NSF Workshop on Frontiers of Additive Manufacturing Research and Education
July 12, 2013

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Discussion Topics

• NAMII Start-up History
• Organizational Framework
• Membership
• NAMII Roadmapping
• Project Calls Process
• Summary
Background: National Network for Manufacturing Innovation (NNMI) and Pilot Institute Announcement

- Proposed one-time, $1B investment (FY13) for up to 15 Institutes of Manufacturing Innovation
- Close the gap between R&D and deployment of technological innovations in domestic production of goods

“institutes of manufacturing excellence where some of our most advanced engineering schools and our most innovative manufacturers collaborate on new ideas, new technology, new methods, new processes.”

“We Can’t Wait” – use existing resources and authorities to demonstrate concept through a pilot institute – select competitively – fit within agencies missions
# Accelerated Start-up Timeline

<table>
<thead>
<tr>
<th>Date(s)</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Mar 2012</td>
<td>Presidential Announcement of NNMI and a pilot institute</td>
</tr>
<tr>
<td>13 Apr 2012</td>
<td>Public Announcement of upcoming BAA</td>
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<tr>
<td>8 May 2012</td>
<td>Broad Agency Announcement (BAA) launched</td>
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<tr>
<td>16 May 2012</td>
<td>Proposer's Day (Q&amp;A)</td>
</tr>
<tr>
<td>14 Jun 2012</td>
<td>Proposals Due</td>
</tr>
<tr>
<td>19-21 Jun 2012</td>
<td>Multi-agency team proposal evaluation and selection</td>
</tr>
<tr>
<td>16 Aug 2012</td>
<td>Award Announcement for NAMII</td>
</tr>
<tr>
<td>26 Nov 2012</td>
<td>First Project Call Announced</td>
</tr>
<tr>
<td>31 Jan 2013</td>
<td>Project Proposals Due</td>
</tr>
<tr>
<td>20 Mar 2013</td>
<td>Projects Announced</td>
</tr>
<tr>
<td>2-3 April 2013</td>
<td>NAMII Program Review and Project Kick-off</td>
</tr>
</tbody>
</table>
• A Defense-wide Manufacturing S&T team-led, Multi-agency collaboration between industry, government and universities
• Public-private partnership

• Shared facilities open to industry
  — Especially attractive to small businesses
• Enabling technology transition and commercialization
• Addressing Technology Readiness Level (TRL) / Manufacturing Readiness Level (MRL) 4-7
  — Bridge the gap in Manufacturing Innovation
• Educational outreach and workforce development
• $ 45M gov’t investment pledged for pilot, $30M CA awarded

A Model for Subsequent Manufacturing Innovation Institutes
Gap in Manufacturing Innovation

Government & Universities

Private Sector

Bridge Begins Here

Technology Readiness Level

1 2 3 4 5 6 7 8 9

Basic Technology Research
Research to Prove Feasibility
Technology Development
Technology Demonstration
System/Subsystem Development
System Test, Launch & Operations
“Industrial Commons”* – collective R&D, engineering, and manufacturing ability that can sustain innovation
Invent stuff, make stuff and train the next generation

*Harvard Business Review, Pisano and Shih

**VISION:** Widespread Adoption of Additive Manufacturing

- **Greater Economic Competitiveness**
  - New and better products and manufacturing technologies
  - Spin-off Companies
  - Highly Skilled Workforce

**Innovators:**
- Full time applied researchers
- Faculty/students in residence
- Engineers
- Entrepreneurs

**Shared Infrastructure:**
- Additive Mfg Equipment
- Design & Simulation
- Part Testing
- Demonstration

**Links:**
- Manufacturing Extension Partnerships
- Other Mfg Innovation Institutes
- International community

**Public Sector**
- Federal agencies
- National labs
- States

**Private Sector**
- “Voice of the Customer”
  - Large Industry
  - Small Businesses
  - Entrepreneurs

**Education Sector**
- Research universities
- Community colleges
- Secondary schools

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Strong, Holistic, Integrated Technology Plan

