

## Testimony

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### Question 1

**Please describe the evolution of your program- how it began in response to industry's stated needs and how the program has changed as the industry needs and focuses have changed. Please describe how the program adjusted after the drop-off in demand for semi-conductor manufacturing technicians that occurred around the year 2000. How do you prepare your students to be adaptable to the changing needs in high-tech manufacturing?**

### *Answer*

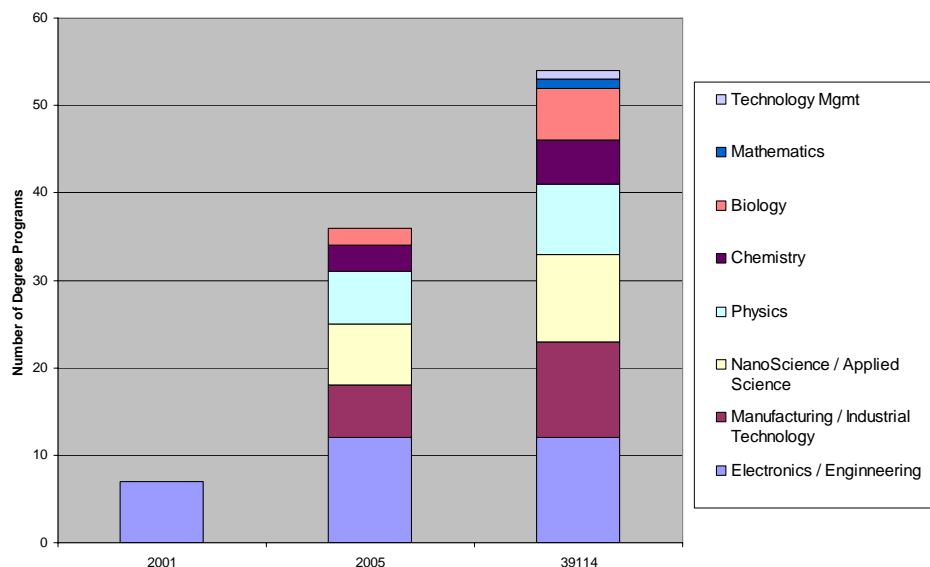
Our program originated from calls in 1998 from Lucent, Fairchild Semiconductor, and Air Products for increased technical education in Pennsylvania in the micro- and nano-scale fabrication and characterization techniques used in the semiconductor industry. To address this need, Penn State University, Pennsylvania community colleges, other two-year-degree granting institutions in Pennsylvania, and industry worked together to create a two-year degree program teaching micro- and nano-scale fabrication and characterization with an emphasis in semiconductor applications. Today, this effort has evolved into the Pennsylvania Nanofabrication Manufacturing Technology (NMT) Partnership. Today, its programs provide a broad micro- and nano-scale fabrication, synthesis, and characterization educational experience addressing the career needs of students and the technician needs of a spectrum of industries. The Partnership has received support from the Commonwealth of Pennsylvania since 1999, and in July 2001, was established as a NSF Advanced Technological Education (ATE) Center. As an NSF ATE center, the Partnership works with numerous institutions in other states to aid in replicating our educational programs and partnership approach.

At the inception of the Partnership, it was decided that each two-year-degree granting institution should formulate its own nanofabrication education program. However, each program was required to include a one semester hands-on immersion in micro- and nano-scale fabrication and characterization which we termed the “capstone semester”. Curriculum development was done in concert with industry through an Industry Advisory Board which oversaw, and today continues to oversee, the program and course development. The key—and unique aspect—of the program was the development of this capstone semester. This capstone semester experience is provided by Penn State three times per year at its University Park campus (fall, spring, and summer) as a service for the two-year-degree granting schools engaged in the education of technicians and production workers.

