WRITTEN TESTIMONY OF

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Professor and UNESCO Chair

Submitted to
Subcommittee on Research and Technology
Committee on Science, Space, and Technology
For the hearing entitled
"Strengthening the U.S. Microelectronics Workforce"

U.S. House of Representatives
Washington, D.C.

February 15th, 2022

Chairwoman Haley Stevens (D-MI), Ranking Member Randy Feenstra (R-IA), and honorable members of the Subcommittee on Research and Technology, my name is Osama O. Awadelkarim, and I am a Professor of Engineering Science and Mechanics, the UNESCO Chair for *"Building Innovation and Manufacturing Capacities through Advanced Technology Education",* the Director of the Center for Nanotechnology Education and Utilization (CNEU), and the Director of the Nanotechnology Applications and Career Knowledge (NACK) Center at the Pennsylvania State University. Thank you for the opportunity to testify in this hearing on strengthening the U.S. microelectronics workforce. The views expressed in this testimony are my own.

With the advent of the internet of things and artificial intelligence, semiconductors in the form of integrated circuits (ICs), or "chips", have become an integral part of our technology driven world today. Almost all products that we use, from a microwave oven to mobile phones to advanced computers, utilize ICs in one way or another. Hence, the need for chips has risen sharply while the chip supply worldwide has fallen significantly short of the demand. The U.S. once led the world in chipmaking, and in the 1990s the U.S. supplied ~ 40% of the world's chips. However, at the present time the U.S. share of chip supply to the world dropped to ~ 10% and the leadership of chip supply is taken over by countries, especially in Asia, that invested in building powerful chip makers in their own countries. Semiconductor products are very critical to our economic and

national security and rank the fifth largest U.S. export sector, providing ~ 250,000 U.S. jobs directly and over a million indirectly.

As IC miniaturization continues and the density of devices in the chip increases, typical feature sizes of devices shrank to the nanometer scale (1 nanometer = 1 billionth of a meter). Microelectronic and semiconductor processing transformed into fabrication at the nanoscale. Therefore, nanotechnology and its nanofabrication tools and processes have become the backbone of advanced semiconductor processing and chip making technologies. Indeed, nanofabrication opens the door to super high-density microprocessors and memory chips, as well as enables future assembly of chips atom-by-atom. Semiconductor and microelectronics processing belongs to the *"top-down"* approaches of nanofabrication, which is broader and encompasses *"bottom-up"* approaches that are used in medicine and healthcare, environmental remediation, and energy applications to name a few. However, for the purposes of this testimony, the terms semiconductor/microelectronics processing and nanofabrication/nanomanufacturing will be used interchangeably. The semiconductor nanomanufacturing has undergone major technological advances and, currently, state-of-the-art nanofabrication facilities or *"Nano-Fabs"* are used to manufacture chips with nanoscale devices in high volumes. For the U.S. to restore world leadership in chipmaking, it is imperative to increase domestic advanced semiconductor nanomanufacturing capacity and capability. An important aspect to capacity and capability building is developing the necessary nanomanufacturing workforce. This testimony focusses on the very important and necessary sector of this workforce, which is the sector of the associate degree technicians.

The Center for Nanotechnology Education and Utilization (CNEU) was created by the Pennsylvania State University (Penn State) in 1998 to address the needs of Pennsylvania (PA) semiconductor industry for skilled workers and is dedicated to preparing workers across the full range of micro- and nanofabrication applications [http://www.cneu.psu.edu]. To meet the industry call, CNEU, PA community colleges (CCs), other two-year-degree granting institutions in PA, and industry worked together to create a two-year degree program teaching micro- and nano-scale fabrication and characterization with an emphasis in semiconductor processing and applications. Today, this effort has evolved into the PA Nanofabrication Manufacturing Technology Partnership (PA NMT), which is a broad micro- and nano-scale fabrication, synthesis, and characterization educational experience addressing the career needs of students and the technician needs of a wide spectrum of semiconductor-based industries (Fig. 1). CCs and two-year-degree granting institutions in PA NMT map out their own nanofabrication education program such that each program includes a *"capstone semester"* developed in coordination with industry through an Industry Advisory Board which oversees the program and course development. The capstone semester comprises six courses (18 credits) of hands-on immersion in micro- and nano-scale fabrication and characterization taken by the students over 12 weeks in CNEU's teaching cleanroom at Penn State's University Park campus. A total number of 991 students have attended the PA NMT capstone semester and have moved on to work in mostly semiconductor companies. Those students were sent to Penn State by 44 PA post-secondary institutions. The hands-on

training that is needed requires equipment, staff, and faculty resources, which are often not available at many post-secondary institutions, especially CCs. In PA NMT, CNEU uses a "*resource-sharing"* approach, whereby its nanofabrication infrastructure is accessible to the PA NMT students. This approach is a proven, working model for accomplishing the needed nanotechnology workforce training crucial to U.S. competitiveness. The approach provides the means for workforce training institutions to have access to the expertise and facilities required to deliver the broad nanotechnology education needed to empower the U.S. and its workforce and give them the resiliency to compete in today's fast-moving world.

