DEPLOYING DIGITAL ENTERPRISE SYSTEMS
A few things to think about…

• Future of Work: https://www.youtube.com/watch?v=59d3UZTUFQ0.
• Digital Twin: https://www.youtube.com/watch?v=iVS-AuSjpOQ
• Digital Twin 2: https://www.youtube.com/watch?v=H6JzPCbyVSM
• Digital Tapestry: https://www.youtube.com/watch?v=8JwkpZzpGd8
A digital enterprise changes the way people work and how they use information.
The Digital Twin and Digital Thread

**MODEL-BASED DEFINITION**

- **Context**
  - assembly
  - machining
  - in use
  - retirement
- **Shape**
  - geometry
  - topology
  - logic
  - constraints
- **Behavior**
  - materials
  - process
  - dim./tol.
  - physics

**DIGITAL TWIN**

- Product Line
- Model 1
- Model 2
- Model N
- Subsystem
- Component

**DIGITAL THREAD**

- Interfaces
- Standards
- Requirements

**MBD + IT architecture + Connectivity**

Temporal, lifecycle-based levels of a model-based definition
Enabling the Digital Twin

Design, monitoring, prediction, diagnosis, solution

As Designed → As Manufactured → As Used

Variability between As Designed and As Manufactured

Variability between As Manufactured and As Used

By comparing digital product data to the physical performance of the object, variation can be tracked and used to inform design of next-generation products, develop predictive modeling and validation schemes for products, and to diagnose and solve problems that occur.
## Major Manufacturing Initiatives at Purdue

### Federal: DOE / Indiana

**Objective:**
Taking next generation composites to high-volume manufacturing, addressing cost-effectiveness and environmental impact.

**Approach:**
1) Composites Virtual Factory Hub
2) Prototyping & Validation Lab
3) Manufacturing Design Lab

### State: Indiana

**JN-MaC**
Indiana Next Generation Manufacturing Competitiveness Center

**Objective:**
- Creating a stronger manufacturing ecosystem by supporting Industry – University collaborations
- Workforce talent support through accessible learning pathways

**Approach:**
1) Technology + Productivity Solutions
2) Research for Future Competitiveness
3) Education + Workforce Development

### Regional: Wabash HL

**WHIN**
Indiana Counties make up the WHIN region

**Objective:**
- Provide a regional testbed to demonstrate advanced manufacturing capabilities and workforce development
- Cultivate a regional ecosystem to support business growth and global competitiveness in the Wabash Heartland
- Boost “Internet of Things” platform through extensive connectivity and integrated sensor development

**Approach:**

---

[iacmi.com](https://iacmi.com) | [Indiana University] | [Purdue University]
Digital Manufacturing Enterprise Testbed: Making the Digital Enterprise Real

purdue.edu/in-mac
Digital Manufacturing Testbed: Rationale

“Manufacturers Need to Adopt Innovative Ways to do More with Less”

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Causes</th>
<th>Effects</th>
<th>Remedies</th>
</tr>
</thead>
</table>
| • *Complexity* to Integrate Across Digital Platforms  
• Product Requirements  
• Product Design  
• Process Design  
• Supply Chain (tracking + fulfillment)  
• Service and Sustainment  
• *Sunk Cost* Trap (technical capacity of installed assets)  
• *Skill Gap* (technical & human) | • Technical Knowledge  
• In-House Know How  
• *Adoption Risk* / Aversion  
• Technologies + Methods  
• *Time* (staff and production)  
• *Business Case* to Invest  
• Captive Asset Base  
• Reference (benefits/cost)  
• Trusted, *Non-Biased Advice* | | • *Comprehensive* Engineering, Manufacturing and Supply Chain *Proving Ground*  
• Leadership in *Discovery*  
• Collaborative Environment  
• Accessible Space  
• Validate and *Demonstrate*  
• Proof-of-Concept / Pilot  
• High TRL, Adoption Ready  
• *Disseminate* Knowledge  
• In-House and On-Site |