The “capstone semester” is taught at Penn State’s University Park campus and it is only there that a critical mass of students must converge. This is an important consideration for three reasons: (1) community colleges across the country find that technology training programs do not attract a large number of students, (2) community

colleges can not afford to have, and even more importantly, can not afford to maintain the expensive equipment needed, and (3) community colleges do not have the resident expertise required to use this equipment to teach micro- and nano-scale manufacturing technology. With the approach taken in the NMT Partnership, each “home school” contributes students to the capstone semester at University Park and the individual home schools need not have a critical mass in order to offer this training. They do not have to create whole new curricula for students but only have to modify course content to prepare students for the capstone experience. With the approach taken, Penn State’s broad facilities and the resident expertise were from the start, and are now, used to teach the defining, hands-on capstone semester exposure to advanced micro- and nano-scale fabrication and characterization. The approach was, and continues today to be, that the two-year degree granting institutions use the capstone semester courses in their programs as they see fit. These six courses are “on their books” as their courses and each home school’s students pay their institution’s tuition even while taking the capstone semester. The State of Pennsylvania enables this by paying the difference between the home school’s tuition and the actual cost of the capstone semester experience.

With the drop-off in demand for semiconductor manufacturing technicians which occurred in the 2000-2001 time period and with the increasing hiring of the NMT Partnership students by chemical, information storage, and pharmaceutical companies, it became apparent that micro- and nano-scale fabrication and characterization training should not be focused only on semiconductor manufacturing but that there was a ubiquitous need. The dramatically changed fortunes of the semiconductor industry at that time also taught the Partnership that students must be prepared for a lifetime of changes and shifts. As a consequence, the capstone semester courses were refocused to provide even more general training in micro- and nano-scale fabrication, synthesis, and characterization. The community colleges of the Partnership responded by modifying



**Figure 1** Evolution of the degree areas using the six-course, hands-on capstone semester immersion in micro- and nano-scale fabrication, synthesis, and Characterization

additional curricula and thereby inserting the capstone semester into degree programs in fields such as chemistry, manufacturing, and life sciences. The on-set of these changes and their continuing evolution may be seen in Fig. 1. With this broadening of the Partnership, micro- and nano-scale fabrication, synthesis, and characterization education areas, companies such as Rohm and Haas, Merck, Johnson & Johnson, PPG, and Lockheed Martin joined the Industry Advisory Board. The current composition of that Board is seen in Table I. The broad spectrum of Pennsylvania companies that have hired NMT Partnership graduates is presented in Table II.

**Table 1**  
**PA NMT Industry Advisory Board Membership as of May 2007**

Agere Systems	Merck
Airgas	Minerals Technologies
Air Products and Chemicals	PPG Industries
Bayer Materials Science	Plextronics
Boy Machines	RJ Lee Group
CarboLex	Rohm & Haas
Crystalplex	Saladax Biomedical
Diamonex	Schott Glass Technologies
Edlon	Seagate Technology
Fairchild Semiconductor	Solid State Measurement
Hanson Technologies	Tyco Electronics
Imiplex	US Steel
Johnson & Johnson	Veeco
Kurt J. Lesker	Versilant Nanotechnologies
Lockheed Martin	

Being designated as an NSF ATE center has been absolutely critical to our being able to broaden our educational impact and to our success. It has enabled the program to go from a Partnership of seven community colleges and Penn State in 2001 to a Partnership of all 14 PA community colleges plus Penn State campuses and the Pennsylvania State System of Higher Education. Today the Partnership's mission can be summarized as the following: to educate a workforce that is skilled in micro- and nano-scale manufacturing concepts in which can be transferred from industry to industry as the economic winds wax and wane. In short, we want to provide students with an excellent, broad education and the ability to take advantage of career opportunities as they may occur across a wide spectrum of industries. We want to make industry cutting edge and competitive and to give it a cutting edge and competitive workforce that can adjust to rapid change. We also want to provide two-year degree students with clearly defined pathways to a variety of four year degree opportunities. With that latter objective in mind, the four-year degree State System of Higher Education schools have been added to the Partnership. Working with the two-year degree institutions, these schools have created pathways whereby two-year degree graduates can use the capstone semester credits to build four year degrees in chemistry with a concentration in nanotechnology, in biology with a concentration in nanotechnology, in physics with a concentration in nanotechnology, and in engineering technology with a concentration in nanotechnology.

