IN-MaC
Indiana’s Next Generation Manufacturing Competitiveness Center

Connecting Statewide and National Resources for Manufacturing Knowledge Creation and Delivery

UPDATE: OCTOBER 2015
IN-MaC: Executive Summary
First Two Years

- **Three Thrusts**
  - Long-term Research Innovation
  - Education & Workforce Development
  - Technology Adoption & Transfer

- **Successful Launch**
  - 34 Tech Adoption contracts in process or completed with Indiana companies; 38 more in discussions
  - Engaged with Ivy Tech, Vincennes, PU Calumet, Purdue North Central & IPFW
  - Five IN-MaC Research Fellows from Engineering, Technology, and Science
  - Purdue a partner with UI Labs on the Digital Manufacturing Design Innovation Institute (DMDII) NNMI;
  - Purdue is the Design and Manufacturing Simulation Technology Area for the Institute for Composites Manufacturing Innovation (IACMI) NNMI

- **Sustainability Model**
  - Create competitive edge via fluid integration of high and low TRL work
  - Leverage Low TRL (1-3) federally funded research to drive future capabilities
  - Engage Industry
    - High TRL (4-7) contract research using NSF IUCRC or similar model
    - Fees for continuing education
    - Consortium membership fees
IN-MaC Executive Committee Members

- Deans of Three Colleges
  - Gary R. Bertoline, Dean, Purdue Polytechnic Institute
  - David Hummels, Dean, Krannert School of Management
  - Leah H. Jamieson, John A. Edwardson Dean, College of Engineering

- Faculty
  - Nathan W. Hartman, Professor of Computer Graphics Technology and Director, Product Lifecycle Management Center of Excellence
  - Thomas H. Brush, Senior Associate Dean for Research, Krannert School of Management
  - John W. Sutherland, Fehsenfeld Family Head of Environmental and Ecological Engineering

- University Level Staff
  - Julie K. Griffith, Vice President for Public Affairs, Purdue University
  - Amy R. Noah, Vice President for Development

- Ronald J. Steuterman, Managing Director, IN-MaC
IN-MaC Thrust Leadership

- **Research**
  - Nathan W. Hartman, Professor of Computer Graphics Technology and Director, Product Lifecycle Management Center of Excellence
  - Thomas H. Brush, Senior Associate Dean for Research, Krannert School of Management
  - John W. Sutherland, Fehsenfeld Family Head of Environmental and Ecological Engineering

- **Technology Adoption**
  - Griffith A Maupin, Purdue Manufacturing Extension Partnership

- **Education and Workforce Development**
  - Geanie Umberger, Associate Dean for Engagement
  - Susan Smith, VP for Technology Division, Ivy Tech Community College
  - David Tucker, VP for Workforce Development/Community Services, Vincennes University
  - Niaz Latif, Dean, College of Technology and Professor, Mechanical Engineering Technology, Purdue University Calumet
IN-MaC: Indiana Next Generation Manufacturing Competitiveness Center

Vision and Scope Overview

- **IN-MaC** has a state/regional/national scope and seeks to be the external interface point for Next Generation Manufacturing at Purdue
- **MEP** is the local dissemination arm for IN-MaC technology adoption and for federal E&WD content
- **The Indiana Manufacturing Institute** is a collaborative work space for Next Generation Manufacturing Research, Education, and Technology Adoption located in the Purdue Research Park

**IN-MaC Technology Adoption Thrust**

- **Staff Engineer** (or Faculty) Consulting
- **Technology Adoption** MEP & Faculty Labs
- **TRL 1-3** Next Gen Manufacturing Research

**IN-MaC Research Thrust**

- **TRL 4-7** Next Gen Manufacturing Research

**IN-MaC Education Thrust**

- **Assessment** < 1 day
- **Seminar** < 1 day
- **Workshop** Days/Weeks
- **Certificate** Days/Weeks/Months
- **Degree** > Years

Note: time line concept and Respond, Diagnose bubble sequence was developed by Purdue MEP
IN-MaC
A Three-Way Collaboration
IN-MaC
A Three Thrust Approach

Technology Adoption & Transfer

Education & Workforce Development

Research for Future Competitiveness
A Model for Impact

IN-MaC

IN-DIANA

Technology Adoption & Transfer

INDUSTRY

EDUCATIONAL INSTITUTIONS

Education & Workforce Development

Research for Future Competitiveness
IN-MaC
A statewide center with global reach in manufacturing competitiveness

