

Welcome to MATEC NetWorks Webinar

Ways of Introducing Nano into Your Program

MATEC NetWorks is an NSF funded ATE Center supporting faculty in Semiconductor, Automated Manufacturing, and Electronics education

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Webinar Procedures

- If you are listening by phone, please mute your phone by pressing #5.
- If you have questions during the presentation, please submit them in the **Chat Window**.
- At the end of the session we will answer as many questions as we can. Please type your questions in the **Chat Window**.



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Poll

Participants

Mark Viquesney (Moderator, Me)

1 Participant

Raise hand/smile/clap

Chat

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Joined on February 25, 2009 at 1:08 PM

Chat

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Audio

Microphone Speaker

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Whiteboard - Main Room

15/29 Welcome to MATEC NetWorks Webinar

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NetWorks Webinar Presenter



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sfonash@engr.psu.edu



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Ways of Introducing Nano into Your Program

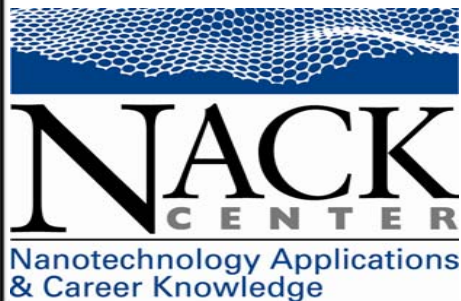
Presented by Steve Fonash

Kunkle Professor of Engineering Sciences

NSF National Center for Nanotechnology
Applications and Career Knowledge (NACK)

www.nano4me.org

Penn State University



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What is nanotechnology?

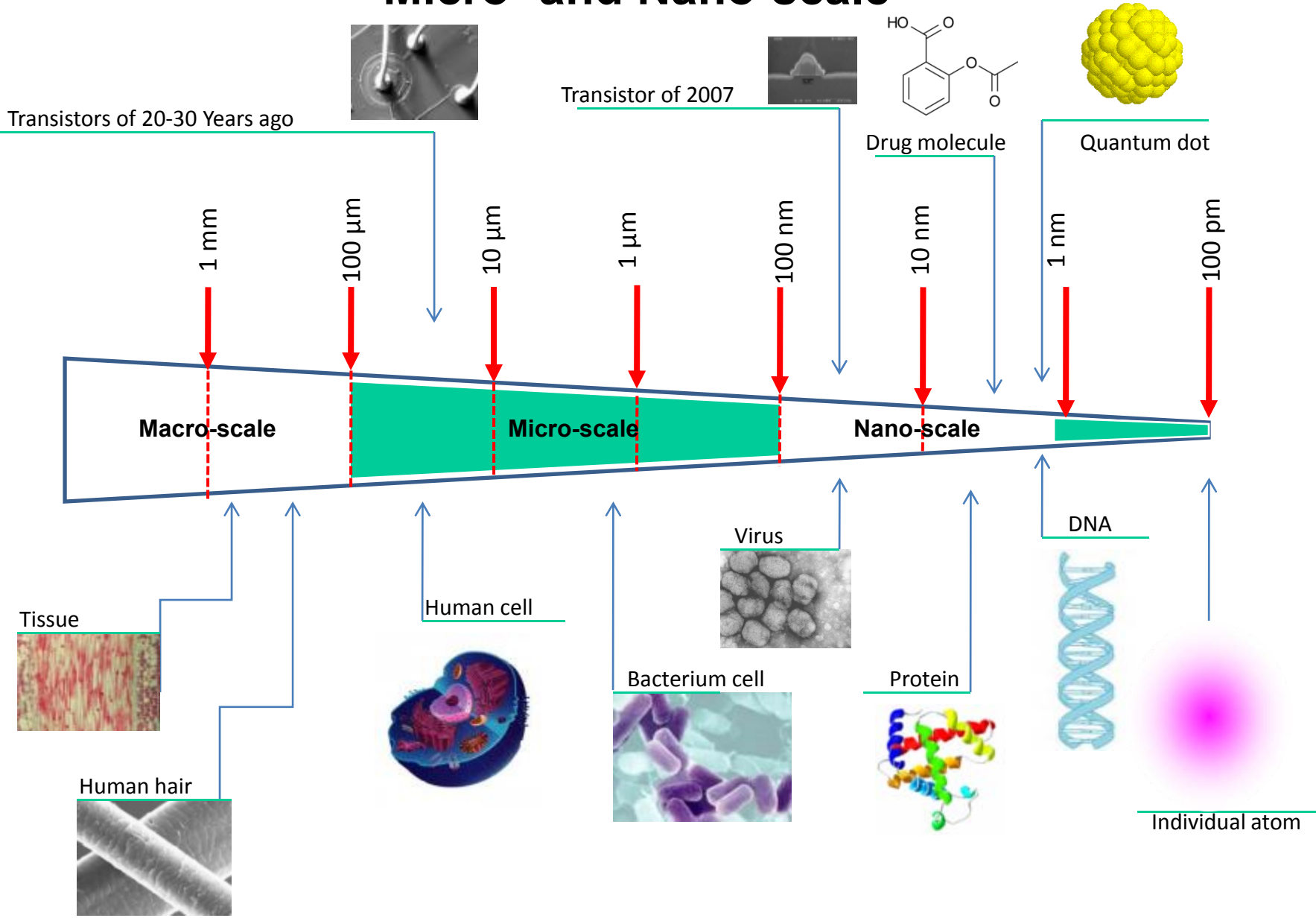
- It is manipulating and characterizing (seeing, feeling) of matter at the sub-100 nanometer scale (the nano-scale).