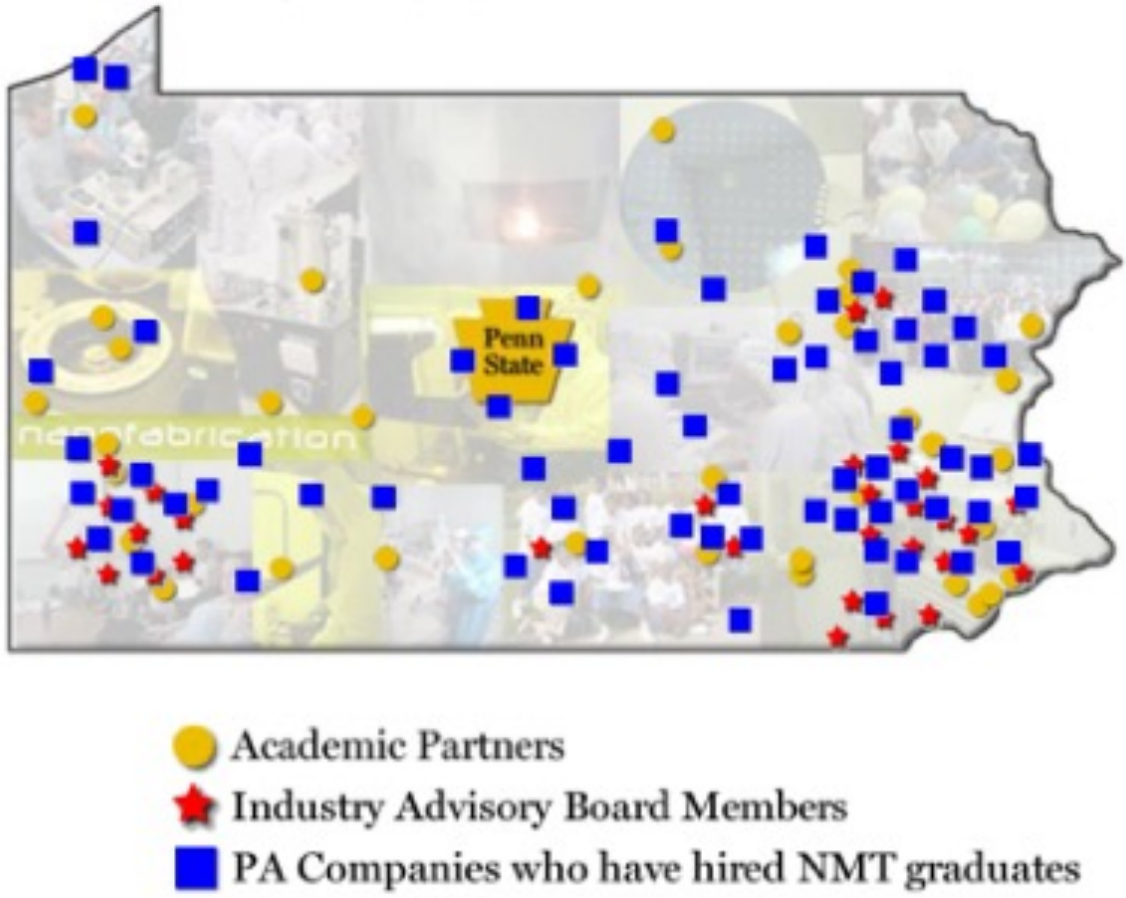


Fig. 1: The PA NMT partners from CCs, universities, and industry from 1998 through 2022.

The pioneering work by CNEU has established PA as a global leader in micro- and nanofabrication education and workforce development. Subsequently, the National Science Foundation (NSF) created the Advanced Technological Education (ATE) Center for Nanotechnology Applications and Career Knowledge (NACK) at CNEU to replicate the PA NMT model nationwide, and to help support, coordinate, and integrate efforts by CCs and technical colleges (TCs) across the country to provide associate degree level micro- and nanotechnology education. NACK has been established to assist in the continued development of a robust