- **Three Thrusts**
  - Long-term Research Innovation
  - Education & Workforce Development
  - Technology Adoption & Transfer

- **Partnership:**
  - Purdue - Ivy Tech - Vincennes

- **Collaboration with**
  - Global Manufacturing Leaders
  - Small to Medium Manufacturing Enterprises
  - and the State
Education & Workforce Development
Thrust Led by Geanie Umberger, Purdue Polytechnic Institute

Susan Smith
VP for Technology Division

David Tucker,
VP for Workforce Development & Community Services

Niaz Latif, Dean,
College of Technology
Professor, Mechanical Engineering Technology
Education & Workforce Development
Funded Projects; Total = $718K over two years

Additive Manufacturing - Orthopedic & Advanced Manufacturing Training Center - Warsaw, IN

Advanced Manufacturing and Workforce Development

Meeting Workforce Needs for Mechatronics Technicians

Advanced Manufacturing Leadership Development Program
College of Education
Product Lifecycle Management Certificate
College of Technology
Technology Adoption & Transfer

Enhancing Competitiveness Today
Thrust Led by Griffith Maupin, Purdue Manufacturing Extension Partnership

Focus Areas for 2015-16

- **Digital Engineering**
  - Finite element methods
  - Materials characterization
  - Computational fluid dynamics

- **Product Lifecycle Management**
  - Supply chain integration
  - Inventory optimization
  - ERP/CAD data integration

- **Production Systems & Modeling**
  - Manufacturing floor optimization and layouts
  - Production line simulations
  - Warehouse systems
Technology Adoption & Transfer
Projects Underway, Completed, or Under Consideration

- **Project Status**
  - Completed (24)
  - In Process (10)
  - Prospects/Leads (38)

- **Campuses Represented**
  - West Lafayette
  - IU-Purdue Ft. Wayne
  - Purdue North Central

- **Purdue Personnel Involved**
  - 23 Faculty (18 WL, 4 IPFW, 1 PNC)
  - 4 AP Staff (3 WL, 1 IPFW)
  - 1 Post Doc
  - 22 Graduate Students
  - 1 Undergraduate Student

Activity Inception (Sept 2013) through Sept 2015
Technology Adoption
Selected quotes from participating Indiana companies

- **Don Dumoulin, CEO/Owner, Precise Mold and Plate, Columbus, IN**
  “... delighted to be awarded an IN-MaC grant in 2013, ... already seeing dramatic results. ... our IN-Mac work set has helped build our overall capacity... 1Q revenue up over 50% versus last year... big believers in the power of the IN-Mac and our expert team from Purdue University.”

- **Craig S. Carson, CEO, Jeco Plastic Products, Plainfield, IN**
  “The direct, immediate result of the IN-Mac support is an initial order of over $110,000 in tooling and $150,000 in parts currently outsourced in China. The growth prospects within 12 months are for 3-5 times that amount. We anticipate adding three high paying jobs (approximately $40,000 annual salaries) within the next 12 months as a result of this program.”
Research

- **Thrust Led by:**
  - Nathan W. Hartman, Associate Professor of Computer Graphics Technology Director, Product Lifecycle Management Center of Excellence
  - Thomas H. Brush, Senior Associate Dean for Research, Krannert School of Management
  - John W. Sutherland, Fehsenfeld Family Head of Environmental and Ecological Engineering

- **Three Focus Areas:**
  - Digital Manufacturing Enterprise
  - Personalization
  - Market Viable Manufacturing Processes

- **Manufacturing Cluster Hire of Six Faculty is Underway**
**Research Focus Area Status**

- **Digital Manufacturing Enterprise Focus Area**
  - Established as the “DNA” of IN-MaC
  - Leverages DMDI

- **Developing Focus Areas:**
  - Personalization Emerging Project
    - Personalized medicines
  - Market Viable Manufacturing Technology Emerging Projects
    - Nano / “Roll to Roll” manufacturing (partner in Flexible Electronics NNMI)
    - Composites manufacturing (major partner in IACMI NNMI)
    - Laser Based Smart Digital Manufacturing
**Research: Federal Funding Successes**

- **IN-MaC is Purdue’s Link to the Recently Awarded Digital Manufacturing Design Innovation Institute (DMDII) awarded Sept 2014**
  - National Network for Manufacturing Innovation (NNMI)
  - Awarded to UI Labs: 5 years / $70 Million Total
  - IN-Mac providing up to $671K in cash cost share