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Naturally Occurring and Man-Made Structures at the Micro- and Nano-scale



Why care about Nanotechnology?

- Because at the nano-scale, properties of matter which we do not see at our scale become important and offer new opportunities.
- And new opportunities mean new industries, a new skill set, new products---
and new jobs, if you are ready.



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How old is Nanotechnology?

Nanotechnology has been employed by humans for a long, long time.

(Except we did not know what we were doing)

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Famous example of an old application of Nanotechnology: The 4th Century Roman Lycurgus Cup



- In reflected light, cup appears *green*; in transmitted light, it appears *red*
- Cause: 40 ppm Au nanoparticles & 300 ppm Ag nanoparticles embedded in silica glass

References: (1) Paul Mulvaney, Not all That's Gold Does Glitter, MRS Bulletin, December 2001, pgs 1009-1013

(2) Barber, D J and Freestone, I C, An investigation of the origin of the colour of the Lycurgus Cup by analytical transmission electron microscopy, *Archaeometry*, **32** (1), 33-45, 1990.



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Why Now?

If nanotechnology has been practiced by humans for almost 2000 years, why is it taking off now?

Why is it so “big” now?

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Why Now?

Because we have learned what's going on-

- We can now controllably and repeatedly make things in the nano-size range.
- And finally we can now see what we have made.

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“It is Sometimes Better to be Little”

- **New doors open at the Nano-scale because materials have new attributes at this scale**
- **New opportunities become accessible**
- **And now we have the understanding, fabrication tools, and characterization (seeing) tools to take advantage**



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Here is a Listing of Some of the Unique Attributes of the Nano-scale

- Very small size—obvious yet the impact is tremendous!
- High surface to volume ratio – resulting in many, if not most, of the atoms being on the surface
- High surface to volume ratio – resulting in a unique surface environment for most of the atoms



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Here is a Listing of Some of the Unique Attributes of the Nano-scale

- **Surface forces dominate over bulk forces – for example, gravity (a bulk force) is not important**
- **Quantum mechanical effects are important**
- **Wave properties of light are important**



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Some of the Unique Attributes of the Nano-scale (continued)

- Sizes corresponding to basic biological structures
- Sizes corresponding to macromolecules
- Molecular self-assembly occurs at this scale