nationwide infrastructure for nanotechnology workforce development. The key feature of NACK's mission is to continue to support the development and sustenance of U.S. nanotechnology workforce education by further growing nano-education partnerships nationwide, by enhancing dissemination of nanofabrication educational resources, and by providing key national infrastructure. NACK strives to build partnerships in nanotechnology education among research universities, two-year CCs/TCs, and four-year colleges/universities through resource sharing. Currently, there are more than ten partnerships that are fully formed and functioning, and NACK continues to work in the formation and growth of more nanotechnology workforce education partnerships. The resources provided by NACK and shared with CCs/TCs include the lecture materials for the six complete core-skill capstone-semester courses available in units' form. The six NACK courses, which capture the industry-ratified, broad fundamentals of nanotechnology concepts and processing, provide the graduating student with the industry approved exit skill set, and can be used as is by teaching institutions or the units in each course can be rearranged as best meets the needs of the particular workforce training institution. The NACK educational resources further include the laboratory experiment sets and videoed lectures for each of the six courses.

One of CNEU's most important contributions is in the nanotechnology professional development (NPD) of CC and TC educators. The NPD, started by CNEU in a face-to-face workshop delivery mode, and was subsequently adapted by CNEU to a web-based live-streaming and fully interactive delivery mode, which has proven to be very effective in reducing cost and in making NPD accessible to a much larger CC educator audience. Fig. 2 shows CNEU's NPD workshop attendance over the years by educators from nationwide CCs, schools, and universities. A total of 1,843 educators and industry personnel have completed CNEU's NPD workshops.

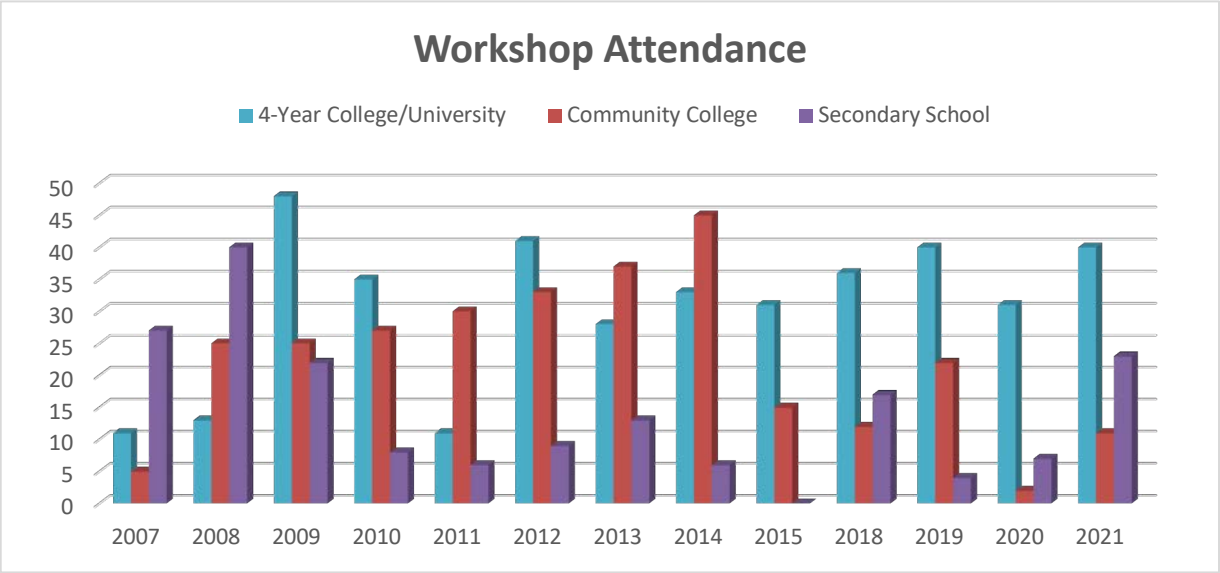


Fig. 2: Attendance by educators in academic institutions nationwide of CNEU's professional development workshops for 2007 through 2021.

Community colleges find recruiting students for technology programs difficult, and some of the reasons for this problem include: disinclination to science, technology, engineering and mathematics (STEM) education; lack of vigorous marketing strategies by CCs; and desire to attend four-year degree institutions among STEM-interested students. Nanofabrication and semiconductor processing is an advanced technology education area and as discussed above requires infrastructure that is beyond the means of most CCs and two-year degree institutions as well as most four-year degree universities. Engagement of research universities with CCs is crucial in circumventing this hurdle through resource sharing. However, there are three major hurdles that preclude university engagement: lack of incentive for the research university to get involved; restriction of nanofabrication facilities for research and the nonavailability of teaching cleanrooms in research universities; and the high cost incurred by the CC student in getting training in a research university (tuition for credits). From 1998 to 2007, the students attending the capstone semester in CNEU's PA NMT were fully supported by a grant from the State of Pennsylvania, and thereafter, the attending students have been self-supported. This transition resulted in about 60 to 70% reduction in the number of students enrolled in the capstone semester.

