Education for the Manufacturing Industries of the Future

presented to the

2006 MIT Manufacturing Summit:
Manufacturing Research and Education in the Global Economy

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Outline

- Background – need for manufacturing R&D initiatives
- The international Intelligent Manufacturing Systems (IMS) Program
- The national Next Generation Manufacturing Technology Initiative (NGMTI)
- Conclusion
Core Message

Assumptions

1. **New manufacturing technologies are essential to the long-term viability of the U.S. industrial base.**
2. **The continued adoption, growth and use of these technologies depends on an educated and motivated workforce.**

**New Technology Transition Models are needed for today’s globally competitive environment.**
Manufacturing is the engine that drives American prosperity. It is central to our economic security and national security.

- **Economic Growth.** Every $1.00 in manufactured goods generates an additional $1.43 worth of additional economic activity - more than any other economic sector.
- **Invents for the future.** Manufacturers are responsible for almost two-thirds of all private sector R&D, which ultimately benefits other manufacturing and non-manufacturing activities.
- **Internationally competitive.** The United States is the world's largest exporter; 62 percent of all U.S. exports are manufactured goods, double the level of 10 years ago.
- **Productivity increases.** Over the past two decades manufacturing productivity gains have been double that of other economic sectors. These gains enable Americans to do more with less, increase our ability to compete and facilitate higher wages for all employees.
- **Rewarding employment.** Manufacturing compensation averages more than $63,000, the highest in the private sector, and manufacturers are leaders in employee training.
- **Pays taxes.** Manufacturing has been an important contributor to economic growth and tax receipts at all levels of government, contributing one-third of all corporate taxes collected by state and local governments.
The Need for Advanced Manufacturing Initiatives in the U.S.

- Manufacturing in the USA is being challenged:
  - Sharpened competition from low cost imports
  - Impacted 2.3 million jobs over the last 3 years
- Investment in both basic and applied manufacturing science and technology is decreasing
- Uncertainties in the global supply chain introduce risks
- Manufacturing companies are primarily focused on the short term, bottom line
- Our trade imbalance is increasing as more manufacturing is being “off-shored”

Offshoring innovation is the real threat.
What is the Intelligent Manufacturing Systems (IMS) Program?

- An industry-led, global, collaborative manufacturing R&D program involving...
  - Large & small companies
  - Users & suppliers
  - Universities & research organizations
  - Governments

- Conceived in 1989

- Phase 1: 1995 – 2005

- Seven member regions

- Phase 2: 2005-2015
The IMS Vision

- Enable greater sophistication in manufacturing operations
- Improve the utilization efficiency of resources (renewable & non-renewable)
- Enlarge & open world-wide markets
- Disseminate results of IMS projects and transfer knowledge
- Significantly enhance the quality of life in the world community through new product creation
- Advance manufacturing professionalism
- Improve the quality of the manufacturing environment & the global environment
Proposed U.S. IMS Projects
Phase 2

- Model Based Enterprise (MBE) for the Electro-Mechanical (EM) Industry
- Sustainable Product Initiative (SPI)
- Radio Frequency Identification (RFID)
- Manufacturing business process Pattern Ontologies for the extended Service-oriented Enterprise (MPOSE)
Total life cycle costs are driven by decisions made during the development phase.

Need to focus on the tools, and their interoperability, and methods to optimize design, effective manufacturing, and supportability.

MBE is defined as the linkage in model based engineering, manufacturing, and sustainability.

Rockwell, Boeing, Raytheon, and other U.S. companies have already begun work on the project.

In the future, designers & customers interact in an immersive environment to explore and evaluate options based on modeling, simulation, optimization, and visualization techniques.
The environmental impact of the *products* of some industries is greater than the impact of the *processes* used to manufacture them. The SPI is looking for market-based incentives to mitigate the impacts of products. Work is now under way in several sectors, including automotive, aerospace, furniture, building and construction materials, batteries, coatings, and others. Biggest project is material substitution data base (to locate more sustainable materials).
Radio Frequency Identification (RFID)

- RFID technology (hardware, software, & services) will reach $6.1B by 2010
- RFID encompasses 4 types of standards:
  - Technology Standards
  - Data Standards
  - Conformance Standards
  - Application Standards
- Project will focus on:
  - Global compatibility
  - Global research agenda
  - Logic & data collection development
- Potential Partners (U.S. Region):
  - Interactive Mobile Systems, Inc
  - Symbol Technologies
  - IDENT-Net
  - I-Mobile Systems
  - Code Plus
  - Acsis Inc.
  - LXE Inc.
Manufacturing business process Pattern Ontologies for the extended Service-oriented Enterprise (MPOSE)

A robust set of formally defined business process templates to vastly improve the integration speed, reliability and maintenance of manufacturing and supply chain IT systems.