• *Long Lead Time*  
• Production Inefficiencies  
• *Sub-Optimal Supply Chain*  
• *Added Steps*, Lost Time  
• *Erosion of Competitiveness*  
• Individual Companies  
• Supply Chains  
• Communities  
• *Intellectual Property Risks*
Smart Manufacturing Proving Ground

Address Challenges for Sustaining Competitive Advantage
- Quality, Due Date Precision, Production Cost and Yield, Responsiveness
- Unscheduled Downtime, Cost / Resource Control
- Supply Chain Efficiency, Risk Mitigation, Workforce Readiness

“Optimize digital information flow between and across the enterprise to accelerate the transition to Industry 4.0”

Discover
- Controlled, Integrative Enterprise Platform
- Overcome Barriers to Digital Information Connectivity
- Generate Preliminary Data for Federal Grants
- Develop Content for Demonstration Showcase and Education Programs

Impacts
- More Modern, More Capable Manufacturers and Supply Chain
- Stronger Workforce, More Attractive Industry and Communities

Demonstrate
- Showcase New Methods, the “Art of the Possible”
- Validate Smart Technologies and Applications
- Modernize Manufacturers and their Supply Chain

Disseminate
- Product and Process R&D
- Robust Digital Enterprise Connectivity
- Next-Generation Workforce Development
- Active Translation Service, with MEP
- Support Innovation and Industry Growth
Facets of Success and Launch Overview

- Site, Tooling, Hardware + Software
- Configurations
- Adaptability

Prepare Manufacturers and their Workforce to:
- Address Digital Information and Connectivity Barriers
- Evaluate Architectures, Tools, Methods and Costs to Optimize Approach
- Receive + Automatically Translate Digital Product Specifications and Design Systems into Machine Instructions
- Provide Customers Real-Time Production Status and Quality Trends During Fulfillment
- Automatically Monitor Input Costs and Workflow
- Anticipate and Mitigate Unplanned Downtime
- Leverage Digital Technologies to Human-Proof Processes
- Automatically Monitor Supply Chain

Digital Manufacturing
Enterprise Testbed
Identity
Revenue
Activities
Infrastructure

Additional Benefits:
- Improve New Product Introduction Time
  Improve Accuracy and Decision-Making, Minimize Human Intervention
- Tighten Relationships with Customers and Suppliers
- Reduce Lead Times from Product Conception to Production
- Reduce Cost of Documentation and Compliance
- Optimize Product Execution (on-time and on-cost)
- Reduce Operating Costs (nimbleness to optimize asset utilization and delivery times)
- Improve Product Quality and Process Uniformity

Preparation for Discovery and Demonstration
- Discovery and Demonstration
  Seminars + Technical Services
  Innovation and Prototyping

- Customer-Facing Brand
- Promotion and Messaging
- Strategic Alignment and Outreach

- Accessibility and Use
- Grants and Recharge Fees
- Products of Value
Scope of Industry and Regional Engagement

Technical Leadership Centers:
- Manufacturing Design Lab (MD Lab)
- Digital Enterprise Center (formerly PLM Center)
- Dauch Center for the Management of Manufacturing Enterprises (DCMME)
- Composites Manufacturing and Simulations Center (CMSC)
- Purdue Discovery Park (>25 Centers and Institutes, dozens of members)

Regional Initiatives and Workforce Development:
- Wabash Heartland Innovation Network (WHIN)
  - 200 Manufacturers in 10-county region, backed by $40M grant
- Leader in Advancing Smart Manufacturing Competencies and Pathways
  - Thousands of K-12 participants in programs and activities
  - Dozens of School Districts and Educators

Innovation Accelerators:
- Purdue Research Park (Innovation and Entrepreneurship Hubs)
- Purdue Aerospace District and WestGate at Crane NSWC
- Purdue Foundry and Elevate Ventures
Infrastructure Overview

