trusted Data Services

WfaaS - OT/IT Construct

<table>
<thead>
<tr>
<th>Marketplace as a Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buyer/Seller Dashboard</td>
</tr>
<tr>
<td>Composable apps &amp; libraries</td>
</tr>
<tr>
<td>Data tools, viewers, metrics, models</td>
</tr>
<tr>
<td>Toolkits, App data services</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Development Deployment Performance Reuse as a Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workflow as a Service</td>
</tr>
<tr>
<td>Validated/licensed software environments</td>
</tr>
<tr>
<td>Data configuration models</td>
</tr>
<tr>
<td>Secure historian &amp; private virtual computation</td>
</tr>
<tr>
<td>Secure data connectors</td>
</tr>
</tbody>
</table>

Cloud Integration Services

Security; Machine & Human Interfaces; Virtual Compartments; Interoperability; Standards

OSISoft
SMR data config
Converged reference model
Company data config
Company config

Ansys Fluent
Single, multi, full tube models
Industry Marketplace
Reusable Configurations

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Example of Reusability and Configurations aaS

High-Fidelity Model for a rectangular furnace with flowing materials in vertical tubes with interspersed burners

<table>
<thead>
<tr>
<th>Reference model</th>
<th>Configuration</th>
<th>Mesh hexagonal polygon</th>
<th>Compute time/platform</th>
<th>First-of-kind development time</th>
<th>Reuse time for similar operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Tube</td>
<td>Tube side heat transfer &amp; kinetics</td>
<td>50 thousand</td>
<td>Minutes/ desktop</td>
<td>6 months</td>
<td>Validate kinetics/heat transfer Days</td>
</tr>
<tr>
<td>Small Furnace</td>
<td>4 tubes/3 burners</td>
<td>2 million</td>
<td>Hours/ 4 core</td>
<td>6 months</td>
<td>Confirm convergence validate results Days</td>
</tr>
<tr>
<td>Fall Furnace</td>
<td>336 tubes/96 burners</td>
<td>30 million</td>
<td>Days/ 48 core</td>
<td>6 months</td>
<td>Converge full model Days</td>
</tr>
</tbody>
</table>
SMLC Smart Manufacturing Platform Ecosystem

SM Commercial Marketplace

<table>
<thead>
<tr>
<th>APPS</th>
<th>Analysis Applications</th>
<th>Turn Key Solutions (WFs of WFs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eternal Connector Services</td>
<td>Visualization &amp; Domain GUIs</td>
<td>Solution Provider Services</td>
</tr>
</tbody>
</table>

SM Open Marketplace Wire Frame Services

User Selected or Defined Testbed Dashboards, Process Functions, Visualization and Metrics Works Spaces

SM Open Cloud Orchestration Wire Frame

Scalable Cloud Computing Service Provider(s)
Public & Private

Business and Capability Oversight Provided by SMLC SM Platform Board
Feature Enhancements Contributed by SMLC Members (SMLC Rights)
SM Platform Specification and Its Management by Nimbis Services

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SM Platform Infrastructure

- Certified app ‘configurations’
- Search Engine
- Compose and reuse
- IoS for manufacturing
- DevOps for manufacturing
- Data to Applications
- Trusted Data, Marketplace, End-to-end State Services

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SM Platform
Collaborative development

Test Bed
Model Exploration & Development

Plant Engineers Portal

Dynamic Model & WF Development

Modelers Portal

Provider Support

Metrics Modelers

Product Testing

Marketplace

Ansys, Mathworks, Tableau

Joint Development & Deployment

Real Time Data

Plant Sensors

Continuous Process

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SM Platform for Systems Engineering

Praxair, OSI/PI, Emerson, Nimbis, UT Austin, UCLA

Matlab, UT Austin

Optimizer

Soft Sensor

Optimize

Ansys, UCLA

UT Austin, UCLA, Nimbis, Tableau

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Managing Projects, Systems, Apps and Composability with Images and Security

Access to data from Application container is through Public/Private Key Trust relationship

PPKTR
= Public-private key Trust relationship

ODBC
= Open Database Connectivity
Systems Engineering, Development & Execution as DevOps

PCA = Principal Component Analysis (statistical)
IPOPT = Interior Point Optimizer
PPKTR = Public-private key Trust relationship
ODBC = Open Database Connectivity

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Security Gets Complicated

SLA’s

Copies of Data

Integration
Applications, i.e. calculations, Events, Alerts
Data Framework/Model
Database Structures, i.e. Historian, SQL.
Connectors Interfaces

Push Pull

Secure

3rd Party Partnerships

Integration
Web Services
Data Framework/Model
Database Structures
Gateway Connector Interfaces

Training

Regulation

DMZ Zones

Reality & Misperception

Zones

Copies of Data

Secure

Off Premise Network

Validation

Off Premise Network

On Premise Network

Off Premise Network

Off Premise Network

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### Wire Frame Economics

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease First of Kind System</td>
<td>25%</td>
<td>30%</td>
<td>35%</td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>Accelerated outcomes</td>
<td>2 years to 1 year</td>
<td>+5% faster</td>
<td>+10% faster</td>
<td>+15% faster</td>
<td>+20% faster</td>
</tr>
<tr>
<td>Decrease Replication cost/risk</td>
<td>60% first replication</td>
<td>65% multiple replication</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Putting My University Hat On?
• UCLA interests
  – Research funding reallocated to institutes like this one
  – Public private partnership
  – Value of data and algorithms
  – Tech transfer
    • Test, evaluate and productize University IP
    • Commercial data with which to develop university IP
    • New pathways to productization
  – Researcher/capabilities discovery and cross linking
  – Integrated infrastructure
  – Training, education and STEM in data, analytics, and data sciences
  – Integration of research universities, CSUs and CCCs
  – Public mission around economic development, energy productivity and environmental sustainability
• **Academic Interests**
  – Not a Grant; Industry Driven
  – The value of real data
  – Requires inverse thinking
    • Connecting TRL 1 – 3 to TRL 4 - 7
    • Expertise on problems and data
    • Training and education in data analytics and sciences
    • Platform for training
    • Spin off research and development projects
  – Implementing new academic infrastructure
    • Faculty and students participating in projects
    • Avenue for tech transfer
    • Avenue for great student and faculty involvement
    • Access to real world problems
A Comprehensive Approach to Manufacturing

At the Intersection
- Workforce Productivity
- Business & Product Agility
- Supply Chain Agility & Optimization
- Asset Management and Risk
- Product Lifecycle
- Energy & Material Productivity
- Environment, Sustainability & Safety

Next Generation IT for Next Generation Manufacturing
- Make Data a Key Asset
- Advanced Real-Time Sensing, Controls, Platform and Modeling

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