The Digital Manufacturing and Design Innovation Institute (DMDII)

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Director of Research and Development
DMDII

SMART Manufacturing
Call to Action...

"If you went to bed last night as an industrial company, you're going to wake up today as a software and analytics company. The change is happening in front of us."

Jeff Immelt, Chairman and CEO of General Electric
Challenge: US Losing Leadership in Manufacturing

ISSUE: Economy, Jobs, and future competitiveness
  - When U.S. loses manufacturing base in advanced technology products, we lose ability to innovate on next generation of those products

U.S. Trade Balance for Advanced Technology Products

![Graph showing the U.S. Trade Balance for Advanced Technology Products from 1988 to 2010. The balance starts around +40 billion in 1988, drops significantly by 2002, and continues to decline.]
The application of computing and data analytics to improve manufacturing across the product lifecycle is being implemented throughout the world today. It’s a continuous race to stay one step ahead.

The race to stay ahead of the global competition
The Global Digital Revolution in Manufacturing

Evolution within Digital Environment

The Fletcher School at Tufts University
The US Manufacturing Business Today - Observations

• **A Set of Extremes** – Sophisticated Early Adopters of Digital Manufacturing Technology compared to SME’s Not Able to Comprehend the ROI Let Alone Implement for the ROI

• **Social Stigma** Surrounding Manufacturing Work – Most Universities Aren’t Seeing the Market for the Manufacturing Curriculum – Lack of student demand despite 100% placement

• **Lack of** Sufficient **Regional Infrastructure** – IoT Will Saturate the Existing Data Transports; rural areas affected most

• **Need for** an Emerging Wave of **New Standards** to link Tools – More Value from Tool to Tool Data Exchanges

• **An Emergence of** **Regional Cooperation** in the US to Address Specific Export Markets – State Interactions and Politics
What is DMDII?

• One of the Institutes for Manufacturing Innovation (IMI) established as part of National Network for Manufacturing Innovation (NNMI)

• Set up under parent organization UI Labs 501c(3) non-profit organization

• A public-private partnership created to foster development and implementation of digital manufacturing technology to US industry to accomplish goals that neither industry, academia nor government can accomplish on its own

• Leverage best pre-competitive applied research and technology in the country to deploy solutions on a broad scale

• Established through 5-year cooperative agreement w/$70M in federal government funding + over $250M in matching funding from industry, academia, local govt, community partners

• DOD is primary federal sponsor; U.S. Army executing Program Management for DMDII
Digital Manufacturing Vision

- **Digital link** between design and fabrication
- **Connected machines**, factories, and supply chains
- **Transparency** into supplier factories
- **Data aggregation, analysis, and action** across the product lifecycle
- **Technology transition** to Small/Medium Enterprises
The DMDII Today

New facility located on Goose Island in northwest Chicago, Illinois

- 96,000 ft\(^2\) of Leased Space
- 41,800 ft\(^2\) of Collaboration and Office Space
- 25,200 ft\(^2\) of Manufacturing Space
- 29,000 ft\(^2\) of Expansion Space
Inside the Demonstration Test Facility

Cell #1 – Multi-Axis High End Machining
Cell #2 – Traditional/Legacy Standard Machining
Cell #3 – Additive
Cell #4 – Metrology Room
Cell #5 – Welding & Fabrication
Cell #6 – Micro Machining
Cell #7 – Electronics
Tool Crib – Auto Tool Pre-setter

<table>
<thead>
<tr>
<th>Cell</th>
<th>Equipment</th>
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<tbody>
<tr>
<td>#1</td>
<td>Haas Machines</td>
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<td>#2</td>
<td>Haas VMC</td>
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<tr>
<td>#3</td>
<td>Zeiss CMM &amp; Software</td>
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<td>DMG NHX6300</td>
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<td>DMG NZ2000 T3Y3</td>
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<tr>
<td>#4</td>
<td>Wolf Robot Cell</td>
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<td>#5</td>
<td>Haas ST-10 Lathe</td>
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<td>Haas ST-30 Lathe</td>
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<td>#6</td>
<td>Haas VF-2 3-Axis VMC</td>
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<td>Haas VF-5/50 3-Axis VMC</td>
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<td>#7</td>
<td>Haas UMC-750 5-Axis</td>
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<td>Haas OM-2A Micro Mill</td>
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<tr>
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<td>Haas TM-2 Tool Room Mill</td>
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Typical Cell
40” x 40’
2 cells/bay

