National Nanotechnology Coordinated Infrastructure

# NNCI Coordinating Office Annual Report (Year 2)

**April 1, 2017 – March 31, 2018**

**NSF Award 1626153**

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# NNCI Coordinating Office Annual Report 2018

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# 1. NNCI Overview

## 1.1. Introduction

The National Nanotechnology Coordinated Infrastructure (NNCI) is an NSF-funded network of academic nanofabrication and characterization sites and their partners, formed to advance research in nanoscale science, engineering and technology. The NNCI site awards were the culmination of a competition conducted by NSF, under Program Solicitation NSF 15-519, which was generated as a result of input from the science and engineering community following the completion of the National Nanotechnology Infrastructure Network (NNIN, 2004-2015). Over 50 proposals from potential NNCI sites were submitted, resulting in 16 awards. The NNCI network is funded by the NSF through cooperative agreements with the individual sites, with the initial site awards being made around September 15, 2015 with an initial award period of 5 years. The Coordinating Office for the network was awarded to the Georgia Institute of Technology on April 1st, 2016. The total NSF funding for the initial 5 years of the NNCI network is $81 million.

The NNCI sites are located in 17 states and involve 29 universities and other partner organizations (see Figure 1) that provide researchers from academia, small and large companies, and government with access to university user facilities with leading-edge fabrication and characterization tools, instrumentation, and expertise within all disciplines of nanoscale science, engineering and technology.

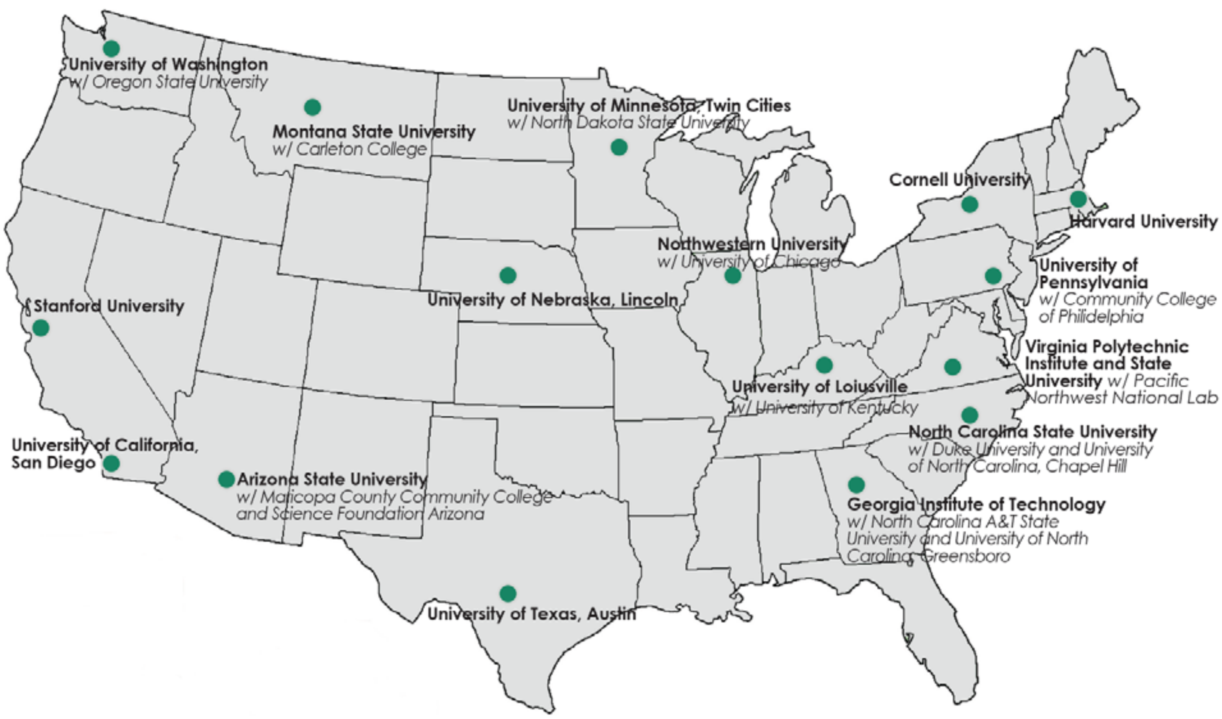



*Figure 1: US Map with Locations of the 16 NNCI Sites*

The goal of the NNCI network is (1) to provide open access to **state-of-the-art nano-fabrication & characterization facilities**, their tools and staff expertise across US, and (2) to use these resources to support **education & outreach (E&O)** as well as **societal & ethical implications (SEI) programs** in/of nanotechnology.

The 16 NNCI sites and their 13 partners (university, college, national lab, and non-profit foundation) provide access to more than 2,000 tools located in 66 distinct facilities. As will be detailed later in this report, these tools have been accessed by more than 12,000 users including nearly 3,200 external users, representing >200 academic institutions, >900 companies, ~40 government and non-profit institutions, as well as 56 foreign entities. Overall, these users have amassed more than 900,000 tool hours. During the second year, the network has trained more than 4,500 new users.

This report summarizes the activities and progress for Year 2 of the Georgia Tech Coordinating Office of the NNCI, from April 1, 2017 - March 31, 2018. NNCI sites are funded via separate cooperative agreements between NSF and each site, with reporting of site specific data and activities corresponding to Year 2 (October 1, 2016 – September 30, 2017).

### 1.2. NNCI Organization

All of the NNCI facilities, most of which have partners and multiple locations, are available for use by students and professionals from around the country and globally. The sites and facilities within NNCI (Table 1) support research and development for academic education and research purposes, as well as product and process development for commercial purposes. Each site operates under its own procedures for user recruitment, user access, training, rates, billing, and other logistical details. However, each has agreed to provide open access, with as minimal a burden as possible, to their state-of-the-art nanofabrication and characterization facilities, their tools, and staff expertise. All sites use the resources provided by NSF to support a variety of education and outreach activities (see Section 4.1), and many also offer programs or research in societal and ethical implications (SEI) of nanotechnology (Section 4.2).

Table 1: NNCI Sites, Locations and Facilities

| NNCI Sites and Locations | NNCI Facilities |
|---|---|
| **Cornell Nanoscale Science and Technology Facility (CNF)**<br>Cornell University | Cornell Nanoscale Science and Technology Facility |
| **Center for Nanoscale Systems (CNS)**<br>Harvard University | Center for Nanoscale Systems |
| **Kentucky Multi-Scale Manufacturing and Nano Integration Node (KY MMNIN)**<br>University of Louisville<br>University of Kentucky | Micro/Nano Technology Center<br>Center for Nanoscale Science and Engineering<br>Huson Nanotechnolgy Core Facility<br>Electron Microscopy Center<br>Conn Center for Renewable Energy Research<br>Center for Applied Energy Research<br>Center for Advanced Materials<br>Rapid Prototyping Center |
| **Mid-Atlantic Nanotechnology Hub (MANTH)** | Singh Center for Nanotechnology Quattrone Nanofabrication Facility |

| | |
|---|---|
| University of Pennsylvania<br>Community College of Philadelphia | Singh Center for Nanotechnology Nanoscale Characterization Facility<br>Singh Center for Nanotechnology Scanning Probe Facility |
| **Midwest Nanotechnology Infrastructure Corridor (MINIC)**<br>University of Minnesota<br>North Dakota State University | Minnesota Nano Center<br>NDSU Packaging Center |
| **Montana Nanotechnology Facility (MONT)**<br>Montana State University<br>Carleton College | Montana Microfabrication Facility<br>Imaging and Chemical Analysis Laboratory<br>Center for Biofilm Engineering<br>Proteomics, Metabolomics and Mass Spectroscopy Facility<br>Center for Bioinspired Nanomaterials |
| **Virginia Tech National Center for Earth and Environmental Nanotechnology Infrastructure (NanoEarth)**<br>Virginia Tech<br>Pacific Northwest National Laboratory | Virginia Tech Center for Sustainable Nanotechnology<br>Virginia Tech Nanoscale Characterization and Fabrication Laboratory<br>PNNL Environmental Molecular Sciences Laboratory |
| **Nanotechnology Collaborative Infrastructure Southwest (NCI-SW)**<br>Arizona State University<br>Maricopa County Community College District<br>Science Foundation Arizona | ASU NanoFab<br>LeRoy Eyring Center for Solid State Science<br>Solar Power Lab<br>Peptide Array Core Facility<br>Nano in Society User Facility<br>Center for the Life Cycle of Nanomaterials |
| **Nebraska Nanoscale Facility (NNF)**<br>University of Nebraska-Lincoln | Nebraska Center for Materials and Nanoscience |
| **Northwest Nanotechnology Infrastructure (NNI)**<br>University of Washington<br>Oregon State University | Washington Nanofabrication Facility<br>Molecular Analysis Facility<br>Advanced Technology and Manufacturing Institute<br>Materials Synthesis & Characterization Facility |
| **Research Triangle Nanotechnology Network (RTNN)**<br>North Carolina State University<br>Duke University<br>University of North Carolina at Chapel Hill | Analytical Instrumentation Facility<br>NCSU Nanofabrication Facility<br>Shared Materials Instrumentation Facility<br>Chapel Hill Analytical and Nanofabrication Laboratory<br>Zeis Textiles Extension for Economic Development<br>PULSTAR Reactor<br>Public Communication of Science & Technology Project<br>Center for the Environmental Implications of Nanotechnology<br>Duke Magnetic Resonance Spectroscopy Center |
| **San Diego Nanotechnology Infrastructure (SDNI)** | Nano3 Cleanroom<br>Microfluidic Medical Device Facility |

| | |
|---|---|
| University of California - San Diego | Chip-Scaled Photonics Testing Facility<br>NanoMagnetic Material Processing Facility |
| **Southeastern Nanotechnology Infrastructure Corridor (SENIC)**<br>Georgia Institute of Technology<br>Joint School of Nanoscience and Nanoengineering | Institute for Electronics and Nanotechnology - Micro/Nano Fabrication Facility<br>Materials Characterization Facility<br>JSNN Cleanroom and Labs |
| **Soft and Hybrid Nanotechnology Experimental (SHyNE)Resource**<br>Northwestern University<br>University of Chicago | Northwestern University Atomic and Nanoscale Characterization Experimental Center<br>Integrated Molecular Structure Education and Research Center<br>Northwestern University Center for Atom Probe Tomography<br>J.B. Cohen X-ray Diffraction Facility<br>Northwestern University Micro/Nano Fabrication Facility<br>Simpson Querrey Institute<br>Pritzker Nanofabrication Facility |
| **NNCI Site @ Stanford (nano@stanford)**<br>Stanford University | Stanford Nano Shared Facilities<br>Stanford Nanofabrication Facility<br>Stanford Mineral Analysis Facility<br>Stanford Environmental Measurement Facility |
| **Texas Nanofabrication Facility (TNF)**<br>University of Texas -Austin | Microelectronics Research Center<br>Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies<br>The Center for Nano and Molecular Sciences<br>Texas Material Institute |

Sites have identified approximately 250 staff that support the NNCI program (Table 2), although some individuals fulfill multiple roles within a site's operations. In general, Site Leadership includes Site Directors, Deputy Directors, and Associate/Assistant Directors. Some of these individuals also serve as project co-PIs. New User Contacts are those site staff responsible for coordinating access to facilities for external users. Program Managers are identified as those staff who most interact with the Coordinating Office, providing data as requested and communicating information to appropriate site staff. Facility Managers are responsible for the operations of site facilities, often assisted by Technical Staff when identified. Education/Outreach Coordinators handle the K-12 activities and sometimes the university student and professional education as well. SEI and Computation Coordinators are responsible for those aspects of site operations.

Table 2: NNCI Site Staff

| **NNCI Site Staff** | |
|---|---|
| Site Directors | 16 |
| Other Site Leadership | 38 |

| | |
|---|---|
| New User Contacts | 32 |
| Program Managers | 18 |
| Facility Managers | 59 |
| Education/Outreach Coordinators | 33 |
| SEI Coordinators | 8 |
| Computation Coordinators | 5 |
| Safety/Facility Director/Technical Staff | 30 |
| Facility Administrative Staff | 12 |

## 2. NNCI Coordinating Office

The NNCI Coordinating Office is led by Prof. Oliver Brand (Executive Director, Georgia Tech Institute for Electronics and Nanotechnology (IEN) and Director, SENIC) who serves as **Director**. Dr. David Gottfried (Senior Assistant Director, Georgia Tech IEN and Deputy Director, SENIC) serves as **Deputy Director** and oversees the Coordinating Office day-to-day operations, assisted by a **Program Manager** (Amy Duke). Three **Associate Directors** manage the network activities in specific areas. Dr. Nancy Healy (Georgia Tech) coordinates the NNCI education and outreach programs. Dr. Healy was the Education Coordinator of the NNIN and in that role shaped the successful E&O program of the previous network. Prof. Jameson Wetmore (Arizona State University) coordinates the Societal and Ethical Implications (SEI) activities. Prof. Wetmore is an Associate Director within the Center for Nanotechnology in Society at ASU and has been coordinating SEI activities on a national level as Co-Director of the Center for Engagement and Training in Science & Society. Prof. Azad Naeemi (Georgia Tech) coordinates the computational activities and facilitates interactions with nanoHUB/NCN at Purdue University. Prof. Naeemi is currently responsible for SRC-funded benchmarking efforts for emerging "beyond-CMOS" devices and in that role already collaborates with nanoHUB/NCN to make computational tools for benchmarking widely available. This executive staff meets monthly by conference call. The originally proposed Web Developer has not been hired, as NNCI website design and creation used an external vendor (see more below).

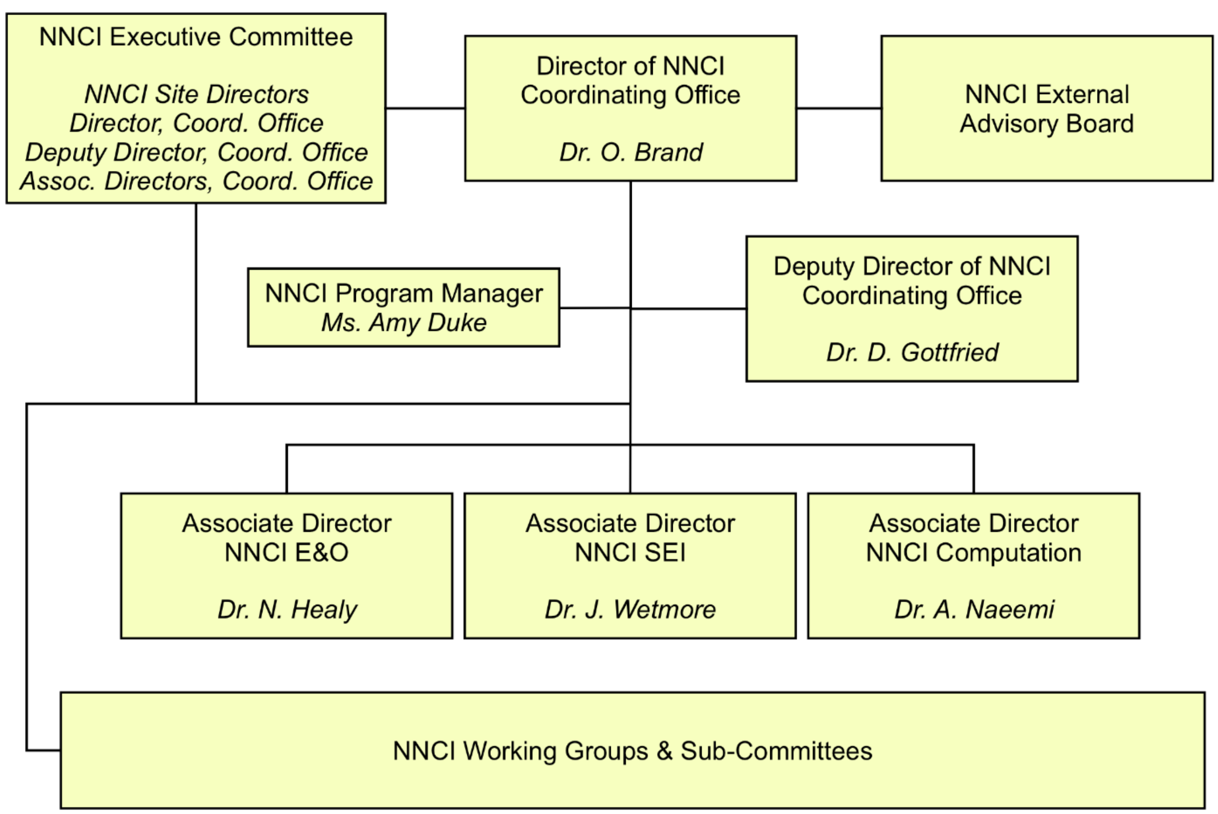



*Figure 2: NNCI Coordinating Office Organizational Chart*

The core staff is guided by an **Executive Committee** which includes the 16 NNCI site directors. The Executive Committee met every other month in the first year via teleconference/WebEx and annually in person at the NNCI Conference. Starting in April 2017, the Executive Committee began meeting monthly. The Executive Committee and Coordinating Office are advised by an **External Advisory Board** (EAB, see Section 3) comprised of members representing industry, academia, government, education and outreach, SEI, computation and non-traditional disciplines in nanoscience and nanoengineering. The EAB meets in person as part of the NNCI Conference, with additional conference calls as determined by the EAB.

In addition to the work of the Associate Directors, several **subcommittees** of the Executive Committee have been formed to tackle high-level issues related to the NNCI network as a whole (see Section 5). Finally, leveraging the distributed expertise at the network level, several **working groups**, composed of staff members from the NNCI sites, have been formed to share and develop best practices for site and network operations, technical areas, research areas, and education and outreach (see Section 6).

Other tasks of the Coordinating Office include:

- creation and maintenance of the NNCI website
- organization of the annual conference
- interfacing with NSF and the External Advisory Board
- facilitating interactions among the sites via an email listserve
- incentivizing sites to collaborate via support of workshops
- marketing the NNCI at conferences and trade shows and through printed and electronic collateral
- organization of an annual REU Convocation
- collection of site usage statistics
- development of an annual user satisfaction survey
- preparation of this annual report

More details on these activities are shared in the sections below, and plans for future activities are provided in Section 12.

To learn more about the NNCI sites and their partners, the Coordinating Office started visiting the individual NNCI sites, with initial priority given to NNCI sites that were not part of the NNIN network. The goal of these visits is to get to know site staff, learn about the facilities and programs, share success stories, and discuss challenges. Within the first two years, the Coordinating Office visited the following sites and has several more planned for 2018:

- Montana Nanotechnology Facility (June 2016)
- Mid-Atlantic Nanotechnology Hub (Aug. 2016)
- Kentucky Multi-Scale Manufacturing and Nano Integration Node (Sept. 2016)
- Virginia Tech National Center for Earth and Environmental Nanotechnology Infrastructure (Nov. 2016)
- Research Triangle Nanotechnology Network (Nov. 2016)
- San Diego Nanotechnology Infrastructure (Feb. 2016)
- Nanotechnology Collaborative Infrastructure Southwest (Feb. 2016)
- Soft and Hybrid Nanotechnology Experimental Resource (March 2017)

- NNCI Site @ Stanford (April 2017)
- Nebraska Nanoscale Facility (Aug. 2017)
- Texas Nanofabrication Facility (Nov. 2017)
- Center for Nanoscale Systems (planned March 2018)
- Cornell Nanoscale Science and Technology Facility (planned April 2018)
- Midwest Nanotechnology Infrastructure Corridor (planned May 2018)

## 3. External Advisory Board

During the NNCI first year, the Coordinating Office established an NNCI External Advisory Board. To this end, names for potential advisory board members were solicited from the 16 NNCI sites. The Coordinating Office then assembled the Advisory Board from the solicited list, ensuring a diverse board in terms of gender, ethnicity and disciplinary background. During year 2, one of the board members was unable to continue and was replaced by another with similar expertise, while another resigned due to time commitments. Table 3 shows the Advisory Board members and their affiliations as of January 2018.

Table 3: NNCI External Advisory Board

| Name | Affiliation |
|---|---|
| **Prof. Reggie Farrow** | Department of Physics<br>New Jersey Institute of Technology |
| **Dr. Andrew Greenberg** | Associate Director, Institute for Chemical Education<br>University of Wisconsin |
| **Dr. Elaine Cohen Hubal** | Acting Director, Computational Exposure Division<br>US Environmental Protection Agency |
| **Dr. Angelique Johnson** | MEMSTIM<br>Louisville, KY |
| **Mr. Joe Magno** | Executive Director<br>The North Carolina Center of Innovation Network |
| **Prof. Richard Osgood** | Department of Electrical Engineering & Department of Applied Physics<br>Columbia University |
| **Dr. Kurt Petersen** | Band of Angels<br>Palo Alto, CA |
| **Dr. Andreas Roelofs** | Founding Director, Nano Design Works<br>Argonne National Laboratory |
| **Prof. Ken Wise** | Department of Electrical Engineering and Computer Science<br>University of Michigan |

The Advisory Board meets in person during the annual NNCI Conference and virtually via Webex or conference call as needed. Ahead of the first NNCI Conference in January 2017, the Coordinating Office asked the Advisory Board to take a critical look at what NNCI is doing well and areas where it can improve. In particular, the Advisory Board considered the following questions:

1. What activities can/should NNCI support to achieve the goal of the network surpassing the sum of the parts? This should involve not only research facilities aspects, but also consider support of education/outreach, computational tools, and societal and ethical implications activities.
2. The NSF considers increasing usage by external users as well as usage by “non-traditional” users of prime importance. Considering the current activities of the sites and the network, what can be improved to achieve this aim?
3. Since NNCI serves to support cutting-edge research in both academia and industry, what capabilities should sites begin to acquire to anticipate 5-10-year research trends?

From the feedback of the Advisory Board at the January 2017 NNCI Conference it became clear that a more detailed “Charter Letter” with input from the NSF on what would constitute a successful network was needed. This document was created during 2017 and communicated to the Advisory Board (Appendix 13.1). The report of the Advisory Board following the October 2017 NNCI Conference is provided in Appendix 13.2.

# 4. Associate Director Reports

## 4.1. Education and Outreach

NNCI's Education and Outreach (E&O) mission seeks to:

1. Offer education and training to address the growing need for a skilled workforce and informed public.
2. Provide resources, programs, and materials to enhance knowledge of nanotechnology and its application to real-world issues.
3. Support the US economy by enabling a STEM-literate workforce ready to meet the technological challenges of a nano-enabled economy as well as an informed citizenry that supports continued and safe growth of nanotechnologies.

Towards these goals, the 16 sites of the NNCI have developed 16 individual E&O programs that have common themes, which lend themselves to collaboration and support. We envision a two-pronged approach to our efforts: (1) programs and activities that address local needs and interest and (2) programs and activities across the network that will have national reach.

The second year of the NNCI's E&O efforts was very productive with approximately 325,000 individuals reached (13 of 16 sites reporting). A large number of these individuals were the result of NanoEarth's *Pulse on the Planet* radio broadcasts (220,000) and NNF's traveling nano exhibit (30,000). This number does not include the 3-5 million who visit Disneyworld's Epcot where the *Nanooze* exhibit is housed nor the thousands of print editions of *Nanooze* that were distributed to schools and classrooms.

To coordinate the common efforts across the network and to determine efforts worthy of scaling up to other sites, the Coordinating Office developed E&O working groups (WG). The groups that have continued into year two are: Research Experience for Undergraduates (REU), K-12 and Community, Community College and Workforce Development. Additional working groups for Evaluation and Assessment as well as Technical Content Development were also initiated during this period. This report will highlight efforts across the network and in particular those that demonstrate network interaction and collaboration.

Thirteen of the 16 NNCI sites had Research Experience for Undergraduates (REU) programs during summer 2017. The ***REU Working Group***, led by Dr. Lynn Rathbun of CNF, gathered REU program descriptions to populate the NNCI REU web page so that interested students would have a common site to search for nano-focused REU programs (http://nnci.net/research-experience-undergraduates). The NNCI REU site programs were also posted on the NSF REU programs page under the Georgia Tech NNCI Coordinating Office for even wider dissemination (https://www.nsf.gov/crssprgm/reu/list_result.jsp). Georgia Tech hosted the first NNCI REU Convocation August 6-8, 2017. Ten sites, with a total of 56 undergraduates, presented their research results

at the 2½ day meeting. The program, videos, and PowerPoint presentations are available on the NNCI website (http://nnci.net/reu-convocation-2017).