Fig. 3: RAIN membership locations in the U.S.

NACK created the Remotely Accessible Instruments for Nanotechnology (RAIN) Network, which provides web access to state-of-the-art characterization and fabrication tools to enable the teaching of nanotechnology characterization at workforce training institutions and, with NSF support, sends Penn State experts to these teaching institutions to assist faculty in learning and using these web accessible tools. NACK's RAIN Network, with members all over the U.S. (Fig. 3), continues to become a more established community, as well as grow its membership ranks. At the present time, there are 28 RAIN Network partners (Fig. 4) and work is in progress to

admit more partners to the Network to meet the high demand for the remote equipment accessibility. RAIN has currently enabled remote access to 43 discreet nanotechnology instruments and has created seven "Remotely Enabled" laboratory user guides. To date, the RAIN Network held 300 sessions which impacted more than 10,000 students (Fig. 5), and 11 RAIN members participated in National Nanotechnology Initiative's (NNI's) National Nanotechnology Day festivities entitled "Nano in Motion". RAIN publishes a triannual newsletter, "NANOWIRE", to highlight RAIN efforts, achievements, and impact, as well as to market RAIN Network site availability. RAIN Network continues to work with nanoscale equipment suppliers to explore RAIN sustainability options. Also, NACK is working with the NSF ATE Micro Nano Technology Education Center (MNT-EC) to further enhance RAIN capabilities and expand the professional development activities. MNT-EC is a national center and its goal is to grow the MNT technician workforce by fostering academic and industry partnership between existing MNT partners and CC educators.

Fig. 4: RAIN Network membership.

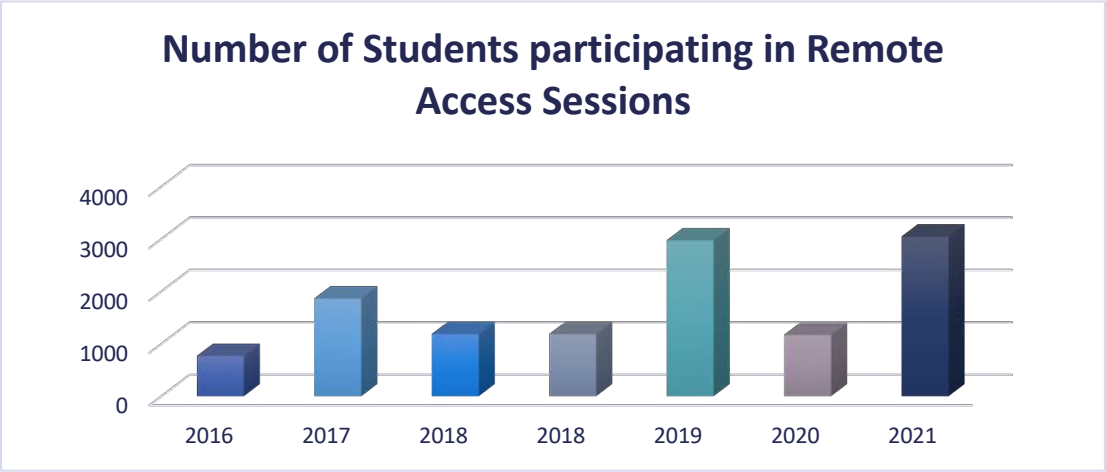


Fig. 5: Number of students who attended RAIN sessions between 2016 and 2021.

Research universities have an important role to play in assisting CCs/TCs and 2-year institutions in preparing skilled technical microelectronics workforce. The wish list of areas in which universities can help includes:

- Share infrastructure, in the form of cleanrooms, laboratories, and tools, as well as resident expertise as a service to enable CCs/TCs students to acquire a cutting-edge hands-on training/education.
- Share infrastructure, in the form of cleanrooms, laboratories, and tools, as well as resident expertise as a service to professionally develop CCs/TCs educators and teach them how to teach and train their students in microelectronics.
- Assist CCs/TCs with remote access to nanofabrication and semiconductor processing and characterization equipment.
- Balance the near-term perspective of industry with the longer-term perspective of a research university.
- Work with and assist CCs/TCs with the development of student recruitment materials (e.g., provide brochures, web access to equipment, web available informational materials).