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Some of the Unique Attributes of the Nano-scale (continued)

- Unique chemical bonding configurations possible
- Provides us with new epistemologies (Working at the nano-scale has caused us to learn new ways of “seeing” our world)



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Nano is exciting



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Nano is exciting

Nano is the key to the future of
technology—and to the economic
health of the US



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health of the US

**Nano is the source of new products
and jobs**



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**Nano Needs to be in Your Courses and
Programs**



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Ways of Introducing Nano Into Your Courses and Programs



Helping you start hands-on Nanotechnology
Courses and Degree Programs is NACK`s Job



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NACK Philosophy

- Share the facilities, technical staff, and expertise of Penn State with college and university partners across the nation to bring hands-on nanotechnology workshop opportunities, courses and programs to every section of the US.



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NACK Philosophy

- Empower students with a broad approach to nanotechnology giving them the base for a lifetime of adapting and learning



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NACK National Center Institutional Partners



- **Penn State**
- **Pennsylvania Commission for Community Colleges**
- **Dakota County Technical College/U. of Minnesota**
- **Maricopa Advanced Technology Education Center (AZ)**
- **Museum of Science, Boston**
- **National Coalition for Advanced Manufacturing**
- **Northwestern University**
- **University of Puerto Rico**



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NACK Overarching Goals

- Develop a workforce for existing and emerging micro- and nanotechnology-based US industries
- Bring the high-paying jobs of micro- and nanotechnology to Americans



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NACK Overarching Goals

- Encourage the use of nanotechnology by industry
- Create a nanotechnology-knowledgeable citizenry



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NACK Overarching Goals

- Continue the very successful, resource-sharing model—with partners using NACK course materials, workshop opportunities, web access to equipment, web-taught course lectures, and sending students to capstone semester at Penn State



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NACK SHARED RESOURCES

Available to You

**Set of 6
Nano 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**

**Equipment and
Facilities Resources**

**Alumni
Services**

PA Results So Far

- 508 students have completed the Center's capstone semester in nanofabrication at Penn State
 - (*Gold standard* for nanofabrication technician education)
- 895 educators and industry personnel have completed workshops
- 1,289 secondary students have completed *Nanotech Academies*



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PA Results So Far

- The 2007 survey of capstone semester graduates shows that:
 - 55 percent of graduates are employed full-time and are no longer students
 - 20 percent are employed full-time and are also full- or part-time students
 - 25 percent are full-time students not employed full-time



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PA Results So Far

- Of the 75 percent of graduates who are employed full-time, two thirds are employed by 72 companies using nanotechnology
- Of the capstone semester graduates who are full-time students:
 - 15 percent are finishing their associate degree
 - 65 percent are pursuing a baccalaureate degree
 - 20 percent are pursuing graduate degrees



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Micro and Nanotechnology Companies That Have Hired Capstone Semester Graduates

II-VI Corporation
Accellent
Adhesives Research, Inc
Advanced Gas Technologies
Advantech
AGAM
Agere
Alcoa
Allied Electronics
Alden Products
Amedeo
Amgen Inc.
Apogee Photonics
Arrow International
Avail Technologies
BioElectroSpec
B. Braun
Boston Applied Technologies
BD (Becton, Dickinson)
BP Solar
Cabot
Cabot Microelectronics
Correge Sensors
Cosmos Technologies
Crystalplex
Cyoptics
DRS Laurel Technologies
Dana Corporation
Doucette Industries
Dupont

Ex One
Fairchild Semiconductor
Fincor Automation
First Energy
F.S. Elliott
General Dynamics Robotic System
GlaxoSmithKline
GTS
Hershey Medical Center
Illuminex
Intel Corporation
IQE
Johnson & Johnson
Johnson Matthey
Judson Technologies
Keystone Communications
Keystone Engineering
Kurt J. Lesker
LCM Technologies
Leighton Electronics
Lockheed Martin
Lucent Technologies
Lutron Electronics
Maxima Technologies
Membrane Assays
Merck
Mintera Corporation
NanoHorizons
Natural Nano, Inc
Northrup Grumman, Inc