All participants were asked to participate in the NNCI REU Post Survey which has been ongoing since the NNIN program (2004-2015). As can be seen in Table 4, the students were particularly pleased with the convocation. In addition, we surveyed all of the interns regarding the technical aspects of their particular REU program (Table 5). These results also indicate that the individual NNCI sites are providing high quality summer research experiences which the participants would recommend to others. As with results under NNIN, students never feel they had enough time to complete their projects which appears to be a common theme across most REU programs.

Table 4. NNCI REU Post Survey - Convocation (Likert Scale 1= Poor 5=Superior)

| Question | Poor | Somewhat | Good | Very Good/ Excellent | Superior | Weighted Average |
|---|---|---|---|---|---|---|
| The convocation as a TECHNICAL experience. | 0% | 3% | 25% | 56% | 16% | 3.84 |
| The convocation as a Social/ Professional Networking experience | 0% | 22% | 22% | 34% | 22% | 3.56 |
| Was the NSF Fellowship presentation useful/interesting? | 0% | 0% | 25% | 47% | 28% | 4.03 |
| Was the Career Panel session useful/interesting? | 0% | 16% | 22% | 38% | 25% | 3.72 |
| Was the Societal session by Dr. Wetmore useful/interesting | 0% | 9% | 31% | 44% | 16% | 3.66 |
| Did you find the international presentation interesting/informative | 0% | 3% | 38% | 31% | 28% | 3.84 |
| Was the poster session useful? | 0% | 13% | 34% | 34% | 19% | 3.59 |

Table 5. NNCI REU Post Survey – Technical Program (Likert Scale 1= Poor 5= Superior)

| Question | 1 | 2 | 3 | 4 | 5 | Weighted Average |
|---|---|---|---|---|---|---|
| Did the program offer you a substantial independent research project with a strong intellectual focus? | 0% | 2% | 4% | 32% | 62% | 4.54 |
| Were you able to execute the research project | 0% | 2% | 2% | 28% | 68% | 4.62 |

| | | | | | | |
|---|---|---|---|---|---|---|
| using the available equipment and facilities? Note, not completing or getting good results does not meant it was not a reasonably well formed concept and that you were able to make an attempt at it. | | | | | | |
| Did you consider your project a "good" project- interesting, right scale, right complexity, etc.? | 0% | 4% | 12% | 28% | 56% | 4.36 |
| Were you reasonably able to complete the project? | 4% | 4% | 18% | 40% | 34% | 4 |
| Were you satisfied with how much you were able to complete, given the time constraints? | 4% | 4% | 20% | 32% | 40% | 4 |
| Did you receive significant scientific interaction with the faculty/member/senior staff in charge of your project? | 2% | 2% | 16% | 24% | 56% | 4.3 |
| Were you included in group meetings and seminars? | 0% | 2% | 6% | 20% | 72% | 4.6 |
| Did the program provide you with an experience which allowed you to see the breadth of nanotechnology applications? | 0% | 0% | 12% | 26% | 62% | 4.5 |
| How well did you learn to use advanced equipment and processes in nanotechnology? | 0% | 0% | 2% | 3% | 50% | 4.3 |
| How well did the program assist you in understanding the scientific basis of nanotechnology equipment and processes? | 0% | 0% | 10% | 52% | 38% | 4.3 |
| How well did the program provide you with an understanding of graduate research life? | 0% | 0% | 12% | 29% | 59% | 4.5 |
| How well did the program provide you with an understanding of the scope of possible careers in nanotechnology? | 0% | 10% | 24% | 36% | 30% | 3.9 |
| How well did the program provide you with an exposure to the societal and ethical issues related to nanotechnology and research in general? | 0% | 12% | 32% | 32% | 24% | 3.7 |
| Did the program assist you in making future educational and/or career choices? | 0% | 2% | 6% | 42% | 50% | 4.4 |
| How likely is it that you will choose a career in nanotechnology? | 2% | 14% | 40% | 24% | 20% | 3.5 |
| How likely is it that you will go to graduate school in science/engineering? | 4% | 6.% | 6% | 18% | 66% | 4.4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Did the program assist you in developing presentation and writing skills? | 0% | 0% | 6% | 28% | 66% | 4.6 |
| Would you recommend the program to a friend? | 0% | 0% | 0% | 20% | 80% | 4.8 |
| How likely is it that you will share your experiences with fellow students and faculty at your home campus? | 0% | 0% | 2% | 10% | 86% | 4.9 |
| How do you rate the overall quality of the program? | 0% | 0% | 4% | 28% | 68% | 4.6 |
| Did you think that your experience with the program was positive? Would you do it again? | 2% | 0% | 4% | 20% | 74% | 4.6 |

The NNCI Coordinating Office also surveyed faculty advisors and mentors to assist in the selection of participants for CNF's international REU in Japan (iREU). The faculty/mentor evaluation of the interns is one part of the assessment of the applicants for the international program. CNF's pool of applicants for its 2018 summer internship at the National Institute for Materials Science in Tsukuba Japan will come from NNCI's REU participants of summer 2017.

Workforce development at the post-secondary level is a common activity across most of the sites which utilize a variety of approaches. Several sites provide undergraduate internships and work experiences either for their own students or for those from nearby community colleges. NNI, NCI-SW, MINIC, and Stanford offer cleanroom and facility support for courses at community colleges or four-year colleges (Stanford). RTNN, NNF and SENIC-GT joined the Nanotechnology Applications and Career Knowledge Networks's Remote Access Instrumentation in Nanotechnology (RAIN) coordinated by Pennsylvania State University. NCI-SW provided a demonstration of its remote capabilities with RAIN at the first annual NNCI Conference as a recruitment tool for NNCI sites. RAIN instrumentation is particularly useful for community colleges and high schools which need access to costly equipment such as scanning electron microscopes. RTNN provides a workshop for community college faculty which presents an overview of nanotechnology tools and techniques. CNS's community college program focuses on veterans who are hired part-time as technicians in its facilities and associated labs. They have expanded their veteran recruitment by working with the Warrior Scholar Program and the Posse Veterans Program. The ***Workforce Development Working Group***, led by Dr. Ray Tsui of NCI-SW, is collecting information from sites on activities with community colleges to determine the scope of programs and to share best practices across the network.

NNCI sites continue to offer a wide variety of activities to reach K-12 students, K-12 teachers and the general public. These include NNF's traveling NanoExhibit, SENIC-JSNN's NanoBus, and CNF's *Nanooze*. Sites sponsor K-12 visits as well as participate in community science events, some offer summer camps, others participate in career fairs, etc. For K-12 teachers, NNF offers workshops for Title 1 teachers and Native Americans which include free teaching kits, SENIC-GT provides teacher workshops, Nano@Standord offers the Nanoscience Summer Institute for Middle School Teachers, NNI has an Educator-in-Residence

program, and SDNI and NCI-SW have Research Experience for Teachers (RET) programs. Through the efforts of the ***K-12 and Community Working Group***, led by Dr. James Marti of MINIC, five NNCI sites submitted a Research Experience for Teachers proposal to the NSF in October 2018. The sites are NCI-SW (lead), MINIC, KY-MMNIN, NNF, and SENIC (GT). NNCI sites celebrated National Nanotechnology Day (an NNI national celebration on October 9) with many of the events listed on the NNCO website https://www.nano.gov/nationalnanotechnologyday. Four sites rose to the challenge of "How Fast can your Mascot Run 100 Billion Nanometers?" and their videos can be viewed at: https://www.youtube.com/channel/UCwO7o2ZT-ATkbl0KrJXXhdA. The NNCI Coordinating Office exhibited with NNI and NanoHUB at the annual meeting of the National Science Teachers Association. SENIC-GT offered a two hour workshop at the NSTA which had a standing room only audience.

NNCI workshops and symposia were offered across the network. These technical workshops reach undergraduates, graduate students, post-docs, faculty, and industry and government professionals. They serve to not only educate individuals about particular aspects of nanoscale science and engineering but also serve as a means to introduce NNCI capabilities to current and potential users. Examples of these activities during year two include:

- NanoEarth - NanoEHS Webinar Series
- CNF - Technology & Characterization at the Nanoscale
- TNF - TMI mini-course on TEM
- NNI (UW) - Nanofabrication Intensive Short Course
- SENIC (GT) - Soft Lithography for Microfluidics and Microfabrication Workshops
- SHyNE - 6 major workshops on various topics

MONT and NanoEarth (with support from SENIC-GT) also provided a two-day workshop at the Goldschmidt 2017 conference, the largest international geochemistry conference sponsored by the Geochemical Society and the European Association of Geochemistry. Approximately 35 enthusiastic scientists attended the workshop:

http://serc.carleton.edu/msu_nanotech/goldschmidt2017/index.html

A new ***Evaluation and Assessment Working Group*** lead by Nancy Healy was started in year two. The group collected survey instruments that were used under NNIN and at various sites. These have been grouped into categories and shared via Dropbox with sites which can then adopt and adapt the instruments to meet their own needs. Sites not part of the WG have been encouraged to submit their own instruments. The categories are: 1. Evaluation Plans/Logic Models; 2. Facility Satisfaction Assessment; 3. Outreach Assessment; 4. RET/Teacher Workshops; 5. REU; 6. K-12 Student Nano Content; 7. Workshop Assessment.

Another new working group created this year is the ***Technical Content Development Working Group*** being led by Angela Hwang of nano@Stanford and Maude Cuchiara of RTNN. Stanford is developing a library of technical content for existing and potential users to provide foundational knowledge on general techniques

https://lagunita.stanford.edu/courses/course-v1:Engineering+NanoFab01+Ongoing/about

and RTNN has developed a Coursera MOOC titled *Nanotechnology: a Makers Course*

https://www.coursera.org/learn/nanotechnology

The WG plans to use the network to expedite content development and share resources and training materials. Working with the sites, they seek to expand the modules to include process recipes, background information about fabrication or characterization as well as modules on techniques, operations, or processes.

Reaching a diverse audience across NNCI sites is particularly important. Examples of some of the activities include:

- NNI (UW) First Nations Engagement
- NanoEarth Multicultural and Underrepresented Nanoscience Initiative (MUNI)
- NCI-SW recruitment of REUs from Native American serving community colleges
- Nano@Stanford facility use by Cal State University East Bay (most ethnically diverse institution in CA and 5th in US)
- SENIC (GT) high school intern program with Atlanta Public Schools (minority majority district - 82% black, 11% white, 3% Hispanic)
- NNF Title 1 schools program.

Finally, the “Learn” page of the NNCI website has been populated with new materials including all of the K-16 learning modules previously developed under NNIN. The REU page is the stepping off point for finding the REU programs with 34% of 2017 REUs indicating they found the NNCI programs by the NSF REU site. The NSF page directs them to the NNCI REU page which lists all the NNCI REU programs and links to individual site applications. Metrics of visits to the Learn section of NNCI.net (performed by Dr. Dan Ratner of NNI) indicates that the majority of traffic is for the REU page. With new content being added and increasing our social media presence we hope to increase traffic to the remainder of the NNCI Learn content.

### 4.2. Societal and Ethical Implications

Nanotechnology holds great promise, but the NNCI CO recognizes that the introduction of any new technology can have significant societal and ethical consequences. We believe it is important to think about the impacts of nanotechnologies as we conceive them, develop them, and implement them. To that end, the Coordinating Office is working to help all of the NNCI sites develop Societal and Ethical Implication (SEI) research and engagement programs. Associate Director Jameson Wetmore (also part of the NCI-SW site) is leading these activities.

In the initial year of the NNCI, 7 of the 16 NNCI sites had efforts in SEI. During this reporting period we have increased this number to 10 sites actively working in the SEI area.

| NNCI Site | SEI Coordinator(s) |
|---|---|
| **NCI-SW** | Jameson Wetmore, Ira Bennett |
| **TNF** | Lee Ann Kahlor |
| **SENIC** | Jan Youtie |
| **RTNN** | David Berube |
| **NNI** | Daniel Ratner |

| | |
|---|---|
| **MINIC** | Jim Marti |
| **SHyNE** | Chad Goeser, Amy Morgan |
| **SDNI** | Michael Kalichman |
| **MONT** | David Mogk |
| **NanoEarth** | Matthew Hull |

The work being done at these different sites spans a variety of activities. For instance, at SENIC, Jan Youtie has been working to develop a model which incorporates societal impacts in a pragmatic manner that parallels elements of the I-Corps program. She is currently scheduled to pilot the program at the 2018 NNCI Winter School in January. Mike Kalichman at UCSD has organized a special presentation on Nanoengineering at the Exploring Ethics Forums he hosts at San Diego's Fleet Science Center. Even though the program isn't happening until March 2018, he already has over 100 RSVPs. To reach those who can't make it, the program will be recorded for television broadcast. Past programs have averaged over 100,000 views each.

The NNCI CO is working to foster the development and improve the quality of SEI programs across the NNCI. Thus far we have done this by bringing together the SEI coordinators of the active sites to discuss their programs and best practices via conference calls. We also hosted a half-day workshop on SEI at the end of the annual conference in October 2017. Through these meetings we have been able to present to each other and provide feedback. For instance, we recently reviewed the SEI training video that Lee Ann Kahlor put together at Texas, gave her feedback, and a number of sites are working to find ways to pilot it at their own lab trainings.

The NNCI CO also arranged for Jameson Wetmore and Ira Bennett (of ASU) to run a half-day workshop on SEI at the University of Minnesota in March 2017. The program attracted 15-20 students, faculty and staff and ultimately helped to recruit some participants for the DC policy program the following June. We are currently working to run similar programs at other sites with fledgling SEI programs.

The NNCI CO helps to host two major SEI training efforts every year. The first, a policy workshop in Washington, DC for graduate student scientists and engineers, is co-sponsored and largely funded through the Nanotechnology Collaborative Infrastructure Southwest. In May 2017, 14 students from the NNCI met with over 25 policymakers, funders, regulators, lobbyists, and judges in the second Nano "Science Outside the Lab" (SOtL). This year we had the time to recruit from across the network to get even more sites involved in SEI programming. NNCI universities represented included Northwestern University, NC State University, University of Minnesota, University of Pennsylvania, University of Nebraska, and a student who recently graduated from Cornell University. The University of Washington made a special effort to get students involved and ultimately six of their graduate students participated and an alum from the first year's program – Patrick McGurrin of ASU – served as the teaching assistant this year. This year the students met with program managers at the NSF, the National Nanotechnology Coordinating Office, the CDC, the federal judiciary program that trains judges in how to use scientific evidence in the court room, and both researchers and regulators at the EPA. One participant summed up their experiences in the following e-mail:

> "SOtL was an eye-opening experience about how science, policy and government influence one another. The information I learned and the skills I gained will stay with me throughout my graduate and future careers. Most importantly, I have learned how to communicate with the general public in a way that is simple and engaging. SOtL has solidified my interest in science policy and reinvigorated my passion in science communication and engagement with the public. Thanks again for such an amazing week! I'm already telling everyone in my program they have to apply next year."

This year's SOtL program will be held June 3-9, 2018. Again we will recruit graduate students from across the NNCI.

The NNCI CO also sponsored its first annual "Winter School on Responsible Innovation and Social Studies of Emerging Technologies" on January 3-10, 2017. The goal of this program is to train the next generation of SEI scholars. The Winter School brought together fifteen early career social science researchers for a week of learning a variety of research tools from around a dozen social scientists and other scholars. The first four iterations of the Winter School were sponsored by the Center for Nanotechnology in Society-ASU. During that time the program built up a respected reputation amongst SEI scholars around the world and a healthy alumni network. The NNCI is building upon this success and will continue the tradition. From January 3-10, 2017 the NNCI hosted the fifth Winter School at Saguaro Lake Ranch, just east of Phoenix. The student and young faculty participants unanimously agreed that it was an important opportunity to reflect on and build their career. In the follow up survey one participant wrote:

> "Thank you all for running such a wonderful winter school. It was one of the most fun and rewarding experiences I've had as a graduate student, and I look forward to working with the ideas and techniques that we discussed. I hope our paths cross again in the future! I've become a full-on winter school evangelist, so you can expect lots of applications from VT next year."

The next iteration will be held on January 3-10, 2018. Recruiting students through NNCI site administrators has proven difficult since they have few contacts with social science graduate students. But we did manage to get students from Virginia Tech, Cornell, ASU, and NC State in this year's cohort. To broaden the perspectives on hand we will have students from Spain, Canada, China, and the Netherlands as well.

### 4.3. Computation

Modeling and simulation play a key role in enhancing nanoscale fabrication and characterization as they can guide experimental research, drastically reduce the required number of trial and error iterations, and enable more in depth interpretation of the characterization results. To facilitate access to the modeling and simulation capabilities and expertise available within various NNCI sites, an inventory of available modeling and simulation resources and expertise has been complied. The directory is hosted by nanoHub.org and can be accessed via http://nanohub.org/groups/nnci_computation. So far, 10 sites have reported collectively more than 65 commercial simulation tools and 40 internally developed simulation tools (see Figure 3) available for internal and/or external users (with and without fee).

In addition to software resources, 8 supercomputers or major computing clusters are available at various sites. These hardware resources serve internal uses only with the exception of the UT-Austin computing cluster which can be accessed by external users with a nominal fee.

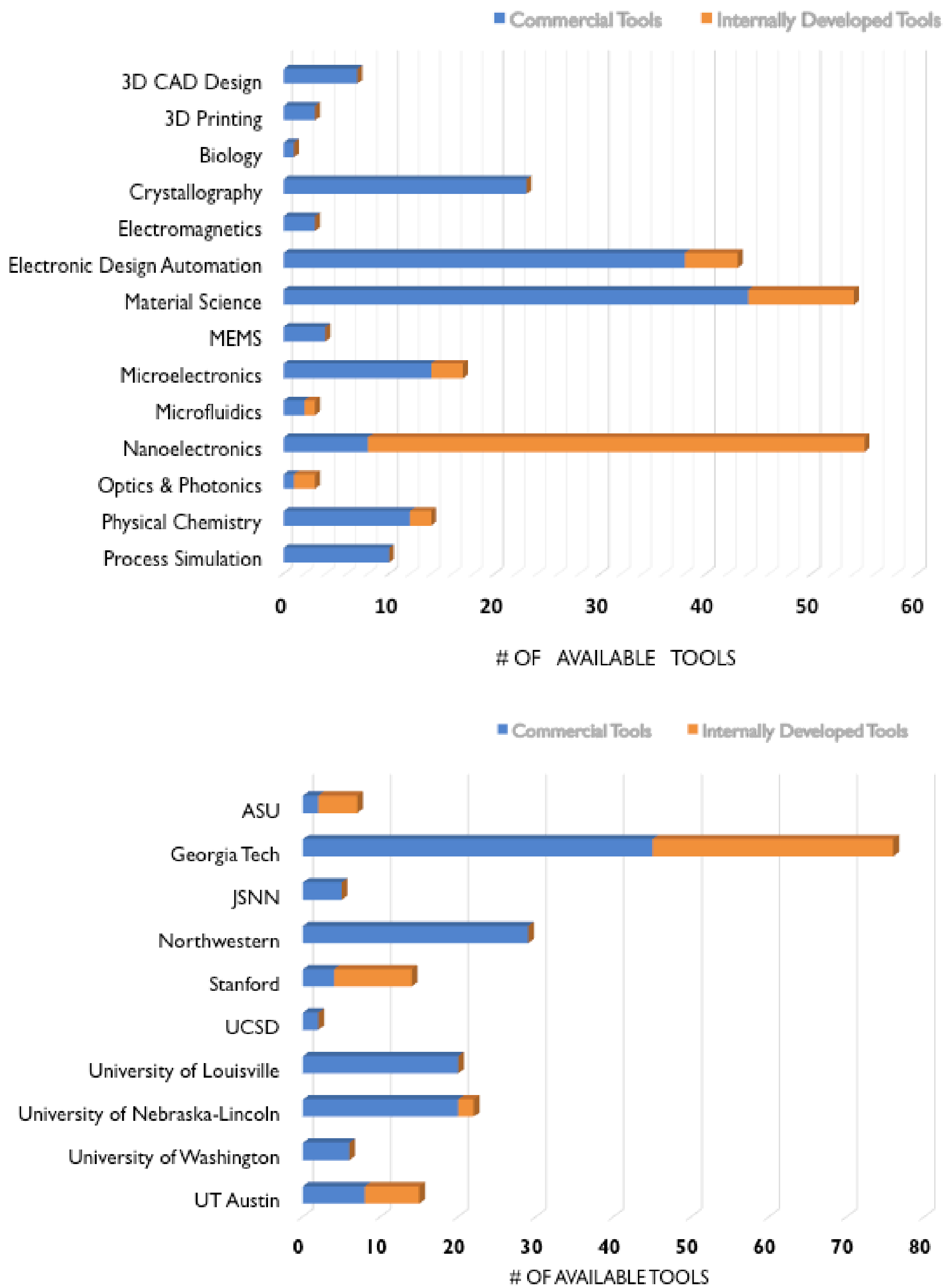



*Figure 3: Number of commercial and internally developed simulation resources by (top) area and (bottom) NNCI site.*

A major challenge is that many simulation tools are not readily available for external users as demonstrated in Figure 4.

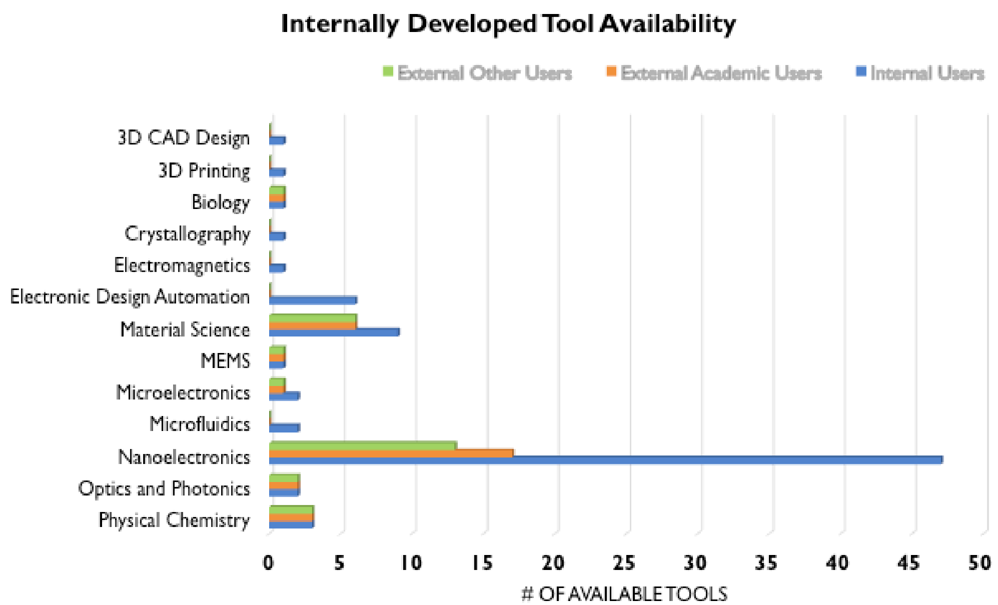



*Figure 4: Availability of internally developed simulation tools and resources for internal users, external academic users and other external users.*

To address this challenge, NNCI sites have been encouraged to publish their internally-developed simulation tools on nanoHUB. Tools published on nanoHUB have the potential of reaching many users across the globe. For instance, *Cu in CdTe Lab* published by Arizona State University, which is a 2D diffusion-reaction simulator of Cu migration in polycrystaline CdTe solar cells with grain boundaries, currently has more than 58 users residing in North America, Asia, Europe, and Africa. SPICE *Subcircuit Generator for Spintronic Nonmagnetic Metallic Channel Components* published by Georgia Tech researchers has 12 users in North America and Asia only two months after its release.