- Process development: metals, polymers, ceramics, electronics, hybrid
- Digital thread / AME
- Specialized, portable AM systems
- Open Architecture
- Process planning

- Process Control
- Material Development
- Component Design
Governance Structure – Shared Leadership

**Executive Committee**
“Champions” - Vision, Policy and Long-term Strategy and Planning

**Technical Advisory Board**
(12 gov’t members)
Link to Gov’t Agencies, Technical Strategy, Program Operating Guidance

**Governance Board**
Technical strategy, program operating guidance

**Deputy Director: Technology Development**
- Facility Management
- Project Management
- IP Management

**Deputy Director: Technology Transition**
- Outreach & Engagement
- Technology Dissemination
- Conferences & Events

**Deputy Director: Advanced Manufacturing Enterprise**
- SME Coordination
- Incubation/Commercialization
- Supply chain and design modeling
- Digital Thread
- Sustainability Thread

**Deputy Director: Workforce/Educational Outreach**
- Education Outreach
- STEM activities
- Workforce Training
- Integrated Education thread

*Executive Committee (11): Industry, For-profit Organization (2), Non-profit Association (2), Academic (2), Government (3), At-large (2)*

**Governance Board**: All 1st and 2nd Tier Members, Small Business, MEP Director Members, States Ex-Officio

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### Hub AM Equipment Entrusted To Date

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Manufacturer</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fused Deposition Modeling</td>
<td>Stratasys</td>
<td>Fortus 400MC</td>
</tr>
<tr>
<td>Selective Laser Melting</td>
<td>Renishaw</td>
<td>AM 250</td>
</tr>
<tr>
<td>Bonded Plaster</td>
<td>Z-Corp</td>
<td>Z-Printer 310</td>
</tr>
<tr>
<td>Selective Laser Sintering</td>
<td>3D Systems</td>
<td>SLS sPro 60</td>
</tr>
<tr>
<td>Wax Depositon</td>
<td>3D Systems</td>
<td>Thermojet</td>
</tr>
<tr>
<td>Bonded Refractory Material</td>
<td>ExOne</td>
<td>M-Lab</td>
</tr>
<tr>
<td>Material Extrusion (3D Printer)</td>
<td>3D Systems</td>
<td>Cube</td>
</tr>
<tr>
<td>Direct Metal Deposition</td>
<td>POM</td>
<td>Synergy 5</td>
</tr>
<tr>
<td>Material Extrusion (3D Printer)</td>
<td>3DCAD Printer</td>
<td>Hyrel</td>
</tr>
<tr>
<td>Plunge / &quot;Dry&quot; EDM</td>
<td>Sodick (w/ POM Upgrades)</td>
<td>AQ55L</td>
</tr>
</tbody>
</table>

Ancillary/support equipment: CNC milling machine, ovens, chillers, etc.

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NAMII Membership – 77 Organizations (6/24/13)

