Smart Manufacturing:
21st Century innovation

The SM Platform
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THE ORIGINATION OF THE SMART MANUFACTURING PLATFORM

Industry Defining Industry Requirements

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
Priority actions in four categories:

- Industrial Community Modeling and Simulation Platforms for Smart Manufacturing
- Affordable Industrial Data Collection and Management Systems
- Enterprise Wide Integration: Business Systems, Manufacturing Plants and Suppliers
- Education and Training in Smart Manufacturing
SMLC Program Agenda for a Smart Manufacturing Platform

- **Lower the cost** for applying advanced data analysis, modeling, and simulation in core manufacturing processes
- Build **pre-competitive infrastructure** including network and information technology, interoperability, and shared business data
- Establish an **industry-shared, community-source platform** and associated software that functions as an “apps” store and clearinghouse
- Create and provide broad access to next-generation sensors, including **low-cost sensing and sensor fusion technologies**
- Establish **test beds** for smart manufacturing concepts and make them available to companies of all sizes
Achievable Meaningful Use Goals & Magnitude of Impact

• **Demand-driven efficient use of resources and supplies in more highly optimized plants and supply**
  – 80% reduction in cost of implementing modeling and simulation
  – 25% reduction in safety incidents
  – 25% improvement in energy efficiency
  – 10% improvement in overall operating efficiency
  – 40% reduction in cycle times
  – 40% reduction in water usage

• **Product safety**
  – Product tracking and traceability throughout the supply chain

• **Sustainable production processes for current and future critical industries**
  – 10x improvement in time to market in target industries
  – 25% reduction in consumer packaging

• **Maintain and grow existing U.S. industrial base**
  – Environment for broad innovation
  – 25% revenue in adjacent industries
  – 25% revenue in new products and services
  – 2x current SME’s addressing total market
  – More highly skilled sustainable jobs created

• **Positive public perception about U.S. Manufacturing**
  – Americans feel our continued leadership as the world’s largest manufacturer has strategic national importance
Develop and Evolve Platform Based on Defined Industry Problems

TEST BED DRIVEN PLATFORM REQUIREMENTS
Our customers demand capital discipline and high reliability
Our goal is to meet their demands and maintain high energy efficiency
Smart Manufacturing Helps Meet Our Goals

- Low cost sensors and wireless enable real time decisions
- Hosted computing improves results at a lower cost
- Common infrastructure facilitates supply chain collaboration
General Mills

- Customers “pushing” demands
- Tracking & Traceability

Farming

Supply Chain

Manufacturing Plant

Distributor

Customer

DEMAND DRIVEN

DRIVE OUT VARIABILITY
General Mills
Networked-Based Manufacturing
Intelligence & Collaborative Manufacturing

EDI transaction & quality certifications
Recipe Management
Mapping formula into operating recipes
Mapping SAP information into operation

Supply Chain
Business Systems, ERP
Smart Factory
Distribution Center
Customer
Smart Grid

FDA Tracking & traceability

Green Light
Analyze - to put into production
Make – right ingredients – confirmation on recipe
Release – meet requirements to release
Machine Function Benchmarking & Integrated Line and Energy Management

Managing Power from the Grid
FORD In-Production
Virtual Aluminum Castings

Target Strength = 220 MPa

Aging temperature 240°C for 5hrs

Initial Heat Treatment Process

Optimized Heat Treatment Process
Faster and Stronger !!
Test Bed Generated SM Systems

Smart Machine Operations

- In production machine-product management
- Benchmarking machine-product interactions
- Integrated dynamic management of machine-electrical power interactions
- Adaptable machine configurations

In Production Use of High Fidelity Modeling and Simulation

- High fidelity modeling for better management
- Rapid qualification of components and products

In Production Decision Making with Global Integrated Metrics

- Dynamic Business and Operational Tradeoff Decision-Making
- Dynamic performance management of global integrated metrics
- Untapped cross factory degrees of freedom for optimizing efficiency and performance and compressing time

Supply Chain Management

- Supply chain variability reduction and management of risk
- Tracking and traceability
Industry-Driven
Defined from Test Bed systems

BUILDING THE FEATURES OF THE SM PLATFORM
The Technical Basis for Collaborative Manufacturing and the SM Platform

**Challenge 1**
Factory and supply chain demonstrations sites of applied manufacturing intelligence

**Meta 1**
Integrated Workforce, Cyber, Physical System Performance
Variability Reduction
Benchmarking

**Challenge 2**
Integration of manufacturing enterprise data, control, automation, management and optimization infrastructures

**Meta 2**
Demand-Dynamic Customer to Source Variability Planning

**Meta 3**
Higher Fidelity Production
Real-time Qualification
Integrated Computational Materials Engineering
Materials & Energy Mgmt.