## 5. NNCI Subcommittees

In addition to the work of the Coordinating Office and specific topical areas of the Associate Directors, several subcommittees of the Executive Committee were formed to tackle high-level issues related to the NNCI network as a whole (Table 6). Positions on these committees were offered to each member of the Executive Committee (site PIs), along with any site co-PIs who wished to participate. Each Site Director serves on two of these subcommittees with a subcommittee chair selected by the Coordinating Office. Additional input may be sought from members of the External Advisory Board and other experts as needed. Members of the Coordinating Office serve on some of the subcommittees as ex-officio members. The first six topics were selected as part of the Coordinating Office proposal to NSF, while the last topic was added upon request of the Site Directors. As a starting point, the Coordinating Office created a number of guiding questions for each subcommittee. One of the subcommittees is selected to report to the full group of site directors and coordinating office (Executive Committee) every other session during the regular monthly meetings. Reports of the subcommittees on current and future activities are presented below as provided by the subcommittee leads.

Table 6: NNCI Executive Committee Subcommittees

| Subcommittee Topic | Subcommittee Lead |
|---|---|
| **Diversity** | Mike Hochella (NanoEarth) |
| **Metrics and Assessment** | Stephen Campbell (MINIC) |
| **Global and Regional Interactions** | Vinayak Dravid (SHyNE) |
| **New Equipment and Research Opportunities** | Kevin Walsh (MMNIN) |
| **Entrepreneurship and Commercialization** | Mark Allen (MANTH) |
| **Workforce Development** | Trevor Thornton (NCI-SW) |
| **Building the User Base** | Nan Jokerst (RTNN) |

### 5.1. Diversity Subcommittee

This report originated following the NNCI Annual Meeting at the University of Pennsylvania in October, 2017. There, the Diversity Subcommittee met (as a breakout session) to continue discussions that had taken place over the first two years of the NNCI. The diversity programs at some of the NNCI nodes have generally reached a level where it is now productive to report on our collective diversity issues and best practices. In addition to the members of the subcommittee (see below), David Gottfried from the NNCI Coordinating Office at Georgia Tech was also involved. We welcome input and updates from all NNCI nodes. We especially welcome success stories involving any aspect of diversity. We will incorporate aspects of these successes into the development of our best practices.

NNCI's Statement of Diversity and Inclusivity:

The NNCI embraces diversity and welcomes, recruits, educates, employs, serves, and engages a diverse group of users, students, faculty, and staff with a wide variety of backgrounds, perspectives, interests, and talents, creating a community of teachers, learners, and researchers that exemplifies the best in all of us – in our intellectual pursuits, our diversity of thought, our personal integrity, and our commitment to excellence.

We believe that diversity includes the individual differences among people, including:

- Gender
- Social, racial, or ethnic backgrounds
- Disabilities or handicaps
- Socioeconomic class
- Gender identity or expression
- Sexual orientations
- Appearance or personal characteristics
- Political affiliation and opinion
- Language
- Religion or beliefs
- Economic circumstances
- Philosophical outlooks
- Veteran status
- Life experiences

All of these characteristics, both singularly and in combination, contribute to the richness of the NNCI community.

Examples of NNCI Success Stories

There are already several success stories from the NNCI involving the many forms that diversity principals encapsulate. Below, we only list two, and only as examples. NNCI sites are encouraged to provide additional example, big or small, involving one person or many. There is no time or space limit on this. If you have something, and are proud of it, send to us whenever, and as often as you wish. See below (under "Action items") on how to send us your successes in this regard.

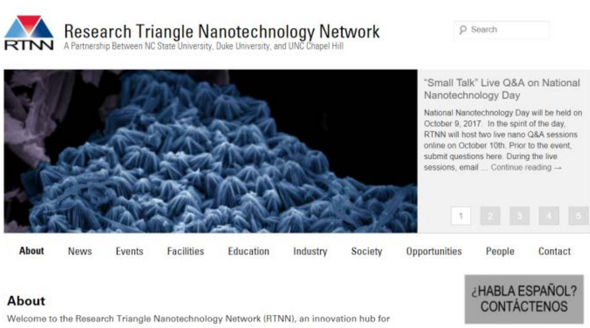
**NanoEarth MUNI Program:** Multicultural and Underrepresented Nanoscience Initiative (MUNI) is an initiative that strives to provide an opportunity for underrepresented groups (Hispanic or Latino, American Indian or Alaska Native, Black or African American, and Native Hawaiian or Other Pacific Islander) in science and engineering to pursue or just become exposed to nanoscience and technology. MUNI provides access to and training opportunities on state-of-the-art nanoscience-relevant characterization instrumentation, as well as nano-synthesis and processing laboratories that do not require clean rooms. For students, MUNI serves all academic levels, from K-12, to community college students, to students in four-year programs and even graduate school. For professionals and students, MUNI provides access to NanoEarth facilities and expertise free of charge. MUNI covers all travel costs, lodging, food, and usage fees, and requires no previous experience in nanoscience or nanotechnology. MUNI participants also have the opportunity to interface with a variety of professors and gain valuable insight into especially the nano-geo, environmental, and bioscience fields.

*Georgia State MUNI visitors prepare for demonstrations, research, and discussions at NanoEarth*

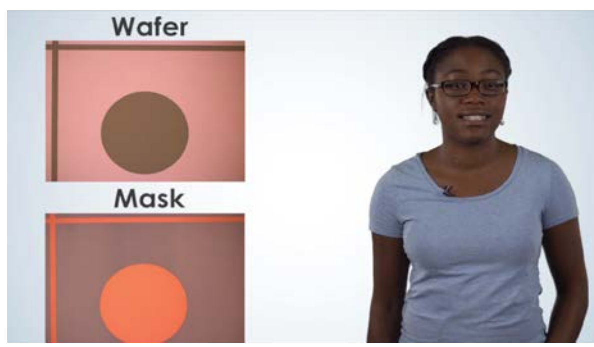
Since its launch in February 2016, MUNI has supported nearly 70 visitors from 16 different universities and colleges (from Virginia schools to as far away as New York, Georgia, and New Mexico for research and workshops, and a Virginia Tech hosted HBCU Summit for which MUNI was a major sponsor on par with entire colleges. Funding for MUNI, which is substantial, was built directly into NanoEarth's NSF budget. NanoEarth spends about $40K per year on the MUNI program. For nodes that do not have specific diversity funding, MUNI principles could be exercised on a limited basis at whatever cost a node might be able to support.

**RTNN Welcoming Diverse Individuals:** The RTNN has thoughtfully presented itself to the public, in a conscientious effort to welcome persons from underrepresented groups in STEM disciplines. All online and printed materials are reviewed prior to posting to ensure that they promote broadening participation in our NNCI site and the NNCI, in general.

The RTNN website ([www.rtnn.org](http://www.rtnn.org)), for example, contains a link in large font to contact us using Spanish language. Two RTNN staff members are Spanish-speaking and respond to inquiries in Spanish. The RTNN recently released an online course, "Nanotechnology: A Maker's Course." The course was created with diversity in mind, and >50% of the presenters are from underrepresented groups in STEM. In the two months since its release, the course has been viewed by over 3,000 individuals and over 1,300 are formally enrolled in the course. Through these efforts, the RTNN is promoting broadening participation.




*RTNN website with Spanish-language contact button.*




*Screenshot of the online Coursera course, "Nanotechnology: A Maker's Course."*

<u>Abbreviated thoughts to keep in mind:</u>

- Diversity comes in all shapes and sizes, and by using innovative ideas. There is nothing that is too small to take on. It's all important.
- Don't forget: Local diversity projects are as important, and as interesting, as national or international programs. Utilize and leverage your local resources and community.

- You will also get ideas from success stories from NNCI nodes, and elsewhere on your campus or from your colleagues in other locations.
- Working with, promoting, and executing diversity issues and practices are most often highly rewarding.

*How can NNCI increase the diversity of users and participants in education and SEI activities?*

- Ensure the public information about NNCI encourages diverse participation
- Facilitate entry of users classified as adding to diversity
- Offer cost assistance
- Offer internships
- Provide a Spanish homepage button to click
- Advertise on our homepages with videos
- Work with local college diversity offices

*What forms of marketing and recruitment can we use to reach a diverse user population?*

- Utilize personal visits to schools that provide diverse users (e.g. HBCUs)
- Host targeted workshops
- Utilize professional societies that serve underrepresented demographic groups

Action items going forward:

1. Each node, during their next node group meeting, should read and discuss NNCI's Diversity statement on the first page of this document. There is no substitute for discussing these issues face-to-face. Do not reply solely on distributing this text in written and/or electronic form. It is recommended that each node revisit diversity issues with their staff at least once each year.
2. Please send your success stories to the Diversity Subcommittee. Send your stories, in whatever form you wish, to Michael Hochella (hochella@vt.edu) and Jacob Jones (jljone21@ncsu.edu). Mike and Jacob will collect and distill these stories to their most useful form(s) and distribute to the entire NNCI network in future postings and/or meetings. David Gottfried at the NNCI Coordinating Office will use information from these stories, along with Diversity Subcommittee assessments, to continue to help develop best practices across the network, and to report these to NSF.
3. The Diversity Subcommittee, in conjunction with the NNCI Coordinating Office, will work on ways for the nodes to report diversity information on both the technical and administrative staffs of each node, and the users of each node.
4. All node presentations/reports to their external advisory committees/boards should include diversity assessments in whatever form they find most useful. Discussion and assessment in these matters with each node's advisory boards are important

Members: Mike Hochella (Virginia Tech, Chair), Jacob Jones (NC State), Chris Ober (Cornell), Jim Pfaendtner (Univ. of Washington), Beth Pruitt (Stanford), Bob Westervelt (Harvard).

### 5.2. Metrics and Assessment Subcommittee

The charge to the Metrics Subcommittee included three elements:

- What is the definition of a "user" and what constitutes measured usage of a site?
- What are the best quantifiable metrics for measuring site performance, based on categories of site usage, site productivity and impact, education/outreach/SEI, and contributions to the network?
- What assessment methods can be used to indicate the combined impact of the NNCI network as "greater than the sum of its parts"?

The committee met with Dr. Larry Goldberg and discussed NNCI operation with the coordinating office. Quarterly teleconferences were also held starting in late 2016, culminating in reporting at the Directors' monthly meeting in September of 2017.

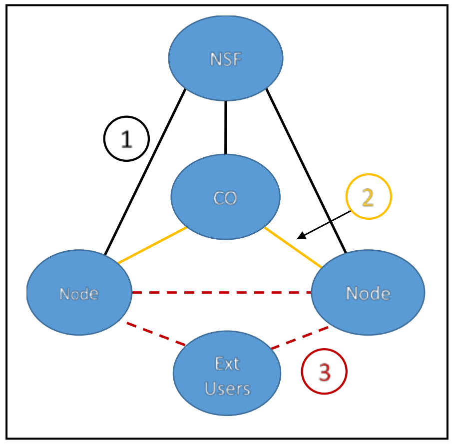



*Figure 5: Types of metrics*

The committee recognized the importance of metrics both for measuring performance against proposed goals but also to incentivize behavior that improves the network performance. After considerable discussion, we divided metrics into three categories (Figure 5). Type 1 metrics measure the performance of individual nodes against their individual goals as stated in their proposals to NSF. Table 7 (below), taken from the Coordinating Office proposal, summarizes *possible* type 1 metrics. The current type 1 metrics are felt to be effective and so no change is needed.

Table 7: Menu of typical type 1 metrics

| Site Usage | Site Productivity & Impact |
|---|---|
| Numbers of internal and external users | Publications, presentations, and patents |
| Amount of facility hours used | Research grant funding enabled |
| Revenue from user fees | Graduate degrees supported |
| User affiliations and discipline | Numbers of spin-off companies |
| Numbers of new annual users | Economic impact of industry users |
| Users at multiple partner sites | User and PI satisfaction survey |

Type 2 metrics evaluate the working relationship between the nodes and the Coordinating Office for reporting requirements and top-down network activities. These include timely responses to information requests from the Coordinating Office for user statistics, participation in working groups and network committees, providing website contributions, and participation in network-wide NNCI marketing efforts. The Coordinating Office felt that these activities have been very good during the first two years of operation and that additional metrics in this area are not warranted at this time.

Type 3 metrics evaluate the performance of nodes working together to provide services to users and other nano researchers. This type of metric primarily evaluates and so incents network-centric activities, where the network impact is greater than the sum of its parts. Examples include: 1) Sharing information and ideas through technology forums for user facilities, 2) Coordinating ongoing or planned activities through activities such as an emergency-tool access system and joint-tool acquisition and/or operation, 3) Fostering synthesis and new collaborations, 4) Developing/disseminating standards and best practices including EHS standards and clean room operating best practices, and 5) Advancing science and education through joint RET, REU, and similar activities. While the committee felt that the level of network-centric activities has increased compared to NNIN, more emphasis in this area could result in more of these joint bottom-up initiatives. This in turn could improve NNCI's appearance as a network rather than a collection of individual labs. The committee is evaluating how this might be done.

Members: Sanjay Banerjee (Texas), Stephen Campbell (Minnesota, Chair), David Gottfried (Ex-officio, Georgia Tech), Michael Hochella (Virgnia Tech), and David Sellmyer (Nebraska)

### 5.3. Global and Regional Interactions Subcommittee

The Global and Regional Interactions (GRI) subcommittee was formulated with the underpinning that NNCI should coordinate to leverage (and vice versa) other local, regional and global nano-initiatives, share good practices and feed off each other to enhance overall impact of nanoscience and nanotechnology. In the second year of the NNCI program, the GRI subcommittee has held several meetings to discuss both existing activities at NNCI sites as well as potential future endeavors for NNCI in the context of regional, national and international activities. The first activity was to take stock of existing programs and NNCI sites were surveyed to assess the different modes of interactions with a primary focus on both international activities (to assess potential for NNCI-wide involvement) and regional activities (to assess and share best practices). For international activities, responses from sites indicate a wide variety of interactions that are largely limited to a single site within the network, as may be expected at this early stage. The types of activities include student exchanges, joint workshops, research partnerships and, notably, the international REU program led by the Cornell site which has some participation across the network. International partners include institutions from 6 continents, but with higher concentrations in Europe and Asia.

For regional interactions, activities are similarly diverse across NNCI sites and depend to a large degree on the demographics of any particular site. We conducted a survey of regional activities and found that sites interact with a number of different categories of organizations in their regions including community colleges, national labs, non-profit organizations (e.g. museums, etc.) as well as regional industry and government. Nearly all sites interact with these organizations by providing demos and facility tours. Some sites provide facility access for courses taught at community colleges and teaching universities and several sites report joint workshops and short courses with regional colleges, industrial partners and national labs. User recruitment activities include exhibitions at regional trade shows and interaction with regional start-up incubators. Specific examples include: the facility usage for Maricopa Community College courses through a collaboration with the NCI-SW site; the regional micro/nanofab network Northern Nano Lab Alliance, which is led by the MINIC site; and the StartUP CNF program, which leverages state economic development resources in NY State.

After taking stock of existing activities, the GRI Subcommittee has proposed a series of initiatives to build on the existing NNCI global, national and regional activities:

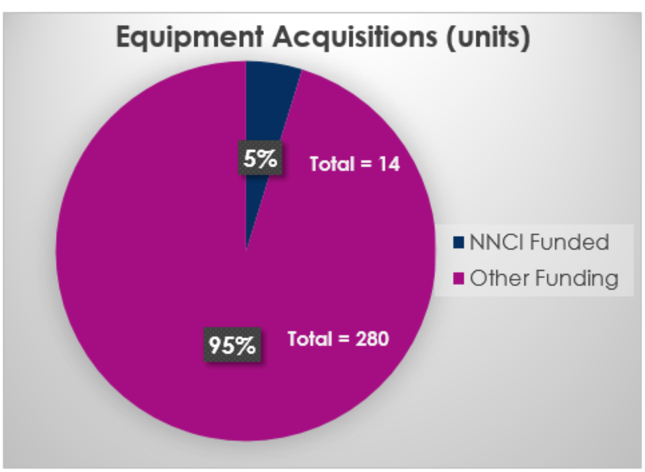
1. Staff exchange program – establish a program to allow staff to travel between sites and share expertise, conduct workshops and network between NNCI sites.
2. Joint workshops with national labs – for sites with regional national labs, we propose establishing joint user meetings and workshops to build connections with these facilities.
3. Rotating workshop series – establish partnerships with international nano organizations to establish a series of bi-lateral workshops that would rotate between sites.

Members: Karl Bohringer (Wash), Vinayak Dravid (NU, Chair), Bob Westervelt (Harvard), Chris Ober (Cornell), Bruce Alphenaar (Louisville)

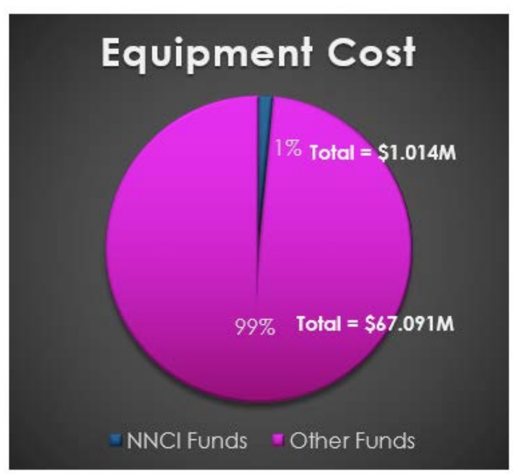
### 5.4. New Equipment and Research Opportunities Subcommittee

The New Equipment and Research Subcommittee performed an extensive survey of the NNCI network to determine exactly what type of equipment was being purchased by each of its 16 sites. Each site was asked to complete the survey and report on new equipment acquired since the start of the new NSF NNCI network (i.e. the first 1.5 years of the NNCI). All 16 sites completed the survey. The committee was also interested in identifying the categories of funding sources used to support the equipment purchases. The survey produced some interesting findings which are summarized below.

As shown in Figure 6, the NNCI network purchased an amazing 294 tools for a cost of $68M during its first year and a half in existence. The vast majority of those purchases were funded using sources outside the NSF NNCI award. Only 14 (or 5%) of the 294 tools were acquired using NSF NNCI financial support. These 14 tools totaled ~$1M (<2%) of the $68M spent on the entire toolset. This illustrates the tremendous leveraging power of the NNCI funds on equipment acquisitions by the network.




294 tools acquired since the start of NNCI




Total = $68,104,620

*Figure 6: Summary of number and total cost of tools acquired by the 16 NNCI sites during the first 1.5 years.*

The committee next analyzed what funding sources were used for the $68M investment of capital equipment purchases. As shown in Figure 7, 194 of the 294 tools were purchased using university funds (a surprise for some of the committee members). This constituted $44M of the $68M total cost. The next largest funding source was the federal government at 46 tools for a cost of $10.2M. A close third, at least in terms of cost, were foundations at 12 tools for $9.1M. Program income, donations and NNCI funds made up the remainder. Figure 8 presents a breakdown of the same information for each of the 16 NNCI sites.

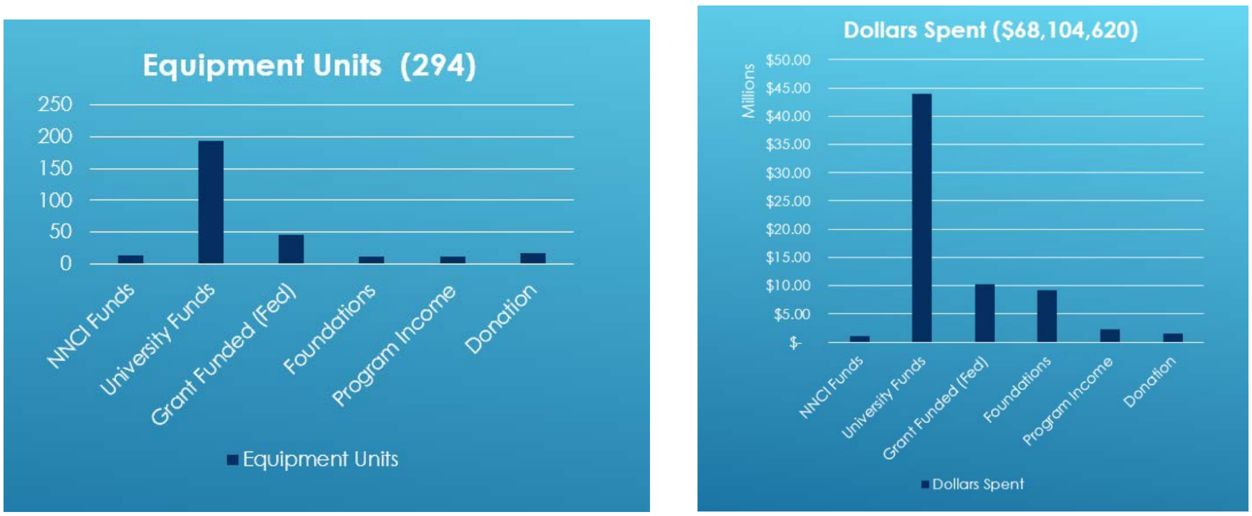



*Figure 7: Funding sources for the NNCI equipment acquisitions.*

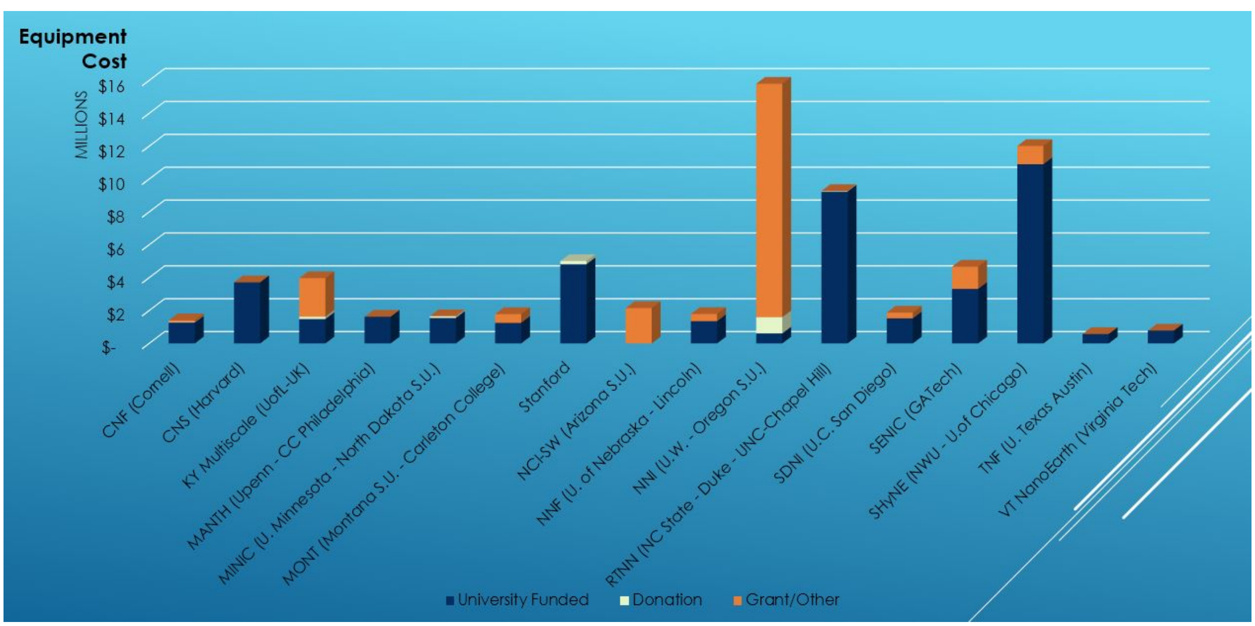



*Figure 8: Funding sources for equipment acquisitions at each NNCI site.*

Finally, the committee examined the types of equipment purchased. We asked each site to categorize each purchase as either “Fabrication/Processing” or “Metrology/Testing”. Table 8 presents a breakdown of the types of tools by NNCI site. As shown in the table, 177 (or 60%) of the 294 tools were targeted for fabrication/processing. Although the majority of the purchased tools were for fabrication/processing, Table 9 shows that these 177 tools made up only $23M (or roughly 40%) of the total $68M spent on equipment. The reason for this is the significantly higher cost of some of the very high end inspection/metrology tools, such as aberration-corrected TEMs, etc.

