A University-Community College Partnership Model for Meaningful Advanced Manufacturing Workforce Education

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Presentation Outline

1) **Historical**
2) CNEU/NACK Approach
3) Resource Sharing and the Pennsylvania Nanofabrication Manufacturing Technology Partnership
4) NACK Partnership and How it Works
5) What the Community Colleges Find Helpful
6) What the Community Colleges Utilize
7) Advantages to Research University in Partnering with Local Community Colleges, Colleges, and Small Universities
8) How to Implement Model for Other Advanced Manufacturing Fields
9) Conclusion
Historical

- Penn State’s Center for Nanotechnology Education and Utilization (CNEU) established in 1998. Focused on education across all aspects of micro- and nanofabrication
- With PA state support PA Nanofabrication Manufacturing Technology (PA NMT) Partnership for nanofabrication workforce development established at CNEU in 1998
- National Science Foundation (NSF) Advanced Technology Education (ATE) Regional Center for nanotechnology workforce development at CNEU from 2001 to 2008 (National role since 2005)
- NSF ATE National Nanotechnology Applications and Career Knowledge (NACK) Center created at CNEU in 2008 and funded through 2012
- Renewed by the NSF as NACK Network for 2012 through 2015
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CNEU/NACK Approach

1. **Build partnerships in nanofabrication manufacturing education among Research Universities, 2-year Community and Technical Colleges, and 4-year Colleges/Universities through:**
   - Resource sharing (courses, laboratory facilities, staff, programs)
   - Creating education pathways through these institutions for student development

2. **Develop the means to enable a broad nanofabrication manufacturing education in synthesis, processing, characterization, and applications at 2-year Community and Technical Colleges in every region of the US**

3. **Educate students for careers in a spectrum of industries by advocating a knowledge base which can be used in many types of applications and companies**

4. **Insure that this broad nanofabrication and manufacturing education is one which students can build upon throughout their professional careers**
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What is the PA NMT Partnership?

**Capstone Semester** = 18 credit hands-on immersion experience offered at Penn State for all PA partner schools
What is the PA NMT?

- **Suite of Hands-On Courses in processing, process control, characterization, & applications**

  Available to PA College and University Partners

- A one-semester hands-on immersion in nanofabrication technology.
- Courses taught at the sophomore level-ideal for permitting one suite of courses for community college students, 4-year university students, and incumbent technicians.
- **Classroom and laboratory components taught at Penn State.**
CNEU created and provides a suite of six 4th semester (sophomore) level nanofabrication manufacturing courses

<table>
<thead>
<tr>
<th>The Courses</th>
<th>Skills Necessary for the Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESC 211  Material, Safety and Equipment Overview for Nanotechnology</td>
<td>Basic properties of matter: atoms, molecules, gases, liquids, solids</td>
</tr>
<tr>
<td>ESC 212  Basic Nanotechnology Processes</td>
<td>Basic concepts of chemistry</td>
</tr>
<tr>
<td>ESC 213  Materials in Nanotechnology</td>
<td>Basic concepts of electro-magnetic phenomena</td>
</tr>
<tr>
<td>ESC 214  Patterning for Nanotechnology</td>
<td>Basic concepts of electrostatics</td>
</tr>
<tr>
<td>ESC 215  Nanotechnology Applications</td>
<td>Interaction of energy and matter</td>
</tr>
<tr>
<td>ESC 216  Characterization, Testing of Nanotechnology Structures and Materials</td>
<td>Physics of light</td>
</tr>
<tr>
<td></td>
<td>Introduction to biology (Optional)</td>
</tr>
</tbody>
</table>
Skill set developed in the courses

Basic Nanotechnology EHS Awareness
- Basics of Chemical and Material Properties—Role of Scale
- Chemical and Materials Handling, Storage, and Disposal
- Nanotechnology Health, Safety, and Environmental issues

Nanotechnology Equipment and Processing Foundation Skills
- Chemical Hoods and Glove Boxes: Use and Maintenance
- Cleanrooms: Use and Maintenance
- Pumps, Flow Control Systems, Scrubbers, Sensors: Use and Maintenance
- Vacuum Systems: Use and Maintenance
- Plasma Generating Systems: Use and Maintenance
- Furnaces, Ovens, and Rapid Thermal Annealing Equipment: Use and Maintenance
- Chemical Facilities and Maintenance
- Contamination Control
- Process Integration
- Introduction to Statistical Process Control