**Challenge 3**
Real-time syncing virtual models and physical operations

**Challenge 4**
Precompetitive and competitive community source modeling innovation & simulation assimilation platform

**Meta 4**
Interoperable Supply Chain Network
Control, Automation, Optimization
Management & Decision

Enabling New & Dormant Technologies
Enabling Dormant Technologies: Model Based Design & Engineering Framework

Product Concepts

Model Based Engineering Design & Manufacturing Environment

Concept Engineering
- Conceptual System Functional Simulation Environment
- System Functional Models
- Sub-System Models

Model-Driven Design, Prototyping
- Multi-Scale Model Based Design Environment
- System Structure
- Sub-System Structure
- Virtual/Physical Models/Elements

Virtual Product Line Models

Design Plans, Models, Test Data, Design Intent, Knowledge etc.

Product Line Model Data

Use Patterns

Solution “Hints”

Design Patterns

End Products

Output

Physical Products

Input

USER

USER
First Concept of the Smart Manufacturing Platform

*Infrastructure for Real-Time Data Driven* Modeling and Simulation

**Key Development Resources**
- Universities, SME’s
- Manufacturers, Labs

**Community Source Resources**
- Pre-competitive & Competitive Hub
- Apps Store Cloud Services
- Benchmarking Rapid Qualification ICME

**Variability Management**
- Real-time Plan Passes

**SMLC Industry-Driven**
- Integrated Performance Metrics
  - Micro, Meso, Macro

**SMEs**
- Small & Medium Enterprises
- Manufacturing Consortia

**Test Bed**
- Manufacturer & Supplier Crosslinking Engagements

**Real Time Virtual Manufacturing Demonstration Facility (VMDF)**

**Standards and Reference Architecture**
- IT Providers

**Community Source**
- Market Place
Multi-Layer Smart Manufacturing (MLSM)

**Workflow Foundation**

- **Design Data**
  - Prototype
    - APP Store
      - Reference Flows
      - Process Models
        - Control
        - Metrics
  - Materials & Process Tech
    - Macro Layer
      - Product Volume
      - Scheduling
      - Supply Chain
  - Product Manufacturing
    - Meso Layer
      - Management
      - Machine Flow
      - Optimization
  - Qualification
    - Micro Layer
      - Sensors/Actuators
      - Control/Optimization
      - Automation

- **In Service**
  - People Involved
    - Integrated Metrics & Decision Making
  - Virtual MDSM Host
    - Dash Board
    - Collaboration
  - MDSM Program
    - “Host” Manufacturing Initiatives

**People Involved**

- Model building & updates
- Model insertion
- Conditional decisions

**APP Store**

- Reference Flows
- Process Models
  - Control
  - Metrics
Control & Automation
Distinguished from Workflow
**Control/Automation Hardware Layer**

1. (days-months) Planning and scheduling
2. (hours-days) Real-time optimization
3. (minutes-hours) Multivariable control
4. (seconds-minutes) Regulatory control
5. (< 1 second) Safety, environmental, equipment protection
6. (< 1 second) Measurement and actuation
7. Process

**Applications (Software) Layer**

- Demand Forecasting, supply chain management, raw materials and product planning/scheduling
- Plant-wide and individual unit real-time optimization, parameter estimation, supervisory control, data reconciliation
- Multivariable control, model predictive control
- PID control, advanced control techniques, control loop performance monitoring, fault detection
- Alarm management, emergency shutdown
- Sensor and actuator validation
Check Table
Optimal Machine Usage
Calculate Machine, Energy, Product Metric
Dashboard
Recommend Tradeoff Points
Process & Line Set Point Conditions
Check Table Optimal Machine Usage
Calculate Machine, Energy, Product Metric
Dashboard Recommend Tradeoff Points
Batch Scheduler
New Machine Maintenance Process Data
Run Machine Usage Pattern-Based Analyzer
Update Machine Usage Model
Build Table Optimal Machine Usage Windows
Table Model Accepted
General Dynamics Benchmarking Model
Workflow Service Framework
Factory Data Control Automation Factory Workflow
Process & Line Data
Machine Benchmark Data
Workflow Service Framework
Computational Resources
General Dynamics Benchmarking Model
Factory Data Control Automation Factory Workflow
Multi-Layered Smart Manufacturing Management (MLSMM)

Time Managed as Workflow Not Control

Transformational Machines – People - Materials Dynamic Manufacturing Ecosystem

Design Data

Prototype

Materials & Process Tech

Product Manufacturing

Qualification

In Service

Current Practice – One Pass per Day per Event; Too Late, Stale Data, Slow Responsive Manufacturing

Goals: 100x Event Variability Adjustment Capability & Dynamic Certification Improvement

Focus: Integrated metrics, Qualification, Computational Materials Engineering, High Fidelity Dynamic Operations

Macro Layer

Meso Layer

Micro Layer

10s of control loops
Control Points - ?
Manpower - X
Time – days

100s of control loops
Control Points - ?
Manpower – 10X
Time - hours

1000s of control loops
Control points - ?
Manpower – 100X
Time - minutes
The Concept of Data-to-Applications

Performance Management Data & Modeling Workflow

Process sensor data
- Ref Arch Data Collection Manufacturer
- Ref Arch Data Collection Supplier