Table 8: Breakdown of number of different types of new equipment purchases by NNCI site.

| | Fabrication/Processing | Metrology/ Testing | Total |
|---|---|---|---|
| CNF (Cornell) | 5 | 10 | 15 |
| CNS (Harvard) | 4 | 10 | 14 |
| KY Multiscale (U. Louisville/U. Kentucky) | 58 | 9 | 67 |
| MANTH (U. Penn/CC Philadelphia) | 5 | 1 | 6 |
| MINIC (U. Minnesota/North Dakota S.U.) | 6 | 4 | 10 |
| MONT (Montana State U./Carleton College) | 4 | 5 | 9 |
| Stanford | 21 | 11 | 32 |
| NCI-SW (Arizona State U.) | 1 | 1 | 2 |
| NNF (U. of Nebraska-Lincoln) | 6 | 4 | 10 |
| NNI (U. Washington/Oregon State U.) | 19 | 7 | 26 |
| RTNN (NC State/Duke/UNC-Chapel Hill) | 9 | 9 | 18 |
| SDNI (U.C. San Diego) | 4 | 8 | 12 |
| SENIC (Georgia Tech/JSNN) | 11 | 16 | 27 |
| SHyNE (Northwestern/U. Chicago) | 22 | 18 | 40 |
| TNF (U. Texas-Austin) | 0 | 3 | 3 |
| VT NanoEarth (Virginia Tech) | 2 | 1 | 3 |
| **TOTALS** | **177** | **117** | **294** |

Table 9: Breakdown of cost of types of new equipment by NNCI site.

| | Fabrication/Processing | Metrology/ Testing | Total |
|---|---|---|---|
| CNF (Cornell) | $790,000 | $615,000 | $1,405,000 |
| CNS (Harvard) | $1,539,017 | $2,177,816 | $3,716,833 |
| KY Multiscale (U. Louisville/U. Kentucky) | $2,296,053 | $1,675,655 | $3,971,708 |
| MANTH (U. Penn/CC Philadelphia) | $1,550,000 | $75,000 | $1,625,000 |
| MINIC (U. Minnesota/North Dakota S.U.) | $1,486,000 | $173,000 | $1,659,000 |
| MONT (Montana State U./Carleton College) | $72,055 | $1,714,560 | $1,786,615 |
| Stanford | $2,076,000 | $2,937,000 | $5,013,000 |
| NCI-SW (Arizona State U.) | $150,000 | $2,000,000 | $2,150,000 |
| NNF (U. of Nebraska-Lincoln) | $1,000,448 | $791,534 | $1,791,982 |
| NNI (U. Washington/Oregon State U.) | $5,024,316 | $10,773,758 | $15,798,074 |
| RTNN (NC State/Duke/UNC-Chapel Hill) | $1,269,605 | $8,005,000 | $9,274,605 |
| SDNI (U.C. San Diego) | $235,000 | $1,640,000 | $1,875,000 |
| SENIC (Georgia Tech/JSNN) | $3,697,620 | $971,483 | $4,669,103 |
| SHyNE (Northwestern/U. Chicago) | $1,547,700 | $10,466,000 | $12,013,700 |
| TNF (U. Texas-Austin) | $0 | $575,000 | $575,000 |
| VT NanoEarth (Virginia Tech) | $180,000 | $600,000 | $780,000 |
| **TOTALS** | **$22,913,814** | **$45,190,806** | **$68,104,620** |

Membership: Kevin Walsh (Louisville, Chair), Jacob Jones (NCSU), Yuhwa Lo (UCSD), Mark Allen (Penn), Stephen Campbell (Minn), David Dickensheets (Mont State), Karl Bohringer (Wash), Vinayak Dravid (NW), Oliver Brand (GaTech CO, ex officio)

### 5.5. Workforce Development Subcommittee

This subcommittee reported to the Executive Committee via WebEx in May 2017. One of its recommendations was to merge this subcommittee with the Working Group on Workforce Development and Community Colleges. This working group is chaired by Ray Tsui from NCI-SW (ASU), and its report is provided in Section 6 below. Interested members of the former Subcommittee continue to participate in the working group's activities.

Members: Trevor Thornton (ASU, Chair), Ray Tsui (ASU), Lara Gamble (Univ. Washington), Shamus McNamara (Univ. Louisville), David Sellmyer (Univ. Nebraska), Bill Wilson (Harvard), Nancy Healy (Ex-Officio, Georgia Tech)

### 5.6. Building the User Base (BUB) Subcommittee

The goal of the NNCI Building the User Base (BUB) Subcommittee is to discuss best practices for sites and the NNCI as a whole to increase the user base, with particular emphasis on non-traditional users. The discussions in 2017 focused around the following questions:

- How can we leverage activities going on at our institutions for marketing and/or for engagement of new users?
- What are the opportunities for leveraging local and national programs, including databases, to market to new users?
- Discuss long term approaches to building the user base through K-12 efforts.

Users:

What constitutes a non-traditional user?

Non-traditional users include the following:

- Demographic groups: women and under-represented minorities
- Research areas: those that do not typically use nanotechnology facilities
- Users from non-Research I educational institutions
- Small companies
- Students: K-12 students, community college students, and teachers (K-12 and community college)

Users typically exhibit some common attributes:

- Training on equipment usage
- They provide samples for characterization or they fabricate samples
- They use the equipment to characterize or fabricate their sample
  - In person
  - Through remote control of the equipment
  - By remote use through a staff member
- Fees are paid (although not necessarily by the user)

Key Factors:

In building the user base there are key factors that have an impact on the growth of the user base, including awareness, cost and distance

- Awareness- the following are different strategies that can be used to bring awareness to the program to build the use base
  - Direct outreach to targeted groups
    - STTR/SBIR database mining
    - Incubator contacts
  - Social media & websites
  - Coursera free online courses

  - Targeted marketing thru Linked-in
  - Seminars for Teachers
  - Workshops (training, or with vendors)
  - Students in summer camps
  - Tours

  Note: Assessment is key; need to collect data on how they heard about the program

- Cost- determine ways to make use cost effective for users
  - Consider programs that enable external users to achieve preliminary results through free use
- Distance – remote usage will be important to implement large change, especially to reach rural areas
  - Remote usage by running equipment remotely – slowly emerging
  - Remote usage aided by facility Staff
  - Live stream demos
    - Classrooms, K-12, College, Community College
    - Libraries
    - Community Centers
    - Museums
  - Take portable SEM and light microscopes to off site locations
    - Classrooms, K-12, College, Community College
    - Libraries
    - Community Centers
    - Museums

<u>Building the User Base Approaches:</u>

Short term direct approaches being tested now in the NNCI:

- Awareness:
  - SBIR/STTR database mining for contacts
  - Small business incubator contacts
  - Websites (including Spanish language access)
  - Coursera Nanotechnology course
  - Workshops
  - Display booths at conferences
  - RET and REU programs
  - Seminars, webinars, live stream Q&A on Nanotech
- Cost:
  - Encourage sites to offer free use funds to non-traditional users
- Distance:
  - Portable SEM
  - Nano Bus
  - Remote use of equipment
  - Live stream equipment use with staff; mail samples

Longer term, increasing the user base develops future users through programs such as

- Summer Camps at regional institutions;

- Integration of tours/demos/experiences into K-12 science curricula – target specific classes, grade levels
- Science Fairs, Science Olympiad
- Girls/Boy Scouts, 4H Clubs

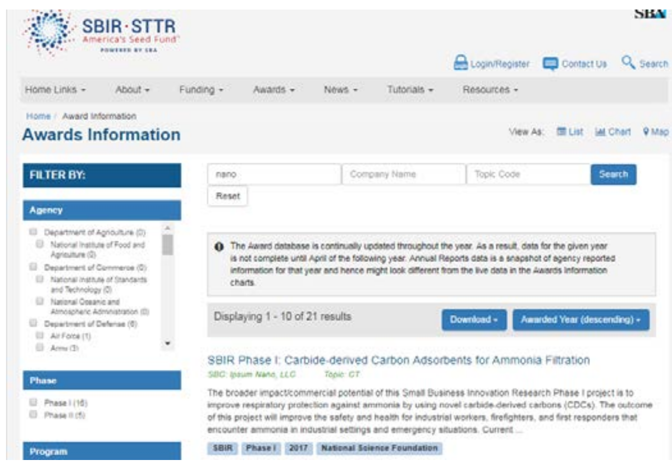
In this report, we focus on three areas:

1. Engaging the startup/small business community through SBIR/STTR databases and through local incubators;
2. Enabling remote use of facilities;
3. Longer term building the user base investments through K-12 user engagement.

*1. Engaging the Startup/Small Business Community*

*A. Data Mining of SBIR/STTR Awards*

One of the goals of the NSF-NNCI program and specifically of the NNCI Building the User Base (BUB) subcommittee is to attract and serve a diverse user base, which includes small companies that do not have access or are aware of open-access user facilities in academia. Manu small companies (with employees fewer than 500) that conduct research and development (R&D) activities are funded by federal SBIR/STTR contracts or grants. By using a combination of specific keywords (e.g. nano, materials, MEMS, optics, biomedical, electronics etc.) and appropriate filters (e.g. funding year, federal agency, geographical area), a list of SBIR/STTR funded small businesses can be generated for targeted contact and marketing campaigns. A complete list of SBIR/STTR awards can be found on sbir.gov website, specifically on - [https://www.sbir.gov/sbirsearch/award/all](https://www.sbir.gov/sbirsearch/award/all).




For example, using a keyword as "NANO" and filters for funding year (2017, 2016, 2015) and states in the southeast (AL, FL, GA, NC, SC, TN, VA) yielded the following 21 SBIR/STTR awards (see image below). The results can be exported into XLS, JSON or XML formats. The downloaded info includes Company name, Project title, Abstract, Funding agency, Phase I/II, Funding period, Topic code, PI and company contact information.

***The BUB Subcommittee recommends that the NNCI CO encourage and aid all NNCI sites to contact small companies through the STTR/SBIR database, and provide coordination between sites*** (e.g. some sites may overlap in geographical purview, and companies may be engaged by more than one site).

*B. Cultivation of Incubator Activity*

One engagement option viable for many of our network nodes is direct engagement with technology incubators. This interaction has several benefits to the nodes. 1) It affords access to a number of technology companies under the same roof, without the need to develop individual agreements with each company. 2) If an MOU is developed with the incubator itself, (a entity with a more stable revenue source), one can simplify the MOU development, one can have the incubator serve as the invoicee, (that is the incubator can offer access to the users in the companies it houses access to the resources at the node). The node in turn charges the "incubator" for usage by all its tenants, (though tenants users will be trained as all users are trained.) Note the node could develop a refined rate for the incubator, (fully cost recovered). At Harvard CNS, we've already developed MOUs with two local facilities, Greentown Labs and the Engine, and we are in discussions with a third.


Goals:

- Support of small business technology development
- Leverage and optimize local research community interactions with NNCI node
- Provide an opportunity for students to see the *"start-up"* world

There are some questions to consider as part of this activity: Is the rate set such that we are subsidizing industry? Are we positioning the node to pick *"winners and losers"*?

For the former question, the answer is likely determined locally. At Harvard, a number of local start-ups are using "Harvard-owned" IP so the subsidy concerns are minimal. For the latter, it still is an open question. As long as we are not turning start-up users away, we are not steering support in any particular direction. Note: Incubator activity can be coupled with a "Kick-Starter" type program to incentivize use.

***The BUB Subcommittee recommends that the NNCI CO develops and distributes a sample MOU to all NNCI sites, and encourage each site to contact their local small company incubator to engage startup companies.***

*2. Enabling Remote Use of Facilities*

With respect to overcoming the barriers imposed by distance between users and sites, one solution is remote access to real-time education, training, characterization, fabrication, and even equipment control. There are many situations in which recorded video is adequate for education and training; however, the committee recognizes that live interaction is far more engaging and sometimes essential (e.g. interactive training, processing, or characterization). There are many readily available tools for real-time, online interaction; however, implementation of these tools in fabrication and characterization shared facilities remains in its infancy.

***The committee recommends that NNCI CO survey the sites, and share best practices with the sites in regard to both the type of online remote interactions to provide and the tools that are best suited to this use.***

For example, it is often difficult to host large groups for demonstrations even if those groups are on campus. Such large groups are common in K-12 summer camps, process specific workshops, and larger enrollment courses that only have one or two classes on fabrication or characterization. One possible solution is to bring small groups into the facility for tours and then have these participants gather in a nearby auditorium for a live demonstration of the tool or process. Live-streaming is reliable in this case because it is confined to campus. After touring the facility and meeting the staff, participants are more inclined to ask questions and engage in the demonstration process. Similar educational efforts for remote groups, especially those in underserved rural areas, can be technically problematic.

Ensuring sufficiently fast broadband access to urban and rural areas, particularly under-privileged areas, can be problematic. One approach being investigated at the RTNN site is the use of 4G hotspots provided by the RTNN to ensure high-speed broadband access during the live stream event. It is also very useful to have a trained student or staff member present at the user site to personalize the experience for the remote users.

Portable equipment, such as a portable SEM, has been used extensively by some NNCI sites, and is highly effective when used in summer camps, schools, libraries, and community centers. This is particularly important in addressing access in rural areas. The individuals gaining access to the equipment can provide their own samples, be trained to use the equipment, and can use the equipment, thus breaking down the barrier of "that's not something that I can do." The acquisition and use of portable equipment should be a priority for NNCI sites for building the long term user base.

Remote control of equipment is currently possible and is widely used for troubleshooting. It has also been used for remote training of users by the manufacturer, but the committee shared concerns that remote control for routine use remains too high risk for most tools.

***Thus, the committee recommends that the NNCI CO survey the sites regarding remote and portable equipment activities, and share with the network experiences, positive and negative, with live-streaming, remote instrument control, and portable equipment.***

Members: Nan Jokerst (RTNN/Duke, Chair), Bill Wilson (Harvard), Todd Hastings (MMNIN/UK), Shyam Aravamudhan (SENIC/JSNN)

# 6. Working Groups

One of the greatest strengths of the NNCI network is the combined staff expertise of the individual sites. To leverage this expertise at the network level, the Coordinating Office has initiated the formation of working groups composed of staff members from the NNCI sites. While these working groups meet primarily via teleconferences and WebEX, they also have the ability to organize workshops and/or dedicated sessions at the annual NNCI Conference. We have created and are encouraging working groups (Table 10) in (1) important "network" responsibilities, such as environmental health & safety, vendor relations, or equipment maintenance and training, (2) particular process technologies, such as lithography or characterization (although these are only examples of possible topic areas), (3) research areas of nanoscience and nanoengineering, in particular those targeting "non-traditional" disciplines, such as bio, geo and environmental sciences, and (4) education and outreach activity. Most of these working groups began in Year 1, while new ones started in Year 2. Additional topics will be added later on as interest and need arises, and some topics may sunset if importance wanes. In addition, some topical areas (EBL, Etch, and ALD) have begun working groups through grass-roots efforts of NNCI staff, with support from the Coordinating Office. The outcomes of these working groups can have many forms, including process recipes, recommendations to vendors for future equipment development, maintenance and training videos/webinars, recommendations on how to evaluate the safety of new processes, or direct recommendations for new users. Each working group has one or more dedicated coordinators selected from one of the NNCI sites, and staff participation in the working groups can be one measure for site performance. Participation in these working groups can also be considered as a mechanism for staff growth and career development, which might be further supported through certificates earned when participating in related workshops, for example, and this is being explored. Received reports of current working groups, as provided by the leads, are presented below.

Table 10: NNCI Working Groups

| Working Group Topic | Working Group Lead(s) |
|---|---|
| **Network Support Working Groups** | |
| Equipment Maintenance & Training | Meredith Metzler (Univ. Pennsylvania) |
| Vendor Relations | Mike Khbeis (Univ. Washington) |
| Environmental Health & Safety | Nasir Basit (Northwestern) and Greg Cibuzar (Minnesota) |
| **Technical Working Groups** | |
| XPS/UPS | Carrie Donley (UNC), Walter Henderson (Georgia Tech) |
| E-Beam Lithography | Devin Brown (Georgia Tech) |
| Etch Processing | Vince Genova (Cornell) |
| Atomic Layer Deposition | Michelle Rincon (Stanford), Xiaoqing Xu |

| | |
|---|---|
| | (Stanford), Mac Hathaway (Harvard) |
| Photolithography | Pat Watson (Penn) |
| Additive Manufacturing | TBD |
| Metrology and Characterization | TBD |
| **Education and Outreach** | |
| K-12 and Community | Jim Marti (Univ. Minnesota) |
| Research Experience for Undergraduates | Lynn Rathbun (Cornell) |
| Workforce Development and Community Colleges | Ray Tsui (Arizona State) |
| Evaluation and Assessment | Nancy Healy (Georgia Tech) |
| Online Technical Learning | Angela An-Chi Hwang (Stanford) |
| **Societal and Ethical Implications** | Jameson Wetmore (ASU) |
| **Research Area Working Groups** | |
| Geo and Environmental Sciences | |
| Life Sciences | |
| Next Generation Electronics | |
| Optics and Photonics | |
| MEMS and Sensors | |

### 6.1 Equipment, Maintenance, and Training

The technical working group conducted several discussions via email/phone. We have started discussions of ways for network sites to help with emergency backup support with spare parts. Also, efforts continue to control the costs associated with long term maintenance and service. To this end, the group continues to leverage our existing relationships with equipment manufacturers. A second commitment was secured from a major equipment manufacturer (details are proprietary to NNCI members) to provide discounts on parts to those NNCI sites not already participating in service agreements for the duration of the NSF Grant for NNCI.

Members: Meredith Metzler (Penn), Bob Geil (UNC), Jesse James (UT), Mary Tang (Stanford), Al Bailey (UW), Jeremy Clark (Cornell)

### 6.2 Vendor Relations

This working group aims to improve NNCI site engagement with various vendors, namely equipment vendors and consumable suppliers. The working group established a site survey to identify preferred vendors, most cost-effective consumables, and challenges. Unfortunately, response to the survey was limited. The working group pivoted to discuss strategic acquisitions and equipment selection criteria and results from multi-vendor performance evaluations such as comparisons of differing Atomic Layer Deposition (ALD) and Transmission Electron Microscopy (TEM) systems. Currently, members of the working group are soliciting network-wide discounts for initial sales and post-sales support (service contracts, parts, and labor) from equipment vendors that they have a strong working relationship with. It is the hope of the working group that these offerings will increase the buying power of the network while simultaneously establishing new strategic partnerships for vendors by utilizing NNCI sites for equipment demonstrations, process co-development, and new collaborative industry-academic research initiatives.

Members: Michael Khbeis (U Washington), Ana Sanchez (Louisville), Andrew Ott (Northwestern), Matthew Hull (Virginia Tech), Noah Clay (U Penn)

### 6.3 Environmental Health & Safety

The EHS working group members, as of now, are listed in the table below. All these members have volunteered to take on the task of ***developing a safety guideline for all NNCI nodes*** and have shown great interest and enthusiasm in pursuing it. All members have several years of safety experience with unique expertise as is also listed in the table. Some members have a combination of a valuable industry and academic experience. This diversity of experience will be an asset in coming up with robust recommendations. The means of communications so far have been emails, phone calls, and a meeting of two members, Greg Cibuzar (co-lead) and Mark Walters at the October 2017 NNCI Annual Conference. After introductions and initial discussion, an outline presented below was developed to move discussions further along.

The discussion is continuing about the following outline. The recent topics of discussion have been related to emergency procedures and major incidents. Specifically, emergency response teams (ERTs), and their coordination with local fire departments, and chemical safety (HF exposure) have been touched upon. We plan to continue the discussion of these and other topics on the list below in 2018 and also visit and learn safety protocols followed by as many facilities as possible. To do that, one possible meeting to attend would be UGIM 2018 at U Penn. As UGIM attracts not only many university facilities but also government labs and industry, and have sessions on safety, it will be a good avenue to meet and share experiences.

The outline developed for further discussions is given below:

1. <u>Emergency Procedures</u>
    a. Evacuation Plan
    b. Emergency Equipment (safety showers/eye wash, fire extinguishers, fire alarms, toxic gas alarms, emergency phones, first-aid kits …)
    c. Emergency Response Teams
2. <u>Safety</u>
    a. Chemical Safety
    b. Chemical Waste
    c. Hazardous Gas Safety
    d. Process Equipment/Instrument Safety
3. <u>Incidents</u>

   a. Major Incident Response (Active shooter, Major chemical spill, Lab user in safety shower, Severe weather, Lab fire/smoke, Earthquake, …)
   b. Minor Incident Response
   c. Incident Reports
4. New Material Requests
   a. Hazardous Materials
   b. Hazardous Reactions
5. Buddy Rule
   a. When
   b. Where
   c. Enforcement
6. Safety Training
   a. University Safety office (EHS) training
   b. Site-specific training

Members:

| | Affiliation | Safety Expertise |
|---|---|---|
| **Nasir Basit (Co-lead)** | NUFAB<br>Northwestern University | Microfabrication equipment safety, facility setup and growth |
| **Greg Cibuzar (Co-lead)** | Minnesota Nano Center<br>University of Minnesota | Facility management and safety protocols |
| **Philip Infante** | Cornell Nanoscale Facility<br>Cornell University | Lab safety and safety related infrastructure |
| **Robert Rose** | IEN<br>Georgia Tech | Lab safety, policies & procedures, emergency response |
| **Laura Scholer-Bland** | EHS<br>Georgia Tech | Chemical Safety (Hazard Assessments-chemical/process reviews, procedure development) |
| **Mark Walters** | Shared Materials Instrumentation Facility (SMIF) Duke University | Research facility management, cleanroom fabrication, XPS, SEM, TEM |

### 6.4 XPS/UPS

Carrie Donley (RTNN) and Walter Henderson (SENIC) lead the working group on x-ray and ultraviolet photoelectron spectroscopies (XPS and UPS). The group's main activity is a listserv/online forum that allows members to communicate with each other regarding issues related to instrument maintenance, interpretation of data, and other related issues. Ten NNCI sites currently have XPS instruments, and staff from all these sites are participating. In addition, XPS/UPS experts from outside the NNCI have been recruited to participate in order to leverage a greater pool of expertise in this area. We have recently added seven new people to the listserv and are actively recruiting others.

Members:

| Name | Site | University |
|---|---|---|
| Recep Avci | MONT | Montana State University |
| Dmitri Barbash | -- | Drexel |
| Dongmei Cao | -- | LSU |
| Hugo Celio | TNF | UT Austin |
| Xinqi Chen | SHyNE | Northwestern |
| Matthew Dabney | -- | Cornell |
| Carrie Donley | RTNN | UNC |
| Gerry Hammer | NNI | University of Washington |
| Walter Henderson | SENIC | Georgia Tech |
| Chuck Hitzman | nano@stanford | Stanford |
| Jacek Jasinski | KY MMNIN | U Louisville |
| Timothy Karcher | NCI-SW | Arizona St. |
| Paul Lee | -- | U of Arizona |
| Tom Mates | -- | UCSB |
| Ben Meyers | SHyNE | Northwestern |
| Mitsuhiro Murayama | NanoEarth | VaTech |
| Robert Opila | -- | University of Delaware |
| Jonathan Shu | -- | Cornell |
| Fred Stevie | RTNN | NCSU |
| Mark Walters | RTNN | Duke |
| John Wilderman | -- | University of New Hampshire |
| Dmitry Zemlyanov | -- | Purdue |
| Elaine Zhou | RTNN | NCSU |

### 6.5 Etch Processing

The objective of the Etch Working Group is to provide an interactive forum for all etch personnel from all the NNCI participating sites. This interaction includes but is not limited to the sharing of information regarding etch capabilities, established etch processes, processes under development, maintenance issues, preventative maintenance, baselining efforts, equipment modification, and the acquisition of new etch tools. Identification of the broad and complementary etch tools within NNCI allows us to effectively process wafers within the network to meet the diverse specifications of individual projects, and to provide back-up systems within the network to avoid any extensive downtimes in user processing.

A couple new communication paths for members of the NNCI etch community were created in the past year. A LinkedIn "NNCI Etch Group" has been created, along with a "NNCI-etch" mailing list where members can discuss any process, materials, or equipment issues with the entire group. This forum is also used for announcements on upcoming events such as networking online meetings or onsite workshops.