Optellius
Optinel Systems
Philips Medical Systems
Plextronics
Probes Unlimited
PPG
PPL
Rhotech
Rohm and Haas
Ross Technologies
RJ Lee
Seagate Technologies
Siemens Co.
SI International
Solarity
Spectrum Technologies
Strategic Polymers
Synthes
Textron Lycoming
Thermo Electric PA
Transene
Tyco Electronics
US Air Force
Uniroyal Optoelectronics
Vectron International
Velox Semiconductor
Westfalia Technologies
Westmoreland Mech. Testing & Research
Xactix

Some Details on What is Shared

- Course materials
- Labs for courses
- Web accessed lectures



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Some Details on What is Shared

- Web accessed equipment
- Equipment expertise—suggestions on how to start, what to buy for which labs
- Experience teaching hands-on nanotechnology experience



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NACK Instructional Materials for your Courses and Programs



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Set of 6 Nanotechnology Courses

1. Materials, Safety, and Equipment Overview
2. Basic Nanotechnology Processes
3. Materials in Nanotechnology
4. Patterning for Nanotechnology
5. Materials Modification in Nanotechnology
6. Characterization and Testing

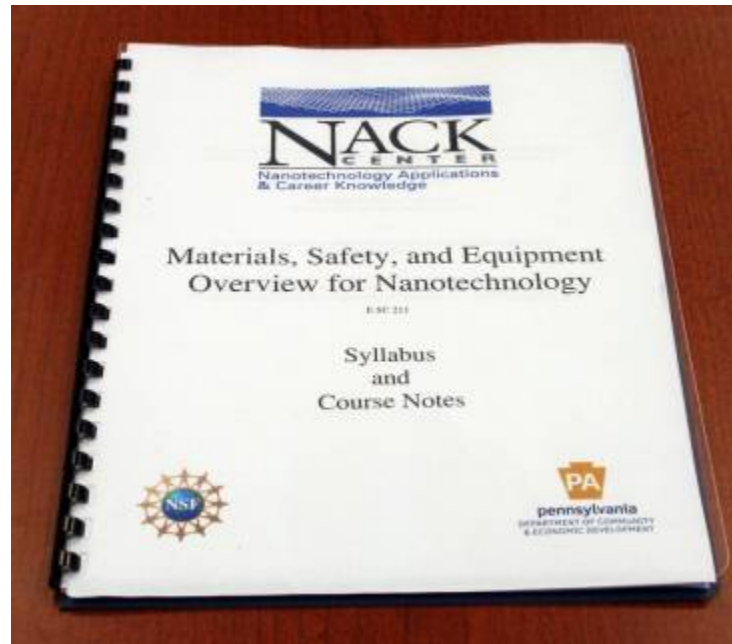


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Resources Available

- Course Notes for each of the 6 courses
- Lab Manuals for each of the 6 courses



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Summary of Prerequisite Skills Necessary to Take the Set of 6 Nanotechnology Courses

- Basic concepts of algebra
- Basic concepts of chemistry



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Summary of Prerequisite Skills Necessary to Take the Set of 6 Nanotechnology Courses

- Basic properties of matter
 - Atoms, molecules, gases, liquids, solids
- Basic concepts of electro-magnetic phenomena
- Basic concepts of electrostatics



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Summary of Prerequisite Skills Necessary to Take the Set of 6 Nanotechnology Courses

- Interaction of energy and matter
- Physics of light
- Basic concepts of biology



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Summary of Skills Taught in the Set of 6 Nanotechnology Courses

- Micro- and Nanotechnology Foundation Skills
- Micro- and Nanotechnology Fabrication Skills
- Micro- and Nanotechnology Characterization Skills
- Micro- and Nanotechnology Professional Skills



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Summary of Skills Taught in the Set of 6 Nanotechnology Courses