- U.S. project team defining technical task details
- Team members include:
  - Intel
  - Arizona State University
  - TopQuadrant, Inc.
  - Visual Knowledge, Inc.
  - NIST
- Participants from other regions are being solicited
- Web-based collaborative work environment (CWE) is being established to enhance distributed collaboration

Ontology: A computer-readable set of definitions of terms, relationships, and the logic rules that describe behavior
Global Education in Manufacturing (GEM) Deployment in the U.S.

- Identified U.S. educational point of contact – Professor Tom Kurfess of Clemson University
- Attended Education Working Group Meeting in Leuven, Belgium, in Nov 05
- Curricula content currently being reviewed by several other U.S. universities – Massachusetts Institute of Technology, Purdue University, etc.
- Planning a national summit to review and discuss GEM deployment opportunities throughout the U.S.
U.S. On-going Plans include ...

- Conducting workshops and forums to allow businesses to learn how to position themselves in a global economy
- Continuing to support the creation of “what’s next” and technical infrastructure projects that lead to timely decision making
- Focusing on the global needs of the community and the workforce
- Influencing government understanding of the global dynamics of competition, collaboration, and trade
A U.S. Initiative
Next Generation Manufacturing
Technology Initiative will...

- Energize a consensus for a U.S. manufacturing technology investment strategy
- Initiate the transformation of the U.S. industrial base by investing in high-leverage, high-impact manufacturing technologies
- Facilitate increased innovation, productivity and competitiveness enabling rapid delivery of advanced systems
- Support a reduction in the trade deficit
Technology and Technical Approach

Thrust Areas

- Emerging Process Technologies
- Model-Based Enterprise
- Intelligent Systems
- Enterprise Integration
- Knowledge Applications
- Safe/Secure/Reliable Manufacturing Operations

Technical Approach

- Develop Technology Roadmaps
- Create Strategic Investment Plans
- Value-Based Prioritization of Key Goals
- Develop Focused White Papers
- Form Teams and Launch Projects

Results/Relevance

- Breakthrough, transformational technologies that radically improve design and manufacturing
- Improve affordability and sustainability, reduce cycle time
- Create innovative opportunities for fast-response manufacturing of new products
Evolving List of “Significant” Emerging Technologies

- Product-Embedded sensors
- Electro-optic sensing
- Wide-band electronics
- Affordable fuel cell component manufacturing methods
- Low-cost titanium and processing methods
- Friction-stir welding of Al, Fe, Ti
- Digital-Direct manufacturing (advanced freeform)
- Microdrilling of shaped precision holes
- Manufacturing methods for long-length superconducting wire
- Defect-free thin wall investment casting technology
- Small-infrastructure, low-energy primary metal manufacture
- Integrated unit manufacturing & materials process models and simulation tools
- Computational materials development
- Automated manufacturing process planning
- Nanometer additives to polymers
- Nanoscale manufacturing methods
- Nanoscale multifunctional coatings
- Microfabrication of electro-mechanical devices (MEMS)
- Plastic composite material systems
- Affordable, lightweight structural composites manufacturing
- Microreactors for chemical processing
- Net shape, flashless forming of plastics and metals
- Multi-functional film coating systems to replace traditional painting
- Environmentally benign paint and coating stripping methods
- In-mold coating methods for net-finished product
- Joining and adhesive technology for rapid assembly
- 95% recyclability and biodegradability
- Modular machine tools and tooling for low-lot manufacturing
- Intelligent machine tools
- Sensor technologies as a broad topic (microscale, affordable, reliable)
NGMTI projects