This December, an online etch group meeting was held via "Zoom" and members from the following sites participated: Cornell, Harvard, Stanford, Minnesota, Nebraska, and UC San Diego. The agenda of the meeting included:

- Updating the etch tool database for the network. The creation of a detailed database listing equipment and process capabilities is an invaluable resource for etch personnel and user managers. The changes are reflected in the updated database.
- New or modified process updates. Cornell presented new metal etch processes on its ICP platforms. Cornell also discussed the designation of an RIE system where exposed Gold is allowed, along with etching down to a Gold interface.
- A discussion of any process, materials, or maintenance issues.
    - We discussed chamber conditioning strategies which are necessary in a multi-user environment.
- Discussion of a planned on-site NNCI Etch Workshop in 2018. We are planning a two day workshop with updates from the sites, technical talks by etch members on specialized topics in etching, and participation from vendors where technical experts present their latest process & equipment developments. Cornell, Stanford, and Harvard all indicated a growing need for Atomic Layer Etching for the demanding requirements of III-nitride and 2D material processing. Stanford expressed an interest in providing the venue for the workshop where Stanford, Cornell, and Harvard will share the responsibility of planning and organizing (ie, co-hosting) the workshop.

Future plans for the NNCI Etch Working group:

- An on-site 2 day workshop to be held tentatively in July at Stanford in coordination with Semicon West, so that we can attract leading vendors in the R&D etch market to the workshop for presentations on their latest developments in etch processes and equipment. A cited critical need is for Atomic Layer Etching to meet the stringent requirements of high performance III-nitride and 2D materials based device development. In addition, there will be invited technical talks by NNCI etch members on specialized topics in etching.
- A "WebEx" or "Zoom" teleconference to be held on a 3-6-month basis to collectively discuss any equipment or process issues, along with any new process developments. The

next teleconference will likely be held in April 2018 so that we can provide additional input for the upcoming onsite workshop.

- The use of the NNCI-Etch mailing list to provide a continuous forum for discussion and announcements.

Members:

Cornell University: Vince Genova, Jeremy Clark, Tom Pennell, Jerry Drumheller
Harvard University: Ling Xie, Kenlin Huang
Stanford University: Usha Ranghuram
Georgia Tech: Thomas Johnson-Averette, Hang Chen
University of Pennsylvania: Meredith Metzler
University of Texas at Austin: Ricardo Garcia
University of North Carolina-Chapel Hill: Bob Geil
University of Nebraska-Lincoln: Jiong Hua
University of Louisville: Evgeniya Moiseeva, Xiaojin Wang
University of Washington: Mark Morgan
University of Minnesota: Tony Whipple
Arizona State University: S.Ageno
Montana State University: Phil Himmer
University of California-San Diego: X. Lu
Virginia Tech: Donald Leber
University of Chicago: Peter Duda

### 6.6 Atomic Layer Deposition

Stanford University and Harvard University co-hosted a 2017 NNCI/NNIN ALD/MOCVD Symposium in April, 2017. The goal of the symposium was to build networks between university shared labs by sharing knowledge focused on the specific areas of ALD and MOCVD. The meeting was a two day event. The first day was a closed session for NNCI/NNIN participants only, and the second day was open to the public. Day 1 included presentations by each of the attending universities explaining shared facility capabilities, ALD tool management, support, and process knowledge sharing, and an introduction to MOCVD. Window tours of the Stanford shared facilities were also given. 13 different universities, including 4 schools that were both NNCI and NNIN (Harvard, Stanford, University of Minnesota, and Cornell), 3 schools that are not part of NNCI but were part of NNIN (Penn State, UT Austin, and University of Michigan), and 6 schools that are new to the NNCI network only (Montana State, Northwestern University, UCSD, UNC, UPenn, and UW). Four of the universities participated via Blue Jeans (similar to Skype) since they were not able to attend on site. There was a mix of lab capabilities as well- ranging from well-established ALD systems with relatively a large ALD user base, to labs who were considering purchasing their first ALD tool and were interested in learning what some of the applications were and hearing recommendations about equipment purchase and management.

Day 2 was an opportunity for engineers from both industry and academia to attend talks and network over lunch and breaks. There were technical talks by vendors interspersed with research-oriented talks from noted ALD and MOCVD faculty from four different universities.

Professor Sean Barry from Carleton University, Professor Andy Kummel from UCSD, and Professor Stacey Bent from Stanford gave presentations highlighting new areas of ALD research. Professor Debbie Senesky from Stanford University and Professor Connie Chang-Hasnain from UC Berkeley gave talks focused on MOCVD. All of the speakers did a marvelous job presenting to a broad audience and educated the attendees who were both new to the areas of ALD and MOCVD as well as provided insight to the attendees that work with those systems. Many times our labmembers are familiar with the benefits of ALD for their device and research, but they are not necessarily focused on the field of ALD and don't often get a chance to learn about other applications. There were many participants to whom MOCVD and it's applications was a brand new topic. We received a lot of feedback from the group that they really appreciated being given the chance to learn in this setting. All told, there were over 100 participants in Day 2, 46 of whom were industrial participants. Funding for the event was supported by donations from seven vendors ranging from equipment, simulation, and precursor suppliers.

In the spirit of keeping that momentum going, a continuing working group was formed including all of the members that participated in Day 1 of the symposium. This email list serves as an opportunity for shared learning to continue, including tips about alternative sources for ALD parts, novel ALD processes, and troubleshooting.

Members:

| Location | Site | Equipment | Name |
|---|---|---|---|
| Cornell | CNF | ALD: | Vince Genova |
| | | Oxford PECVD | Tom Penell |
| | | | Jeremy Clark |
| Univ. of Louisville | KY MMNIN | ALD | Julia Aebersold |
| | | MOCVD | |
| Univ. of Pennsylvania | MANTH | ALD | Noah Clay |
| | | | Meredith Metzler |
| Univ. of Minnesota | MINIC | PECVD | Robert Amundson |
| Univ. of Montana | MONT | ALD | Phil Himmer |
| Virginia Tech | NanoEarth | ALD | Don Leber |
| Arizona State | NCI-SW | ALD | Stefan Myhajlenko |
| Univ. of Washington | NNI | ALD | Darick Baker |
| | | ALD | Al Bailey |
| Virginia Tech | NanoEarth | ALD | Fred Newman |
| North Carolina | RTNN | ALD | Bob Geil |
| Georgia Tech | SENIC | ALD | John Pham |

| | | | |
|---|---|---|---|
| Northwestern | SHyNE | ALD | Anil Dhote |
| | SHyNE | ALD | John Ciraldo |
| Stanford | | ALD | Michelle Rincon |
| | | MOCVD | Xiaoqing Xu |
| | | NNCI | Shivakumar Bhaskaran |
| Univ. of Texas | TNF | ALD | Marylene Palard |
| | | ALD | Jesse James |
| | | ALD | David Farnsworth |
| Penn State | | ALD | William Drawl |
| Penn State | | ALD | Bangzhi Liu |
| Howard | | | James Griffin |
| Harvard | CNS | ALD | Mac Hathaway |
| Harvard | CNS | ALD | Philippe DeRouffignac |
| UC Santa Barbara | | ALD | Bill Mitchell |
| U. Maine | | ALD | David Frankel |
| | | | Michael Call |
| Univ. of Michigan | | ALD | Matt Oonk |
| University of San Diego | | ALD | Xuekun Lu |
| | | ALD | Bernd Fruhberger |
| Univ. of Minnesota | | | Tony Whipple |

### 6.7 Photolithography

Photolithography, an essential component of micro and nano fabrication technology, is available in some form in all cleanroom facilities. However, there are restrictions on the substrate size, the topography of the substrate surface, the chemistry of the substrate surface, resist type and thickness, and especially feature size, that limit the type of devices some researchers can construct at some facilities. This working group intends to construct a database of the expertise and special equipment available across the network so that when researchers have unique requirements, site staff can search to see if a process is available to help create in-house capability, or which network lab can run the process for that user. A database would also allow the working group to identify where gaps in capabilities are, and what new equipment or process development may be required in the future.

The database would make use of the new capabilities that are planned for the NNCI website; a password-protected part of the site may be used to store, grow, and share this information across the network. A public access version of this information will also be made available. The database can be expanded in the future to keep track of other capabilities, such as lithography simulation software.

Ten members of cleanroom staff from 8 NNCI sites expressed interest in participating in the NNCI Photolithography Working Group.

Members: Paul Kimani (Minn), Phil Himmer (Montana State), Jiong Hua (Neb), Xuekun Lu (UCSD), Garry Bordonaro (Cornell), Curt McKenna (UofL), Vinh Nguyen (GT), Pat Watson (Penn), David Jones (Penn), Gyosok Kim (Penn)

### 6.8 K-12 and Community Outreach

*Past Activities (10/1/16 - 9/30/17):*

The initial K-12 Teachers and RET working group was organized and held two phone conferences in September and October of 2016. In November the group chair offered to absorb the roles and membership of the K-12 Students and Community Outreach working group, since a) the latter group had not yet met, and b) many of the programs our group was discussing were both K-12 and community outreach in nature, making it more efficient to address education and outreach efforts as a whole. The larger group held a phone conference in December to discuss common goals and current activities.

The group's first task was to identify and review education and outreach programs in place at NNCI institutions that have potential for network-wide application. Members of the group summarized the outreach programs and activities they have used successfully to reach K-12 teachers, students, and the general public. After some discussion, we prepared a list of programs we believe are worthy of consideration for scale-up to the full (or partial) NNCI network. These programs, summarized in Table 11, were presented and discussed at the NNCI first year conference, Jan. 18-19 at Georgia Tech.

*Current Activities:*

1. Identifying, collecting, and editing content for the NNCI website pages on K-12 education and community outreach. As part of this effort, the group is reviewing developed classroom activities on nanoscience and technology available elsewhere on the Web, including the old NNIN site.

2. Assessing the impact of NNCI's education and outreach activities. A sub-group of three members has begun this work.

Table 11: Education programs that may be expanded to the NNCI network.

| Activity | Description | Audience |
|---|---|---|
| NanoDay events | hands-on activities paired with short presentations, lab tours, cleanroom gowning demonstrations, and other activities. | K-12 Students |
| RET programs | provide teachers with new skills and knowledge they could use to improve their science curriculum in | Teachers at high school and |

| | | |
|---|---|---|
| | their home institutions when they return. | community colleges |
| Developing training videos | videos for equipment training that can be applied to teacher training and outreach. May incorporate on-campus student effort. | Teachers grades 7-12 |
| Nanocamps | partial or full day experiences for students to explore nanotech topics in depth | Students grades 7-10 |
| Remote access and/or traveling tool programs | Either remote access tool use (ala RAIN) or investing in small table-top scale tools and bringing these to schools. | Students and teachers, grades 7-14 |
| Activity kits | distributed to schools for in-class use, either all materials provided (like Nano-Link's Modules), or with the teacher responsible for acquiring supplies (like NNIN's activities). | Students and teachers, grades 7-14 |

Members: Dan Ratner (Washington), Maude Cuchiara (NCSU), Terese Janovec (Nebraska), Kristin Field, (Penn), Jim Marti (Minnesota)

### 6.9 Workforce Development and Community Colleges

In the spring of 2017, the Workforce Development Subcommittee evolved into the Working Group on Workforce Development and Community Colleges. This WG is chaired by Ray Tsui from ASU/NCI-SW. Interested members of the former Subcommittee continue to participate in the WG's activities.

On 4/27/17 the WG held its kick-off teleconference with 5 participants on the call. Four other people provided input via email and through a one-on-one call. In the meeting, activities at the participating sites that pertain to the focus areas of the WG were described, including surveys conducted to gauge local industry needs. As a result, relevant activities and plans were collected from 8 sites (NCI-SW, NanoEarth, MANTH, NNF, RTNN, NNI, SENIC, and CNS) and summarized in the meeting minutes (see below). A Dropbox was also created to share documents.

The meeting minutes were distributed to the E&O Coordinators at all sites, with a request that the other 8 sites also each provide a similar summary. The objective was to produce a network-wide record of the relevant activities and goals in the focus areas. Inputs were obtained from MINIC and nano@stanford, and the information was used to create an updated summary of site activities (see Table 12 below, which contains the names of the site representatives).

A follow-up teleconference was held on 12/13/17, with 10 people participating in the call from 8 sites (MANTH, MONT, nano@stanford, NanoEarth, NCI-SW, NNF, NNI, and RTNN). Representatives from CNS and SENIC were unable to call in due to last-minute scheduling conflicts. Key items discussed during the call include the following (the meeting minutes with more detailed information is under preparation).

1. Industry surveys

| | |
|---|---|
| - Who to send surveys to? | In earlier surveys, targeted audience include: (a) industry users of cleanroom, (b) databases from local/regional industry associations, and (c) facility managers' contacts. |
| - Best practices: | Uploading these to the WG's Dropbox viewed as most practical way to disseminate information network-wide. |

2. Community college engagement

| | |
|---|---|
| - Faculty: | Need to increase their awareness of nanoscale science and technology. |
| - Students: | Should emphasize self-advocacy for students ("I too can be a nanotechnologist"). |
| - Marketing: | Sites to (a) collect/develop material for faculty awareness for network-wide use, and (b) review industry survey data and connect marketing materials with industry feedback. |

3. Next steps

| | |
|---|---|
| - CC Database: | Create database of CC interactions for all sites. |
| - Review of existing surveys: | Sites to identify key points in industry survey data for use in marketing material development to drive student demand. |
| - ATE proposal? | Explore with ATE program manager at NSF on the feasibility of a multi-site proposal to work with CCs. |

NNCI Workforce Development and Community College Working Group

Minutes of Kick-off Meeting

*Thursday 27th April 2017, 1PM- 2PM PDT*

Attendees: Ray Tsui (WG Chair), Arizona State University

Debora Berti, Virginia Tech

Kristin Field, University of Pennsylvania

Terese Janovec, University of Nebraska-Lincoln

Trevor Thornton (Workforce Development Subcommittee Chair), ASU

The following people were unable to call in to the meeting due to conflicts, but provided site information and other inputs separately:

Maude Cuchiara, North Carolina State University

Nancy Healy, Georgia Tech

Dan Ratner, University of Washington

Bill Wilson, Harvard University

Introductions and summary of site activities:

- ASU is partnering with Rio Salado College to support the laboratory component of their AAS degree in Nanotechnology. For its 2017 REU program, 4 students were selected from CCs in the region, including 2 from rural schools.
- Virginia Tech has established connections with the faculty at two liberal arts colleges in VA, Longwood University and Roanoke College, and at the Kingsborough Community College of CUNY, to provide their students training and instrument time.
- Penn is partnering with the Community College of Philadelphia (CCP) to develop a training program for nanotechnology technicians. Local industry has been engaged to determine their workforce needs through presentations, one-on-one conversations, and a survey. While CCP programs including a 2-year degree and a 16-credit certificate are being considered, initial efforts may focus on the development of introductory course.
- At the University of Nebraska-Lincoln, conversations with regional CCs have been initiated and some faculty have toured the UNL facilities. A workshop was also held to introduce the site's capabilities to industry.
- For the RTNN, NCSU hosted a 2-day CC workshop that had 9 participants. Nanofabrication was introduced to the group, and samples were provided for familiarization with characterization methods. There were also discussions on how to incorporate nanotechnology into STEM curricula. Year 2 of this workshop will be held at UNC-Chapel Hill.
- At UW, cleanrooms are used by students from North Seattle College's Nano AAS program for labs. Furthermore, some of them join UW students as paid interns in the cleanrooms. The interns become proficient with tools and processes. Many are funded by fees from industry users, with some being hired eventually by the companies. This cohort

is being supplemented in 2017 by high school seniors from one of the region's tribal nations.

- For SENIC, the Joint School of Nanoscience and Nanoengineering hosts 4 interns per year from Forsyth Technical Community College, which has the only 2-year nanotechnology degree program in NC. There have been 24 interns to date, with 2 hired as technicians in JSNN's cleanroom. Meanwhile, Georgia Tech will re-submit a ATE proposal to NSF jointly with Atlanta Technical College, following a previous attempt that was unsuccessful. GT also hosted an intern from Athens Technical College which has an AAS degree in nanotechnology.
- In addition to a conventional REU program for undergrads from 2- and 4-year institutions, Harvard continues to work with Bunker Hill Community College to provide training and research opportunities (including a REU-like program) for returning veterans.

Discussion

- For collaborations with CCs to become successful, getting local industry involved as well is very important. CCs need to know technician jobs are available for their graduates. Surveys are good vehicles to gauge industry needs, but are time consuming since a lot of following-up is needed to generate sufficient responses to have the information be representative. Examples of surveys conducted by GT and ASU were described. The survey forms used were essentially identical since they were based on a template developed at Penn State. The survey results also showed a lot of similarities. Incidentally, basically the same survey form was used by Penn.
- Attendees of the call were reminded that a Dropbox has been created and its link shared. The Dropbox contains information related to the GT and ASU surveys mentioned above, as well as flyers for upcoming conferences for 2-year colleges involved with STEM education. It was mentioned that these conferences could present good opportunities to network with CCs and become more engaged.
- The next steps for the WG were discussed. The present call was geared towards NNCI sites that have expressed interest in topics related to collaborations with CCs as well as workforce development. There was consensus that an effort be made to engage all NNCI sites, so there is better information exchange and coordination across the entire network.
- In a follow-up call, Dan Ratner at UW suggested that sites with well-established programs with CCs should also discuss what could be potential next steps. He mentioned the possibility of expanding the education/training to cover technicians already in the workforce to update or upgrade their skills.

Action Items

- Share this document with all sites and ask for updates from all on activities related to work-force development and interactions with CCs.
- Schedule another call, and invite all sites to participate and discuss how to move forward in the focused areas of the WG.

The following is a 2017 summary for NNCI sites that have reported activities related to workforce development and community college (CC) engagement. It is updated with information collected during the October NNCI Conference and from site websites. Contact information for obtaining more information from each site is also included.

Table 12: Summary of NNCI Workforce Development and Community College Activities

| | |
|---|---|
| CNS | In addition to a conventional REU program for undergrads from 2- and 4-year institutions, Harvard continues to work with Bunker Hill Community College to provide training and research opportunities (including a REU-like program) for returning veterans.<br><br>(Bill Wilson: wwilson@cns.fas.harvard.edu) |
| MANTH | Penn is partnering with the Community College of Philadelphia (CCP) to develop a training program for nanotechnology technicians. Local industry has been engaged to determine their workforce needs through presentations, one-on-one conversations, and a survey. While CCP programs including a 2-year degree and a 16-credit certificate are being considered, initial efforts may focus on the development of introductory course.<br><br>(Kristin Field: kfield@seas.upenn.edu) |
| MINIC | Minnesota (UMN) is in its 13th year of working with a community college. Students from the Nano-Link program at Dakota County Technical College spend their 4th semester capstone in UMN's cleanroom. Kits to replicate lithography and etching processes are being developed for use in places without cleanrooms. UMN is also providing teacher training and lab internships for CCs.<br><br>(Jim Marti: jmarti@umn.edu) |
| nano@stanford | Stanford is partnering with a Cañada College faculty to use the SEM for characterization work and to develop experiments for her students. There have also been class visits from Foothill College, another 2-year school.<br><br>(Angela Hwang: aahwang@stanford.edu) |
| NanoEarth | Virginia Tech has established connections with the faculty at two liberal arts colleges in VA, Longwood University and Roanoke College, and at the Kingsborough Community College of CUNY, to provide their students training and instrument time.<br><br>(Debora Berti: dberti@vt.edu) |
| NCI-SW | ASU is partnering with Rio Salado College to support the laboratory component of their AAS degree in Nanotechnology. For its 2017 REU program, NCI-SW selected 4 students from CCs in the region, including 2 from rural schools. A talk highlighting the NNCI's interest in working with CCs was presented jointly with SENIC at the 2017 Micro Nano Technology Conference that is geared towards 2-year schools and technician education.<br><br>(Ray Tsui: raymond.tsui@asu.edu) |

NNF At the University of Nebraska-Lincoln, conversations with regional CCs have been initiated and some faculty have toured the UNL facilities. A workshop was also held to introduce the site's capabilities to industry.

(Terese Janovec: tjanovec@unl.edu)

NNI At the University of Washington, cleanrooms are used by students from North Seattle College's Nano AAS program for labs. Furthermore, some of them join UW students as paid interns in the cleanrooms. The interns become proficient with tools and processes. Many are funded by fees from industry users, with some being hired eventually by the companies. This cohort is being supplemented in 2017 by high school seniors from one of the region's tribal nations.

(Dan Ratner: dratner@uw.edu)

RTNN NCSU hosted an inaugural 2-day CC workshop that had 9 educators in attendance. Nanofabrication was introduced to the group, and samples were provided for familiarization with characterization methods. There were also discussions on how to incorporate nanotechnology into STEM curricula. Year 2 of this workshop was held at UNC-Chapel Hill. A desktop SEM has also been designated for education use.

(Maude Cuchiara: maude_cuchiara@ncsu.edu)

SENIC The Joint School of Nanoscience and Nanoengineering hosts 4 interns per year from Forsyth Technical Community College, which has the only 2-year nanotechnology degree program in NC. There have been 24 interns to date, with 2 hired as technicians in JSNN's cleanroom. Meanwhile, Georgia Tech will collaborate with Atlanta Tech if the latter's ATE proposal for teacher training in nanotech and biotech is funded. GT also hosted an intern from Athens Technical College which has an AAS degree in nanotechnology.

(Nancy Healy: nancy.healy@ien.gatech.edu)

### 6.10 Evaluation and Assessment

A new working group on Evaluation and Assessment was created in year two. At its first meeting, the group discussed what the needs of sites might be in terms of assessing programs and what would be feasible based on the scope of NNCI education and outreach activities. Two of the members of the group are evaluators at their sites (Mary White, NCI-SW and Carolyn Plumb, MONT) which has been very beneficial in directing our focus.

The first order of business was to collect survey instruments that were previously used under NNIN, used by other programs at the WG member sites, and instruments developed under NNCI by WG member sites. Once collected, Mary White and Carolyn Plumb developed categories for the instruments and placed each of the instruments into these categories in a Dropbox folder. The Dropbox folder has been shared with all NNCI sites that can then adopt and adapt the instruments to meet their own needs. Sites not part of the WG have been encouraged to submit their own instruments and both nano@Stanford and TNF have uploaded additional instruments.

The categories are: 1. Evaluation plans/logic models; 2. Facility Satisfaction Assessment; 3. Outreach Assessment; 4. RET/Teacher Workshops; 5. REU; 6. K-12 Student Nano Content; 7.Workshop Assessment.

The WG met by conference call in December 2017 with all members present. We met to discuss how to ensure that sites are evaluating some of their E&O activities and that the results are presented in the NSF annual reports and at the NNCI Conference. The suggestion was made that the presentation template used by sites for the annual conference should include a section on evaluation results of E&O. This recommendation will be forwarded to the Coordinating Office. It was also recommended that all sites do their best to collect participant demographics such as race, gender and ethnicity to be aggregated to determine scope of impact. This is part of the collection template that has been distributed to sites and a reminder will be sent regarding this collection.

The group had a discussion of what are we to collect and what does NSF seek with regards of impact of E&O. We all agreed it is difficult to assess large public events and some K-12 events. Mary White will send the group links to sites that will assist us in determining the type assessment that can be determined for a variety of E&O activities. Our next meeting will discuss these and how they can be used by NNCI sites.

Finally, a discussion arose about how many sites are increasing interest in STEM yet some institutions do not have the capacity to meet enrollment demands. While this is not a problem for all sites, it was felt that the WG should explore how to present career and education path options for students in the STEM pipeline. The group will explore what metrics we should use to examine who we are reaching and encouraging in our efforts.

Members: Nancy Healy (SENIC-GT), Carolyn Plumb (MONT), Tonya Pruitt (NanoEarth), Matt Hull (NanoEarth), Dan Ratner (NNI), Ana Sanchez Galiano (KY MMNIN), Ray Tsui (NCI-SW), Mary White (NCI-SW)

### 6.11 Online Technical Learning

The Technical Content Development working group is still in its infancy as it was formed this Fall 2017. To date, it consists of three NNCI sites: RTNN, MANTH (UPenn), and nano@stanford, and we have begun to meet on a monthly basis. Each of these sites have been developing or in the process of developing online resources for users and the general public to utilize. We have begun to leverage our NNCI network by aggregating some resources with an online collaborative document that can be used to support the NNCI webpage. We hope to see more integration in each other's online courses as well as sharing more network materials in the future as the collaboration grows.

