Smart Manufacturing and Modularization
(Process Intensification with Data)

Jim Davis
CTO/CIO UCLA & CESMII
NSF DOE Modular Process Intensification Roadmap Workshop
January 17 – 18, 2017
CESMII’s proposed measured goals include:

• 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 supply chain rate of increase in value and participation
• Reduce U.S. energy use in 10 years while increasing manufacturing competitiveness

CESMII, as proposed, will use an open platform and marketplace to integrate advanced sensors, controls, platforms, and modeling technologies into commercial SM systems.
CESMII
A National Network of Capability
Headquartered in LA
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’.

In the elevator: The “Uber” of manufacturing
SMLC History with Modularization

- DOE/DOD Workshop October 2014
- Sessions on Process Intensification and Smart Manufacturing
  - SM and PI related – should PI and SM be considered together
  - Modularization of large scale system
    - Economies of scale vs. economies of numbers
    - Geographically distributed systems managed as coherent enterprises
SMLC’s View on Modularization is old 2010 - Manufacturing Today: Islands of Efficiency

Most plants use **multiple separate** manufacturing control and information technologies
End-to-end data and information connectivity across the plant floor

- Networked sensors
- Data interoperability standards
- Systems communications standards
- Automated control systems
- Data fusion
- Production management modeling

- Industrial Energy Management
- Motion
- Drive
- Continuous
- Batch
- Discrete
- Safety
- e.g., Ethernet/IP
Enterprise Thinking and Practice

LET’S CONSIDER SOME EXAMPLES
First Steam Methane Reformer Furnace
*Port Arthur, TX*

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

**Process Intensification through Measurement & Operational Integration**

- Simple Model
- Reduction of wasted energy

- HPC Model
- Burner Controls
- Dynamic energy management

- Reduce Cameras
- Halve capital cost

- Metrics

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**Praxair**

Extend to 20 U.S. SMRs
Business Virtual Enterprise & Distributed Asset Modularization

Real-time measuring, managing and optimizing:
- Workforce Productivity
- Business & Product Agility
- Supply Chain Agility & Optimization
- Asset Management and Risk
- Product Lifecycle
- Energy & Material Productivity
- Environment, Sustainability & Safety

Enterprise thinking: virtual enterprise model that incorporates physical assets as components to execute production of the right product, at the right time, in the right amount.

Port Arthur TX
2nd Location

Customers
Production on Demand

Steel
Energy
Bio/Pharma
Electronics
Healthcare
Compartmentalization & Seams

General Dynamics
Scranton, PA

Enterprise Value and Supply Chains

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Manufacturing Enterprises defined by SEAMs

- Location where two or more parts of a manufacturing operating enterprise or supply chain are joined together by transaction

- Parts differ by time horizon, lexicon, technology, human in loop, culture, business drivers, vendors, or priorities.

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Seam description and diagram by Evan Wallace and Frank Riddick NIST.
Production on Demand & Intensification

General Dynamics
Scranton, PA

Integrated line management of part precision, materials/metallurgical properties, dynamic part movement, defect reduction, energy management

Part Tolerances
Part Properties
Recuperation
3D Radiation
Dynamic machine configuration

Improve gas flow control
Reduce idle time
Reduce defects
destructive tests
Part quality
Part quality
Part quality

Billet quality
Variable Contracts
Predictive Maintenance
Supply Chain General Mills Field to Fork

Supplier-side actors

- 3rd party lab
  - Remote eCOA client App
- Grain wholesaler
  - ERP
  - MQIS
  - MES
  - Inventor y system

OEM Enterprise and factory systems

- PLM
- ERP
- QA system

SM Platform

- Grain assessment App
- Remote eCOA server App
- Process reformulation App
- Workflow execution engine
- Receive shipment workflows
- Source material for production workflows
- Shipment approval workflows

Computing resources

HPC resources

Storage

Enterprise Computing resources

Supplier-side key systems:

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Computing resources
Corning – modularize upstream
LA & Orange County – small metals, food & apparel
utility demand-response/renewables
Pfizer – micro reactors for product customization
qualification

Enterprise Thinking and Practice

PATTERNS OF APPLICATION
Modularization & Interoperability

SM Value propositions

– 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
Operational Space of Seams, Time, Data & Action

Sweet Spot for Operational Modularization

Machines – People - Materials Dynamic Manufacturing Ecosystem

<table>
<thead>
<tr>
<th>Data</th>
<th>Training</th>
<th>Analysis/Evaluation</th>
<th>Systems Integration &amp; Engineering</th>
<th>Validation</th>
<th>In Service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Business Systems</td>
</tr>
</tbody>
</table>

Control & Automation

- Macro Layer
  - 10s control loops
  - Time – days
  - Multiple Pass Variability Reduction; Supply Chain Performance