- Friction Stir Joining Technology
- Digital Direct Manufacturing
- Low-Cost Titanium Production
- Affordable, Lightweight Large Structural Composites Manufacturing
- Improvements for Investment Castings
- Advanced Casting Processes
- System-of-Systems Modeling
- Shared Model Libraries
- Model-Based, Real-Time Factory Operations
- Product-Driven Product & Process Design
- Multi-Enterprise Collaboration
- Model-Based Distribution
- Configuration Management for the Model-Based Enterprise
- Hybrid Bearing Manufacture
- High-Frequency Laser Machining
- Thin-Film Coating for Paint Elimination
- Manufacturing Applications for Carbon Nanotubes
- Improved Thin-Film Processes for Semiconductor Fabrication
- Precision Optical Finishing
- Nanomaterials for Glass Coatings
- Model-Based Resource Management
- Model-Based Product Life-Cycle management
- Intelligent Models
- Flexible Representation of Complex Models
- Enterprise-Wide Cost Modeling
- EM -- MBE
What’s wrong with this picture?

An Innovative and Comprehensive Approach:
- Building on national educational programs
- Linking Technology Programs to Innovation Labs and education programs in Universities

An educated and motivated workforce
Conclusion

- While U.S. manufacturing is diminishing …
  - More aggressive participation in IMS will improve our position in the global marketplace
  - Programs like NGMTI will help re-energize our competitiveness
  - Establishing strong, effective relationships with the education and university research community will help to solidify our future position as a nation

_Innovation in products, manufacturing technologies and processes, and business models is the path to remaining globally competitive_
Backup
PROJECT OBJECTIVE

Fighter engine costs need to be reduced. Castings comprise ~1/3 of the engine component costs. In producing castings, the inspection, rework and scrap is ~35% of the casting cost.

This project is to upgrade the inspection systems to digital radiography and incorporate the standard e-process with all jet engine and casting suppliers. By qualifying and implementing digital radiography, we can reduce inspection expenses and cycle times. Quality issues can be handled instantly across the country. In addition, environmental concerns and increasing cost of silver from x-ray films is reduced.

Advanced Aerospace Castings – Digital Radiography

PROJECT TEAM

AFRL  |  RALDEN
Belcan  |  Rolls-Royce
GE  |  Pratt & Whitney
USAF  |  Belcan
Boeing  |  Howmet
PCC  |  Army/ARL

ROI > %

Turbine Blade

Digital Image of Internal Walls
PROJECT OBJECTIVE

New 3D designs and the introduction of non-metallic components require gentler, higher speed dimensional data systems. Current systems of CMM require a compromise of data points with cycle time. The new light and laser gages offer more data collection at faster rates without touching the parts or needing expensive fixturing. The goal of this project will be the establishment of industry standards and methodologies for non-contact 3D inspection techniques. Data format, transfer/exchange and engine supplier acceptance criteria will be addressed.

Advanced Aerospace Inspections

PROJECT TEAM

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<tr>
<td>Belcan</td>
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<td>PCC</td>
<td>Army/ARL</td>
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Light and Laser gaging systems

ROI > %
PROJECT OBJECTIVE

Provide the critical technologies for the development, specification, demonstration and deployment of manufacturing capabilities which result in affordable fuel cells.

Alternatives energy source for both hybrid and battery replacement for power generation. Alternatives energy source to motor driven applications where higher power requirements exist.

Defense Fuel Cell Manufacturing

PROJECT TEAM

Belcan
Boeing
CAPITOL CONNECTIONS LLC
Caterpillar
Clemson University
Delphi
DuPont
Festo
Fuel Cell South
General Electric
General Motors
Honeywell
IdaTech LLC
John Deere
LANL
Lockheed Martin

Mississippi State University
NASA
NCMS
Palmetto Fuel Cell Technologies, LLC
Pantex
Parker Hannifin Corporation
Praxair
Purdue University
Raytheon
Rockwell Automation
Rolls Royce
Tetramer Technologies
University of Missouri-Rolla
University of South Carolina
US Navy
**PROJECT OBJECTIVE**

This phased project will utilize a spiral development approach to develop a robust, scalable manufacturing method that may integrate layered manufacturing, real time inspection, and in-situ machining technologies for direct manufacturing of high tolerance parts.