For the U.S. to fill the gap in semiconductor workforce need, it is important to draw significant numbers of skilled workforce from underrepresented minority (URM) populations. However, it has been found that URM students from African American and Hispanic ethnic groups are less likely to join STEM than white students in general, let alone microelectronics and semiconductor processing. To address the preclusion of African American and Hispanic student enrollment in STEM-related fields, it is critical to identify the issues. There are several issues interfering with the success of our nation's African American and Hispanic students' progress in STEM-related degrees and career attainment. These issues include motivation and identification

with STEM professional careers, cultural dissonance with typical STEM college programs or faculty, preparation and skill development, and financial challenges. Also, enhancing the representation of females and other minority groups such as, native Americans and military veterans, is very crucial in diversifying and promoting equity and inclusion in microelectronics workforce. The total percentage of students from African American and Hispanic ethnic groups who graduated from our capstone semester is ~ 15%, whereas female graduate percentage is ~ 10%.

As a broader CNEU impact and service to underrepresented minorities, in the summers of 2018 and 2019, CNEU held two 12-week "Nanotechnology Summer School (NSS)" sessions for a total of 29 Hispanic students, including 10 female students, from the University of Puerto Rico at Humacao (UPRH). The objective of the NSS was to help our NACK Network partners in UPRH maintain their nanotechnology programs and ensure their continuity in the aftermath of Hurricane Maria. Also, in 2018 CNEU utilized its resources and partnered with Norfolk State University (a Historically Black College and University (HBCU)), Tidewater CC, National Aeronautics and Space Administration Langley Research Center, Jefferson National Research Laboratory Applied Research Center, and Eastern Virginia Medical School to form the South-eastern Coalition for Engagement and Exchange in Nanotechnology Education (SCENE) as a NSF Louis Stokes Regional Center of Excellence. SCENE utilizes nanotechnology as a conduit for engaging and inspiring talented African American students and promoting their participation in STEM education. This past summer CNEU instructors presented nanotechnology lectures and provided nanotechnology training and research experiences to 26 African American students.

Military service members and veterans bring valuable skills and experience from their military service to nanotechnology workforce. Strong work ethics and commitment are just a few of the qualities that veterans bring back to the civilian lifestyle. In the past two years, CNEU has developed and offered the "Nanomanufacturing Certificate Program (NCP)" for veterans recruited from military installations in Norfolk and Virginia Beach, Virginia. The NCP comprises six modules adapted from the course material developed and widely utilized by CNEU and partners. The NCP lectures are delivered in a "live stream and fully interactive" format using web conferencing technologies. The veterans are recruited and enrolled in Tidewater Community College (TCC) in Virginia and the lectures are hosted and webcast by CNEU instructors to personal computer and iOS/Android device audience, i. e., portable learning format, as well as desktop participants. The delivery is immersive in a dynamic multimedia and video conferencing environment with extensive interactive options that maximize and monitor engagement. The NCP provides hands-on and virtual laboratory experiences on nanofabrication processing. The hands-on component is provided in the Norfolk State University cleanroom facility in Norfolk, VA. The virtual laboratory component is live streamed utilizing: live demonstrations of nanofabrication equipment; remote accessibility of nano-characterization tools; and virtual experimental assignments and data analysis. NCP courses are delivered over 12 weeks, and upon the successful completion of the NCP instruction, veterans will receive a Nanomanufacturing Certificate issued by CNEU and continued education credits by TCC, and are appropriately prepared to take the tests

administered by the international standards organization ASTM International and obtain nanotechnology stackable certificates (discussed below). The NCP is now eligible for Virginia military SkillBridge offering and CNEU is working to add NCP to the list of other eligible military education and training programs. To bring the NCP to veterans' attention, CNEU is reaching out to several veteran education resource centers in military branches, including Airforce, Army, Marines, and Navy, and in CCs/TCs with large veteran enrollment.

CNEU and NACK resources are on-line and available for free at NACK's website www.nano4me.org. Also, working with CNEU, nanoHUB production specialists evaluate and post-process existing and/or newly developed CNEU course content into professionally delivered course modules to be deployed on the nanoHUB website, which is a NSF funded science and engineering gateway comprising community-contributed resources and geared toward education, professional networking, and interactive simulation tools for nanotechnology [https://nanohub.org]. The nanoHUB team also deploys the "NACK series of teaching materials and RAIN Labs", which are designed to teach K-12 and college students in STEM programs how to access and control advanced nanomanufacturing tools such as scanning electron microscopes.