Nanotechnology Patterning
- Optical, e-beam, and Ion Beam Lithography
- Stamping and Imprinting Lithography
- Chemical techniques; e.g., Block co-polymers and SAMs

Nanotechnology Fabrication
- Top-down Fabrication
  - Reactive Ion, Sputter, and Wet Etching
  - Chemical Vapor and Physical Vapor Deposition Systems
  - Ion Beam, Plasma, and Chemical Materials Modification
  - Nanoparticles: Etching and Grinding Approaches
- Bottom-up Fabrication
  - Chemical, Physical, and Biological Self-Assembly
  - Nanoparticles: Colloidal Chemistry
  - Nanoparticles: Plasma Approaches
  - Nanoparticles: Chemical Vapor Deposition Approaches

Nanotechnology Characterization
- Optical Microscopy
- Scanning Probe Microscopy
  - Atomic Force Microscopy
- Electron Microscopy
  - Scanning Electron Microscopy (SEM and FE-SEM)
  - Transmission Electron Microscopy (TEM and FE-TEM)
- Chemical Characterization
  - X-ray (EDS)
  - Secondary Ion Mass Spectroscopy
  - Auger Electron Spectroscopy
  - Fourier Transform Infrared Spectroscopy
- Electrical Characterization
  - Current-Voltage Measurements
  - Capacitance Measurements
  - Opto-electronic Device Measurements
- Physical Characterization
  - Spectrophotometer
  - Profilometer
  - X-ray Diffraction

Nanotechnology Professional Skills
- Team Building
- Problem Solving
- Project Organization and Planning
- Research Skills
- Assessing Cost of Ownership
- Presentation Skills
- Technical Reporting and Documentation
- Handling and Generating Intellectual Property
Central Facility “Physical Offering”: The PA NMT Example

- This suite of six courses is taught twice/year – as a service by Penn State – for PA 2-year and 4-year degree-granting institutions
- **PA NMT is supported by funds provided by the State of Pennsylvania**
- Central Facility Approach—i.e., facility for a region. However credits come from “home” school
- Taken to-date at University Park by 774 students from community colleges, colleges, and universities.
  - 95% of those graduates think that it was a valuable education and 90% said it influenced their educational pathways.
  - 60% of survey respondents in the pool of graduates are continuing for a 4-year or graduate degree.

- Advantages
  - Resource sharing (Equipment and staff needed to support equipment only at one place)
  - Expensive equipment dedicated - only needed at one location
  - Staff available at research university with awareness of, and giving attention to, health, safety, and environment issues
Resource Sharing between Research Universities and Community and Technical Colleges for Facility and Equipment Hands-On Experience

- Hands-on components taught at research university, community college, industry, and national lab hub sites (where there is equipment and resources to support it).
- In PA NMT: The 6 Nanotechnology Courses in Pennsylvania are taught for PA post-secondary institutions *(more than 30)* using the teaching cleanroom and PSU NNIN facilities at University Park.
- In PA NMT: The students spend 3 hours per day in lecture and 3 hours per day doing labs in cleanroom.
- The goal is hands-on total immersion in nanofabrication and characterization.
Participating Institutions in the PA Central Offering Approach

- Academic Partners
- Industry Advisory Board Members
- PA Companies who have hired NMT graduates
NMT Capstone Semester Completers
(Fall 1998 - Summer 2013)
Total = 774
Diversity & Growth of Disciplines Housing Degree Programs in Nanotechnology: The PA Experience

Taking the six courses in nanotechnology results in:

1. **Nanotechnology Concentration,** or **Nanotechnology Minor** within a Major degree

2. **New degrees** e.g., Associate Degree in **Nano-Chemical Technology**
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What is NACK?