Data and Computation
- Manufacturer Real-time
- Manufacturer Data Warehouse

Management Dashboard
- Local/Global Integrated Productivity Metric
  - Dash Board

SM Platform Workflow, Data and Computation Services
- Data Validation App
- EPM App from Toolkit
- Risk Scenarios App
- Real-time Action & Risk Support App
- Reduced Order Model Scenarios App

Linked Apps to Form Function

Encrypted links
• Multi-Layer Workflows interface with control and automation and factory optimized workflows
• Real-time is defined by the workflow & actionable objective
• Data-to-Application instead of Application-to-Data
• Workflow as a Service (Wfaas)
Implementation

ENGINEERING THE PLATFORM FOR THE USE CASES
Visual Model of NIST Working Definition Of Cloud Computing
http://www.csrc.nist.gov/groups/SNS/cloud-computing/index.html

- Broad Network Access
- Rapid Elasticity
- Measured Service
- On-Demand Self-Service

- Resource Pooling

- Software as a Service (SaaS)
- Platform as a Service (PaaS)
- Infrastructure as a Service (IaaS)

- Public
- Private
- Hybrid
- Community

Source of graphic IDC’s Cloud Survey 2011
Workflow as a Service (WFaaS)

Factory Data Control & Automation Workflow

- Provisioning
- Orchestration
- Tasking
- State
- Security
- Provenance
WfaaS Integrated with SaaS, PaaS, IaaS

Factory Data Control & Automation Workflow

Workflow (WfaaS)
- Provisioning
- Orchestration
- Tasking
- State
- Security
- Provenance

Technical Computing Marketplace

Buyer/User (SaaS)
- Buyer Dashboard
- Buyer Catalog
- Portal Apps

Seller/Provider (PaaS)
- Seller Dashboard
- Dev Tools
- Software Images

Compute Platform (IaaS)
- Cycles
- Software / Licenses
- Storage
Nimbis Secure Cloud Portal Architecture

Data and Application Management Foundation

- Web Browser / Desktop Application
  - URL Dispatcher
  - Caching
  - Template
  - View
  - Model

- Nimbis Ecommerce Subsystem (NES)
  - Message Queue
  - Database
  - Asynchronous Task Queue
  - Tasks
  - HTTP / REST / SOAP
  - OAuth-OpenID

- Nimbis Broker Subsystem (NBS)
  - Compute Provider Interface (CPI)
  - Compute Cluster
  - License Manager
  - Application Images

- Compute Platform
  - Remote Access Node
  - PBS
  - Shared Storage

- Navigation:
  - Browse, Configure, Price, Purchase
  - HTTPS / SSH
  - VPN / VNC
  - Job/Session Management
  - Resource/License Metering

Nimbis Services Inc. Proprietary
SM Platform Apps Store, Shared Market Place & Distribution Hub

Multiple Service Environments

Figure 2: SM Platform Apps Store, Shared Market Place, and Distribution Hub for Manufacturers

- Buyer Account
- Authenticated Buyer
- Buyer Dashboard
- Portal App
- Internet
- “App Store”
- Portal Baseline Services
- Portal Extensions
- Data
- Comp
- Seller Account
- Authenticated Seller
- Seller Dashboard
- Remote Desktop
- UCLA
- Nimbis Services
- Community, Open source
- IP, Restricted, Marketplace
- Compute Platform
- Cycles
- Software
- Storage
Provisioning is what **IaaS** cloud is all about.
- OpenStack Nova, Amazon EC2, Windows Azure

Orchestration is readily available in **PaaS** solutions.
- Nimbis, RightScale, Amazon CF, Chef, Puppet, Azure WASM

Tasking mature in **science workflows** (i.e. Kepler).
- Development focus is on a set of services on top of cloud

State has migrated from filesystem to **object store**.
- Amazon S3, OpenStack Swift, RackSpace CloudFiles, Google Docs

Provenance mature in bioinformatics and big pharma.
- Development focus is on a set of metadata services on top of cloud.

Security is always a concern, but can do **private clouds**.
- Continuing focus security services (openid, oauth, pki).
Launch secure web services

Data Selection Tools

Data Definition Maps
SAP, PLC, Control Platform Apps

Local Web Server

Process Data

New Data Return

Data Control Automation
Proprietary Workflow

Workflow Control Server

Data Validation and filtering

Validated Data

Local Storage

Secure & Timely Data Transfers
SM Platform

Foundational Framework

- Workflow as the primary structure for composability & app definition
- Workflows interfacing with workflows
- IaaS, PaaS, SaaS, WfaaS
- Data-to-Application
- Open architecture
- Apps store for apps, app toolkits, workflow components, workflow libraries
- IT Provider reference architecture

Key Features

- Security at data selection and technical layers
- Workflow composability
- Private (in factory) and Public (shared) cloud structures
- Real-time workflows defined by actionable window in time
- Branch workflows to enhance control and automation and private workflow capabilities
- Cross company workflows with selectively aggregated data
- Generic workflow engine if needed
- Buyer & User and Seller & Community Provider App structure