**RTNN** has debuted a full Coursera course entitled "Nanotechnology: A Maker's Course", which encompasses nanoscale fabrication and characterization tools. These modules in particular are catered to audiences with some high school chemistry and physics background. Since launching the course, they have seen 5,500 visitors, over 2,000 enrolled students, and almost 70 course completions. Demographics show 30% of students are primarily in based in India, 80% are male, and 60% are ages 18-34. Looking forward they plan to connect students to their institutions and facilities, update and modify course based on course feedback and survey data, as well as integrate more active components into the course like live online Q&A sessions.

**UPenn**, our newest member, has an excellent repository of protocol and report documentation on their Scholarly Commons site. Eric has already shared a few of his own documents and we will be working together to find a method to integrate the information there into the other online resources.

**nano@stanford** has also developed an online course that is more geared towards supporting staff in training users or potential users. Our course is entitled "NanoFab01", which is an ongoing as we add more tool and processing sections (utilizing information from our current web pages, and creating new material), and also as we add and change tools and procedures in our ever-evolving facilities. Since launch of our course, we have seen almost 4,000 visitors--currently our course does not have any requirements to enroll but are reevaluating. Demographics show 55% of students are based in US, 70% are male, and 55% are ages 26-40. We are continuing to build more modules on a wider set of tools and have offered graduate student fellowships to further document training and/or novel procedures. Along with adding more content, we plan to update and modify based on course feedback, as well as integrate more of the NNCI network's resources to build a strong resource library.

Members: Maude Cuchiara (RTNN), Eric Johnston (MANTH), Angela Hwang (Stanford)

# 7. NNCI Network Promotion

## 7.1. Marketing and User Recruitment

Marketing and user recruitment strategies vary widely across the NNCI network, based on particular site local and regional needs and situations. During the January 2017 NNCI Conference, a breakout session on marketing and user recruitment identified a number of strategies as a way to help sites develop their plans to increase facility usage. While much of the focus is on recruiting new external users, many of the approaches and best practices apply to internal users, particularly non-traditional users, as well. Some sites have staff with external user engagement as a primary job responsibility, while other sites do this on a more ad hoc basis. Previous NNIN sites generally seem to have a more mature marketing strategy based on previous trial and error, although most new sites have significant pre-NNCI experience with external users as well. Challenges to any marketing strategy include the often significant time lag between when a certain marketing tactic is employed and when actual usage may happen. This can make it particularly difficult to gauge the effectiveness of various approaches. Certain NNCI sites also possess geographic advantages and a built-in clientele of tech companies, start-ups, and other academic users, while other sites need to work hard to engage non-traditional users. Finally, IP concerns and overly burdensome access agreements can often discourage new users.

*Marketing Strategies:*

1. Engage former users – either internal users moving on to industry or external users that change jobs.
2. Word of mouth advertising.
3. Connect with regional (county) economic development offices – this was seen as something easy to do, but not necessarily very successful.
4. Find start-up companies that have SBIR funding, particularly those outside the university community that may not be aware of resources.
5. Build a good web site. The group noted that typical site websites list equipment, but that potential users would be better served by an applications-focused site.
6. Hold open houses. This approach has been met with mixed success from different sites, but it helps build awareness of capabilities.
7. Exhibit as a vendor at conferences/tradeshows. This approach has also been met with varying degrees of success. Choosing an appropriate conference seems to be a key here to connect with the right audience.
8. Cold calls. Generally seen as ineffective.
9. Produce a single summary slide of your site for faculty to present at meetings and conferences.
10. Print advertisement. One site tried this without success.
11. To increase internal users, work with departments to recruit faculty that will take most advantage of the shared facility infrastructure.
12. Post SOP documents online. These show up in internet searches as people are trying to learn about a technique and provide simultaneous advertisement for your facility.
13. Assemble a database of current/potential users to track contact/usage.
14. Coordinate with other non-NNCI core facilities. This casts a wider net for potential users who are already using facilities in your university.

15. Hold vendor workshops. This helps build relationships with your vendors while leveraging their contacts to help promote your facilities.
16. Work with other research centers on campus. Many research centers may have sponsored research activities with companies and they may also be interested in core facilities access, but aren't aware of what is available.
17. Provide user grants to promote initial usage. Small grants (~$1000 seemed to be a common number) are provided with a simple application to get small companies and startups in the door.
18. Use social media. Many sites seem to recognize the importance of social media, but are just beginning to explore.
19. Develop webinars. This is a good way to fulfill an educational/outreach component while advertising your capabilities.
20. Evening classes/short courses.
21. Interact with less well-equipped universities/colleges in your area and make sure they know they can leverage your site's equipment in grant proposals, etc.
22. Prepare industry-specific marketing materials. Not all of the tools and techniques at your site are applicable for all potential users, so target your capabilities to the potential customer.

*Best Practices:*

1. Provide excellent customer service.
2. Make a personal connection with users and be sure to follow up.
3. Make usage/access easy. Try to minimize the bureaucratic red tape associated with onboarding a new user.
4. Provide quick turnaround times.
5. Provide users with a single point of contact for your site.

The consensus of the sites is that the role of the Coordinating Office in marketing and user recruitment efforts should include the following:

1. *Represent the network at national conferences.* An exhibit booth was hosted at the May 2017 TechConnect conference outside Washington DC. Staffing of the booth was provided by volunteers from MANTH, SENIC, RTNN, and NanoEarth. Suggestions for additional conferences for national attention were solicited from the sites. Collateral at the booth was provided by sites. In addition, banners and an NNCI flyer were prepared by the Coordinating Office. Several individual sites also hosted booths at this national event. In addition, a new section of the NNCI website was created to highlight participation by NNCI sites at expos and other regional and national expos, trade shows, and conferences.

2. *Provide an NNCI website with tools and expert databases.* At the January 2017 NNCI Conference, there was significant discussion about the website and a desire to present a more applications-focused user experience. It should be noted that during the first year of its existence (2017), the website contact forms generated approximately 25 inquiries related to becoming a new user, education/outreach, or other general information. This resulted in 10 referrals of potential users to NNCI sites for follow-up. More discussion of the website is provided below.

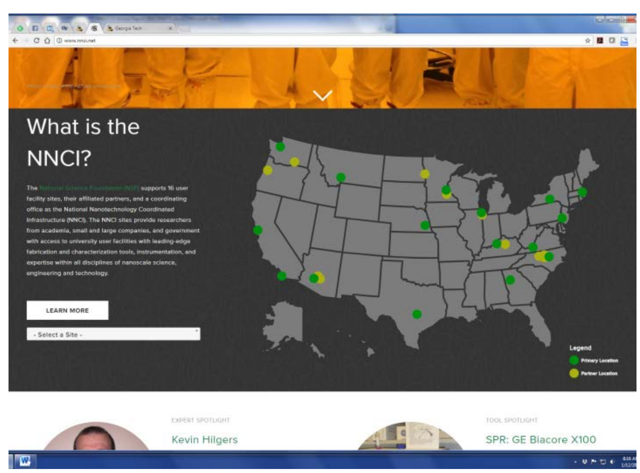
3. *Create an NNCI email list.* During 2017, a listserve was created for subscription by all interested NNCI site staff to share information on site activities, as well as provide another mechanism for sites to solicit assistance on technical and user support matters. Currently there are 68 subscribers to this email list.
4. *Create an NNCI newsletter for periodic distribution by all sites.* This is currently under discussion.

### 7.2. NNCI Website

During the first year of the NNCI Coordinating Office, one of the main activities was the creation of a web portal (www.nnci.net) to provide a comprehensive list of tools and experts available within the network for both user recruitment and support. The design of a new, comprehensive website was predicated on the desire to accommodate the different needs of users, potential users, the public, and NNCI staff. The design concepts and structure of the website were reported in detail in the Year 1 report, and here we report on upgrades made during Year 2.

The original launch of the NNCI website (December 2016) included the following basic components:

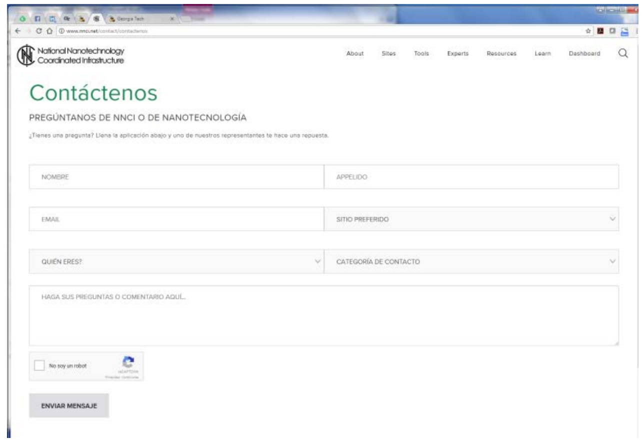
1. Overall design implementation
2. Basic NNCI information
3. Individual site pages
4. Tool database (>2000 tools)
5. Experts database (>200 experts)
6. Contact forms (general information and new user gateway)
7. Education and outreach content (including REU and site-specific information)
8. SEI programs (including site-specific information)
9. Additional resources (other nano infrastructure, link to computation at nanoHub)
10. NNCI news blog




Beginning in March 2017, and with input from site directors, site staff, the External Advisory Board, and our website vendor (Cool Blue Interactive), planning began for the website's Phase 2 development. This plan included changes that improved on existing content and design elements, as well as implemented new features and content. Phase 2 was launched in 2 steps in October 2017 and January 2018.

1. Improvements to Home page
    a. Preview image for blog post on home page
    b. More "Did you know?" content

   c. Addition of global website search capability
   d. Changes to NNCI site map
      i. Added new drop-down menu
      ii. Changed colors to better differentiate primary and partner sites
      iii. Ability to edit map sites
2. Improvements to contact forms
   a. Multiple email recipients allowed
   b. Use of Captcha for improved spam detection
   c. Improved email formatting
   d. Added Spanish language Contact Us form (this was achieved with the support of Spanish-speaking staff at RTNN who have taken on responsibility for responding to inquiries via this form)




3. Improvements to tools/experts database searches
   a. Changes in tool taxonomy
      i. Allow use of multiple categories for tools
      ii. Allow un-restricted searching across categories
   b. Design refinements
      i. Improved visibility of "Search" in Tools and Experts pages
      ii. List number of search results
      iii. Automatic scroll down to results
      iv. Consistent styling of drop down boxes
      v. Expert detail page added site name and cleaned up format
4. Improvements to site pages
   a. Include longer site descriptions
   b. Editable site contacts with a link to full staff contact list
   c. Site-specific tool spotlights
   d. Links to individual site facilities
   e. Enhanced map features
5. Alternative to 3rd level menus which provides improved navigation of the Learn pages
6. Fixes to Nanooze page

In addition, since the original launch new content has been uploaded including:

1. News items on the blog
2. NNCI Annual Reports
3. NNCI Annual Conference agendas and presentation materials
4. NNCI On the Road (updated list of upcoming NNCI site presence at meetings and conferences)
5. Diversity Statement
6. K-16 Educator Resources

Items remaining within the Phase 2 development plan include:

1. Private pages for working group activity. The code for this feature has already been implemented, but this has not been rolled out to working group leads and members yet.
2. Add a new homepage section highlighting application and fabrication proficiencies, with links to sites possessing that experience and capabilities. This is content that was desired by sites and the EAB, and will require significant input from sites to implement. Creation of this content is planned for 2018.
3. Updates to site detail pages and tool/experts databases.
4. Creation of a materials matrix, indicating which materials can be processed at different sites.

Google analytics for www.nnci.net indicate that in calendar year 2017 there were more than 13,000 visitors to the website (68% new visitors, 32% returning visitors) with 84.5% from the US. The average session duration was more than 3 minutes, with an average of 3.2 page views/session. During this time period, the top ten pages visited are shown below:

| **Page** | **Pageviews** |
|---|---|
| / | 13498 |
| /research-experience-undergraduates | 4955 |
| /sites/view-all | 4626 |
| /search/tools | 2475 |
| /about-nnci | 1996 |
| /search/experts | 1744 |
| /welcome-nnci-learn-and-explore | 1158 |
| /learn | 820 |
| /resources | 816 |
| /reu-university-washington-nni-clean-energy-bridge | 697 |
| | Total: 61377 |

Site acquisition (how visitors get to the website) is primarily through three routes: organic search, direct, and referral from another website (see Figure 9).

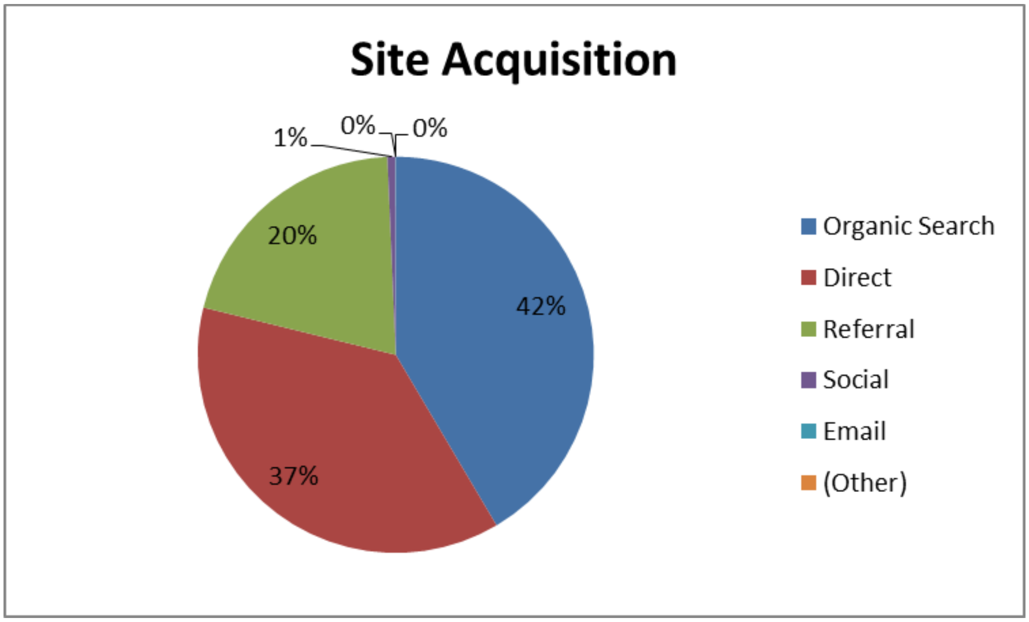



*Figure 9: Site acquisition (how visitors get to the website) for www.nnci.net*

### 7.3. NNCI Video

In July 2017, after discussion during the monthly site director's conference call, a decision was made to contract with an external vendor for production of a short video to promote NNCI for general awareness and public relations purposes. Based on her past experience working with NSF programs, Dr. Kirsten Sanford of Broader Impacts Productions was hired to develop and produce a 3-5 minute video. Initially, a set of points to guide the messaging of the video storyline were developed:

- Nanoscale science and engineering is a research area that can provide significant technical advancement as well as economic growth.
- The infrastructure and expertise for performing this research are intensive and costly, and not available to all those without the financial resources.
- The NNCI network (16 sites and their partners) provides researchers from academia, small and large companies, and government with access to university user facilities with leading-edge fabrication and characterization tools, instrumentation, and expertise within all disciplines of nanoscale science, engineering and technology.
- The network is geographically distributed for ease of access and is available at a reasonable cost.
- The program aims to make these capabilities broadly available to the nation's researchers in academe, industry, and government to help catalyze new discoveries in science and engineering and to stimulate technological innovation.
- In addition, the NNCI sites are expected to leverage their user facilities and staff to provide innovative education and outreach programs, and activities on social and ethical implications of nanotechnology.

Interviews with some key NNCI figures were scheduled to take place during the Annual Conference in October 2017 and a set of draft questions were also developed:

1. What is the NNCI?
2. What sorts of capabilities are available at the NNCI sites?
3. What do the NNCI facilities offer beyond access to state-of-the-art tools and expertise (e.g. training, workshops, collaborations, connections to industry)?
4. Outside of the site universities, who else can benefit from this resource?
5. Many of the 16 sites have local/regional partners? What do these partners add to the NNCI network?
6. As a national resource network for nanoscale science and engineering research, why did you choose to participate in this network?
7. All NNCI sites are also required to run programs in education and outreach for the broader public. What do you see as the importance of these activities and what are some examples of these programs?
8. How can the NNCI network achieve the objective of being more than the sum of its parts?

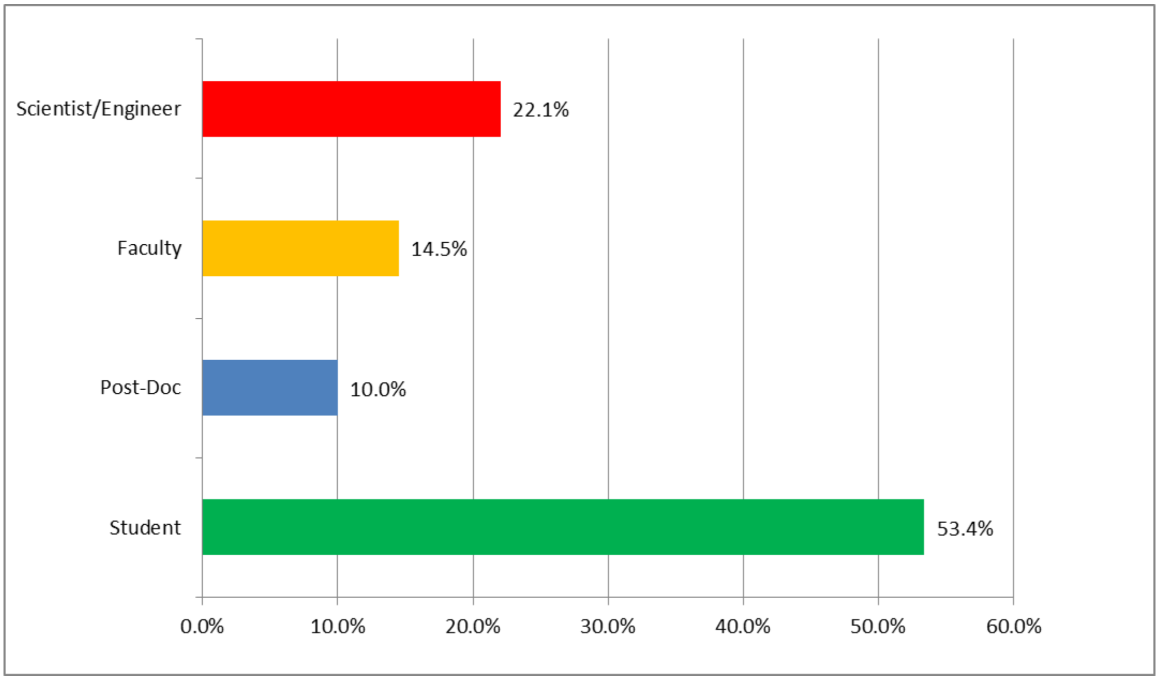
Finally, B-roll video was obtained from several sites (SENIC, RTNN, NNI, Stanford, SDNI, CNF, KY MMNIN, and SHyNE) consisting of both laboratory operations and education activities and this was provided to Broader Impacts. As of this writing, a draft version of the video has been created and final editing is in progress.

### 7.4. User Satisfaction Survey

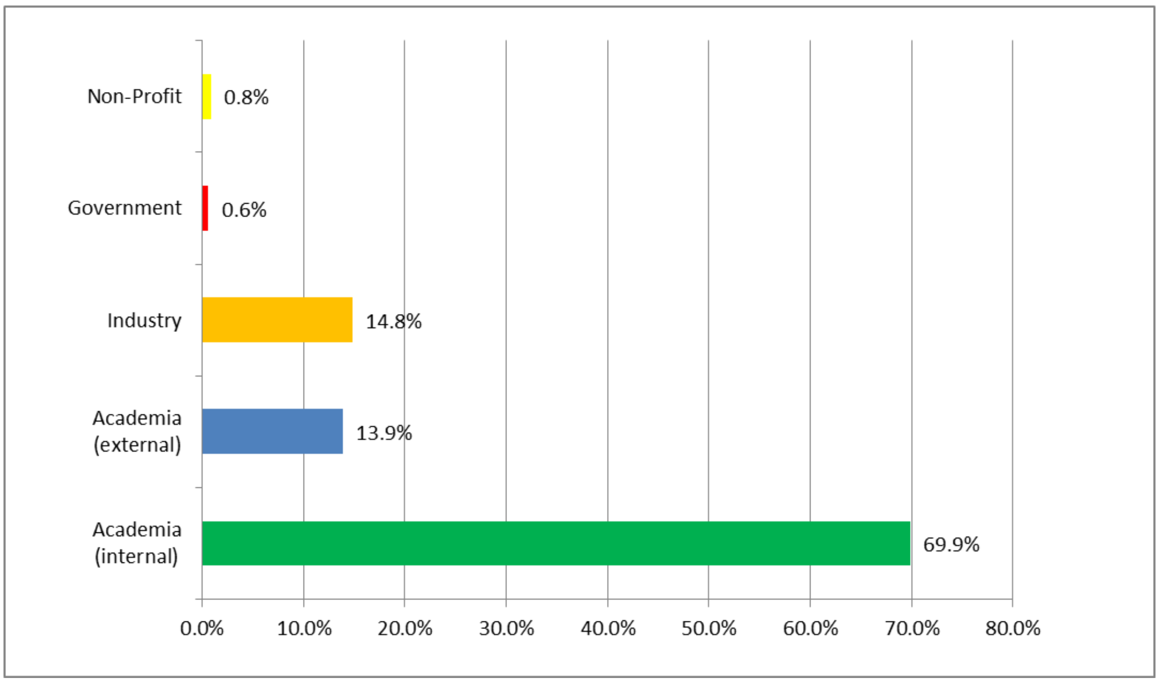
As a result of site director discussions, as well as recommendations from the Advisory Board, the Coordinating Office created a User Satisfaction Survey for implementation throughout the NNCI network. Using a *Survey Monkey* platform, the survey was made available to sites for forwarding to their user bases starting on October 11, 2017. As of January 4, 2018, 699 responses had been received from the ten sites which opted to participate. In addition, five sites had already developed their own internal surveys which generated an additional 634 responses. These separate surveys did not all use the same questions as the common version on Survey Monkey, but responses were added to the overall results when possible. One site did not participate in any user survey this year, but plans to in future years. Based on this first year of the common survey suggestions include addition of a question on safety (Did the user feel health and safety practices were satisfactory?) and refinements to some of the existing questions.

In total, more than 1300 respondents (approximately 10% of users) participated in either the common or individual site surveys. The site-specific filtered results, with comments, were provided to individual sites for identification of action as needed. The results below are from the network aggregate data (15 sites) with the number of responses (N) indicated.