The Mission of NACK is to enable Nanofabrication Manufacturing Education at:

- 2-year Community & Technical Colleges in every region of the U. S.
- 4-year Universities and Colleges in Partnership with Community & Technical Colleges in every region of the U. S.
Building Partnerships: NACK Network Hubs

- **PA**
  - NACK - ATE Center in PA
  - PA Community Colleges
  - Penn State University (PA NMT)

- **MN**
  - Dakota County Technical College
  - University of Minnesota

- **Puerto Rico**
  - University of Puerto Rico, Humacao

- **WA**
  - North Seattle Community College
  - University of Washington

- **TX**
  - Northwest Vista College
  - University of Texas

- **NY**
  - NEATEC - ATE Center in NY
  - University at Albany (SUNY)

- **AZ**
  - Central Arizona Community College
  - Maricopa Community Colleges
  - Arizona State University
  - MATEC - ATE Center in AZ
The Portal to NACK Resources

Nano4me Resource Downloads

Nano4me.org Web Site
Undergraduate Level Course Material for 6 NACK Courses

- Classroom component lectures available on the web as PowerPoint presentations and as videos.
- Lab components also available as videos for students limited by travel distances to hubs.

Undergraduate Level Course - Classroom Presentations

Undergraduate Level Classroom Presentation Materials

ESC 211: Materials, Safety, and Equipment Overview for Nanotechnology

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>PDF File</th>
<th>PowerPoint File</th>
<th>Videotaped Lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Safety and Environmental Concerns</td>
<td>Download</td>
<td>Download</td>
<td>Lecture 1, Lecture 2</td>
</tr>
<tr>
<td>2. Vacuum Function, Operation and Systems</td>
<td>Download</td>
<td>Download</td>
<td>Lecture 1, Lecture 2</td>
</tr>
<tr>
<td>3. Materials Overview</td>
<td>Download</td>
<td>Download</td>
<td>Lecture 1, Lecture 2, Lecture 3, Lecture 4, Lecture 5, Lecture 6</td>
</tr>
<tr>
<td>4. General Processing, Contamination, and Damage</td>
<td>Download</td>
<td>Download</td>
<td>Lecture 1, Lecture 2</td>
</tr>
<tr>
<td>5. Basic Characterization Tools</td>
<td>Download</td>
<td>Download</td>
<td>Lecture 1, Lecture 2</td>
</tr>
</tbody>
</table>
### Some Job Titles Held by Nanofabrication Manufacturing 2-Year Degree Graduates

<table>
<thead>
<tr>
<th>Biological Laboratory Tech.</th>
<th>Laboratory Tech.</th>
<th>Production Scientist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Laboratory Tech.</td>
<td>Materials Science Lab Tech.</td>
<td>Research Assistant</td>
</tr>
<tr>
<td>Cleanroom Tech.</td>
<td>Medical Devices Tech.</td>
<td>SEM Operator</td>
</tr>
<tr>
<td>Deposition Tech.</td>
<td>Microfabrication Tech.</td>
<td>SPM Operator</td>
</tr>
<tr>
<td>Device Tech.</td>
<td>Nanobiotech Researcher</td>
<td>Scientist Specialist</td>
</tr>
</tbody>
</table>
Employment Statistics/Metrics

• The total number of companies employing graduates from NACK hubs is approximately 200 (141 from PA NMT).
• Number of survey respondents, in the pool of graduates, who are employed in nano-related field is 69%.
• 100% of the industry respondents expressed very positive feedback on the 6 NACK core-skills courses.
• 75% of industry respondents recommended NACK work with a professional society for a national accreditation for the NACK core-skills set.
• Associate degree graduates who had taken the immersion semester had an average salary of $37,000.
• BS degree graduates who had taken the immersion semester had an average salary of $56,000
Institutions That Have Hired Capstone Semester Graduates for Micro- and Nanofabrication Manufacturing Jobs