Shipping/Receiving
Regular & Secured Storage

Team Area

Tool Room & Maintenance

Equipment Storage
DMDII HWIL - Capabilities Description

- Duplicate manufacturing enterprise IT configurations
- Enable On-site and Off-site factory connectivity software verification
- Enables debugging of system related latencies
- Functions in an isolated environment to test Cybersecurity capabilities

- **VMWare** – Incorporating two hosts
  - 32 (2x16) Core Processor on each host
  - 192 GBytes RAM in each host
  - *Extra provision space description*

- **Nimble Storage Area Network (SAN)**
  - 80% Solid State / 20% Spinning
  - 11.5 TB storage
  - *Extra provision space*

- **Machine Tool Connectivity**
  - 10G CAT6 A drops connecting to IDF Switch Closet
  - 40G Fiber Optic Backbone to Central Data Center

- **External Connectivity**
  - Palo Alto Network 5060
  - I2 or Dark Fiber (2 lines 10G each)
  - Firewall handles 20G data
Membership Types in DMDII

- 3 Industry Tiers
- 4 Academic/Non-Profit Tiers
- State & Local Government Partner
- U.S. Government

- Open to all U.S.-based companies, academic institutions, non-profits and other organizations
- Membership not offered to individuals
- Also open to affiliates and subsidiaries of foreign-based companies...IF the entity was incorporated under the laws of one of the 50 U.S. states
- No specific technical qualifications or other obstacles to membership
## DMDII Consortium Membership Status:

**100+ members to date**

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<tr>
<th>Industry</th>
<th>Academic / Non-Profit</th>
<th>State/Local Govt</th>
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<tr>
<td>Advanced Dimensional Mgt, LLC</td>
<td>Arizona State University</td>
<td>American Foundry Society</td>
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<td>aPriori Technologies, Inc.</td>
<td>Brigham Young University</td>
<td>Bethel New Life</td>
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<td>Astronautics Corp of America</td>
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<td>University of Alabama-Huntsville</td>
<td>National Center for Mfg Sciences</td>
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<td>Bi-Link</td>
<td>University of Delaware</td>
<td>NA Die Casting Assoc (NADCA)</td>
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<td>Vanderbilt University</td>
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<td>Chicago Scenic Studios</td>
<td>Western Illinois University</td>
<td>Rockford Area Econ Dev Council</td>
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<td>Concurrent Technologies Corp</td>
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<td>SME</td>
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<td>Dynamic Motion Control</td>
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<td>Science Olympiad</td>
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DMDII Technical Focus Areas

1. **Advanced Manufacturing Enterprise**
   Digital links between design and fabrication

2. **Intelligent Machining**
   “Self-Aware” machining. Smart sensors and controls to enable equipment to automatically sense and understand current production environment

3. **Advanced Analysis**
   Use of high performance computing to model materials, products and processes to enable design for manufacturability

**Additional programs/initiatives:**

- **Digital Manufacturing Commons** - open source software platform that enables data aggregation, analysis, and action.

- **Cyber Physical Security** - Meet industry and national needs for security, trust, and IP protection within the manufacturing environment.
R&D/Demonstration Projects
Visit [http://dmdii.uilabs.org/projects](http://dmdii.uilabs.org/projects) for details

Distributed Manufacturing—Operating System for Cyberphysical Manufacturing: Develop an operating system for manufacturing that provides both horizontal and vertical resource management from the lowest hardware to the highest enterprise level.

Integrated Design and Manufacturing Models with Metrology: Reduce system costs and accelerate time to market through the use of advanced computational models, estimation, and metrology tools that enable predictive assessment of the manufacturing process and influence on the performance of resulting parts.

Plug-and-Play Toolkit for Geometric-adaptive Machining: Develop a generic and effortlessly portable “plug-and-play” hardware and software toolkit that addresses industrywide problems related to efficient machining, machine setup and fixturing.