**Table II**  
**PA Companies Who Have Hired NMT Capstone Semester**  
**Graduates for Micro- and Nanotechnology Jobs (As of December 2006)**

II-IV Corporation	Johnson & Johnson
Agere	Johnson Matthey
Allied Fueling	Keystone Engineering
Alden Products	LCM Technologies
Amedeo	Lockheed Martin
Apogee Photonics	Lucent Technologies
Avail Technologies	Lutron Electronics
BioElectroSpec	Membrane Assays
B. Braun	Merck
Cabot	NanoHorizons
Correg Sensors	Optellios
Cosmos Technologies	Philips Medical Systems
Cyoptics	Plextronics
DRS Laurel Technologies	Probes Unlimited
Dana Corporation	PPL
Doucette Industries	Rhetch
Ex One	Seagate Technologies
Fairchild Semiconductors	SI International
Fincor Automation	Spectrum Technologies
First Energy	Textron Lycoming
F.S. Elliott	Transene
Gas Technologies	Westfalia Technologies
GlaxoSmithKline	Xactix
Hershey Medical Center	

**Question 2**

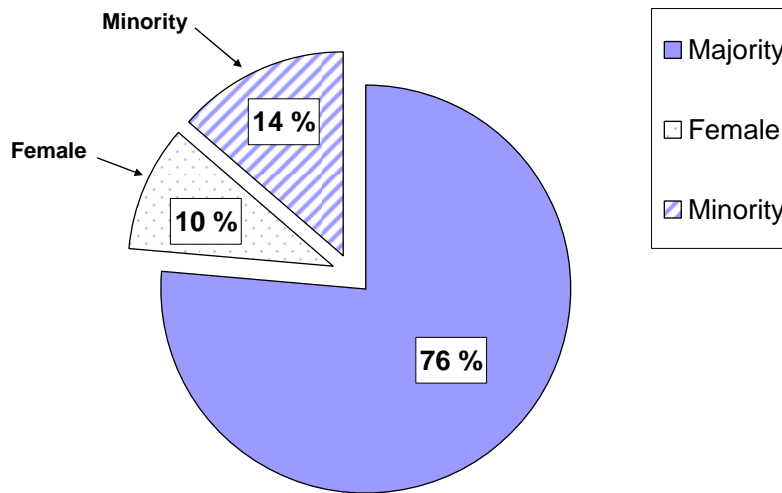
**What demographic profile does your program draw? How have you faced the challenge of recruiting more students to your program?**

*Answer*

The demographic profile of the students at NMT Partnership schools is that of the 21 community colleges and other two-year-degree granting institutions in the Partnership from across Pennsylvania. Figure 2 gives the female and minority compositions of the students who take the capstone semester. The representations for females and minorities

## Enrollment Diversity

Fall 1998 - Spring 2007 (423 Students)



**Figure 2** Enrollment diversity for 423 student attendees beginning winter semester 1999 through spring semester 2007

is close to that seen across the country for engineering. The Partnership has embarked on using three day Nanotech Camps, held in the summer at University Park for high school students, as a recruitment tool and a means to increase female and minority interest in nanotechnology-based manufacturing. Last summer a total of 206 high school students attended these Nanotech Camps at Penn State. Of these students, 50% were under-represented minorities and 56% were female. This summer, it is anticipated that 50% of the attendees will be female. Further, of the 10 Nanotech Camps scheduled, 4 will be exclusively for under-represented minorities.

Community colleges find that recruiting students for technology programs is difficult whether addressing minority, female, or general populations. At least some of the reasons for this problem lie in (1) parental desire for students to attend a four-year degree school, (2) a perceived lack of clear paths to four-year degrees for students attending two-year degree schools, (3) a nation-wide aversion to science and technology, and (4) lack of aggressive marketing by the community colleges. In the NMT Partnership, the various schools recruit their students. Partnership participation arms them with distinct, advantageous points to convey to prospective students and their parents. These include: (1) students will have a hands-on opportunity to work with the latest equipment and learn the very latest technology from practitioners, (2) students will spend one semester in the environment of a research university, (3) students will get more hands-on experience than four-year engineering students, (4) pathways are in place for two-year students to continue to four-year degree programs with nanotechnology concentrations, and (5) two-year degree NMT graduates of Partnership schools have been

receiving salaries in the \$30,000 to \$50,000 per year range. Even with these “sales-points”, the marketing of the unique micro-and nanotechnology education opportunities provided in Pennsylvania to counselors, teachers, parents, and students has been hampered by (4) above; i.e., lack of aggressive marketing by the community colleges.