- **Micro- and Nanotechnology Foundation Skills**
- Basics of Chemical and Material Properties
- Chemical and Materials Handling
- Health, Safety, and Environmental Concerns
- Cleanroom Use, Design, and Maintenance
- Pumps, Flow Control Systems, Scrubbers, Sensors: Use and Maintenance
- Vacuum Systems: Use and Maintenance
- Plasma Generating Systems: Use and Maintenance
- Chemical Reaction Systems: Use and Maintenance
- Contamination Control
- Process Integration
- Introduction to Statistical Process Control
- Biocompatibility



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Summary of Skills Taught in the Set of 6 Nanotechnology Courses

- **Micro- and Nanotechnology Fabrication Skills**
- **Top-down Fabrication**
 - Lithography
 - Reactive Ion, Sputter, and Wet Etching
 - Chemical and Physical Vapor Deposition
 - Ion Beam, Plasma-Based, and Chemical Materials Modification Processing
- **Bottom-up Fabrication**
 - Self-Assembly
 - Block Co-polymers
 - Nanoparticles: Colloidal Chemistry
 - Nanoparticles: Plasma and Grinding/Milling Approaches
 - Nanoparticles: Chemical Vapor Deposition



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Summary of Skills Taught in the Set of 6 Nanotechnology Courses

Micro- and Nanotechnology Characterization Skills

- Scanning Probe Microscopy
- Electron Microscopy
 - Scanning Electron Microscopy
 - Transmission Electron Microscopy
- 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



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Summary of Skills Taught in the Set of 6 Nanotechnology Courses

- **Micro- and 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



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All 6 Courses or Pieces Can Be Used

- (1) Materials, Safety, and Equipment Overview for Nanotechnology
- (2) Basic Nanotechnology Processes
- (3) Materials in Nanotechnology
- (4) Patterning for Nanotechnology
- (5) Materials Modification in Nanotechnology
- (6) Characterization, Testing of Nanotechnology Structures and Materials

A post-secondary institution can use these as-

- (1) A stand-alone two course introduction to nanotechnology
- (2) An institution's first offerings in nanotechnology and then gradually add the other 4 courses
- (3) Source to be mined for materials/labs
- (4) Source of web accessed lectures and labs

A Train-the-trainer workshop on teaching these two courses and labs is coming up April 5-10. Attendance support available.

See www.nano4me.org



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How These 6 Courses Can Be Used

- (1) Materials, Safety, and Equipment Overview for Nanotechnology
- (2) Basic Nanotechnology Processes
- (3) Materials in Nanotechnology
- (4) Patterning for Nanotechnology
- (5) Materials Modification in Nanotechnology
- (6) Characterization, Testing of Nanotechnology Structures and Materials

A post-secondary institution can use the 6 course set as-

- (1) A “capstone semester” in nanotechnology. Prerequisite skill set obtained from courses already offered at the institution
- (2) NACK can provide web lectures, as needed
- (3) Can use a “Teaching Cleanroom”. We give you the equipment list
- (4) Or use limited equipment (we give you a basic set list) and use “web access” to NACK equipment or use a research university partner



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How These 6 Courses Can Be Used

A post-secondary institution can be a **regional/state resource-**

- (1) Materials, Safety, and Equipment Overview for Nanotechnology
- (2) Basic Nanotechnology Processes
- (3) Materials in Nanotechnology
- (4) Patterning for Nanotechnology
- (5) Materials Modification in Nanotechnology
- (6) Characterization, Testing of Nanotechnology Structures and Materials

(1) Providing the “capstone semester” in nanotechnology as a service to the region/state. Prerequisite skill set obtained from courses already offered at each partner institution

