Academic/Industrial Roadmap for Smart Process Manufacturing (SPM)

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Outlines of this Presentation

- Background
- Objectives
- NSF Workshop (2008)
- Key Issues and Obstacles/Solutions
- Next Steps
What is SPM?

- **SPM** is the enterprise-wide application of advanced technologies, tools, and systems, coupled with knowledge-enabled personnel, to plan, design, build, operate, maintain, and manage manufacturing facilities.
- The **SPM** enterprise ensures safe and health-conscious operations with full recognition of people as the most important resource for success.
What is SPM?

- Able to apply learning processes to determine optimal responses and implement them (e.g., adaptive, predictive, proactive), adapting to new or abnormal situations by evaluating present circumstances and applying captured knowledge.
- Proactive, incorporating real-time data sensing to eliminate failure before it happens.
- Assets are integrated and self-aware (via sensors) of their state. Assets include plants, equipment, processes, knowledge, models, and data properties.
Drive Toward Zero Emissions and Zero Incidents Within SPM

• Incorporate zero-emissions into the smart manufacturing paradigm, recognizing that energy usage, energy production, and environmental impact are tightly linked in high volume manufacturing.

• Coal and biomass-based energy alternatives that are designed to minimize greenhouse gas emissions will be key future elements.
SPM and the PSE Community

Four Key Premises
- Highly trained personnel are critical
- Seize opportunities to optimize operational and financial performance
- Prevent environmental, health, safety, security problems
- Work for the global enterprise

New Ways of Doing Business
- Decisions based on profitability not expediency
- Opportunities for future profitability
- Faster time to profits
- Smaller “time constants” for operations
- EH & S performance
Steering/Oversight Board
Smart Process Manufacturing EVO

- Jim Davis (PI) - CIO UCLA, ChE, ASM
- Tom Edgar (co-PI) - ChE UT, CACHE, AICHE
- Jay Boisseau - Dir TACC
- Jerry Gipson - Dow, FIATECH
- Ignacio Grossmann - ChE CMU, NAE
- Peggy Hewitt - Dir ASM, Honeywell
- Ric Jackson - Dir FIATECH
- Jim Porter - Du Pont, FIATECH
- Rex Reklaitis - ChE Purdue, NAE
- Allan Snavely - SDSC
- Bruce Strupp - CH2M Hill, FIATECH
- Jorge Vanegas - A & M
Smart Manufacturing
Participating Organizations

FIATECH
Annual Technology
Conference & Showcase
March 31 - April 3
New Orleans

Plant Sensors
Plant Actuators
FI 1211
LI 1167
TI 4367
Operations Personnel

ASM

Operations Personnel

 CACHE

TACC

Participating Organizations
TeraGrid: Integrating NSF Cyberinfrastructure

TeraGrid is a facility that integrates computational, information, and analysis resources at the San Diego Supercomputer Center, the Texas Advanced Computing Center, the University of Chicago / Argonne National Laboratory, the National Center for Supercomputing Applications, Purdue University, Indiana University, Oak Ridge National Laboratory, the Pittsburgh Supercomputing Center, and the National Center for Atmospheric Research.

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NSF Engineering Virtual Organization (EVO) Deliverables (24 months)

- An industry/academic/government steering and oversight team
- An organized PSE community and CI supported processes to develop a technology roadmap
- Sustainability modeling following FIATECH processes
- Articulation of the value of smart, 0-incident, 0-emission manufacturing
- An initial ‘phase 0’ roadmap produced by industry/academic working group
- A workshop and interactive gateway to promote broad participation and produce a phase 1 roadmap
- A mediated “living” roadmap that is updated continuously through community involvement
- Increased critical mass of an involved and aligned industry-academic community
- Creation of a CI tools clearinghouse
Why a Technology Roadmap?