Model-Based Enterprise (MBE) Data and Infrastructure: Integrate, mature, and demonstrate enterprise-wide data, infrastructure, and methods that will provide industry an approach that delivers better, faster, and less costly solutions to a fully enabled digital manufacturing enterprise.

Open Source Software Applications for Digital Manufacturing: Populate the DMC online community with open data and open software, and to demonstrate use cases that solve real world problems for manufacturing businesses.

Cyber Security for Intelligent Machines: Mature and demonstrate technologies that improve the security of digital manufacturing solutions. Develop tools that will increase the cyber security of manufacturing organizations.
R&D/Demonstration Projects

Visit http://dmdii.uilabs.org/projects for details

Agile Manufacturing to Compensate for Production Variability: Demonstrate revolutionary new approaches to measuring the geometry and composition of manufactured components, and to use this data in other parts of the digital thread. The ultimate goal is to use digital manufacturing technologies to mitigate production variability, and to reduce the time and cost to develop and maintain manufactured products.

Hardware/Software Toolkit for Real-time Machine and Process Diagnostics, Monitoring and Self-Correction: Implement machine intelligence into manufacturing machines. It is also aimed at promoting the adoption of relevant standards for sensing systems, sensing system communications and integration into manufacturing machines and systems. The scope includes both new machines having built-in sensors and intelligence as well as legacy machines and systems that have been retrofitted with sensors and intelligence.

Technologies Enabling Supply Chain Visibility: Demonstrate technologies that can provide real-time, dynamic visibility into the status of key information to facilitate efficient response to rapidly changing conditions.

Completing the Model-Based Definition: Demonstrate Model-Based Definition (MBD) as the key to gathering, organizing and managing product/process data within the Digital Thread. This project call will focus on seamless flow of the MBD information characterized by a heterogeneous software application environment and sufficient information content to accomplish life cycle activities. Potential life cycle activities for this project call should focus on enabling the Digital Thread in MBD for Detail Design, Manufacturability & Affordability Analysis, and Design to Manufacturing.
R&D/Demonstration Projects

Visit [http://dmdii.uilabs.org/projects](http://dmdii.uilabs.org/projects) for details

**Shop Floor Augmented Reality and Wearable Computing:** Form new digital connections between the manufacturing shop floor worker and the digital thread, through the application of wearable computing, mobile computing and data visualization.

**Communication Standards for Intelligent Machines:** Apply standards and demonstrate plug-and-play digital integration that enables machine tool data collection, transfer and analysis.

**Smart Factory Visibility and Real-Time Optimization:** Advance the visualization of real-time data within a factory, and the use of this data for real-time optimization of factory efficiency, robustness, and profitability.

**Factory Infrastructure Cybersecurity Assessment:** Develop a baseline understanding of costs, capabilities, and effectiveness of DoD-required cyber security measures for factory operations.

**Virtually Guided Certification:** Demonstrate technologies that use advanced computing, modeling and simulation, and data analysis to significantly reduce the time and cost of certifying a material, manufacturing process or design.

**Systems Design Using the Digital Thread:** Demonstrate technologies that can use data from across the product lifecycle and from across the value chain to improve product design and manufacturing.
WFD Input from Stakeholders - Six Key Initiatives

DMDII leverages a network of partners and existing infrastructure across industry, education, government, and NGOs

**Define & Distribute**

1. **Taxonomy**
   - Classify new digital jobs and associated descriptions based on technology use cases
   - Define the skills and training required to execute defined job classifications

2. **Thought leadership and use case definitions**
   - Aggregate available content on workforce trends; define gaps
   - Define digital manufacturing technologies and use cases
   - Disseminate digital expertise via publications, member networks, conferences etc.
   - Establish award to encourage information sharing on new topics

**Education**

3. **Content aggregator**
   - Publish inventory of existing digital manufacturing training materials and programs

4. **Content creation facilitator**
   - Digital 101
   - Develop and publish digital case studies
   - Deep dive on a topic area with limited content
   - Bachelor’s degree in digital mfg. and design

5. **Vision Center**
   - Create demonstration production line at DMDII to showcase digital use cases and technologies
   - Develop corresponding program to immerse various stakeholders in new technologies