(2) Need “Teaching Cleanroom” at central facility

(3) May need or provide “web access” to some equipment



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Approach Number	How Partner Institutions Use Six NACK Courses	Example Implementation	Equipment Purchased by Partner Institution
1	Students attend all six courses at the NACK center.	Out-of-state students spend one semester at PSU. They take all 6 courses/labs.	None
2	Exactly reproduce the NACK capstone semester.	Complete 18 credit offering with full lectures and labs. Partner buys and maintains all equipment and employs required instructors and technicians.	Replicate NACK lab space (possibly without the cleanroom but with all equipment).
3	Reproduce NACK course set with limited lab resources.	Complete 18 credit offering with full lectures and labs. Partner buys and maintains a subset of equipment and retrofits an existing laboratory. Any deficiencies are made up by NACK: shipping samples and remote access to characterization equipment.	A sizeable subset, for example: <ul style="list-style-type: none"> • Vac Trainer • Reactive Ion Etcher • Furnace • rf sputtering tool • Wet bench and spinner • Profilometer • No AFM or SEM • No lithography tools
4	Teach a subset of the NACK courses. Selected lectures and labs can be provided remotely by NACK.	Partner offers 2 courses (6 credits). They buy equipment that fits into their budget. They conduct most labs using their set of equipment and use NACK remote access to fill any gaps.	Minimal equipment purchase. Only enough to be able to teach 2 courses, which may not contain exactly the same labs as NACK currently offers.
5	Completely remote NACK capstone semester.	Lectures are given on-site at the partner institution, with option for remote lectures from NACK. All labs are done remotely.	None
6	Use NACK as a resource for partners to construct their own programs (Pick and Choose).	Partner institution takes bits and pieces of our class notes/labs and plugs them into their existing curriculum.	Variable. Ranges from none or minimal up to replicating CNEU lab space.



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Approach Number	Cost to Partner (\$)	Staff Requirements at Partner (1-10 scale)	% Labs Transferred to Partner	Industrial Readiness of Graduates (1-10 scale)
1	12 k per student	0	0	10
2	≥ 600 k	10	100	10
3	250 k	6-8	30-60	6-8
4	50 k - 250 k	3-4	20-50	3-4
5	0	2	10-40	2
6	0 – 400 k	1-10	0-100	0-10