II-VI Corporation
Accellent
Adhesives Research, Inc
Advanced Acoustic Concepts
Advanced Cooling Technologies
Advanced Gas Technologies
Advanced Powder Products
Advantech
AGAM
Agere
Allied Electronics
Alcoa
AMAX Minerals
Aiden Products
Amedeo
Amed Inc.
Apogee Photonics
Arrow International
Avail Technologies
BioElectroSpec
B. Braun
Boston Applied Technologies
BD (Becton, Dickinson)
BP Solar
Bridge Semiconductor
Busch Vacuum
Cabot
Cabot Microelectronics
Carbon NanoProbes
Celgene-LifebankUSA
Chemcut
Correge Sensors
Cosmos Technologies
Crystalplex
Cyoptics
Dendreon
DRS Laurel Technologies
Dana Corporation
Doucette
Don’s Salads
Dow Chemical
Drexel University
Eastman Chemical Company
East Penn Manufacturing
Ex One
Fairchild Semiconductor
Fincor Automation
First Energy
F. S. Elliott
General Dynamics Robotic System
General Electric
Glass automatic
GlaxoSmithKline
GlobalFoundries
GTS
Haraeus Noblelight
Hale Products
Hershey Medical Center
Illuminex
Infinera
Innovative Micro Technology
Intel Corporation
iNOEX
IQE
Johnson & Johnson
Johnson Matthey
Judson Technologies
Keystone Communications
Keystone Engineering
Keystone Research & Pharmaceuticals
Kongsberg Defense
Kurt J. Lesker
Kyowa America
LCM Technologies
Lehighton Electronics
Lockheed Martin
Lucent Technologies
Lutron Electronics
Maxima Technologies
Max Levy Autograph
Meadow Burke Products
Membrane Assays
Merck
Mintera Corporation
NanoHortons
Natural Nano, Inc
North American Hoganas
North Carolina State University
Northrup Grumman, Inc
Optelios
Optinel Systems
P2i
Penn State CNEU
Penn State Dubois
Penn State Applied Research Lab
Penn State Electro-Optics Center
Pfister Energy
Philips Medical Systems
Philips Respironics
Plextronics
Probes Unlimited
Proconex
PPG
PPL
QorTek
Restek
Rhetech
Rohm and Haas
Ross Technologies
RI Lee
Schroeder Industries
Scientific Systems
Seagate Technologies
Siemens Co.
SI International
Slack Pek
Solar Innovations
Solarity
Spectrum Technologies
Strainrite
Strategic Polymers
Structure Probes Inc.
Synthes
Telecardia
Textron Lycoming
Thermo Electric PA
Transene
Tyco Electronics
US Air Force
Uniroyal Optoelectronics
University of Florida
University of North Carolina - Charlotte
University of Pittsburgh
Vectron International
Velox Semiconductor
Western Digital
Westfalia Technologies
Westmoreland Mech. Testing & Research
Xactix
National Advisory Council

- Alcatel-Lucent
- Bio-Link Center
- Boeing
- Corning
- Cyoptics
- Dupont
- General Electric
- Imerys
- Information & Communications Technology Center
- Johnson & Johnson
- Lockheed Martin
- 3M
- National Council for Advanced Manufacturing
- National Coalition for Advanced Technology Centers
- Northrop Grumman
- PPG
- Plextronics
- Semiconductor Research Corporation
- Strategic Polymers
- Stryker
- Tyco
- University of Minnesota
Remote Access & Control of Nano Equipment

From our lab…

- Established web access procedures for nanocharacterization, e.g. FESEM
- Established low-cost methodology for web access and control

…to any classroom
Remote Access can be utilized

- For an outreach experience
- For workshop demonstrations
- For class demonstrations
- To supplement the equipment at an institution
- For “Hands-On” access by students in laboratory experiences
Would you recommend remote access to another teacher/classmate, faculty member/colleague?

RESULTS FROM MORE THAN 600 PARTICIPANTS

Would you recommend remote access to another teacher/classmate, faculty member/colleague?
Did you find remote access more valuable than traditional textbook and/or lecture-based learning?
Faculty development: Educator Workshops

- Hands-on Introductory Workshop for Educators
- Nanotechnology Course Resource Workshops on “how to implement and teach courses”
- **Attendees to Date**
  - 1115 Educators
  - 36 States, DC, and Puerto Rico

**Attendance Options:**

- Attending a workshop at NACK
- Host an on-site/off-site workshop
- Utilizing NACK workshop material and/or remote lecture and/or remote equipment access at local workshops
NACK Services to Secondary and Post Secondary Institutions

• Series of thought-provoking nanotechnology presentations
  o in-depth material for students and workers of all knowledge levels.