User Status (N=839)



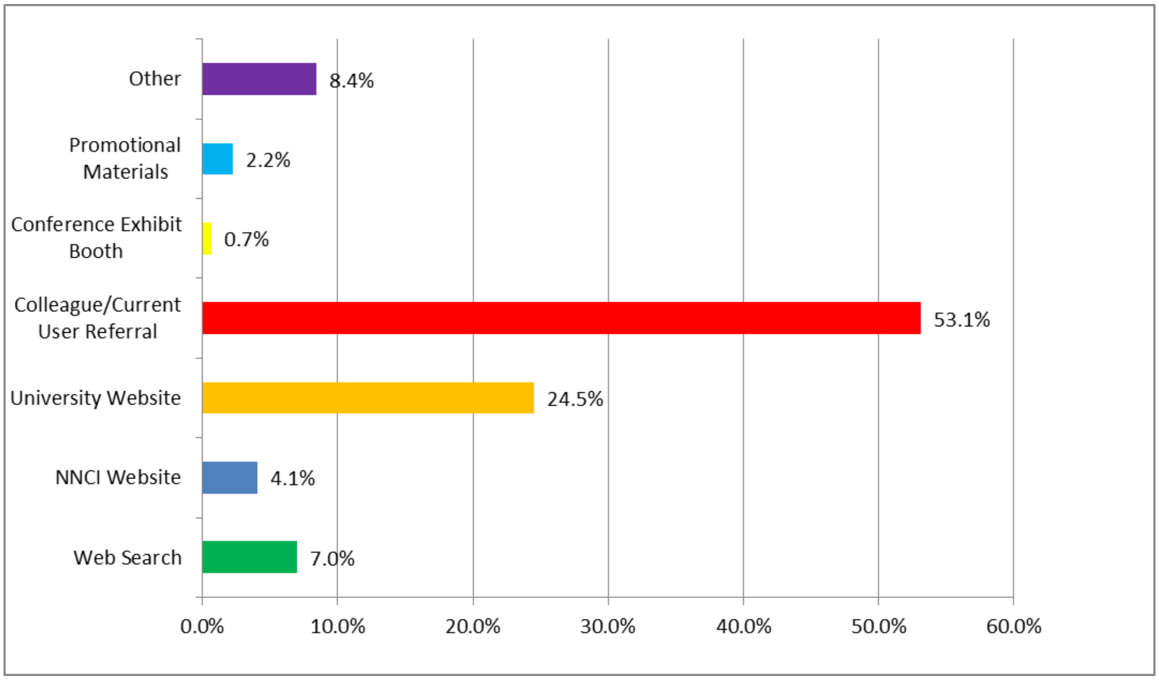

User Affiliation (N=844)



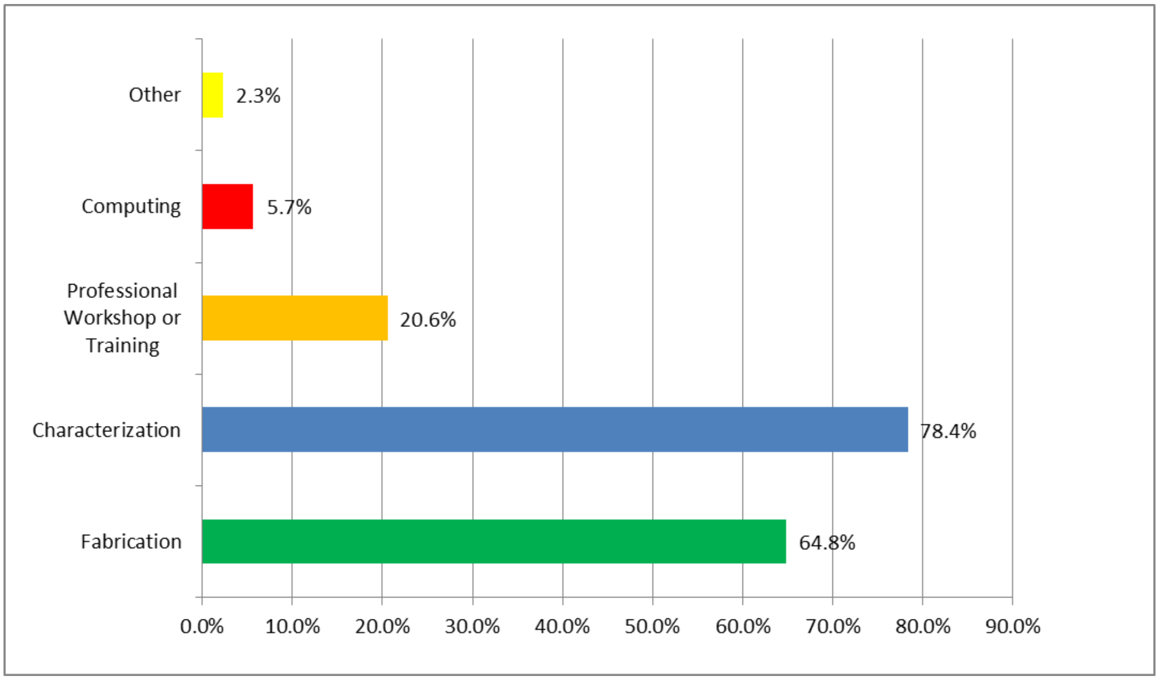

Which site(s) are/were you a user at?

The number of responses from each site varies from 12-277. In addition, some users indicated multiple sites, which may be due to sequential usage (e.g., as an undergraduate or graduate student at one site and then as an industry researcher at another) or parallel usage of more than one site. In future years, responders will be asked to indicate their most recent usage only.

How did the user find the NNCI site? (N=742)




Which services were used at the NNCI site? (N=1021)



<u>Where you able to complete your project in a timely manner? (N=721)</u>

Yes: 93.6%

No: 6.4%

<u>Would you recommend this site to a colleague? (N=1015)</u>

Yes: 97.3% (The range of positive responses by site was 90-100%.)

No: 2.7%

<u>Provide an overall rating for the site facilities (1=Poor, 2=Fair, 3=Good, 4=Very Good, 5=Excellent). (N=1017)</u>

Network Average: 4.36, with 85.7% responding Very Good or Excellent

<u>Provide a rating of your overall experience of the NNCI site (1=Poor, 2=Fair, 3=Good, 4=Very Good, 5=Excellent). (N=748)</u>

Network Average: 4.43, with 88.4% responding Very Good or Excellent

In addition, more than 100 individual comments were provided, both positive and negative, and a selection of these is provided here:

*“This is an excellent facility especially for a growing small business like ours. It helps us a lot to prototype and debug our designs in a timely fashion. Excellent work! Thanks!”*

*“The director and staff scientists are superb and the facility is fantastic. The ease of access to characterization tools coupled with the knowledgeable staff has bolstered my research productivity and served as an added educational opportunity for my undergraduate research students.”*

*“This site is doing an outstanding job and plays a central role in enabling us to carry out competitive research and education. The support from NNCI makes a difference and is absolutely necessary if we want to maintain a vibrant innovation ecosystem to sustain future economic growth in the US.”*

*“This site is a great place to do research in nanofabrication. Staff is very supportive and skilled. The availability of a comprehensive set of tools is critical to accomplish complex projects without keep moving around different fabs. However, some tools are old and need updates or replacement.”*

*“Fantastic facility. As an undergraduate, I've gained so much experience and enjoyed working hard in research. My opportunity to work here has encouraged me to pursue a graduate degree and has definitely strengthened my applications for grad programs.”*

*“The site will benefit from continued growth, especially in engineering staff.”*

*"Some of the staff do not involve in intellectual thinking or scientific discussion, and do not seem to be interested in user's projects. They behave as this is the tool, I teach you how to use as it is configured now, don't ask more."*

*"Facility managers are adequately helpful. However, user training is poor. Certification to use a certain instrument needs to be more stringent."*

*"It takes a lot of time to get into their systems. A lot of bureaucracy and complications for external users…I wish I had to deal with just one group/person not like now that I have to go through multiple departments to get my work initiated. The infrastructure is amazing! I keep coming back."*

# 8. NNCI Annual Conference (October 2017)

In the proposal for the Coordinating Office, it was suggested that "A flagship event for the NNCI network will be the annual ***NNCI Conference***, which will be held at different network sites and will not only highlight the research supported by the NNCI facilities, but also provide a venue to share best practices as a result of the work of various working groups and committees." It was further detailed: "The Coordinating Office will work with the site directors to organize the annual ***NNCI Conference***, which will be held each year at a different NNCI site. The conference attendees will include the site directors and other site management personnel, the External Advisory Board, as well as NNCI site staff who are members of the working groups. As mentioned above, individual working groups might organize parallel sessions where findings in the specific topical area can be shared with other interested NNCI staff...We envision a 1.5-2 day meeting, that includes half-a-day of network overview and site presentations, half-a-day of user presentations, possibly in parallel sessions, and at least a half-a-day of time for dedicated panels on E&O, SEI, computation and select working groups (safety, vendor relations, etc.). The goal is to have a working meeting that strengthens the network and its sites, helps with future planning and is not just a review. As an example, each year's conference could have a dedicated panel on "Emerging Research Areas", using invited talks to stimulate discussion among the NNCI sites on promising future research directions and the tools required to support these. We also envision that satellite events, such as an SEI Conference, could be organized in conjunction with the annual NNCI Conference. Poster and presentation awards as well as certificates for certain panel participation may be a way for student and staff development, respectively, as part of the annual event."

The first NNCI Conference was held on January 18-19, 2017 at the Georgia Institute of Technology (SENIC site) in Atlanta, GA. Based on the results of attendee, EAB, and NSF feedback, adjustments were made to future conferences. It was concluded that a fall meeting date was more compatible with the NNCI year and the desire to collect information in advance of the annual reporting date to NSF (Jan.-March). Furthermore, while the initial desire was to include attendees outside of the NNCI community, it was felt that the limited time for the meeting was better spent discussing issues specific to NNCI rather than the broader topics that might be covered at other meetings such as the annual NSF Nano Grantees meeting or the biannual UGIM conference.

The second annual NNCI Conference was held October 16-17, 2017 at the University of Pennsylvania (MANTH site) in Philadelphia, PA. The 1.5-day event had an attendance of nearly 80, including 14 site directors (and 2 co-directors), 7 of 10 advisory board members, Dr. Larry Goldberg and Dr. Kershed Cooper, NSF program directors, Dr. Lisa Friedersdorf, Director of the NNCO, as well as three invited speakers (see photo below). The invited lectures were used to highlight an NNCI user, an emerging research area, and a comparison to another shared facility network. The titles of their talks are:

- Prof. Mehdi Javanmard (Rutgers University): "Electro-Fluidic Micro- and Nanotechnologies for Health and Environmental Monitoring"
- Prof. Eric Stach (University of Pennsylvania): "Advanced Electron Microscopy at the Singh Nanotechnology Center"
- Dr. Andrew Fung (CMC Microsystems): "Canada's National Design Network (CNDN) and Tapping into Nanolabs"

The agenda also featured:

1. Presentations by the Director and the three Associate Directors of the Coordinating Office with an NNCI Overview and Reports on Education & Outreach, Societal & Ethical Implications and Modeling/Simulation, respectively.
2. Short site reports from each of the 16 NNCI sites. To assist with the flow of these reports, each site was provided a template presentation to follow. The reports were grouped into four panel sessions, each with a different theme. Each site presenting in that panel provided one slide on the topic and participated in the open discussion. These themes were:
    - Redefining Traditional Users
    - Resource Allocation and New Equipment
    - Future Research Directions
    - New Education and Outreach Concepts
3. Four breakout groups in 2 sessions with subsequent reporting back to all attendees. Topics included: Facility Management and Operations, Diversity, New Business Development Concepts, and Training Programs and Workshops.
4. A separate half-day meeting of the Education and Outreach Coordinators held in parallel with the breakout sessions.
5. A meeting of SEI coordinators held immediately after the main conference concluded.
6. Separate meetings of the External Advisory Board and the Site Directors/Coordinating Office. The Advisory Board discussions resulted in a written report to the Coordinating Office which is attached here as Appendix 13.2.

Both the Coordinating Office presentations and the site reports are provided, along with the full meeting agenda, on the NNCI website at http://www.nnci.net/nnci-annual-conference.

Future NNCI Conferences are scheduled for the following locations:

- 2018 Annual Conference, University of Washington (NNI), September 13-14, 2018
- 2019 Annual Conference, Cornell University (CNF)
- 2020 Annual Conference, Northwestern University (SHyNE)

# 9. Cooperative Network Activity

The NNCI sites and coordinating office made a concerted effort during this program year to develop and engage in activities that demonstrate the network "whole being greater than the sum of its parts." These activities include the following: (1) activities where all (or nearly all) NNCI sites participated, (2) activities with multiple NNCI site partners, (3) activities which involved interactions between NNCI sites, and (4) activities where a single NNCI site acted on behalf of the entire network. Below are provided examples of such activities during the first two years of the NNCI program.

<u>Network-Wide Activities</u>

1. Participation in National Nanotechnology Day Activities (October 9, 2016 and 2017)
2. Attending NSF Nano Grantees Conference (December 2016 and 2017)
3. Attending NNCI Annual Conference (January 2017 and October 2017)
4. Sending students to REU Convocation (August 2017)
5. Chairing and membership of Subcommittees
6. Leading and membership of Working Groups
7. Participation in NNCI site visits with the Coordinating Office
8. Providing content for the NNCI website
9. Participation in NNCI Workshops (Etch, ALD/MOCVD, Direct Write Lithography)
10. Discussions between site staff on equipment repair and maintenance issues
11. User referrals to other sites, via NNCI email list or responses to NNCI website contact form

<u>Multi-Site Activities</u>

1. USA Science and Engineering Festival: CNF and SENIC participated in the biannual USA Science and Engineering Festival in D.C. (next in April 2018).
2. Joint RET Proposal: "Research Experiences for Teachers across the National Nanotechnology Coordinated Infrastructure" (Arizona State University (lead), Georgia Institute of Technology, U. of Minnesota, U. of Louisville, U. of Nebraska-Lincoln). Six-week summer research experience, with continuing support during the following academic year, for 20 high school teachers and community college faculty with projects focused on nanoscale science and engineering. The program objectives are: 1) grow a national cohort of educators with experiences that reflect broad educational, industrial, and societal nanoscience and engineering (NSE) activities; 2) build and disseminate a library of NSE educational materials; 3) highlight the work of RET teachers/CCF at Professional Development Workshops; and 4) encourage RET participants to present at professional society meetings.
3. Japanese NNCI/NIMS Graduate Exchange Program (coordinated by CNF)

   a. 6 NNCI REU "alumni", from 5 different NNCI sites, participated in a program at NIMS during summer 2017
   b. 4 Nanotech Platform students were interns at NNCI Sites (Texas, Louisville, RTNN, ASU)
4. Joint marketing efforts (NNCI exhibit booth at Hilton Head Sensors, Actuators and Microsystems Conference, TechConnect, SERMACS)
5. MANTH hosted the Mid-Atlantic Cleanroom Managers' Meeting (50 attendees, including representatives from CNF)
6. Dave Mogk (MONT), Michael Hochella (NanoEarth), and Nancy Healy (SENIC) organized the "*Nanoscience in the Earth and Environmental Sciences – Research and Teaching Opportunities"* workshop for the 2017 Goldschmidt Conference (an international conference on geochemistry and related subjects). The workshop, moderated by Mogk and Hochella, introduced fundamental principles of nanoscience, with an emphasis on the instrumentation and facilities that are now available for characterization of naturally occurring and incidental nanomaterials, and to determine how chemical and physical behaviors deviate from bulk behavior at the nanoscale. Thirty-five people attended the workshop, and opportunities to participate in the NNCI were promoted.
7. NanoEarth and Stanford participated together in the NanoEHS Webinar Series: "The National Nanotechnology Coordinated Infrastructure (NNCI) Nodes and Environmental Research: Examples from the Field" moderated by Larry Goldberg, Senior Engineering Advisor, Directorate for Engineering, at the NSF.
8. RTNN, NNF and SENIC joined the Nanotechnology Applications and Career Knowledge Networks's Remote Access Instrumentation in Nanotechnology (RAIN) coordinated by Pennsylvania State University. NCI-SW provided a demonstration of its remote capabilities with RAIN at the first annual NNCI Conference as a recruitment tool for NNCI sites.
9. Multi-site Project Example: Dense, high aspect ratio through-silicon-via (TSV) array capability [SDNI (UCSD): TiN coating, SNSF (Stanford): XRR analysis, NNI (OSU): Ru coating, SENIC (GaTech): TiN/Pt coating]
10. NNCI ALD/MOCVD Symposium - Stanford and Harvard co-hosted this symposium April 2017 at Stanford University, with participation by 13 universities, including 9 NNCI sites.
11. Participation in SEI Programs:
    a. ASU Winter School on Responsible Innovation and Emerging Technologies. Thirteen students from four countries participated, including participants from NNCI sites at NC State University and University of Pennsylvania. Instructors included the SEI Coordinator from SENIC.
    b. Science Outside the Lab (SOtL). Thirteen participants from seven NNCI sites (ASU, Washington, Northwestern, NC State, Minnesota, U-Penn and Nebraska) participated in SOtL in June 2017.

<u>Site-Site Interactions</u>

1. User project support: Multiple instances of users from one NNCI site also using another NNCI site. In addition, referrals of users from one site to another are common and aided by a new NNCI email listserve as well as the NNCI website contact forms.
    a. A MONT user (Ph.D. student Tianbo Liu) has incorporated a processing step at Cornell (CNF) into his device development project, travelling two times to perform his work. Multiple MONT users made use of mask writing services at Minnesota (MINIC), while MONT faculty user Wataru Nakagawa is using e-beam lithography capability at UCSD (SDNI).
    b. RTNN connected users to other sites (example: Proton Induced X-ray Emission (PIXE) and Rutherford Backscatter Spectrometry at MANTH)
    c. CNF has assisted KY MMNIN and MANTH by providing processing support for their users.
    d. Coordinating Office referred potential users to RTNN, MANTH, SENIC, TNF, and others.
2. Equipment/parts backup/exchange:
    a. CNF and MANTH have exchanged spare parts (e.g. turbo pump) and materials (e.g. source gases) in times of exigent needs.
    b. SDNI provided loaner equipment to reduce downtime and fabrication services to MONT (electron beam lithography and dry etch).
3. Staff technical interactions:
    a. CNF and MANTH staff interact frequently on process and maintenance issues, particularly regarding plasma based tools (e.g. etchers, ALD)
    b. Mitsuhiro Murayama (NanoEarth) and Yuhwa Lo (SDNI) started a discussion regarding the user reference protocol development for TEM characterization services.
    c. RTNN assisted with guiding assessment strategies for the Texas Nanofabrication Facility
    d. SDNI hosted Stanford Facilities Director in March 2017 to discuss possible collaborations on high resolution TEM. SDNI connected faculty users to the Stanford TEM staff to pursue the collaboration.
    e. JSNN (SENIC) collaborated with RTNN to respond to a North Carolina state-wide call for proposals to request new research instrumentation.
    f. NCI-SW and TNF collaborated regarding Electron-Beam Lithography JEOL6000FSE troubleshooting.
4. Prof. Steve Campbell (MINIC) participated in a site review at NNF.
5. MONT's External Advisory Board (EAB) had its inaugural meeting on January 27, 2017 including board members Mike Hochella (NanoEarth) and Mark Allen (MANTH).
6. MINIC hosted a special seminar on science and public policy presented by NNCI's SEI leaders, Prof. Jameson Wetmore and Dr. Ira Bennett (both of NCI-SW).

7. MONT is exploring a close cooperation with Georgia Tech (SENIC) to link to their facility management software (SUMS), leveraging the extensive application development that GT has already done and applying it to the much smaller installation at MSU. If successful, this will save considerable duplication of effort and get MSU instruments online much more quickly and cost effectively than if this were done independently. Staff members at the two facilities are working together and with their respective university IT departments to define the problems and work out solutions.
8. Mitsuhiro Murayama (NanoEarth) is working with Lynn Rathburn (CNF) in support of a joint REU program with the National Institute for Materials Science in Tsukuba, Japan
9. NanoEarth is working with Arizona State University to inaugurate SEI activities
10. SDNI hosted Kevin Walsh, Director of KY Multiscale Manufacturing and Nano Integration Node (MMNIN) to discuss collaboration between the two sites.
11. RTNN has participated in JSNN (SENIC) annual Nanomanufacturing Conference and JSNN faculty and students actively participated in RTNN's Carolina Science Symposium (previously called MRS/ASM/AVS joint symposium).

Site Activity on Behalf of the NNCI

1. NNCI Promotion: CNF has promoted NNCI with vendor booths at the MRS, AVS, and EIPBN conferences.
2. Nanooze: CNF publishes Nanooze, and, in addition to direct distribution to classrooms, distributes it to all NNCI sites for use in their outreach activities.
3. NNCI Web Site: CNF provided the temporary NNCI.net web site until December 2016, assisted in the transition of content to the new NNCI web site, and maintains archival NNIN information that has not yet been transferred. Georgia Tech (SENIC) maintains the current NNCI website.
4. Disney NSF Science Portal: CNF is restructuring the Nanooze Disney exhibit into the Disney NSF Science Portal to promote NSF research, NNCI, and nanotechnology in general.
5. CNF and Georgia Tech (Coordinating Office) have conducted longitudinal tracking of NNUN/NNIN/NNCI REU students since 1997.
6. RTNN initiated and is responding to the ¿Habla español? contact form on the NNCI website.
7. SHyNE organized the 2016 NSF NSE Grantees Conference (Arlington, VA).
8. Hosting of NNCI conference by Georgia Tech (Jan. 2017) and University of Pennsylvania (Oct. 2017)
9. Hosting of REU Convocation by Georgia Tech (Aug. 2017)

# 10. NNCI Network Usage

Individual NNCI site performance, and that of the network as a whole, can generally be assessed based on four major criteria: (1) ability to serve the greatest number and broadest set of researchers from academia, industry, and government, while keeping in mind site's capabilities and focus, (2) impact on the research enterprise and its economic importance in the commercial realm, (3) societal impact based on improved public awareness, diversity, and workforce development for nanoscale activity, and (4) contributions of sites to the NNCI network. Given these broad criteria, each site determines the set of metrics for their annual site report to NSF that best fit their own technical specialization (if any), regional user base and commercial interests, and any partnership arrangements. A non-exhaustive list of examples of potential metrics, many based on experience from NNIN, is provided in the report of the *Metrics and Assessment Subcommittee*.

NNCI sites collect statistical data about their users in an effort to assess the strength and success of the internal and external users program. Research disciplines can be used to help track usage in non-traditional areas. Productivity is implied from annual assessment of user research publications, patents, and presentations that rely on use of the shared facilities and the research budgets enabled. It is more difficult to quantify the productivity of industrial usage, where publications are not the norm, but data on numbers of start-up companies, their financial well-being, patent applications and personnel hiring can be used as indirect measures. In addition, sites may decide to conduct regular user and/or PI satisfaction surveys as a means of assessing site quality and making adjustments to operations as needed (see Section 7.4 above). Education and outreach evaluation plans will provide assessments to guide program improvement as well as impact and effectiveness of programs. Finally, each site's contributions to creating a unified network that surpasses the sum of its parts can be assessed by participation of site personnel in network activities (see Section 9 above).

That being said, it is important that a common set of data for the NNCI network sites, as well as aggregated data for the network as a whole, be regularly collected. The NNCI Coordinating Office has established a *Metrics and Assessment Subcommittee* that has agreed upon a common set of site and network metrics, and the collected data are consistent with the user statistics developed under the NNIN program. The following are the definitions provided to all sites for creating a uniform set of metrics.

1. An on-site user is someone who physically comes to a site facility (or partner facility) to access the tool set. A remote user is someone who contracts to have processing and/or characterization done by site staff for them. In general, there should only be one remote user for any given piece of work. Faculty (both internal and external) and industry PIs, unless they actually do hands-on work themselves, should not be counted as users – only the students/researchers who do the work are users. Site staff should not be counted as users, unless they have a dual role and act as a student/researcher as well. All included facilities are OPEN, SHARED, USER facilities, where the tools are available to all researchers (internal and external) for hands-on use. Purely service facilities or individual PI labs should not be included. It is also important to not count users more than once for using multiple facilities of a single NNCI site. In short, every user in the cumulative user count corresponds to a single, unique individual. Even though summer interns/REU students are typically paid with internal funding and working on internal projects, these users are counted as EXTERNAL users as

their home institution is another university/college, which is the primary factor that governs affiliation.

2. Stats are broken down by Affiliation, meaning the type of institution, and Discipline, meaning the area of research. Local Site Academic refers to users who are either students or employees of a site (or partners). All other Affiliations are for external users. A Small Company is defined as one with <500 employees. Disciplines are often self-selected by the user, or perhaps by site staff. In the Discipline category "Educational Lab Use" is NOT intended to count students in a regular university class which uses the NNCI site facilities. Rather, this category is applied to users who attend workshops or short courses, created as part of a sites NNCI education and outreach, where hands-on work (attendees actually go into the lab) is part of the program.
3. Lab Time refers to actual time in the cleanroom OR tool time for all users during a given month. These should not be double counted. In other words, if a student is using multiple tools in the cleanroom, only the time in the cleanroom should be used. If a student is outside the cleanroom, but a process is still running, the tool time can still be counted. Most characterization tools, outside the cleanroom, are counted as straight tool usage time. For cases when users are logged into a cleanroom tool, but he/she is not inside the cleanroom (for example, during extended furnace runs), tool time is recorded.
4. Monthly Users are the total number of unique individuals who access a site in a given month. In this case, the total number may be different than the sum of On-Site + Remote if a user accesses the site via both methods in a given month.
5. Cumulative Users is the running total of all users since the beginning of the NNCI year on October 1. Each year on October 1, the cumulative count starts over with all users counted again.
6. Fees data are the revenue from all user fees for use of a site's facilities. This data does not include indirect charges (if they are assessed). If a site uses a cap on charges after a certain hour limit, only the actual fees charged are reported, but the actual hours used over the cap limit are reported in Lab Time.
7. New Users Trained refers to those users who are first time users (and go through a site's orientation program) in that month. In this section all users should only be included ONE TIME during the entire life of the NNCI program.