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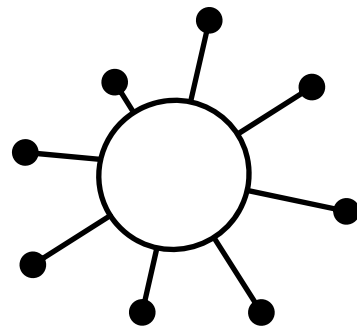
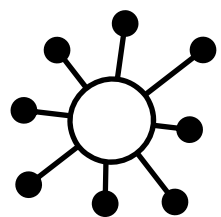
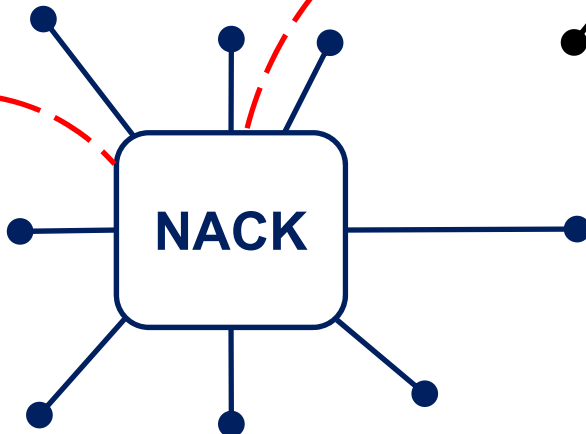
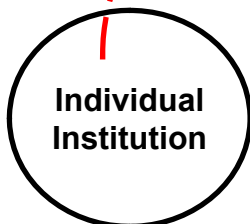
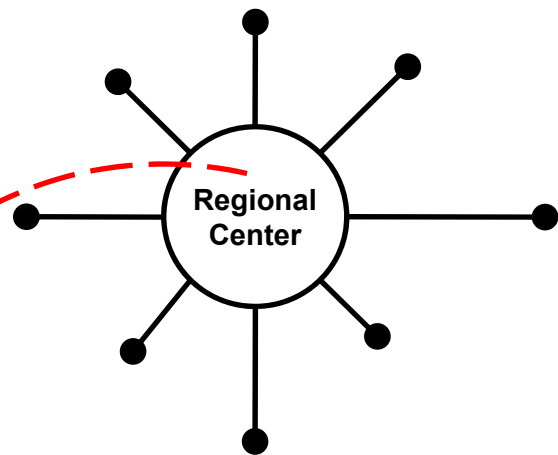
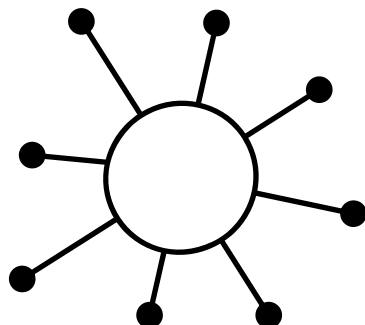
Approach Number	Regional Center		Individual Institution	
	Pros	Cons	Pros	Cons
1 Outsource to NACK	<ul style="list-style-type: none"> No development work required. Alumni are fully trained and ready for industry. Critical mass not an issue. 	<ul style="list-style-type: none"> Cost of Penn State tuition per student. 	<ul style="list-style-type: none"> No development work required. Alumni are fully trained and ready for industry. Critical mass not an issue. 	<ul style="list-style-type: none"> Cost of Penn State tuition per student.
2 NACK Replication	<ul style="list-style-type: none"> Uses skill set for prerequisites. No other courses needed at partner institution. Critical mass of students only needs to be assembled at one location. Alumni are fully trained and ready for industry. 	<ul style="list-style-type: none"> Very high up front expense to partner. Must dedicate staff and resources to establish and maintain equipment and courses. 	<ul style="list-style-type: none"> Uses skill set for prerequisites. No other courses needed at partner institution. Alumni are fully trained and ready for industry. 	<ul style="list-style-type: none"> Very high up front expense to partner. Must dedicate staff and resources to establish and maintain equipment and courses. May be difficult to build critical mass of students.
3 NACK Replication w/Subset of Equipment	<ul style="list-style-type: none"> Uses skill set for prerequisites. No other courses needed at partner institution. Critical mass of students only needs to be assembled at one location. Lower expense than 2. Alumni are fully trained and ready for industry. 	<ul style="list-style-type: none"> Moderate to high up front expense. Partner must dedicate staff and resources to establish and maintain equipment and courses. Students don't get quite as much hands-on experience due to having only a subset of equipment. 	<ul style="list-style-type: none"> Uses skill set for prerequisites. No other courses needed at partner institution. Lower expense than 2. Alumni are fully trained and ready for industry. 	<ul style="list-style-type: none"> Moderate to high up front expense. Partner must dedicate staff and resources to establish and maintain equipment and courses. Students don't get quite as much hands-on experience due to having only a subset of equipment. May be difficult to build critical mass of students.