- Meso Layer
  - 100s control loops
  - Time - hours
  - Event Variability/Tradeoff Adjustment; Dynamic Performance; Integrated Metrics

- Micro Layer
  - 1000s control loops
  - Time - minutes
  - Control & Resilience, Qualification; ICME, High Fidelity Dynamic Operations

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Enterprise Thinking and Practice

INFRASTRUCTURE FOR OPERATIONAL MODULARIZATION
Cloud & Enterprise Virtualization Services
Data to Applications

Smart Manufacturing Platform Open Infrastructure
- SM Software Marketplace
- APPs & Toolkits
- Compose Workflows
- Cloud Deployment
- Private/Public IaaS

SM Value Proposition

Private Smart Manufacturing Platform Appliance

Applications
- Context
- Mapping
- Data

Transformations
- Heating
- Drying
- Cooling
- Mixing

Supply Chain Flow
- Material Conversion
- Productivity
- Quality Right the First Time
- Variability Reduction
- Demand Management

Seams
- Context
- Optimize

Traditional Manufacturing Automation Environment and Software Tools

Event Data
- Calibration & Maintenance
- Production Models
- Sensor Data

Time Series

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Virtualized Operational structure

Joint Development & Deployment

Location 1

Virtualized Enterprise

Location 2

Marketplace

Real Time Data

Plant Sensors

Operational Facility

Real Time Data

Plant Sensors

Operational Facility

Edge Compute Structure
Edge Computing & Data Structure

SM Platform

~45 Sensors
Sample rate: ~45 msec

~78 Sensors
Sample rate 1 min

>1 Million points
Sampled continuously

Key:
End User
3rd Party Software
SM Services

Praxair

On-Premise

Energy Advisor
EMIS

Tableau Data Analytics Tools

OSI PI Historian

"Publish" Secure SFTP Service

Plant Historian

DeltaV DCS

IR Camera Data Acquisition System

IR Cameras

Demo

SM Platform

30 min avg

1 minute snapshots

Workflow Engine

Step 1 
Acquire

Step 2 
Update

Step 3 
Calibrate

Step 4 
Optimize

SFTP Folder - In

Optimizer

Furnace Models

SFTP Folder - Out

Optimizer Results

Web-based User Interface

Optimization Dashboard

Energy Dashboards

Excel

SM Services

Energy Advisor

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Workflow Discretizes and Interoperates Spans Heterogeneous Environment On-premise – Cloud – On Premise

PPKTR
= Public-private key
Trust relationship

IPOPT
= Interior Point Optimizer

ODBC
= Open Database Connectivity

PPKTR

SM Platform
OSIsoft Historian

Data Config

Contextualized Data

Ansys Fluent
HPC

ROM IPOPT

Kepler Workflow

Tableau

Platform Marketplace
Data Apps

PX Data

PPKTR

Platform Deployment

PPKTR

[modeler]

PPKTR

PPKTR

PPKTR

PPKTR

PPKTR

PPKTR

PPKTR

ODBC
Business Virtualization
End to End Enterprise Workflow Data Models
Production, Quality, Materials, Energy

Part Quality
Part Quality
Part Quality
Part Quality

Real Time Data from GD Plant Sensors
Continuous Data Transfer
GD Data Historian
OSI/PI Data Historian
Kepler VM

Reuse Data Structure

Rackspace Infrastructure

Part predictive quality
Maintenance; Identify Defects at each stage

Unit ops efficiency
Scrap Reduction
Part Quality
Predictive Maintenance & Scheduling
Heat Treatment Planning
Condition monitoring
Heat Treatment Planning
Energy Efficiency; prevent heat loss
Part Quality
Part Quality
Part Quality
Part Quality

Unit ops efficiency
Machining
Part Quality
Part Quality
Part Quality
Part Quality

Part predictive quality
Part Quality
# Business Acceleration

<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></td>
<td>60% first replication</td>
<td>65% multiple replications</td>
<td></td>
<td></td>
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</table>

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Operational entity optimized as a discrete but interoperable function in an enterprise to achieve one or more

– Production on demand
– Customization and value add in the trade space
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– Business virtualization & asset modularization
– Modularization and scaling flexibility
Smart Manufacturing
Modularization = management of Intersections to achieve enterprise operation

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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Virtualization of the Enterprise
Data to Applications
Reusable Configurations
Bridging Seams Extending the Real Time Infrastructure

Marketplace as a Service
- Buyer/Seller Dashboard
  - Composable apps & libraries
    - Data tools, viewers, metrics, models
  - Toolkits, App data services

Development Deployment Performance Reuse as a Service
- Workflow as a Service
  - Validated/licensed software environments
  - Data configuration models
  - Secure historian & private virtual computation
  - Secure data connectors

Cloud Integration Services
- Security; Machine & Human Interfaces;
  - Virtual Compartments; Interoperability; Standards

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