• Designed to be used in workshops, courses, and overview lectures
  o introduce nanotechnology and its applications.

• Can be integrated into secondary and post-secondary curriculum as well as for nanotechnology outreach

• Assistance to over 301 post-secondary institutions in their nanotechnology education efforts.

• 1,148 Secondary school students have completed Nanotech Camps.

Modules Downloadable at www.nano4me.org
NACK Portal Downloads by Audience
January 2009 - March 2013
Total Downloads: 28,551
NACK Network Webinars

- Live monthly 90 minute webinars hosted by MATEC
- To engage and educate about nanotechnology related topics
- Archived at www.nano4me.org for convenient viewing
- Why Webinars?
  - 92% Agree – they are valuable
  - 87% Agree – they will impact my students, colleagues and me
- Who has actually done anything with the content?
  - Up to 28% updated materials in their classrooms
- To date 3,254 individuals have accessed these webinars.
- 132 community and technical colleges have used NACK workshops and webinars.
Anticipated impact on teaching and technology programs as a result of attending a 2012-2013 NACK Webinar

- Updating/adding new instructional materials: 35%
- Utilizing the NACK Center for curriculum resources: 44%
- Updating/adding new technology topics to my course: 28%
- Adding a new activity/course: 21%
- Utilizing other micro- and nano center resources: 28%
NACK Alumni Network

• To help graduates of associate degree programs enhance their professional opportunities, inform them of educational opportunities, and connect them with networking groups.

  ✓ Provides online networking opportunities.
  ✓ Accesses career resources.
  ✓ Connects interested alumni and students in mentoring relationships.
  ✓ Keeps alumni informed of current nanotechnology events and activities.
  ✓ Shares alumni success stories.

• 14,379 hits on NACK Alumni network website.
Additional Miscellaneous CNEU/NACK’s Products and Services

• Penn State’s College of Engineering undergraduate manufacturing technology certificate.
• Working on a graduate level distance learning M.S. degree.
• Standard drafts for use by the American Society for Testing and Materials (ASTM) to develop the NACK industry core-skill set into ASTM standards.
• Participation in the Nanoscale Informal Science Education Network (NISE Net) Nano-Days activities for student recruitment and parent education (over 500 students and parents impacted to date with these NACK activities).
• Initiated Nanotechnology Career Days activities for nanotechnology companies to recruit trained students.
Added Miscellaneous CNEU/NACK’s Products and Services (contd.)

- Initiated an e-mail service advertisements and structure for companies to post job openings through local nanofabrication manufacturing education programs.
- Sharing the NACK mission and experience through presentations and table displays at 38 education conferences held in the U. S.
- Initiation of the Annual Micro/Nanotech (MNT) Conference: this conference is a national educators meeting hosted by NACK and the four NSF regional micro/nanotechnology ATE centers.
- Distant Education nanofabrication manufacturing certificate will be offered soon through NACK and will be integrated into community college programs.
Summary of CNEU/NACK Resources

- Six Nanofabrication Manufacturing Courses
- Student Recruitment
- Educators Workshops
- Remote Access Tools
- Nanotech Academies
- Industry Outreach
- 2+2 and 2+2+2 Education Pathways
- Secondary School Curriculum Enhancement
- Incumbent Worker Training
- Nano4me.org Web site
- Teaching Cleanroom
- Alumni Services
Recent National Recognition of NACK

"With the support of the NSF ATE program, Penn State has developed a nation-wide partnership of research universities and community colleges that is bringing meaningful core-skills nanotechnology workforce education to technical and community colleges across the United States......"