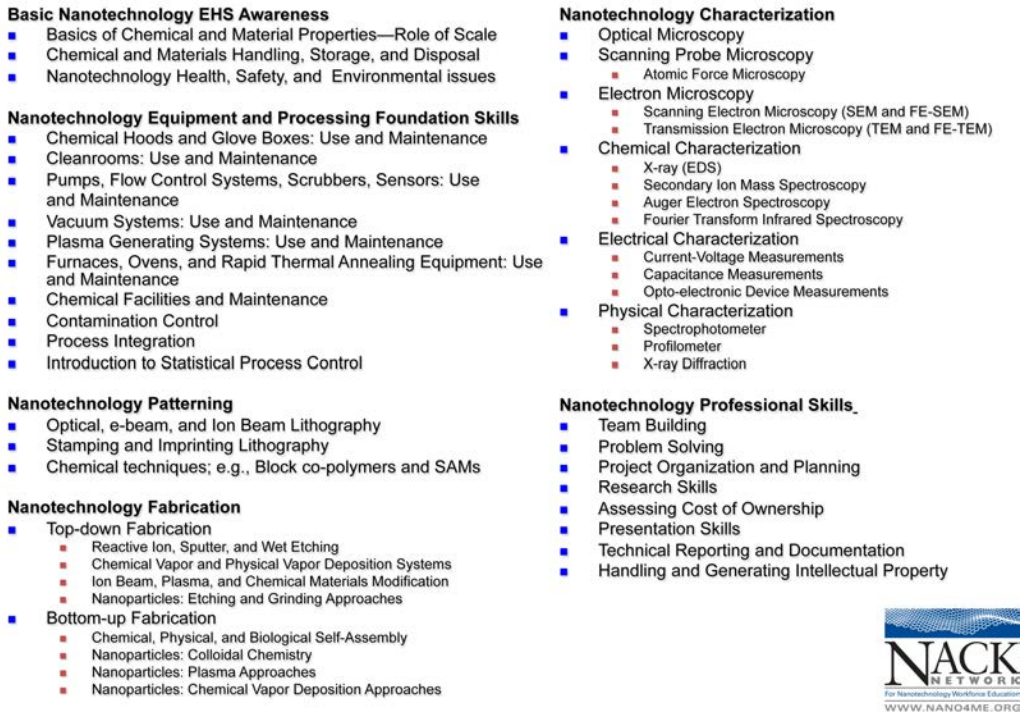


Fig. 6: Summary of core-skills taught in the six CNEU courses

Industry plays a very important role in advanced manufacturing and technology education for the very basic reason that industry informs academicians whether what is being taught to students is meaningful, or not, to companies. Industry has guided every phase of the development of the CNEU's PA NMT. Microelectronics industries constitute the majority participation in the advisory boards of CNEU and its affiliated centers such as NACK and SCENE. MICRON, Global

Foundries, TSMC, and ON Semiconductor are some of the chip producers that are currently very actively engaged with CNEU. Industry input to courses and curriculum has been the principal force in shaping our various education and training programs. Industry reviews the skill set responsibilities of the CCs, the course content of the capstone semester courses taught for the CC students by CNEU, 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 is given in Fig. 6. It is important to note that our skill set covers all that is needed to produce highly skilled microelectronics workforce, however it is also broad enough to provide workforce to a wider spectrum of industries.

Overall, the role industry can play in advancing micro and nanofabrication education and developing the needed workforce is summarized in the following:

- Advise on the skills needed for workers and regularly update these skills as products evolve, and industries react to competition and market forces.
- Monitor courses and curricula to ensure these skills are taught.
- Assist with student recruitment. Effectively advertising the incredible careers available to CC/TC students is extremely important and lacking.
- Provide students and CC/TC educators with development opportunities such as internships, fellowships, and research opportunities.
- Donate and/or provide funding for fully functional equipment to CCs/TCs and research universities that partner with CCs/TCs in workforce development. Also, provide funding for supporting equipment maintenance.
- Provide grants to CCs/TCs and research universities earmarked for funding semiconductor workforce development.
- Give seminars/webinars to CC/TC and university students highlighting the merits and opportunities of joining the microelectronics and semiconductor workforce, i. e. recruitment.
- Participate in job fairs at CCs/TCs and universities and hire graduates.

CNEU has been working with the international standards organization ASTM International to institutionalize CNEU's industry-approved core-skills into ASTM standards. ASTM International is a globally recognized leader in the development and delivery of voluntary consensus standards. Currently, more than 12,000 ASTM standards are used around the world to improve product quality, enhance health and safety, strengthen market access and trade, and build consumer confidence. Specific objectives for CNEU-ASTM work include provision of core-skill standards drafts to assist ASTM International in their development of core skill standards for nanotechnology workers; active participation in the required consensus building on these standards within nanotechnology workforce education community and industry; the dissemination of these standards among educators, industry, and government; and the development of student certification through stackable certificate testing. Six nanotechnology workforce education standards have been approved, published through this CNEU supported process, and are available

at the ASTM International website http://www.astm.org. Three online certification tests have been developed and completed this year and are available to programs across the country.