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Approach Number	Regional Center		Individual Institution	
	Pros	Cons	Pros	Cons
4 Selected NACK Courses	<ul style="list-style-type: none"> • Lower cost to partner than items 2 and 3. • Partners can easily incorporate the courses into programs that already exist at their institution. • Partners utilize NACK resources as an added benefit – able to complement existing curricula. • Only need critical mass for a few courses, not all six. 	<ul style="list-style-type: none"> • Alumni have a lower level of industrial readiness (preparedness) versus options above. 	<ul style="list-style-type: none"> • Lower cost to partner than items 2 and 3. • Partners can easily incorporate the courses into programs that already exist at their institution. • Partners utilize NACK resources as an added benefit – able to complement existing curricula. • Only need critical mass for a few courses, not all six. 	<ul style="list-style-type: none"> • Alumni have a lower level of industrial readiness (preparedness) versus options above. • Critical mass of students could still be an issue, especially if courses are offered every semester.
5 Remote NACK Experience	<ul style="list-style-type: none"> • No cost to partners. • No course development work needed by partners (a turn-key solution). • Critical mass may be less of an issue versus options 1-4. 	<ul style="list-style-type: none"> • No flexibility for partners to pick and choose. • Lower level of industrial readiness (preparedness) due to lack of hands-on experience. 	<ul style="list-style-type: none"> • No cost to partners. • No course development work needed by partners (a turn-key solution). • Critical mass may be less of an issue versus options 1-4. 	<ul style="list-style-type: none"> • No flexibility for partners to pick and choose. • Lower level of industrial readiness (preparedness) due to lack of hands-on experience.
6 Pick & Choose	<ul style="list-style-type: none"> • Ability to choose cost and level of involvement based on available resources. • Partners can assimilate the courses into existing programs. • NACK resources utilized as an added benefit – able to complement existing curricula. 	<ul style="list-style-type: none"> • Industrial readiness of alumni is unknown and will vary from partner to partner. 	<ul style="list-style-type: none"> • Ability to choose cost and level of involvement based on available resources. • Partners can assimilate the courses into existing programs. • NACK resources utilized as an added benefit – able to complement existing curricula. 	<ul style="list-style-type: none"> • Industrial readiness of alumni is unknown and will vary from partner to partner.



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Summary of Course Delivery Options

- Reproduce NACK courses complete with labs
- Reproduce NACK courses with limited labs
 - Delivering most labs remotely through NACK partners
- Teaching some courses and delivering others remotely through NACK



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Summary of Course Delivery Options

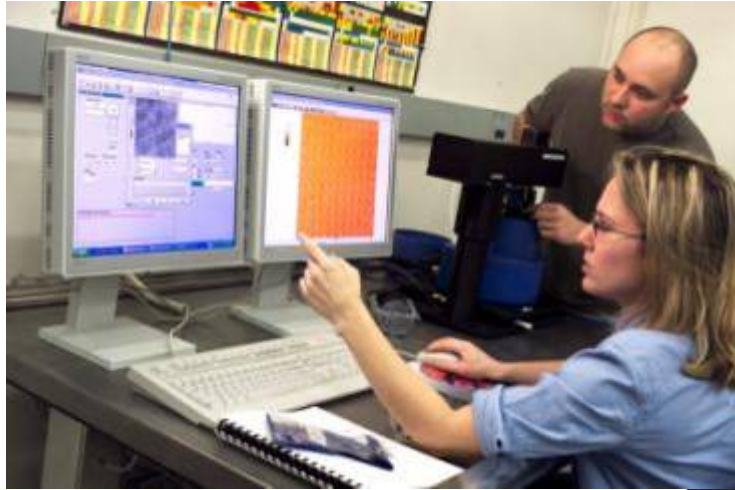
- Delivering all six courses remotely through NACK
- Picking and choosing from among the above options and the six courses to create new courses
 - Using NACK as a resource for course notes and labs



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Remote Access Tools



...to your classroom

From NACK...



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2+2

2+2+2

Education Pathways

Pennsylvania Commission for Community Colleges (14 two-year institutions)

The Pennsylvania College of Technology

Allegany College of Maryland (PA Campuses)

State System of Higher Education (14 four-year institutions)

The Pennsylvania State University

Local School Districts



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Student Recruitment

Materials

Experience

Campus Visits

Open Houses



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Nanotech Academies



Secondary School Curriculum Enhancement Materials



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Educator Workshops

The Next Educators Overview Workshop on Nanotechnology is coming up May 19-21, 2009. Attendance support is available.

See (www.nano4me.org) for details



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Industry Outreach



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Incumbent Worker Training



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Nano4me.org Web Site



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Teaching Cleanroom



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Alumni Services



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Web site**

**Equipment and
Facilities Resources**

**Alumni
Services**

• You can--

- Make use of these resources as you wish
- Promote their availability across the country
- Work with us to evaluate these resources
- Work with us to improve these resources
- Work with us to add additional resources



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