2018
- Benchmark other Testbed models
- Interview Dozens of Manufacturers
- Design and Plan Core Building Site
- University Design Review, with PPI “Smart and Connected Factory”
- Alternate, Low-Cost, Rapid Option
- IMI Final Design, Registration, Bid

2019
- MD Lab, 30-January 2019 Opening
- Expansion Project Q1-Q2
- Launch June (est)
- Further Expand Capabilities, Q3-Q4+
- First Workshop, Q4 2019 (~October)

Physical Capabilities
- Composite Materials and Forming
- Subtractive Machining
- Automation, Sub Assembly and Final Assembly
- Metrology
- Adaptable Configurations and Work Environments
- Material Flows: Work in Process and Warehousing
- Rapid Product + Process Development, Prototyping
- Supply Chain Integration

Infrastructure Highlights
- *Jan*: COMPOSITES MATERIALS and FORMING (MD Lab), to launch 30-January 2019
- Construction Bids (receive); Fully Launch Expansion Project
- SITE NECESSITIES INCLUDE: Integrative MES, Subtractive Tooling (basic), Assembly Area, Metrology (basic), Rapid Prototype (basic)
- Feb – Mar: Finalize Scope and Specifications for Equipment
- Apr – May: Final Install
- Jun – Jul: Occupy + Commission

Adaptable Configurations
Digital Manufacturing Testbed: Will Address

**Trends**

- Industry 4.0
  - Automation and Data Exchange
  - Integration of Physical and Cyberphysical
  - Ubiquitous Interconnectivity
- Internet of Things
  - Sensors, Platforms, Architecture
  - Prevalence of Low-Cost Information
  - Analytics → Insights
- Big Data and Deep Analytics
  - Manage and Leverage Information

**Value Drivers**

- Core Capabilities
  - Production Agility
  - Workforce Competence
  - Equipment Maintenance
- Competitiveness
  - Production Cost & Yield
  - Quality Assurance
  - Due Date Precision

**Industry Needs**

- Operational Performance (line, plant)
  - Timely, In-Shift Information
    - Cycle time, Flow / Throughput, Delivery
  - Adaptability, Resilience
    - Fulfillment, Change Orders, Job Changes
  - Human Factors
- Quality and Acceptance
- Leverage Information (enterprise)
  - Accessible Insights “eliminate paper”
  - Fiscal Control
    - Inventory, Spare Parts, Shipping, Receiving
  - Cost Accounting (material/methods, etc.)
Testbed Use Case

Develop Knowledge

Component Design and Manufacture

Systems Design: Scale for Efficiency & Speed

Supply Chain: End to End Enterprise

Optimize Quality and Productivity

Workforce Development

Demonstration

“Optimize digital information flow between across the enterprise to accelerate the transition to Industry 4.0”

Objective

User Goal

Sub-Function

Testbed Capabilities

why?

how?

what

why?

what

how?

examples

Component Design and Manufacture

Systems Design: Scale for Efficiency & Speed

Supply Chain: End to End Enterprise

Optimize Quality and Productivity

Workforce Development

Develop Knowledge

Validate

Prototype + Develop

Product Lifecycle Management

Operations Mgmt., Distribution, Logistics

Short Courses (seminars, badges, certificates, CEUs)

- PHYSICAL | metrology (contact + non-contact), characterization, disassembly
- DIGITAL | compare model to actual
- COST MODELING | materials selection, manufacturing methods

- MATERIALS SELECTION
- COMPONENT SIMULATION
- DESIGN for MANUFACTURE
- MANUFACTURING METHOD
- BETA TESTING, PILOT RUNS
- TECHNICAL REFINEMENT
- OPERATIONS + MAINTENANCE

- APPLICATION of DIGITAL TWIN | optimal interoperability throughout enterprise
- PRODUCT DEFINITION | 3D model, manufacturing variability
- DATA INTEGRITY | ubiquity, secure / appropriate access, computational efficiency