- **Partner on Institute for Composites Manufacturing Innovation (IACMI), NNMI awarded Jan 2015**
  - Manufacture of Composite Materials and Shapes
  - Indiana Component is a Composites Modeling & Mfg Simulation Technology Area, led by R. Byron Pipes, Materials Engineering
  - $15 million cost share provided by IEDC
  - Awarded to Creative Composites Solutions Corp. (UT Knoxville) 5 yrs / $70 Million Total

- **Partner on the NEXTFLEX (new name for Flexible Hybrid Electronics Institute), NNMI awarded August, 2015**
  - Led by Ali Shakouri, Director, Birck Nanotechnology Center
  - 5 yrs / $75 Million Total; Awarded to FlexTech Alliance
  - Birck Center is a resource center for the Institute
  - IN-MaC providing up to $500K in cash cost share
Research

Emerging Projects
Digital Enterprise

Team:
- Nathan Hartman, CGT
  PLM Center Director
- John Sutherland, EEE
- Tim Ropp, AT
- Byron Pipes, MSE
- Elisa Bertino, CS
- Dan Delaurentis, AAE
- Mark French, SoET
- Bedrich Benes, CGT
- John Springer, CIT
- Voicu Popescu, CS
- Fu Zhao, EEE

Vision & Impact:
- Reduce cost and environmental impact of products while increasing overall quality.
- The current digital product model used by industry is fragmented and domain-specific. The team’s work will:
  - Develop model-based tools to support the complete product lifecycle with geometry, behavior, and context.
  - Develop cost assessments of production, supply network, & sustainment decisions.
  - Deploy a network architecture model to simulate the digital enterprise.
  - Produce the ability and standards necessary to digitally represent a product from conception through retirement & maintain digital access to all points on that continuum with necessary fidelity.

Customer Base:
- PLM Center Members
  - Current membership includes Boeing, Cummins, Rolls Royce, Gulfstream, Procter & Gamble, Textron, and Sandia National Laboratory
Composites Manufacturing

Team:
• R. Byron Pipes, AAE/CHE/MSE
• James Caruthers, CHE
• Gary Cheng, IE
• JohnathanGoodsell, AAE
• Nate Hartman, CIT
• Karthik Ramani, ME
• Thomas Siegmund, ME
• Ron Sterkenburg, AVTech
• Rod Trice, MSE
• Wenbin Yu, AAE

Vision & Impact:
• The Indiana Composites Modeling & Manufacturing Process Simulation Technology Area is one of thrust areas within the just awarded Institute for Advanced Composites Manufacturing Innovation NNMI
• Research focus is simulation of manufacturing of advanced composites for the automotive, aerospace & wind energy industries and recycling of manufacturing scrap and end of life structures.
• Indiana Technology Area engages the simulation tool industry including as listed in the Customer Base section.

Customer Base:
• Ford Motor Company, Honda America, Volkswagen, General Motors, Boeing, Cytec, Hinkle, Toray, Toyota, Rolls Royce, Dassault Systemes, ESI, Siemens, AutoDesk, MSC/Digimat, NASA, DARPA
Laser Based Smart Digital Manufacturing

Team:
- Gary J. Cheng (IE)
- Babak Zaei (ECE)
- Xiulin Ruan (ME)
- Alam Ashraf (ECE)
- David Janes (ECE)
- Collaborators: Bruzzaniti, Angela (IU)

Vision & Impact:
- The team will build a laser based additive manufacturing system for 2D/3D structures of metal, ceramic, functional nanomaterials for biomedical, energy, electronics industry.
- Provide access for the energy, biomedical, and electronics industries to direct printing of multifunctional 3D structures with multiscales (meters to microns) and additive manufacturing of 2D thin films layer by layers.
- Long term impact: Industrial and academic access to this unique test bed will create lower cost, personalized products via close collaboration among industry and faculty from different disciplines, thin-film electronics, biomedical devices, smart sensor development and high speed manufacturing techniques.

Customer Base:
Personalized Medicines

Team:
• Lead Contact:
  - GV Rex Reklaitis, (ChE)
• Purdue faculty:
  - M. Harris (ChE)
  - C. Laird (ChE)
  - ZK Nagy (ChE)
  - J Pekny (ChE, Cancer Care Engr)
  - L Taylor, (Industrial & Physical Pharmacy)
• Indiana University Medical School
  - Dr David Flockhart, Institute for Personalized Medicine

Vision & Impact:
Vision: The PMM Team will lead the development of manufacturing technology for small scale, distributed manufacturing of drug dosage, which enables cost-effective personalized medicine.