The Partnership has prepared materials and tools to assist in marketing efforts. Included are nanotechnology product bags showing some of the latest nanotechnology-based consumer products, web access to nanotechnology tools for remote operation, a movie on a day in the life of a student who is taking the capstone experience, testimonials from industry, testimonials from graduates, and a public service announcement from the PA Governor. Many of these may be seen on the Partnership web site [www.cneu.psu.edu](http://www.cneu.psu.edu). In addition the Partnership holds nanotechnology workshops for middle school and high school teachers to work to create a cadre of teachers who understand the far reaching impact of this technology. To date over 500 teachers have taken these workshops. However, all these efforts are only useful when coupled with a strong marketing effort. Community college faculty do not seem to have the time to do the needed recruiting, community colleges do not seem to have adequate marketing capabilities, and administrators worry support for nanotechnology education programs such as the PA NMT partnership will evaporate.

### **Question 3**

**How do you determine your math/science curriculum? What steps do your partner community college institutions take to ensure students can meet the demands of your program?**

#### *Answer*

With the added resources available since becoming an NSF ATE center, our Partnership has grown to 21 institutions offering 33 nanotechnology two-year degrees across Pennsylvania. Each school uses the capstone semester as an integral part of its two-year degree programs which are based on micro- and nano-scale fabrication, synthesis, and characterization. Each institution has tailored these degrees to meet the industry focus in its area. For example, the two-year degree programs in the Pittsburgh area tend to be materials processing oriented. Those in the Philadelphia area tend to be chemistry and biotechnology oriented. The two-year degrees offered by Partners run the gambit from nano-manufacturing to nano-biotechnology.

With this number of institutions and this variety of degree types feeding into the capstone semester hands-on experience, it is not feasible to even attempt to standardize the math/science courses and curriculum base for the Partnership. To try to do so would take years since each institution has its own course and curriculum committees and procedures. Rather than attempting this approach, we chose to standardize the skill set that must be provided by each math/science curriculum feeding into the capstone

semester. Each institution must certify that this required skill set is met by each student it sends to the capstone semester. The capstone semester then builds on this entry skill set. Students emerge from the capstone semester with the technician skill set established by the Industry Advisory Board. This is shown in Table 3.

**Table III**  
**Skill Set Acquired from the Capstone Semester**

**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
- Furnaces: Use and Maintenance
- Chemical Reaction Systems: Use and Maintenance
- Contamination Control
- Process Integration
- Introduction to Statistical Process Control
- Biocompatibility

**Micro- and Nanotechnology Synthesis and Fabrication Skills**

- Bottom-up
  - Pattern Generation
  - Chemical, Physical, and Biological Self-Assembly
  - Nanoparticles: Colloidal Chemistry
  - Nanoparticles: Plasma and Grinding/Milling Approaches
  - Nanoparticles: Chemical Vapor Deposition
- Top-down
  - Optical, E-beam, Stamping, and Imprinting Lithography
  - Etching and Deposition
  - Chemical Vapor and Physical Vapor Deposition
  - Materials Modification
- Hybrid

**Micro- and Nanotechnology Characterization Skills**

- Optical Microscopy
- Scanning Probe Microscopy
  - Atomic Force Microscopy
- Electron Microscopy
  - Scanning Electron Microscopy (SEM and Field Emission SEM)
  - Transmission Electron Microscopy (TEM and Field Emission TEM)

- Chemical Characterization
  - X-ray (Energy Dispersive Spectroscopy)
  - 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

**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
- Intellectual Property

**Question 4**

**What is the ideal role for industry partners in developing and running a successful tech-training program? Please elaborate on industry's role in creating skill standards, developing curriculum, providing student development opportunities, defraying the cost of equipment, and hiring graduates.**