- DATA ACQUISITION + SENSORS
- INFORMATION MANAGEMENT | AI, IoT, deep learning
- PREDICTIVE MAINTENANCE
- ENTERPRISE STATILITY & CYBERSECURITY | line, plant (boundary layer / edge), supply chain, value chain, global net

- PRODUCT LIFECYCLE MANAGEMENT METHODOLOGY
- INDUSTRY 4.0 | methods, architecture, systems integration
- INDUSTRIAL ENGINEERING
- IoT APPLICATIONS / CODING
- LEVERAGING IoT and BIG DATA (mechatronics, maintenance, operations management)
• Expertise to address chronic manufacturing challenges
• Outreach to stakeholders across Indiana
• Deliver technical solutions throughout Indiana, in partnership with MEP
• Lead portal for workforce development and research

Digital Manufacturing Enterprise Testbed
• Research to address digital information connectivity barriers to overcome chronic Industry challenges
• Demonstration of new technologies
• Next generation workforce development
• Product scaling expertise and capacity for Indiana start-ups and growing enterprises

• Incumbent workforce education
• Manufacturing talent pipeline, K-16
• Accessible, interconnected college to university pathways
• Courses and instructional development in areas of present and emerging demand
• Partnership with professional societies

Leverage Institutional Strengths to Build a Stronger, More Capable Manufacturing Ecosystem
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 – 8:30 AM</td>
<td><strong>Continental Breakfast &amp; Registration</strong></td>
</tr>
<tr>
<td>8:30 – 8:45 AM</td>
<td><strong>Welcome, DEC Updates and Meeting Theme</strong></td>
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<tr>
<td></td>
<td><strong>Nathan Hartman</strong> – Professor, Computer Graphics Technology and DEC Director</td>
</tr>
<tr>
<td>8:45 – 9:45 AM</td>
<td><strong>Implementing Digital Enterprise (DE) Systems</strong></td>
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<tr>
<td></td>
<td>The meeting will open with a panel session covering best known methods from current DE system implementations, how to prepare and execute DE system deployment plans, and how SME anticipate complying with OEM requirements. What are the “ah-hahs” that we will see 2-3 years from now? How will the convergence of different data streams and processes come together to make better organizations?</td>
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<tr>
<td></td>
<td><strong>Moderator: Nathan Hartman</strong> – Professor, Computer Graphics Technology and DEC Director</td>
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<tr>
<td></td>
<td><strong>Michael Hughes</strong> – Manager, Modeling and Simulation Services, Cummins</td>
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<td></td>
<td><strong>John Murphy</strong> – CTO, True Analytics Manufacturing Solutions</td>
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<td></td>
<td><strong>Doug Mansfield</strong> – President, Kirby Risk</td>
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<tr>
<td>9:45 – 10:15 AM</td>
<td><strong>The Future of Work in a Digital Environment</strong></td>
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<td>Building on the opening panel session, this presentation will review the changes in skills and knowledge employees will need to possess, as well as changes to current processes that will be required to implement digital design and manufacturing systems.</td>
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<td><strong>Stephen Ezell</strong> – Vice President, Global Innovation Policy, The Information Technology &amp; Innovation Foundation</td>
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<tr>
<td>10:15 – 10:45 AM</td>
<td><strong>Break and Networking</strong></td>
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<tr>
<td>10:45 – 11:15 AM</td>
<td><strong>The Democratization of Information</strong></td>
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<td>Continuing to expand on the opening panel, this presentation will focus on the technologies and methodologies that will expand the access and use of digital information; analytics and visualization, artificial and physical intelligence, and VR/AR and mixed reality technologies</td>
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<td><strong>James Martin</strong> – Director of Marketing and Sales Enablement, Anark</td>
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<tr>
<td>11:15 AM – 12:15 PM</td>
<td><strong>Digital Enterprise Readiness</strong></td>
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<td>The panelists in this moderated session will present their insights and unique perspectives on the readiness of the manufacturing sector. Topics that will be covered include workforce readiness, business units where the ability to test DE deployment would be most valuable, highest risk areas for DE system deployment, and supply chain readiness from an SME perspective.</td>