Short term impact: Cancer treatment applications developed w/ IU Med School partners

Long term Impact: Minimize serious risk of under-and over-dosing of patients by replacing current “one size fits all” treatments with a drug regimen guided by “Drop on Demand” technology combined with novel NSF funded model-based dose optimization tools.

Customer Base:
• GSK, Eli Lilly, Abbvie, Cancer Care Foundations and patient organizations (e.g. Gateway, Multiple Myeloma), FDA and NIH
Indiana Roll-to-Roll Nanomanufacturing Center

**Team:**
- Ali Shakouri, Director of Birck Nanotechnology Center
- Jan Allebach, Babak Ziaie and Dimitri Peroulis (ECE); Arvind Raman, George Chiu and Tim Fisher (ME); Kinam Park (BME); Alex Wei (Chemistry); Rodo Pinal (Pharmacy); Gary Cheng (IE); Bryan Boudouris (ChemE); Alina Alexeenko (AAE); Teresa Carvajal (ABE); Joe Kokini and Yuan Yao (Food Science); Jeff Youngblood (MSE)

**Vision & Impact:**
- **Within three years:** Develop novel nanomanufacturing R&D platform combining high speed large-area organic electronic manufacturing, flexible displays, and variable data printing together with pharmaceutical formulations and ag products to make SMART films.
- **Within five years:** Develop a Nanomanufacturing Pilot Factory in Indiana
- **Near term Impact:** Smart packages with RFID and sensors, anti-counterfeiting drug formulations.
- **Long term:** Personalized medicine with precise, controlled release of medication. Fast monitoring of animal diseases. Food packages with dynamic expiration date minimizing waste & food poisoning.

**Customer Base:**
- Start ups: BGI, Bearing Analytics, Anfiro; Bio/Pharma: Lilly, IMA Life, Roche, Zimmer; Ag/Food: Dow Agrosciences, Monsanto; Electronics: Landauer, Google, Samsung, Intel; Printing: HP, Océ/Canon; Non-woven films: Kimberly-Clarke, P&G, 3M
Sustainability Model

- Industry based and customer focused
  - Select demonstration test bed from developing projects

- Create competitive edge via fluid integration of high and low TRL work

- Naturally reinforcing funding loops
  - Leverage Low TRL (1-3) research to drive future capabilities
  - Engage Industry with High TRL (4-7) contract research using NSF IUCRC or similar model
  - Fees for continuing education
  - Consortium membership fees
  - Feedback loops to inform and support Low TRL (1-3) research
IN-MaC
Indiana’s Next Generation Manufacturing Competitiveness Center
Connecting Statewide and National Resources for Manufacturing Knowledge Creation and Delivery
ADDITIONAL DETAIL
Commitment from State of Indiana

Renewed for Additional Two years @ $2.5 million/year in May 2015

- **As presented to the Indiana Legislature:**
  - **Vision:** IN-MaC will be a statewide resource providing access to state-of-the-art knowledge and practice in manufacturing processes, metrology, materials, systems, and information sciences for Indiana’s business and industry.
  - **Key Impact**
    - Competitiveness of Indiana Manufacturing Industry
    - Competitiveness of Indiana Manufacturing Workforce
    - Competitiveness for Federal Research Funding
    - National Resource for Training, Research, and Technology Adoption
Commitment from Purdue

Six new faculty members

- Purdue, in a partnership among the Provost and the Colleges of Engineering, Science, and Technology will hire six new faculty members over the next two years in support of model-based personalization of products and services.
  - Cyber-enabled Experimentation
  - Personalization
  - Multi-scale Predictive Modeling
  - Scaling Principles
  - Optimization and Design On-the-fly
  - Social Manufacturing
Education & Workforce Development

Thrust Led by
Geanie Umberger, PhD
Associate Dean for Engagement
Purdue Polytechnic Institute
Education & Workforce Development Partners

Susan Smith  
VP for Technology Division

David Tucker, VP for Workforce Development/Community Services

Niaz Latif, Dean, College of Technology and Professor, Mechanical Engineering Technology

**Partner Responsibilities**

- Administrative lead for institution
- Assess and award programmatic funding
- Set strategic plan
- Participation in meetings and strategy sessions
Education & Workforce Development