Initially this project will extend current DDM technologies to titanium material systems and implement it on selected high value DoD components.

Building on the success of the initial phase the team will transition DDM technologies to other materials.

**PROJECT TEAM**

- Aeromet
- ATI
- BAE Systems
- Belcan
- Boeing
- Caterpillar
- Delphi
- Dow
- Doyle Center
- DuPont
- EWI
- Festo
- General Electric
- General Motors
- Honeywell
- John Deere
- Keystone
- LANL
- Lockheed Martin
- Mississippi State University
- Motorola
- NASA
- NCMS
- Pantex
- Raytheon
- Rockwell Automation
- Rolls Royce
- Solidica
- Southern Methodist University
- Tiburon
- University of Kentucky
- University of Louisville
- University of Missouri-Rolla
- Welding Accessories Technology

**ROI > %**
PROJECT OBJECTIVE

Identify and implement tools/processes to support design decisions which optimize life cycle cost. The tools will support the tracking against targeted cost goals and provide the ability to deliver design trade-off strategies. The project will extend over a three period, with yearly deliverables defined. This project when complete can be commercially adaptable and used for all platform developments.

Electro-Mechanical Industry

PROJECT TEAM

BAE Systems  
Boeing  
DOE  
Honeywell  
InterCax  
LMCO  
NASA  
P&G  
Raytheon  
Rockwell Collins  
Sandia

ROI > %
PROJECT OBJECTIVE

The key is to advance FSJ and mature the process for use in both military and commercial applications. This includes developing process and machine technology for welding high performance alloys and complex configurations, while lowering the barriers to wide process implementation by establishing process standardization, specification and inspection requirements, plus characterizing and disseminating weld joint static, fatigue, corrosion, and other material property data for designers and developers.

Friction Stir Joining (FSJ)

PROJECT TEAM

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<tr>
<th>AFRL</th>
<th>Ford R&amp;D Dearborn</th>
<th>ORNL</th>
<th>Rockwell Scientific</th>
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<td>General Electric Aircraft Engines</td>
<td>Sikorsky</td>
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<tr>
<td>Army -AMCOM-G4</td>
<td>GM R&amp;D Center</td>
<td>South Dakota State - MT</td>
<td>The Boeing Company</td>
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<td>Kirtland AFB</td>
<td>LANL</td>
<td>University Missouri Rolla</td>
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<td>Mississippi State University</td>
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<td>University of South Carolina</td>
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<td>Northrop Grumman NN</td>
<td>University of Wisconsin</td>
</tr>
<tr>
<td>Eclipse Aviation</td>
<td>ESAB</td>
<td>OQR</td>
<td>Wichita State University</td>
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ROI > %
The objective of this project is to establish a high-throughput domestic production source for large diameter bearings employing ceramic rolling elements and corrosion-resistant races. Widespread use of hybrid bearings would allow higher rotational speeds for gas turbine engines, reduce system weight, extend service life, reduce maintenance, and improve “oil out” operating capability. These bearings are of particular interest in applications such as the lift fan system in the short takeoff and vertical landing (STOVL) variant of the F-35 Joint Strike Fighter (JSF), where their use is anticipated to provide a 100+ pound weight savings compared to conventional bearings.
The objective of this project is to develop and demonstrate model-based technologies that deliver information to end users at the point of use, wherever that user might be. The information will be delivered through flexible, affordable systems that provide for heads-up, hands-free operation. Concentrating on graphical views of information provided by model-based systems, this project will demonstrate the sharing of information created in the enterprise’s planning processes (e.g., product design, manufacturing planning) to the four primary “execution systems” of the enterprise: manufacturing execution, product service/support, factory maintenance, and training. It will go far beyond the passing of visual files and text, providing users with interactive access to physical and logical models useful in guiding operations, with appropriate levels of detail and security.

PROJECT TEAM

American Welding Soc.  Lockheed Martin
BAE Systems  Motorola
Belcan  NASA
Boeing  Pantex
Caterpillar  Parker
Delphi  Praxair
DuPont  Proctor & Gamble
Festo  Raytheon
General Electric Aircraft Engines  Rockwell Collins
Honeywell  Rolls Royce
John Deere  Tiburon Associates
LANL

ROI > %
PROJECT OBJECTIVE

The objective of this project is to develop enabling technologies and demonstrate the use of intelligent models that understand, seek out, acquire, and act on the information they need to execute their functions.