http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST_2012_Nanotechnology_FINAL.pdf
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• NACK helps facilitate the development of university and community college partnerships
• Not necessary to create new nano courses
• Course materials kept up-to-date by research university partners
• No need to invest in expensive equipment
• Staff for equipment support is not needed
• Able to offer nano program attractive to multiple disciplines
• Can create pathways for student articulation
• NACK is working with Historically Black Colleges and Universities (HBCU) to build collaborations in nanotechnology education.
• NACK is working with ASTM to develop national standards for nanofabrication manufacturing education and skill sets for technician 2-year degree and shorter certificate programs.
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• NACK has led the development of remote access to its tools, and has developed partner sites in the different regions and time-zones in the U. S. to allow this equipment to be available widely in both rural areas and in locations where access to the equipment in an education setting is not available.
• NACK hosts workshop series for community college educators and administrators and university partners
• NACK is creating an alumni network for the graduates of all nanotechnology AAS degree programs in the United States
• NACK is working with ASTM to develop national standards for nanotechnology education and skill sets for technician 2-year degree and shorter certificate programs.
• NACK has led in the development of the annual Micro/Nanotechnology conference which has brought together 250 educators from community colleges, universities and high schools together with industry and government leaders to share best practices in nano programs and curriculum in the past 3 years.
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• Service to the State and community
• Supporting local economic development
• Can build support for user facilities at research university (resource sharing)
• Graduate student support (need TAs)
• Post-doc support (need skilled teachers)
• Research support
• Pipeline of students from community colleges to 4-year degree programs and beyond
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A Successful Education Model Applicable to Advanced Manufacturing Centers

Diverse Group that Needs to be Served

Community College Students
College & University Students
Incumbent Workers
Veterans, Women, Minorities

Preparation or Entrance Requirements

Entry Skill Set Requirements

Workforce Education (tailored to each manufacturing area)

Suite of Hands-On Courses in processing, process control, characterization, & applications

Available everywhere in the U. S.

Meeting National Standards

Exit Skill Set
- A one-semester hands-on immersion to manufacturing technology.
- Courses taught at the sophomore level- ideal for permitting one suite of courses for community college students, 4-year students, and incumbent technicians.
- Hands-on components taught at research university, community college, industry, and national lab hub sites (where there is equipment and resources to support it).
- Classroom components taught at research universities and community college hubs.
- Classroom component lectures available on the web as PowerPoint presentations and as videos.
- Classroom component videos available with Spanish subtitles.
- Lab components also available as videos for students limited by travel distances to hubs.
• Lab components augmented by web remote-access to equipment operation and to characterization tools.
• PSU College of Engineering undergraduate manufacturing technology certificate.
• Working on a graduate level distance learning M.S. degree.
• Assessment rubrics developed with College of Education.
• Exit skill set resulting from the suite of courses is industry established and reviewed annually by industry for rapid evolution, as needed.
• Exit skill set is embedded in American Society for Testing and Materials standards.
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Conclusion

• Partnerships involving research universities and 2-year degree and 4-year degree institutions which utilize resource-sharing are very effective in delivering nanofabrication manufacturing education.

• The approach developed at CNEU/NACK is very viable in forming these partnerships. It relies on utilizing the teaching facilities, web capabilities, characterization tools, and faculty expertise at one (or perhaps several) advantageously and geographically positioned location(s).

• CNEU/NACK efforts are designed to insure that students emerging from US programs have an industry-established nanofabrication manufacturing skill set in synthesis, processing, characterization, and applications, and have a broad nanotechnology educational foundation on which the students can build upon throughout their professional careers.
Conclusion (cntd.)

• **The resources provided by CNEU/NACK and shared with partnering institutions include:**
  
  o Lecture and laboratory experiment sets for six complete courses.
  o Web available lectures (power-point and video formats) for the six courses to aid institutions in offering these courses.
  o Educators workshops on how to teach these six course.
  o Web access to state-of-the-art tools to enable the teaching of nano-characterization at workforce training institutions and, with NSF support, sends NACK experts to these institutions to assist faculty in learning and using these web accessible tools.
  o Modules for use in recruiting, introductory courses in nanofabrication manufacturing, or general public education.
  o Web resources, e. g., webinars, alumni network, discussion boards, etc.

• **CNEU/NACK’s model can be successfully applied to other types of advanced manufacturing, such as additive manufacturing.**
<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Building</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stephen J. Fonash</td>
<td>Ph. D Director</td>
<td>112 Lubert</td>
<td>814-865-4931</td>
<td><a href="mailto:sfonash@psu.edu">sfonash@psu.edu</a></td>
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<td>814-863-1773</td>
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</tr>
<tr>
<td>Robert Ehrmann</td>
<td>Managing Director, NACK Network</td>
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Questions ??