- 3D Systems Corporation*
  - Abbatron*
  - Alcoa
- Allegheny Technologies*
  - APEX CNC Swiss*
- Applied Systems and Technology Transfer (AST2)*
- Association of Manufacturing Technology*
  - Automated Dynamics*
  - Bayer Material Science*
  - BenFranklin C&N PA*
  - BenFranklin SE PA*
  - BioDevice Design*
  - Boundry Systems*
- Case Western Reserve University*
  - Catalyst Connection*
- Carnegie Mellon University*
- Concurrent Technologies Corporation*
  - DVIRC*
- Energy Industries of Ohio*
  - The ExOne Company*
  - FMW Composites*
  - Fourth Economy
- GE Global Research*
  - Greenleaf*
  - Innovation Works
  - IRC Network, Inc.
  - Johnson Controls, Inc.*
    - JumpStart*
  - Kennametal*
  - Kent Display*
  - Kent State University*
  - Lehigh University*
  - Liquid X Printed Metals*
  - Lockheed Martin*
    - Lubrizol*
    - M-7 Technologies*
    - MAGNET*
  - Manufacturing Resource Center (MRC)
  - Missouri University of Science and Technology
    - Moog, Inc.
    - NE PA IRC*
    - NorTech*
- Northrop Grumman*
  - Northhampton Community College
    - Northrop Grumman*
    - NorthWest IRC
    - nScrypt*
    - Ohio Aerospace Institute*
    - Optomec*
    - OSRAM Sylvania*
  - Oxford Performance Materials*
- Pennsylvania State University*
  - PTC ALLIANCE
  - The POM Group*
    - Raytheon*
  - Robert C. Byrd Institute (RCBI)*
  - Robert Morris University*
    - RP+M
    - RTI*
  - Society of Manufacturing Engineers*
    - Solid Concepts
    - Stratronics*
    - TechSolve*
  - The Timken Company*
- Touchstone Research Lab*
- United Technologies
- University of Akron*
- University of Connecticut
- University of Pittsburgh*
- University of Texas – Austin
- University of Texas at El Paso
  - University of Toledo
- Westmoreland County Community College*
  - Wohlers Associates*
  - Wright State University
- Youngstown Business Incubator*
- Youngstown State University*

Lead Members listed in RED($200K)
Full Members listed in BLUE ($50K)
Supporting Members in GREEN ($15K)
Asterisk* shows Original Members (58)
Membership

As of 6/24/2013:
77 Members from 15 States

Regional Cluster
“Hub and Spoke”

Original Member  New Member
Why Membership

• Community
  – Formalized community looking to leverage AM Technologies
  – Leverage learning curves
  – Cooperatively solve similar issues
  – Direct future equipment, material, and software development
  – Technical strategy input

• Work Force Development
  – Pre-K to grey training resources
  – Immersive training/learning at NAMII facility

• Projects
  – Lead NAMII directed project calls
  – Team with NAMII & members to win additional government project calls
  – Use NAMII resources for targeted company projects

• Enterprise Data
  – Processing & Application data
  – Material properties
  – Supply chain
  – Analysis
<table>
<thead>
<tr>
<th>Benefits</th>
<th>Lead ($200k)</th>
<th>Full ($50K)</th>
<th>Supporting ($15K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAMII Governance Board seat</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Safe harbor for collaboration on research and royalty-free, non-exclusive rights for commercial development for all NAMII intellectual property (IP)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Option to embed one employee on-site at NAMII headquarters for free and more employees at an additional overhead fee</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option to embed employees on-site at NAMII headquarters for an additional overhead fee</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Priority access to NAMII for member self-funded applied research project execution with exclusive rights to IP developed from the project</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Supporting Membership for small and medium enterprise (SME) supplier of the Lead Member’s choice</td>
<td>One Free</td>
<td>One Discounted</td>
<td></td>
</tr>
<tr>
<td>Free access to the NAMII facility and supported technology to incubate a member start-up</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One free “test-fit project” in which NAMII technicians will provide confidential deployment and production strategy consultation</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fee discount for NAMII workforce training courses</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Annual priority nomination and/or selection of a NAMII graduate intern to participate in Lead Member’s project</td>
<td>✓</td>
<td>Non-priority nomination</td>
<td>Non-priority nomination</td>
</tr>
<tr>
<td>Participation in the development of the NAMII National Additive Roadmap process</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Free access to all NAMII-managed technical presentations and workshops</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Participation in all NAMII poster sessions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Free first-article/initial production test accessibility to NAMII’s physical AM infrastructure for non-NAMII, independent projects that are outside of NAMII’s ongoing research efforts</td>
<td>✓</td>
<td>Fee for service basis</td>
<td>Fee for service basis</td>
</tr>
</tbody>
</table>
How To Become A Member (US Owned Companies)