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<td><strong>Moderator: Nathan Hartman</strong> – Professor, Computer Graphics Technology and DEC Director</td>
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<td></td>
<td><strong>Blair Milo</strong> – Secretary of Career Connections and Talent, State of Indiana</td>
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<td></td>
<td><strong>Jeff Hopkins</strong> – Digital Transformation Leader Corporate Quality Assurance, Procter &amp; Gamble</td>
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<td></td>
<td><strong>Sascha Harrell</strong> – Director of Education and Workforce Development, Indiana Manufacturing Competitiveness Center (IN-MaC)</td>
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<tr>
<td>Time</td>
<td>Session</td>
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<tr>
<td>12:15 – 1:45 PM</td>
<td>Lunch Presentation</td>
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<td><strong>Using IIoT Technologies to Drive Cost Modeling in the Digital Enterprise</strong></td>
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<td>One of the more effective opportunities to deploy IIoT technologies is around the ability to capture materials and production data to determine and control costs. This presentation will provide an overview of predictive cost modeling and the use of IIoT technologies to gather process and materials information, with an eye toward closing the feedback loop to the product design function.</td>
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<td><strong>Jan-Anders Mansson, Ph.D. – Distinguished Professor of Distinguished Professor of Materials &amp; Chemical Engineering and Co-Executive Director of IN-MaC</strong></td>
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<tr>
<td>1:45 – 2:45PM</td>
<td>Continuous Digital Value Streams: Challenges and Opportunities</td>
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<td>The panelists in this session will provide their views on a variety of topics that will impact the ability of companies to efficiently and effectively implement DE technologies, including: cybersecurity concerns, employee roles and responsibilities (e.g., off-hours obligations), opportunities for SMEs, and sustainment over the product lifecycle.</td>
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<td></td>
<td><strong>Moderator: Nathan Hartman – Professor, Computer Graphics Technology and DEC Director</strong></td>
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<td></td>
<td><strong>David Ewing – Technical Account Manager, Aras Corporation</strong></td>
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<td></td>
<td><strong>Tim Taylor – VP &amp; General Manager, Haas Automation</strong></td>
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<td></td>
<td><strong>Jennifer Trasti – Title, Sandia National Laboratory</strong></td>
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<tr>
<td>2:45 – 3:15 PM</td>
<td>Break and Networking</td>
</tr>
<tr>
<td>3:15 – 3:45 PM</td>
<td>Impact of Digital Enterprise Systems on User Interfaces and Experiences</td>
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<td>The user experience provided by manufacturing sector companies to their workforces is starkly different from, but needs to become more like, the user experience provided by consumer-oriented businesses to those same workers in their roles as consumers. The presentation will provide inputs into the changes that will need to be made to industrial UI/UX applications to maintain and improve operational efficiencies.</td>
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<td><strong>Nancy Rasche – Asst. Professor of Practice, Computer Graphics Technology, Purdue University</strong></td>
</tr>
<tr>
<td>3:45 – 4:15 PM</td>
<td>How PLM Supports the Digital Value Stream</td>
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<td>This presentation will discuss the role of traditional PLM tools, methods, and systems will be needed, and the need to evolve them, to support the digital value stream.</td>
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<td></td>
<td><strong>Jeff Hopkins – Digital Transformation Leader Corporate Quality Assurance, Procter &amp; Gamble</strong></td>
</tr>
<tr>
<td>4:15 – 4:30 PM</td>
<td>Concluding Remarks</td>
</tr>
<tr>
<td></td>
<td><strong>Nathan Hartman – Professor, Computer Graphics Technology and DEC Director</strong></td>
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</tbody>
</table>