*Answer*

For a meaningful advanced manufacturing and technology education program, industry must be involved from the inception. This was the situation for our Partnership—in 1998 companies such as Lucent, Fairchild, and Air Products went to the Pennsylvania government with Penn State representatives to argue for the semiconductor oriented micro- and nanofabrication education effort. This evolved into the 33 very broad micro- and nano-scale manufacturing technology two-year degree programs of today's NSF ATE center. From the very beginnings these companies, and the 26 additional companies that have joined them over the ensuing nine years, have constituted our program's Industry Advisory Board. We have worked to keep this group small enough to be active and interactive and yet broad enough to encompass representatives from all the



various Pennsylvania industries now impacted by nanotechnology from pharmaceuticals to the alternative-energy companies and from information storage to measurement tools companies. Our current Industry Advisory Board (Table I) last met this past May 2007 in its Partnership guidance role.

An Industry Advisory Board plays an extremely crucial role in advanced manufacturing and technology education for the very basic reason that it tells you if what you are doing is meaningful, or not, to companies. One must temper its advice, however, with the understanding that in some cases an industry view can be a very “this quarter” perspective—after all, in the beginnings of our program, before the collapse of much of the semiconductor manufacturing in this country, we were being told to emphasize the semiconductor industry aspect of micro- and nano-scale manufacturing. Nonetheless, the Industry Advisory Board and its input to courses and curriculum has been the principal force in shaping our program. Every year the Board reviews the skill set responsibilities of the community colleges, the course content of the capstone semester courses taught for the community college by Penn State, and the skill set to be developed in the capstone semester experience. The current capstone semester skill set that comes out of this industry input, just modified as a result of the May 2007 Board meeting, is seen in Table III.

The innovation and vision of research intensive universities is sought after by industry to aid in keeping their products on the cutting edge and competitive internationally. That same innovation and vision of research intensive universities is also needed to aid in keeping community colleges on the cutting edge of skilled technician and production worker education. The “this quarter” perspective that industry can sometimes bring in its assessment of workforce skill needs can be tempered by the “next decade” perspective of products and manufacturing that a research intensive university can bring. This perspective is critical to the students’ well being and to the country’s long term economic health. Students must be educated with an understanding of basic fabrication, synthesis, and characterization and imbued with the basic desire to continue to want to learn. It is only this approach that will allow the workforce—and ultimately the country—to adapt to the changing needs, which surely will come, in high-tech manufacturing.

A proposed list of the ideal roles industry can play in advanced technical education programs such as micro- and nano-scale fabrication, synthesis, and characterization is the following:

- (1) Delineate the skills needed for workers and evolve these as the industries react to competition and market forces
- (2) Monitor courses and curricula to insure these skills are taught
- (3) Assist with student recruitment
- (4) Provide student development opportunities such as internships
- (5) Assist with equipment costs
- (6) Hire graduates

Research intensive universities should have an equally important role in advanced technical education programs such as micro- and nano-scale fabrication, synthesis, and characterization. A proposed list of the ideal roles research intensive universities can play is the following:

- (1) Balance the near-term perspective of industry with the longer-term perspective of a research university
- (2) Provide the facilities and resident expertise as a service to allow community colleges to offer hands-on experiences in a broad variety of micro- and nano-scale manufacturing processes
- (3) Provide the facilities and resident expertise to offer “teaching-the-teachers” education for keeping community college faculty current in manufacturing technology
- (4) Assist community colleges with the development of student recruitment materials (e.g., provide brochures, web access to equipment, web available informational materials)

The motivation for industry to play these proposed roles in advanced technology education is well understood. The motivation for research intensive universities to play the roles proposed for them for advanced technology education is less clear. There is a well established innovation path from research universities to industry which turns new ideas in the laboratory into products. It is considered prestigious to participate in this pathway. There needs to be an equivalent innovation path from universities to technology education which turns new ideas in the laboratory into skills and learning in the technology classroom. Being a participant on this pathway needs to be deemed equally prestigious. Innovation has to move to industry rapidly to keep it competitive. Innovation has to move to the technology classroom equally rapidly to keep the country’s workforce competitive and to provide a lifetime of opportunities for technical workers. Perhaps something like a Morrill Act for the 21<sup>st</sup> century is needed to insure that innovation and cutting edge developments are moved quickly into the teaching of the “branches of learning as are related to...(the) mechanic arts.”