During this challenging time to our nation's semiconductor industry, there is a need to be effective, efficient, and outcome driven. This calls for the Federal Government intervention and action to address semiconductor shortage and grow the semiconductor manufacturing workforce. Ways in which Government can assist may include:

- Provide funding for the creation and sustenance of research university–CC partnerships for semiconductor workforce development.
- Provide funding and ensure that appropriate national laboratories become engaged in helping CCs/TCs through internships and fellowships given to students and educators, respectively.
- Increase student flexibility to use federal higher education grants and student loans, as well as devise new innovative ways for individuals to pay for training and certificates in semiconductor processing.
- Identify ways to incentivize semiconductor industry participation in the creation, delivery, and financing of workforce development at CCs and universities.
- Identify ways to reward semiconductor industry for offering internships, apprenticeship, on-the-job, or incumbent worker training programs.

In closing, CNEU will continue to champion a nation-wide nanomanufacturing skill set education approach; will continue to be the key source of microelectronics education materials; will continue to provide resources and assistance to the nanomanufacturing education partnership infrastructure; and will continue to maintain efforts to bring nanomanufacturing to every corner of the U. S. through web courses and remote equipment access. CNEU and MNT-EC workshops will continue to bring faculty and administrators together from across the country and will promote a better national understanding of nanomanufacturing education demands and requirements, approaches, resources, and sustainability issues. In addition, CNEU's partnering/resource-sharing approach is a proven success and is a model for all aspects of science and technology education. CNEU has established a nation-wide experiential basis for effective, working, CC/TC/research university resource sharing relationships. CNEU will further develop and support its dynamic infrastructure and toolset to continue to advance nanomanufacturing education and workforce development. Fig. 7 compiles the performance metrics of CNEU and NACK and highlights its enormous contributions in nanomanufacturing workforce development. Also, the Appendix attached to this document highlights and summarizes the ongoing CNEU activities in nanomanufacturing workforce development.

On a final note, it is important to acknowledge the support given to CNEU and its associated centers by Penn State, the State of Pennsylvania, the National Science Foundation, and the Advanced Technological Education community. Without their support it would not have been possible to accomplish the work reported in this testimony.

Metrics for Workforce Education: Nanotechnology Applications and Career Knowledge (NACK) Center		
Thrust Area	Description	Total
Students	Students who have completed the on-site semester on the six core skill nanotechnology courses (NMT) (2020 was virtual due to COVID)	991
Students	Students who have completed the Nanomanufacturing Certificate Program (NCP) (Veterans Initiative)	9
Students	Number of post-secondary institutions who have sent students to attend a semester on the six core skill nanotechnology courses	44
Education Standardization	Number of International Standards for Nanotechtnology Workforce Education created under NACK leadership (ASTM International) (started 2016)	6
Education Standardization	Number of International Accreditation Certificates for Nanotechtnology Workforce Education developed under NACK leadership (ASTM International) (started 2018)	3
Education Standardization	Number of ASTM Certificates awarded	28
National WF Infrastructure	Number of national nanotechnology workforce education partnerships formed	14
National WF Infrastructure	Number of states with nanotechnology workforce education partnerships	12
National Infrastructure	Number of partners who have joined NACK's remote access provider network (RAIN)	28
National Infrastructure	Number of community college partners who have joined NACK's remote access provider network (RAIN)	8
National Infrastructure	Number of secondary school partners who have joined NACK's remote access provider network (RAIN)	1
Outreach and Recruitment	Number of remote access (RAIN) sessions provided	579
Outreach and Recruitment	Number of students attending remote access (RAIN) sessions	11,103
Outreach and Recruitment	The "NANOWIRE" newsletter distribution audience reached (started 2016)	65,736
Outreach and Recruitment	Number of "NANOWIRE" newsletter readers - "opens" (started 2016)	10,838
Professional Development	Number of educators and industry personnel who have completed NACK workshops	1,843
Professional Development	Number of participants who have completed NACK live-streamed workshops (started in 2018)	250
Professional Development	Number of NACK National Webinars	60
Professional Development	Number of registrants for NACK National Webinars	4,312
Professional Development	Number of NACK National Webinar recorded video views (For videos recorded in that year)	15,310
Program Development and dessimination	Number of nanotechnology courses developed and regularly updated	11
Program Development and dessimination	Number of registered users for NACK website	3,539
Program Development and dessimination	Number of nanotechnology education material downloads from NACK website	58,025
Program Development and dessimination	Number of users served on nanoHUB website (started 2016)	93,353
Education Impact	Number of Community/ Technical Colleges who use CNEU resources (programs, courses, modules, webinars, professional development)	> 300

Fig. 7: CNEU/NACK's performance metrics.