6. **Train the Trainer**
   - Create demonstration production line at DMDII to showcase digital use cases and technologies
   - Develop corresponding program to immerse various stakeholders in new technologies
   - Educate MEPs on new technologies and WFD needs—program potentially expanded later
WFD Initiatives are closely linked to each other and to technology development within DMDII

### Drivers
- **Define**
- **Educate**
- **Credential**
- **Placement**

### Initiatives
1. Research from TAC
2. Taxonomy
3. Content Aggregator
4. Content Creation
5. Vision Center
6. Train the trainer

### Key links
- Foundational tools to link tech to WFD
- Use to establish the fact base for WFD
- Transformation into educational material
- Used to train influential groups
- Potentially structured into credentials
- Leveraged to enable job placement

### Digital credentials:
(Individual, training institutions, manufacturing companies)

Enable regional stakeholders to place jobs
DMDII WFD - Next Steps:

• Public announcement of the **WFD Roadmap** through DMDII’s communications channels

• Create a **sub-committee** for each thrust area (chaired and staffed by Advisory committee members)

• Execute **launch plans** for each thrust area

• Develop and execute a **fund raising** program

• Establish **quarterly progress reviews** with advisory committee

• Establish an annual **strategic roadmap** review and update meeting

• Recruit **fellows** from Tier I members (they can be part of their in-kind contribution)
OBJECTIVE: A free and open-source collaboration and engineering platform enabling plug-and-play functionality across the entire digital thread from product development to manufacturing and services

Project Deliverables

- Web-based collaboration platform
- Digital service marketplace
- Operational documents & security review
- Management tools & identity services
The Digital Manufacturing Commons (DMC)

- Open Source Software Platform – Launched during DMDII workshop in Sept. 2015
- Created by GE Global Research and provided as unrestricted open source to DMDII
- Website interface, based on the Distributed Object Modeling Environment (DOME)
What does a $500/year Membership Get Me?

Tier 3 Membership
Small / Medium Manufacturer
Benefits to SMEs Now...

- New opportunities through research projects

Benefits to SMEs Coming...

- Low cost, practical manufacturing software tools
- Innovative design assist tools
- Virtual network assistance tools
- No-cost/Low-cost on-line digital training systems

Practical software tools you can easily use - 24/7
Practical Manufacturing Software Tools

Today’s Environment
Practical Manufacturing Software Tools

1. G-Code
2. CAM File
3. Model & Make of the Machine
Interactive Topology Optimization
Inventive Problem Solving

• TRIZ Russian acronym for the Theory of Inventive Problem Solving

• Process for structured innovation using a simple cause and effect data entry method

• Results of 40 years of research based on analysis of over million worldwide patents within all engineering disciplines

• Contains analytical tools and knowledge-based tools
Inventive Problem Solving

The same fundamental solutions for different problems were used over and over again

I-TRIZ Operator: Slowly increase then abruptly drop pressure

Over 400 Operators have been extracted from over 2 million of patents
Design Assist Tools

Thermal Conductive Bulkhead

Light Weight Turbine Blade

Bearing Housing - Load Bearing
The IoT is Evolving the Use of Tools

• Sensors provide data such as Stress, Strain, Deflection, etc...
• The loads are calculated in real time and behavior is predicted...
• Consider:
• The automatic digital feedback of measured loads on product design
• The ability to predict future fatigue failure based on captured thermal/vibration/shock history
Augmented Reality Tools – Internet of Things (IoT)

• The IoT can enhance the design, manufacturing and servicing of all types of products

• Tablets can display sensor data at the right spot *on top* of real time video of the product (*augmented reality*)

• These technologies can improve serviceability by displaying models of the critical components and serviceability guidance graphics on top of real time video
Get Involved in DMDII Now

➢ Go Online – No Obligation
  – http://dmdii.uilabs.org/
  – Sign up for the DMDII Newsletter

➢ Build a Team, Submit a Proposal
  – Next Project Call for White Papers January 2016
  – No membership necessary to submit a proposal

➢ Contact DMDII
  – Ask for Jacob Goodwin – Director of Membership Engagement