- Innovation, Transformative, Computational Thinking
- Industry Driven Development
- Recommend Areas for NSF Research
- Engineering Research

NSF CDI

FIATECH Model
Cyber-Enabled Discovery and Innovation (CDI-NSF)

• Multi-disciplinary research seeking contributions to more than one area of science or engineering, by innovation in, or innovative use of computational thinking

• Computational thinking refers to computational
  – Concepts
  – Methods
  – Models
  – Algorithms
  – Tools
Computational Thinking

Problem domain industry wide; benefit to shared solutions

Dramatically increased amounts of data to derive understanding; increased experimental validation

Requirements for modeling more complexity; coupling models

End-to-end prediction systems; on demand

HPC
Compute reliability
Manage data
Interpret, mine, extract
Software
Community-based
Security tools

Scale beyond local unit; industry, region, Country, global

Dramatic changes in workforce expectations for interpreting situations; in roles with plant objectives

CBET CI “the coordinated aggregation of software, hardware and other technologies as well as human expertise to support current and future discoveries in science and engineering and to integrate relevant and often disparate resources to provide a useful, usable and enabling computational and data framework characterized by broad access.”
FIATECH’s Vision of an Integrated and Automated Capital Projects Industry

Real-time Project and Facility Management, Coordination and Control

- Client/ Customer Needs/ Wants
- Technical Approach
  - ROM Budget and Schedule
- Technical Plan, Target Cost and Schedule
- Resources, Schedules, Cost
- Plan Updates
  - Detailed Work Pkgs
  - Command/ Control Instructions
- Real-Time Status
  - Technical
  - Schedule
  - Cost
  - Issues
- Real-Time Operational Status
  - Systems
  - Processes
  - Infrastructure
- Command/ Control Instructions

Scenario-based Project Planning

- Requirements and Conceptual Design
- Automated Design
- Schedule Info.
  - Drawings and Models
  - Instructions
  - Budget
  - Specs and Contracts

Integrated Automated Procurement and Supply Network

- Materials, Equipment, Labor, Tools
  - Fabricated Products, etc.
- Decision/ Design Support
  - Capacity Mgmt.
  - Upgrades, Renovations
  - Conversions
  - D&D, Recycle, etc.
- Electronic As-Builts
- Facility Sim Model w/ Processes, Materials, etc.

Intelligent and Automated Construction Job Site

- Feedback of O&M Knowledge and Experience
- Supplier Designs/ Capabilities/ Products and Services
- New Materials, Methods, Products and Equipment
- Technology- and Knowledge-enabled Workforce
- Lifecycle Data Management and Information Integration

Fully integrated and highly automated project processes coupled with radically advanced technologies across all phases and functions of the project/facility lifecycle.
Roadmap Elements: Academic/Industrial Focus

“I”
Industry
Technological Development

“A”
Innovation
Transformative Academic

Industry ↔ Academia
SPM Themes

• Simulation
• Multi-scale modeling
• Optimization
• Design (and sustainability)
• Dynamics and control
• Fault detection and monitoring

• Sensing and interfaces
• Data aggregation and management
• Network technology
• ES&L perspectives
• Supply chain management
• Energy and process integration
Phase 0 Roadmap

- Smart Process Manufacturing
  - Technology Management
    - Process Manufacturing Technology
    - Controls Technology Management
    - Information Technology Management
  - Systems and Facilities Management
    - Plant Operations
    - Management of Assets
    - Situation Management
  - Enterprise Management
    - Supply Chain Management
    - Globalization
    - Human Resource Management

- People – Our Most Important Resource
- “Green”, Sustainable Manufacturing
- Exemplary ES&H Operations
Workshop Approach

- Current State Assessment – where do we stand now?
- Define the Vision
- Identify Key Issues and Obstacles
- Propose and Rank Solutions
- Develop a “Roadmap”
Situation Management

**Issue:**
Lack of intuitive technology-based tools to prevent situations and prepare the plant (people and assets) for proper response

**Solution:**
Provide technology (models, sensors, wireless, network architecture, security) that enables assets to self-diagnose, publish state, self-heal, or initiate a proper safe response
Plant Operations

Issue:
Models of processes and operations grow with advancement in demand and capability, leading to computational limitations (hardware, algorithms, model formulation)

Solution:
Develop algorithms for large-scale hybrid (discrete and continuous) optimization, in particular take advantage of parallel computation/multi-core processors
Situation/Asset Management

Issue:
The loss of process operations knowledge/skills works against the ability to diagnose and respond; the lack of a systematic approach to capture the experience and knowledge of the workforce in a usable form

Solution:
Provide a knowledge management solution that allows operators, engineers, - all stakeholders to collaboratively enrich the knowledge base and extract value from the collective knowledge set
Control Technology