APPENDIX: Summary of CNEU Activities

CENTER FOR NANOTECHNOLOGY EDUCATION AND UTILIZATION (CNEU)

PennState

APPENDIX to Written Testimony

House Hearing: "Strengthening the U. S. Microelectronics Workforce"

Submitted To

The House Committee on Science, Space, and Technology
Subcommittee on Research and Technology

Osama O. Awadelkarim
UNESCO Chair and Professor of Engineering Science and Mechanics
The Pennsylvania State University

February 15th, 2022

1

THE QUESTION

How do we undertake the nanomanufacturing education necessary to create a skilled and competitive workforce for strong microelectronics U. S. industry base?

THE PROBLEMS

- *Many people have no idea what microelectronics and nanomanufacturing are*
- *Lack of facilities and equipment in education institutions*
- *Lack of staff/technician support in education institutions*
- *Pockets of expertise*

2

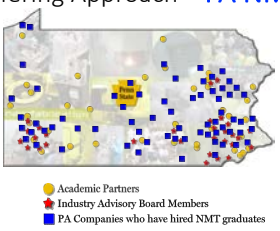
The Center for Nanotechnology Education and Utilization (CNEU) Approach: "Resource Sharing"

Sharing the nanofabrication facilities, faculty expertise, and staff/technician base of Penn State across Pennsylvania

Pennsylvania's Nanofabrication Manufacturing Technology (PA NMT) Partnership

3

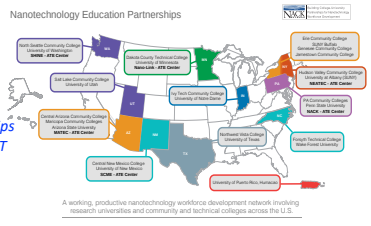
Participating Institutions in the PA Central Offering Approach – PA NMT



4

NSF's Nanotechnology Applications and Career Knowledge (NACK) Network

NACK helps create nanotechnology education partnerships similar to the PA NMT



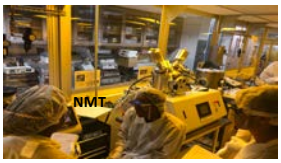
5

CNEU has its own cleanroom dedicated for teaching

6

Course Development

Skill-Set



Six 200-level courses

- *Shared with partner schools*
- *Taught in PA NMT for a nano certificate*
- *As of 2022, the total number of companies employing NMT graduates is ~* ***150.***

7

Remotely Accessible Instruments of Nanotechnology (RAIN)

Nano-equipment includes:

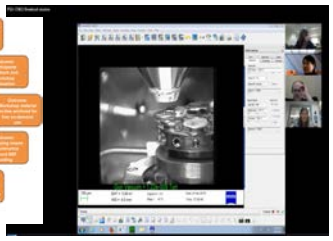
- *Scanning Electron Microscopy (SEM)*
- *Atomic Force Microscopy (AFM)*
- *Profilometry, FTIR, and XRF*
- *Evaporation, Sputtering, RIE*
- *Optical and Confocal Microscopy*
- *Vacuum Training Equipment*

- *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*

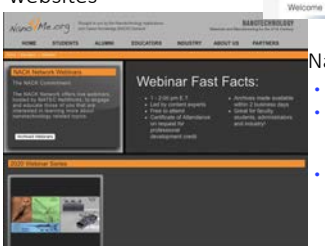
8

NSF's Nanotechnology Professional Development Partnership (NPDP)

9



CNEU and Nano4Me.org websites



Nanotechnology Webinars

- *Live 90 minutes webinars*
- *To engage and educate the public about nanotechnology related topics*
- *Archived at www.Nano4Me.org and nanoHUB for convenient viewing*

10

International Credentialing

ASTM E56 Education Standards

- *Suite of 6 standards is now published covering basic skill sets for nano workforce*
- *Can be accessed at https://www.astm.org/COMMITTEE/E56.htm*

ASTM Personnel Certificates in Nanomanufacturing

The current mission is to create 4 certificates which cover the ASTM Nanomanufacturing Workforce Education Standards that can be attained by individuals completing programs and passing corresponding tests

11

Underrepresented Minorities: Southeastern Coalition for Engagement and Exchange in Nanotechnology Education (SCENE) - Louis Stoke Regional Center of Excellence

12

Military Veterans: Nanomanufacturing Certificate Program **(NCP)**

- *Initiated by a 2020 NSF grant*
- *Piloted in 2021 for Navy veterans*
- *Endorsed by Virginia Department of Veterans Services and approved for "SkillBridge"*
- *To be offered to all military branches: Airforce, Army, Marines, and Navy*

National Recognition