A National Technology and Business Transformation Roadmap for Smart Process Manufacturing

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1. Motivating Smart Process Manufacturing

2. The Business Case and the Business Transformation

3. The Technical Transformation

4. The Smart Process Manufacturing Roadmap

5. The Path Forward
Building the Transformation Priorities and Consensus for Smart Process Manufacturing

Jim Davis, UCLA
SPM EVO Steering Committee
September 2009
Council on Competitiveness
21st Century Manufacturing

Foundations for Competitiveness

Skills Talents Attitudes
Technology & Innovation
Investment
Infrastructure
Cost Basis of Competitiveness
Global Market Access and IP Protection

Discontinuities and Differentiators

Pace of Change
Accelerated Collaboration & Deployment
Resource Cost & Efficiency
Supply Chain Management
SME Networks for Value Creation
Infrastructure & Organization Resilience
Environment, energy & Regulations
The Business Case from SPM Workshops

• Increased pressure to manage risk and uncertainty
• Heightened need for more than incremental energy and raw materials reductions
• Faster and more product transitions to realize economic value
• Enterprise management in response to globalization
• Changing workforce and need to use workforce more strategically
• Pressures to minimize environmental impacts
• Increased focus on EH & S compliance and risks of non-compliance
• Heightened social conscientiousness
• Resilient operations - pressure to increase responsiveness to faults and changing conditions

Increasing dynamic demands on manufacturing
Managing Risk & Uncertainty

• Business decisions *should be* informed with both business and operational uncertainty and risks
• Plant operations *should be able* to “dial in” along the spectrum of risk
• Grade and product transitions *should be* optimized for situational economic, environmental and energy impacts
• Operational decisions *should be* informed by risk of instability
• Responses to abnormal situations *should be* informed by risk and uncertainty in operating limits and constraints

*Increased Emphasis on Risk Management in Resilient Operations*
The Business Case for a User-Provider Approach

Industry
- Global competitiveness with existing assets
- Installed base of equipment is fragile with respect to modern demands
- New plants higher and longer value
- Preparation to address energy and sustainability demands at operational levels
- Multi faceted & objectives
  - Zero incidents & EH&S
  - Reliability and risk management
  - Reliability about product objectives and not about just running
  - Resilient and fault tolerant operations
  - Quality of products

Provider
- Desire to understand multi-company ‘industry vision for first to market and service development
- Large percentage of installed base of automation equipment nearing obsolescence creating large opportunity
- Understand how safe, reliable and profitable must interrelate
- Team with users on early development and co-development
- Understand future resource needs
Definition of SPM

Smart process manufacturing is an integrated, knowledge-enabled, model-rich enterprise in which all operating actions are determined and executed proactively applying the best possible information and a wide range of performance metrics.
## The Key Business Transformations

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment in Facilities</td>
<td>Investment in Knowledge-Embedded Facilities</td>
<td>Investment and management of facilities and knowledge are equally important.</td>
</tr>
<tr>
<td>Reactive</td>
<td>Proactive</td>
<td>Economic optimization is achieved by anticipation and decision, understanding probability, risk and impact.</td>
</tr>
<tr>
<td>Response</td>
<td>Prevention</td>
<td>Sensing, modeling and analysis are used to predict events and operations are controlled to mitigate the impact.</td>
</tr>
<tr>
<td>Compliance</td>
<td>Performance</td>
<td>Zero-incident EH&amp;S is part of the performance culture.</td>
</tr>
<tr>
<td>Tactical</td>
<td>Strategic</td>
<td>Requirements become opportunities, optimizing total enterprise operation.</td>
</tr>
<tr>
<td>Local</td>
<td>Global</td>
<td>Every decision must be made in the context of a globally competitive environment.</td>
</tr>
</tbody>
</table>
An Industry-Academic Consensus-Based Technology Roadmap
Knowledge-enabled Workforce in Global Operation

Resilient Proactive Plant Operations

Knowledge to Operating Models

Key Plant Assets to Enterprise Application

Key Plant Assets to Global Application

People, Knowledge and Models to a Combined Key Performance Indicator

Smart Manufacturing Process

Smart Process

Knowledge-enabled Workforce in Global Operation
Data to Knowledge

Develop standards and tools to enable communication in process manufacturing

Apply standard approaches to model the process manufacturing enterprise and its activities

Get the data. Enable better control, design next-generation actuator/sensor networks for improved model-based state estimation and bias detection knowledge

Lane 1
Implement approaches to develop, manage, and validate models

Enable rapid modeling and evaluation of molecular-based properties

Develop tools for fault detection/isolation and root cause analysis

Develop algorithms for real-time, large-scale operation

Lane 2
Assessment of US innovative capacity in SBE&S

- Nine-person team led by Prof. Sharon Glotzer of U. Michigan visited 59 academic, industrial and government sites in China, Japan, Europe.