• Membership Information
  – http://namii.org/become-a-member/

• Step 1 – Membership Request
  – Download Membership Request Form
  – Return completed form via email to namii.info@ncdmm.org

• Step 2 – NDA Execution
  – NCDMM Non-Disclosure Agreement (NDA) is provided to requester
  – Completed NDA is returned to NAMII

• Step 3 – Membership Agreement
  – NAMII Membership Agreement is provided to requester w/ fully executed NDA
  – Completed Membership Agreement is returned to NAMII

• Step 4 – Membership Dues
  – NAMII returns fully executed Membership Agreement & Membership Dues Invoice
  – Membership dues are payable within 30-days
Membership Dues

- **Cash Payments**
  - Desired to demonstrate membership investment in institute
  - Needed to sustain institute operating costs

- **In-Kind Contributions**
  - Welcome where they contribute to growth of the institute
  - Requires submittal of auditable market value justification

- **Types of In-Kind Contributions**
  - Equipment entrustments (market value)
  - Intellectual Property – reports, material property data, etc.
  - Material donations or cost sharing
  - Services
  - Onsite NAMII Internships (company resource onsite at NAMII for set period)
  - Company-sponsored Internships (company sponsors NAMII selected interns)
AM Technology Roadmap Overall Philosophy

• “Voice of the Customer”

• Investment Strategy

• Strategic Planning, Decision Making, and Collaboration Framework

• Big Impact Outcomes
DRAFT AM Technology Roadmap

• Compiled from 30+ Documents

• Industry leader interviews

• Indexed Under Key Themes

• Project Call #1 Topic Areas

A Technology Roadmap for Additive Manufacturing

~Draft~

Produced for:
The National Additive Manufacturing Institute and
the National Center for Defense Manufacturing and Machining
236 West Boardman Street
Youngstown, OH 44503

Distribution A: Cleared for Public Release # 88ABW-2012-5792
Refined AM Technology Roadmap Development

• Starting with 5 “Why’s” of Additive Manufacturing...
  – Shorter Lead Times
  – Mass Customization
  – Energy Reduction
  – Parts on Demand
  – Enables Design Complexity / Opportunity

• “How” and “What” Defined for the NAMII Technology Roadmap

• Partnering with MAYA Design and AoT
Project Call Key Criteria

• Project Lead must be NAMII Consortium Member
• Project teams – SME involvement stressed
• Diverse team expertise (technical, business development, education)
• 50/50 Cost share
• Strong technical approach
• Sound transition plan
• Advanced Mfg. Enterprise & Workforce/Education elements
• Reasonableness and realism of the proposed cost, proposed cost share, and schedule
Project Call #1 Topic Areas

- **Qualification & Certification**
  - Rapid qualification and certification methods
  - Leverage modeling and simulation
  - Quantification of process variability
  - Variability reduction to increase reliability, process optimization, rate increases
  - Certification of suppliers

- **Materials Understanding and Performance**
  - Materials database designs
  - Design allowable properties for materials
  - Data access and sharing
  - Materials variability and management
  - Material requirements/gaps identification

- **Process Capability and Characterization**
  - Process repeatability and throughput improvement
  - Develop algorithms for modeling expected outcomes
  - Improved part quality
  - In-situ adaptive control systems
Project Call #1 Project:

**Rapid Qualification Methods for Powder Bed Direct Metal Additive Manufacturing Processes**

Partnership with leading aerospace industry companies and university team members

**Impact:**

- Understanding and control of microstructure and mechanical properties across Direct Metal Laser Sintering and Electron Beam Melting (EBM®) processes
Project Call #1 Project:

Thermal Imaging for Process Monitoring and Control of Additive Manufacturing

Partnering with equipment manufacturers, industry thermal sensor and university leaders

Impact:
• Thermal imaging for process monitoring and control of electron beam direct manufacturing (EBDM) and laser engineered net shaping (LENS) additive mfg
• Enable real time control based on thermal image characteristics for greater confidence on part quality
Project Call #1 Project:

**Maturation of Fused Deposition Modeling (FDM™) Component Manufacturing**

Close partnership with equipment manufacturers and University of Dayton Research Institute

**Impact:**
- Design guide for parts
- Critical materials and processing data
- Machine, material, part and process certification for ULTEM™ 9085
Maturation of High-Temperature Selective Laser Sintering (SLS) Technologies and Infrastructure

**Impact:**

- Development of lower-cost, high-temperature selective laser sintering (SLS) process
- Air and space vehicle components, medical and other commercial applications
- Topology optimization
- Recyclability and reuse of materials for sustainability and cost savings
Project Call #1 Project – Near-term Application Opportunity

Sparse Build and Complex Rapid Tooling by Fused Deposition Modeling (FDM™)

Polymer composite tools often involve expensive, complex machined, metallic structures that can take months to manufacture.

Impact:
- Lower-cost, energy saving sparse-build tooling for composite manufacturing and metal hydroforming using ULTEM™ 9085
- Design guide for tooling
Qualification of Additive Manufacturing Processes and Procedures for Repurposing & Rejuvenation of Tooling

Partnering with equipment manufacturers, computer modelers, and the North American Die Casting Association (NADCA)

Die casting tools are very expensive (> $1M each), requiring long lead times

Impact:
• Development, evaluation, and qualification of methods for repairing and repurposing tools and dies
• Extending tool life would enable energy and cost savings
Project Call #1 Summary – Technical Focus Areas and Project Impact

- Sparse-build and Complex Tooling
- High Temp SLS
- Maturation of FDM

- Rapid Qual for Powder Bed Direct Metal AM
- High Temp SLS
- Qualification for Die Cast Tooling Repair
- Thermal Imaging

- Rapid Qual for Powder Bed Direct Metal AM
- Qualification for Die Cast Tooling Repair
- FDM Maturation
- Thermal Imaging

- Sparse-build and Complex Tooling
- High Temp SLS
- Rapid Qual for Powder Bed Direct Metal AM
- Maturation of FDM

Design for AM
Qualification / Certification
Process and Equipment
Materials

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Project Opportunities

• NAMII Project Calls
  – Will focus on TRL/MRL 4-7 issues
  – Must be a member to lead these projects
  – Second round of project calls will be made late Summer 2013

• Strong Teaming for additional Government-Funded Project Calls
  – Team with NAMII & members
  – Show how partnership can leverage existing funds to achieve more

• Use NAMII resources for targeted company projects
  – Companies can use NAMII resources for targeted project needs
  – Immerse with other users to accelerate learning curves
  – Validate before you invest, 3rd Party Advocacy
Doing Business With NAMII

• Is project aligned with TRL/MRL 4-7 Charter?
  – Yes, determine execution model
  – No, TRL/MRL 1-3, work with NAMII partners to find National Lab or University partner to support project
  – No, TRL/MRL 8-10, work with NAMII partners to find a service bureau or equipment provider

• Execution Models
  – Internship
    • Company provides resources that work with NAMII resources (OJT) to fulfill Company’s SOW
  – Project
    • NAMII onsite resources work to a Company’s SOW
  – Membership-wide Project
    • Membership ad hoc teams are formed to address common needs
“State of the Union” – 12 Feb 2013
“Last year, we created our first manufacturing innovation institute in Youngstown, Ohio. A once-shuttered warehouse is now a state-of-the-art lab where new workers are mastering the 3D printing that has the potential to revolutionize the way we make almost everything.”

Brookings Institute / Rockefeller Foundation
This year’s list of “Innovations to Watch” represents the most forward-thinking and effective solutions that are now being implemented by America’s states and metropolitan areas.
Summary

• NAMII shows an unprecedented level of collaboration on manufacturing technology across government, industry and universities
• Huge opportunity and high stakes
• Establishing the framework for continued success
• We welcome your participation!