The project will establish linkages between the physical modeling realm and the logical models that provide intelligence to product, process, and enterprise models. The addition of intelligence in the modeling environment will radically improve the ability of manufacturers to design products and processes, configure and operate production facilities, and manage their business processes.
PROJECT OBJECTIVE

Convert Titanium Industry and applications from use of Kroll Process and Ingot Metallurgy to Direct Alloy Reduction and Solid-State Consolidation.

Expand use of titanium alloys for aerospace applications to the full range of DoD systems, enabling reduction in weight and improvements in durability and corrosion resistance.

Advance state of art of US titanium industry to maintain strategically important dominant competitive and capability position worldwide.

Advance use of titanium in US produced components and systems to maximize efficiency, life-cycle costs, and reliability.

Low Cost Titanium Production

PROJECT TEAM

Army research Laboratory
BAE Systems
Belcan
Boeing
Caterpillar
Delphi
DoE Albany
DuPont
Electric Boat
Festo
General Electric
General Motors
General Electric
Honeywell
ITP

John Deere
Keystone
LANL
Lockheed Martin
NASA
NSWC
Pantex
Parker Hannifin
Praxair
Rockwell Automation
Rolls Royce
TIMET
US Army
Welding Accessories Technology

ROI > %
**PROJECT OBJECTIVE**

The objective of this project is to develop and pilot modeling and simulation capabilities that enable a product model to automatically drive downstream applications. While “product design” creates a model that describes what is to be made, “process design” provides a model of how the product will be produced. These are usually two very different kinds of models requiring highly skilled (and usually manual) translation of information from one domain to another. This project will demonstrate collaborative interaction between product and process models in an enterprise’s product realization environment, to evaluate the current state of capability and provide business-case data regarding the impacts of decisions made at each step of product design and manufacturing.

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**Product-Driven Product and Process Design**

**PROJECT TEAM**

Air Force: John Deere  
BAE Systems: Lanl  
Boeing: Lockheed Martin  
Caterpillar: Motorola  
Delmia: NCMS  
Delphi: NIST  
Doyle Center: Praxair  
Dupont: Proctor & Gamble  
ESAB: Raytheon  
General Electric: Rockwell Automation  
General Motors: Rolls Royce  
Honeywell: Sandia  
HR Technology: Tennessee Tech University

ROI > %
PROJECT OBJECTIVE

The advancements of new hybridized thermoplastic based composite armor solutions have shown to provide additional ballistic protection as well as increased protection from blunt force trauma when compared to traditional “soft armor” solutions. The benefits of this new technology have been demonstrated. However, the lack of a low cost, effective means of rapidly fabricating these materials was also revealed. The utilization of these new materials for the development of personnel protection has presented issues from a manufacturing aspect as well as the ability to “scale up” to meet high volume production needs of our armed services.

Advanced Leg Armor

PROJECT TEAM

ARL
Clemson University
TPI Composites Inc.
MPT
ARDI
Simula
Mentis Science, Inc.
Diaphorm Technologies

ROI > %
PROJECT OBJECTIVE
The military has a need to make its tactical vehicles faster, more mobile, easier to maintain and less detectable with lower life cycle cost. At the same time, the Army and other Services remain committed to improving payload requirements by making its vehicles lighter and stronger allowing them to become quicker and more fuel efficient. The use of lighter weight materials in vehicle structures provides the opportunity to enhance crew protection schemes while increasing vehicle performance during combat and peace time applications.

Next Generation Lightweight Survivable Composites for Tactical Military Vehicles

PROJECT TEAM
TPI Composites Inc.
MPT
ARDI
Army Research Laboratory
Simula
Boeing
Diaphorm Technologies

ROI > %
PROJECT OBJECTIVE

The primary activity of this project will be to develop an integrated metallic Single Wall Carbon Nanotubes (SWNT) manufacturing capability, combining two manufacturing technologies ("forest grown" SWNT synthesis and “chiral separation”) that have been demonstrated at laboratory / pilot scale, and transitioning to commercial production scale.