- Co-sponsored by:
Computer simulations

Key insight: Three key cyberinfrastructure components

Hardware
Software
People
The opportunity: Leading the transition.

- Help specialists make the transition.
  - Educate model builders for the private/public sectors.
  - Support the present workforce in transitioning.
- Educate students and the workforce to understand computing concepts and implementation.
  - Broaden curricula to blend use and innovation.
- Innovate through substantive collaborations of computer scientists with other scientists and engineers.
Knowledge to Operating Models

High fidelity Process models

Distributed MPC stability Based-control

Predictive/Fault-tolerant control

Sensor networks exchanging real time data

Network & cyber security

Networked monitoring/detection/control

Risk & Uncertainty Mgmt

Network, plant-wide monitoring, control and optimization

Organizational Needs

Business systems and market needs

Large multi scale models

Plant Management

Operator situational awareness & management

Corporate Office

Economics, environment, health and safety

The Smart Process Operation

Develop knowledge and data models for data-driven equipment asset life-cycle management

Develop and maintain models as key corporate assets

Enable equipment assets in process operations to autonomously recognize and respond to situations

Develop intelligent real-time tools to manage transitions and respond to process and performance threats

Develop plant-wide status data visualization
### Lane 3: Solution Plan for Operating Models to Key Plant Assets

#### Develop knowledge and data models for data-driven equipment asset life-cycle management and decision-making
- Unified, intelligent manufacturing operations management database
- Critical resource performance indicators
- Knowledge-based asset management
- Critical operations procedures
- Intelligent manufacturing resources

#### Enable equipment assets in process operations to autonomously recognize and respond to situations
- Self-aware assets
- Asset performance analysis tools
- 100% uptime
- Rapid transition management

#### Develop plant-wide status data visualization
- Capture, archival, and make equipment status information available
- Plant-wide process status
- Full sensory plant status simulation
- Vr-based plant scenarios

#### Develop intelligent real-time tools to manage transitions and respond to process and performance threats
- Models for performance tracking
- Risk and uncertainty assessment
- Intelligent monitoring & control systems
- Controller design for fault tolerance
- Off-normal situation response
- Expert process advisors
- Distributed intelligent operating units

#### Develop and maintain models as key corporate assets
- Requirement-driven, automated model generation
- Business case analysis for models
- Enterprise management of models
- Systematic model development
- Integrating architecture
The Smart Process Operation

Economics, environment, health and safety

Networked, plant-wide monitoring, control and optimization

Knowledge-Based Risk & Uncertainty Mgmt

Operator situational awareness & management

Large multi scale models

Distributed intelligence

Operator

Network & cyber security

Sensor networks exchanging real time data

Predictive/Fault-tolerant control

Networked monitoring/detection/control

Distributed MPC stability Based-control

Self aware Self healing Units/systems

Process models self-evaluate performance

Operations

Plant Management

Corporation Office

Process 1

Process 2

Process 3

A Fundamental Transformation Results

- Distributed intelligent manufacturing
- Explicit management of risk and uncertainty
- Distributed business and operating intelligence to units through integrated models
- Resilient Plant Operation
# The Key Technical Transformations

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<tr>
<td>One-Off Models in Operations</td>
<td>Models Integrated Into Operations</td>
<td>There must be pervasive, coordinated, consistent and managed application of models.</td>
</tr>
<tr>
<td>Dispersed Intelligence</td>
<td>Distributed Intelligence</td>
<td>Data, information, knowledge, models and expertise are available and used to make decisions at the right time and place.</td>
</tr>
<tr>
<td>Unintelligent Systems</td>
<td>Self-Aware Systems</td>
<td>There must be autonomous systems that understand their role and performance in the enterprise and systems that take action to optimize performance.</td>
</tr>
<tr>
<td>Proprietary Systems</td>
<td>Interoperable Systems</td>
<td>Systems must communicate through standard protocols for information sharing, capability and best-in-class components.</td>
</tr>
<tr>
<td>Unpredictable Industry</td>
<td>Predictable Industry</td>
<td>Operations within defined operating envelopes must be performed with predictable impacts.</td>
</tr>
</tbody>
</table>
Models as Key Plant Assets to Global Applications

- Create universal metrics to evaluate and integrate global processes
- Integrate enterprise- and plant-level planning for multi-objective optimization
- Develop techniques and standards for integrating across the supply chain
- Standardize cross-industry best practices and tools
Lane 5

Provide comprehensive knowledge capture and knowledge management solutions

Enhance new employee development

Develop Augmented Key Performance Indicators

Reassess curricula and pedagogy, and provide life-long learning

On-the-job training for process manufacturing

Lane 4

Integrated People Knowledge and Models To Competitive KPI
ARC Workshop, Monday February 8, 2010, 9:00 am – 12:00 pm

A Workshop to Develop Industry Priorities and Actions in Smart Process Manufacturing

SPM http://www.oit.ucla.edu/nsf-evo-2008/