Strategic Planning Activity: Possibilities

- Translating applied research
  - Industry-based training
  - Certificate-based training
  - Educational programs

- Develop educational pathways
  - Driven by IN-MaC research
  - Industry input on workforce gaps

- Convene and promote educational partnerships
  - Disseminate curriculum
  - All levels of workforce training and education

- Drive educational research
  - Efficiency
  - Efficacy

- Indiana workforce training and educational programming
  - Identify
  - Inventory
  - Interactive tool
Education & Workforce Development
Projects Awarded

Additive Manufacturing - Orthopedic & Advanced Manufacturing Training Center- Warsaw, IN

• Matching funds to support Direct Metal Laser Sintering (DMLS)
• Curriculum development – AS Machine tool, Advanced manufacturing, Pre-engineering, Engineering technology

Advanced Manufacturing and Workforce Development

• 5 Axis CNC Programming: Certificate based training, Incumbent workforce
• Advanced Manufacturing Machinery Technician Now Program: Curriculum development, Industrial maintenance, Returning veterans
• Jasper Automated Manufacturing Technology Degree Program: Industry based AS degree, Automated manufacturing technology, Supported by industry, Work-based education
Meeting Workforce Needs for Mechatronics Technicians

- DOL Grant: All levels of learners: K-12 Pathways, AS & BS Degree, Credentialing/certification for Incumbent & Underemployed, On-site employee training
- IN-MaC Add-in: Flipped/distance curriculum, Lecture capture, Mobile laboratories

Advanced Manufacturing Leadership Development Program
- College of Education
  - Product Lifecycle Management Certificate
    - College of Technology

- Develop curriculum for CTE teacher professional development: Manufacturing career awareness, Preparation, Career pathways, Program participation
- Teacher training
- Program improvement plan advanced manufacturing education: High school & Middle school
Technology Adoption & Transfer

Thrust Led by
Griffith A. Maupin
Purdue Manufacturing Extension Partnership
Technology Adoption & Transfer
Technology Adoption Focus Areas for 2015-16

- **Digital Engineering**
  - Finite element methods
  - Materials characterization
  - Computational fluid dynamics

- **Product Lifecycle Management (PLM)**
  - Supply chain integration
  - Inventory optimization
  - ERP/CAD data integration

- **Production Systems and Modeling**
  - Manufacturing floor optimization and layouts
  - Production line simulations
  - Warehouse systems
Thrust Led by

**Nathan W. Hartman**
Associate Professor of Computer Graphics Technology
Director, Product Lifecycle Management Center of Excellence

**Thomas H. Brush**
Senior Associate Dean for Research,
Krannert School of Management

**John W. Sutherland**
Fehsenfeld Family Head of Environmental and Ecological Engineering
Research
Three Focus Areas

• Digital Manufacturing Enterprise
  – Forms a digital mirror to the physical product including its geometric, behavioral, and contextual definitions

• Personalization
  – Advances the connectivity and availability of computational resources with potential to allow personalized products with efficiency of mass production

• Market Viable Manufacturing Processes
  – Translate newly invented materials and complex electro-mechanical systems with embedded software to manufacturing processes at market volumes and cost
# Research

## IN-MaC Graduate Student Research Fellows: Inaugural Class

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Proposal Title</th>
<th>Dept/School</th>
<th>Advisor Name</th>
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<tbody>
<tr>
<td>Stephen Hodson</td>
<td>Reel-to Reel (R2R) Manufacturing of Carbon Nanopetal Arrays</td>
<td>AAE / ME</td>
<td>Alina Alexeenko/Tim Fisher</td>
</tr>
<tr>
<td>Elcin Icten</td>
<td>Manufacture of Personalized Medicines</td>
<td>ChE</td>
<td>G.V. Reklaitis/Z.K. Nagy</td>
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<tr>
<td>Juraj Vanek</td>
<td>Optimizing 3D Objects for Effective 3D Printing</td>
<td>CGT</td>
<td>Bedrich Benes</td>
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<tr>
<td>Nigam Arora</td>
<td>Roll-to-Roll Manufacturing of Thermal Separator (TSS) Membranes for Self-Regulating Li-ion Batteries</td>
<td>Che</td>
<td>Alexander Wei</td>
</tr>
<tr>
<td>Qiong Nian</td>
<td>Laser Based Digital Manufacturing Platform for Integration of MultiFunctional Structures in Pharmaceutical and Food Industry</td>
<td>IE</td>
<td>Gary Cheng</td>
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