Issue:
Require methods and algorithms that allow plants to take corrective actions to abnormal situations using more detailed process models and appropriate level of measurements

Solutions:
1. Develop methods for the design of control systems using wireless sensors and actuators
2. Develop methods for fault detection and isolation, accounting explicitly for controller design as well as fault-tolerant control
3. Develop associated actuator and sensor instrumentation networks to accomplish the fault-tolerant control compatible with other functions such as quality control, production accounting, online optimization, etc.
Plant Operations

**Issue:**
Mathematical models need scope, accuracy, and consistency to achieve total value

**Solution:**
Implement a holistic modeling approach leading to evolution of consistent hierarchical approach for scope and fidelity for targeted optimization functions (control, RTO, scheduling) with methods to validate model accuracy and its limitations
Asset Management

Issue:
The lack of a culture and system for creating, managing, valuing, and integrating models as enterprise assets that are maintained just like physical assets

Solution:
Develop a management and technology structure for maintaining models as a corporate asset
Issue:
Need to develop models and algorithms to enable molecularly-informed design and control in a way that exploits emerging computer technologies. Need smart data collection and processing.

Solution:
Develop theories and algorithms that enable the rapid evaluation of thermophysical properties from a molecular model in a way that exploits emerging microprocessor technologies.
Process Manufacturing Technology

**Issue:**
A smart manufacturing plant needs to be fault-tolerant, which requires the plant design and instrumentation design needs to be performed with fault tolerance and bias-free data.

**Solution:**
Develop tools that rate the fault-tolerance of an early process design. Incorporate dynamic simulation into the process design phase. Make pervasive use of process design methodologies that incorporate dynamic simulation to minimize and isolate faults and evaluate process operability on a real-world scale.
Issue:
Design must reconcile multiple objectives and not focus solely on cost

Solution:
Independent group working in conjunction with industry to create a universal set of metrics to evaluate the economic impact of process robustness and flexibility (ability for process to handle multiple feedstocks) and fault tolerance
Supply Chain Management

Issue:
There is a gap between IT infrastructure and math models due to lack of standardization and different terminology in SC. There is a need to know how to reconcile different names, how to automate the mapping different language, how to merge different data base/structure automatically (many are manually done currently)

Solutions:
1. Develop large-scale information retrieval techniques for rationalizing unstructured data and performing feature extraction in SC databases
2. Use self-learning and adaptive techniques to evolve standards (meta models and/or semantic models) and to map process components to meta/semantic models
Supply Chain Management

Issue:
Models are needed to capture the big picture for enterprise management. There is a gap between enterprise level (planning level) and plant level (scheduling); ATP from the planning level needs to be operationalized at the scheduling level.

Solutions:
1. Develop methods to integrate planning and scheduling by identifying key manufacturing constraints that need to be accounted for in planning.
2. Develop algorithm and framework for multi-objectives (e.g., due date vs. capacity utilization), multi-time period. Multiscale approaches for integrating enterprise and plant levels.
Supply Chain Management

Issue:
Need to be able to assess model uncertainty in the entire supply chain (demand/supply disruption) and manage associated risk for any set of KPIs (key performance indicators). Integrate the energy use associated with material flow in supply chain management, and evaluate the carbon footprint, reuse (for zero emission), life cycle/span of the molecule (cradle to cradle)

Solutions:
1. Investigate how structured uncertainty (disruption) and parametric uncertainty can be treated to address KPI’s (e.g., profit, sustainability, carbon footprint)
2. Model energy use in supply chain and evaluate the carbon footprint
Smart Process Manufacturing Workshop Report (Draft)

From
April 21-22, 2008

NSF Roadmap Development Workshop

To download a copy of this report, visit this link:
Next Steps –

Share Workshop Results And Develop Roadmap

A rich set of issues and solutions was created during the workshop; however there was insufficient time to develop a complete and detailed roadmap for each area. Therefore, the next steps are to communicate the workshop results and develop a roadmap that lays out:

• a timeline for delivery of the solutions
• an order-of-magnitude estimate of required financial resources
• metrics by which to measure progress
Networking with Affinity Groups

The IEM Consortium could serve as a network for disseminating information on the roadmap and receiving feedback on ES&L issues that need to be addressed.