## 10.1. NNCI Aggregate User Data (Oct. 1, 2016 - Sept. 30, 2017)

Since each site provides its own usage data as part of their annual report and a subset of this data is provided in the site reports below (Section 11), we have not included individual site data here, but rather the aggregate for the NNCI network. In Table 13 below, we provide the NNCI totals, along with the average for the 16 sites, as well as the minimum and maximum values for the sites as an indication of the wide variation among the sites.

Table 13: Summary of NNCI Aggregate Usage Data (Year 2)

| | NNCI Network | NNCI Sites Mean (Min - Max) |
|---|---|---|
| Unique Facility Users | 12,452 | 778 (160 – 1,620) |
| Unique External Users | 3,176<br>25.5% | 199 (36 – 573)<br>25.8% (10.1% – 45.8%) |
| Industry Users | 1,669 | 104 (8 – 217) |
| External Academic Users | 1,507 | 94 (12 – 428) |
| Average Monthly Users | 4,911 | 307 (51 – 802) |
| New Users Trained | 4,563 | 285 (54 – 698) |
| Facility Hours* | 939,230 | 58,702 (4,713 – 181,826) |
| Facility Hours – External Users* | 191,494<br>20.4% | 11,968 (812 – 48,806)<br>20.4% (4.1% – 44.4%) |
| Hours/User* | 75 | 69 (29 – 145) |
| User Fees | | |
| Internal Users | $23.0M | $1.43M |
| External Users | $14.5M | $0.91M |

*Hours were collected as lab usage hours (time in the cleanroom), tool usage hours (when operated while not in the cleanroom), and tool usage hours for non-cleanroom tools. While we have conveyed this definition to the sites (see above), we have not made an attempt to standardize the data collected.

The >3000 external users come from 1081 distinct external institutions (full list shown in Appendix 13.3), including 222 academic institutions, 564 small companies, 207 large companies, 20 US local/federal government organizations, 56 international institutions, and 12 other institutions (museums and non-profits, for example). This number excludes cases where an external institution (not necessarily the same PI or user) is working at multiple NNCI sites. It also does not include 191 institutions that wished to remain anonymous and may or may not overlap with those listed in Appendix 13.3.

A comparison of the network aggregate usage data between Years 1 and 2 are shown in Table 14 below. As can be seen, all metrics showed significant increases (double-digit percentages in most cases) except the average number of hours/user.

Table 14: Comparison of Year 1 and 2 NNCI Aggregate Usage Data

| | Year 1 | Year 2 | Difference |
|---|---|---|---|
| Unique Facility Users | 10,909 | 12,452 | +14.1% |
| Unique External Users | 2,567<br>23.8% | 3,176<br>25.5% | +23.7% |
| Industry Users | 1,413 | 1,669 | +18.1% |
| External Academic Users | 1,154 | 1,507 | +30.6% |
| Average Monthly Users | 4,427 | 4,911 | +10.9% |
| New Users Trained | 4,116 | 4,563 | +10.9% |
| Facility Hours | 909, 151 | 939,230 | +3.3% |
| Facility Hours – External Users | 173,510<br>20.2% | 191,494<br>20.4% | +10.4% |
| Hours/User | 83 | 75 | -9.6% |
| User Fees | | | |
| Internal Users | $20.6M | $23.0M | +11.6% |
| External Users | $13.5M | $14.5M | +7.4% |

Figures 10 and 11 below show the breakdown of users and lab hours by affiliation for the entire network. Individual affiliation plots are shown for each site in the data of Section 11 below. While external users make up 25.5% of total users, external hours are 20.4% of total hours. As noted in previous reports, this is likely due to the proximity and ease of access of internal users to the facilities, which provides them opportunities for greater overall use. A comparison of Year 2 cumulative users (by affiliation) by site is provided in Figure 12 for all users and Figure 13 for external users only. Care should be taken when analyzing these data and particularly when comparing different sites. The NNCI sites are diverse: some are located in "nanotechnology" hub areas, others are not; some serve a general NSE user base with a broad tool set, others have a particular research focus; some have been part of the NNIN program, others have not; some have a large number of tools and staff, others have not. Thus, it can be difficult to draw conclusions from a site-to-site statistical comparison.

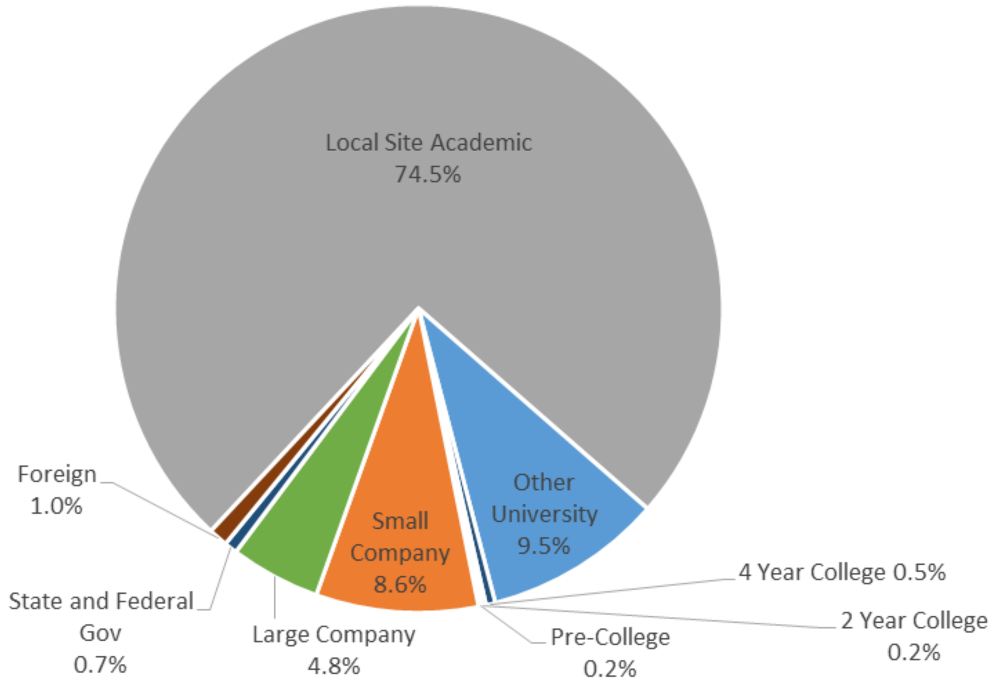



*Figure 10: NNCI Users by Affiliation (Year 2)*

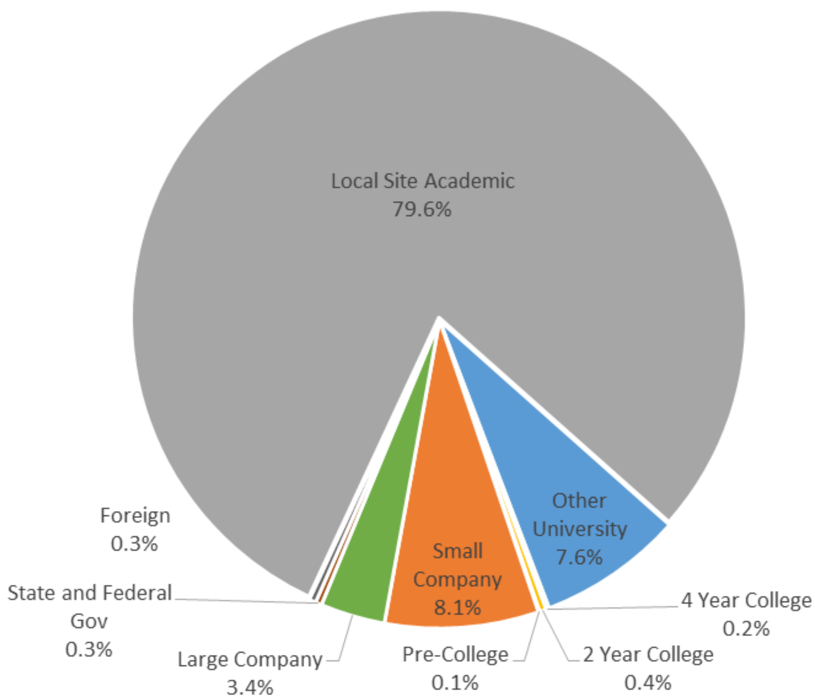



*Figure 11: NNCI Usage Hours by Affiliation (Year 2)*

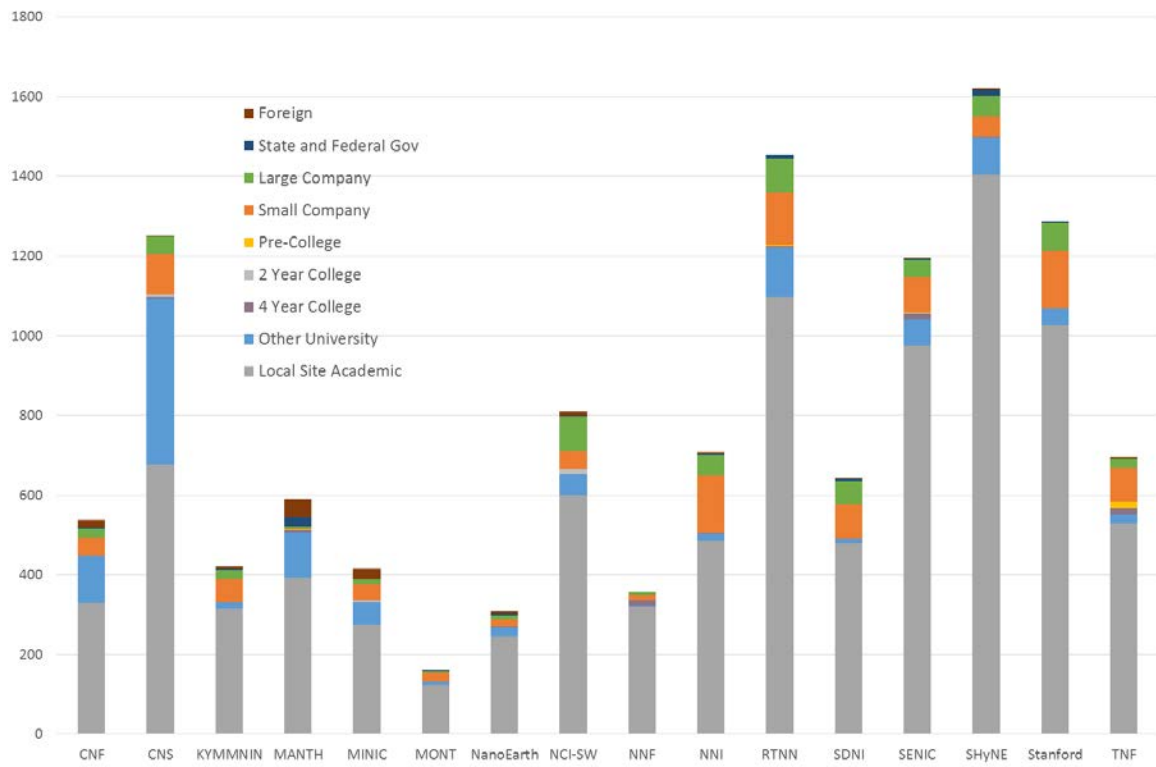



*Figure 12: NNCI Cumulative Users by Site (Year 2)*

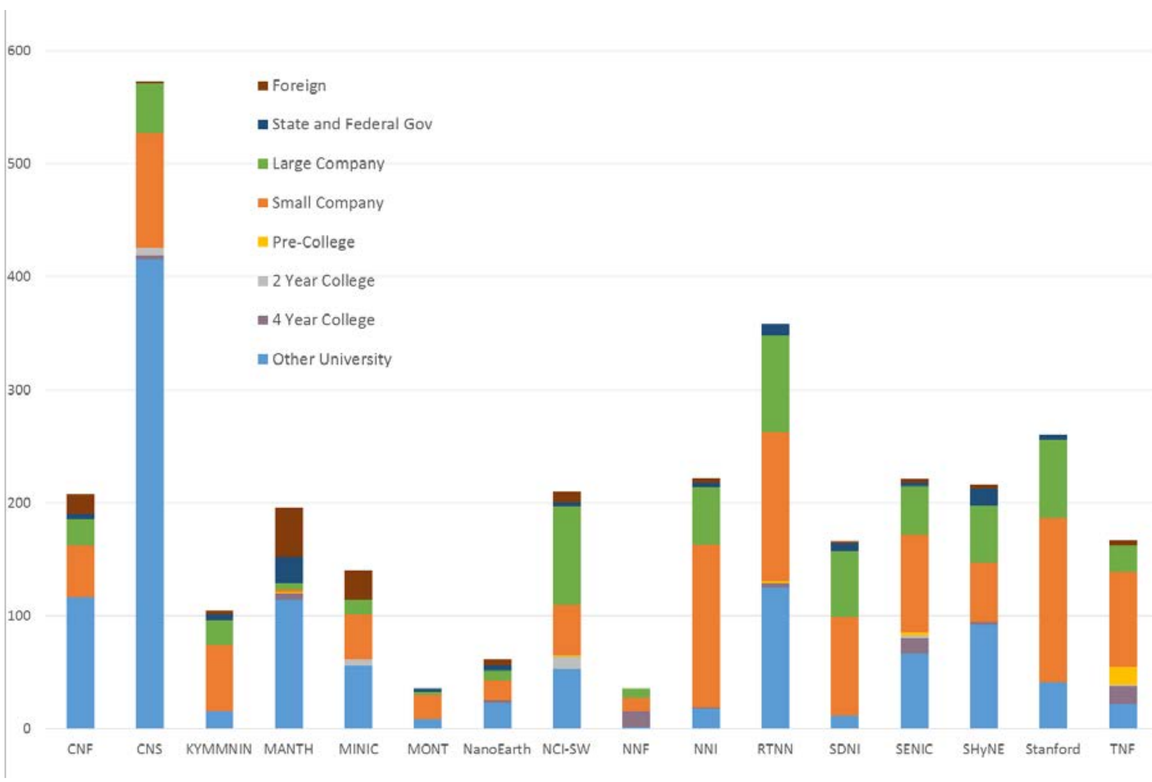



*Figure 13: NNCI Cumulative External Users by Site (Year 2)*

For academic institutions a network map showing the NNCI nodes and associated US colleges and universities (from 43 states and Puerto Rico) is shown in Figure 14 below. Universities with projects at three or more NNCI sites (26 institutions in Year 2 compared to 22 in Year 1) are labeled. Year 1 had 296 linkages, while this increased to 343 in Year 2. In addition to the academic users indicated below, it was also observed that >20 large/small companies accessed facilities at multiple NNCI sites, although it cannot be determined if these resulted from the same or unique users or projects.

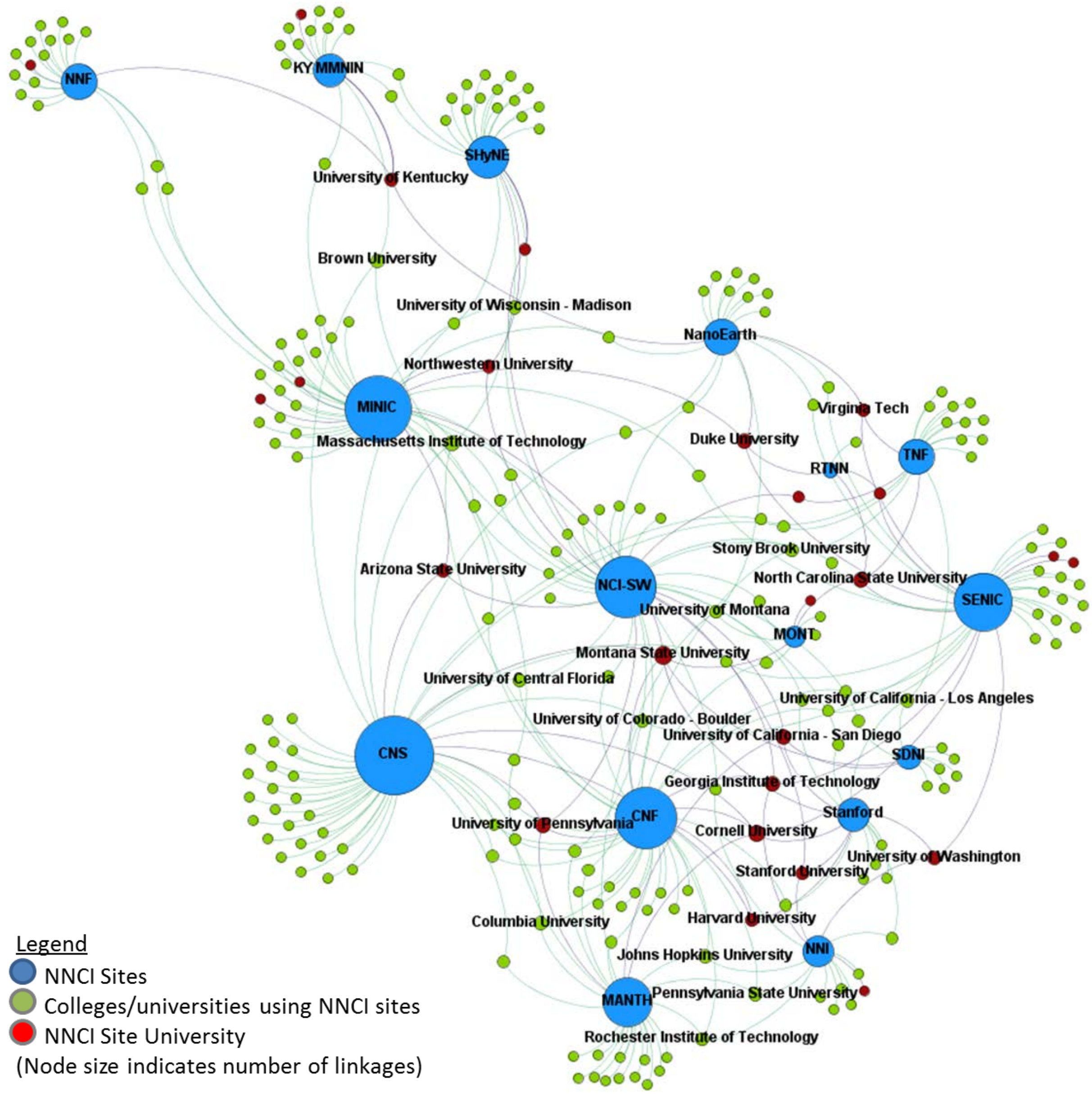



*Figure 14: NNCI Academic User Network Map*

### 10.2. Non-Traditional Users

One important though troublesome metric is how well NNCI reaches and assists non-traditional users. In order to determine the best way to assess this aspect of NNCI activity, a breakout session on this topic was held at the January, 2017 NNCI Conference. A summary of that discussion was included as part of the Year 1 NNCI Annual Report (March 2017).

The charts below illustrate the usage of the NNCI network by users in specific disciplines (internal and external). It is worth remembering that in many cases these disciplines are self-selected, and may reflect the user's home department or their specific area of research. Figure 15 illustrates the breakdown by number of users in specific disciplines, while Figure 16 illustrates the usage hours by discipline. Furthermore, Figure 17 illustrates the average number of hours/user across the network based on the user's discipline, illustrating that the fabrication-heavy disciplines of electronics, MEMS, optics, and physics tend to require more lab usage by researchers.

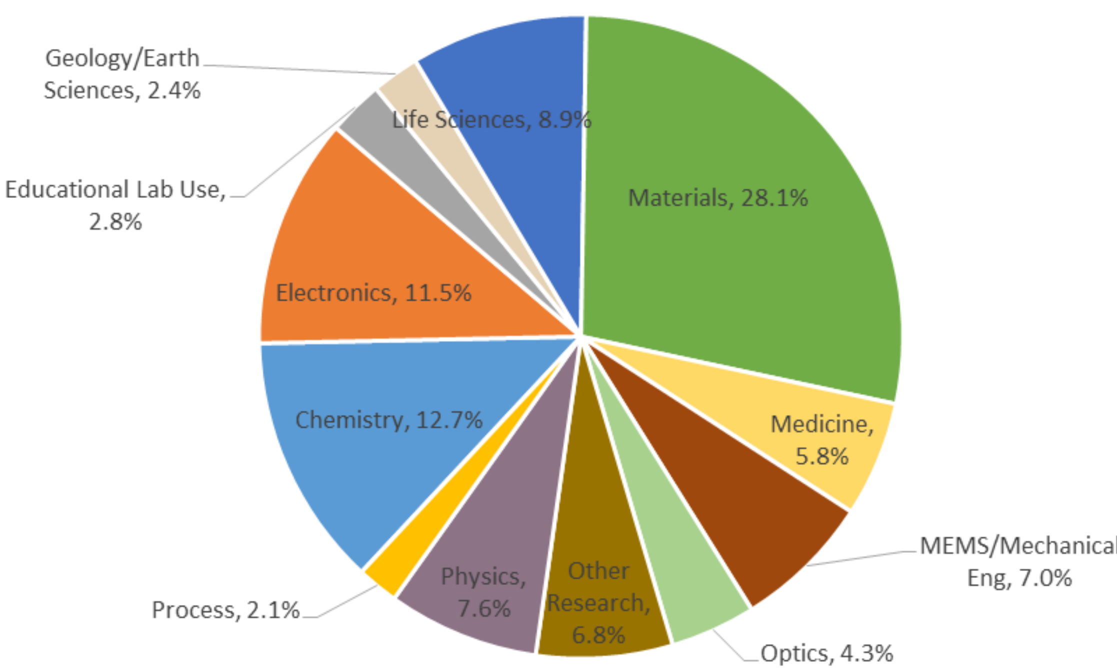



*Figure 15: NNCI Users by Discipline (Year 2)*

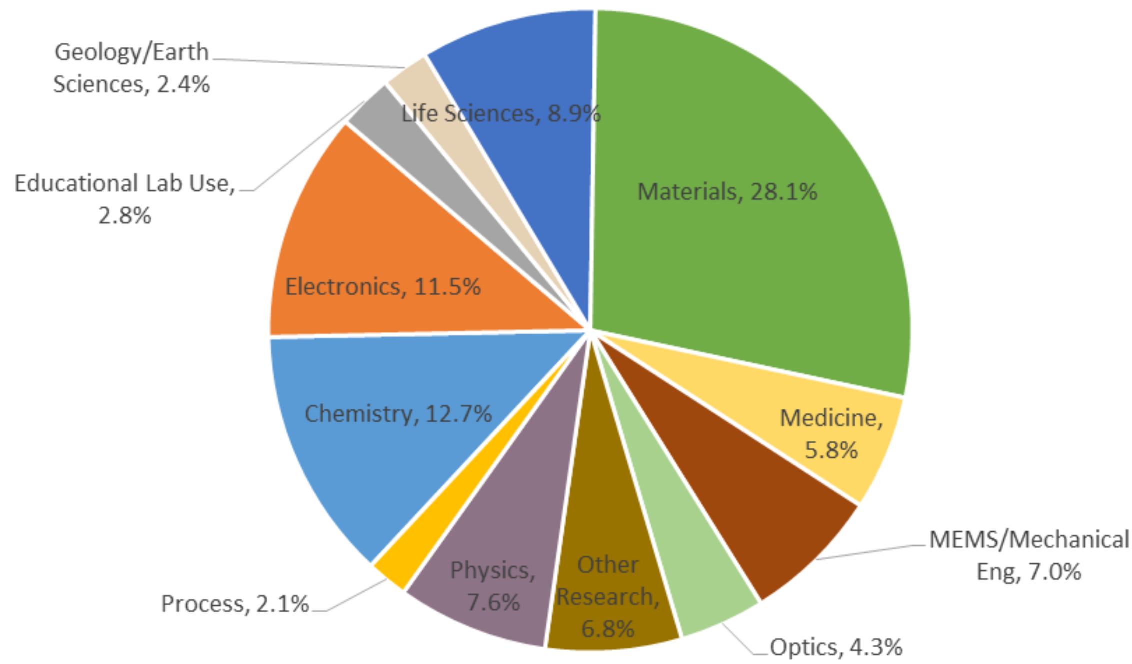



*Figure 16: NNCI Usage Hours by Discipline (Year 2)*

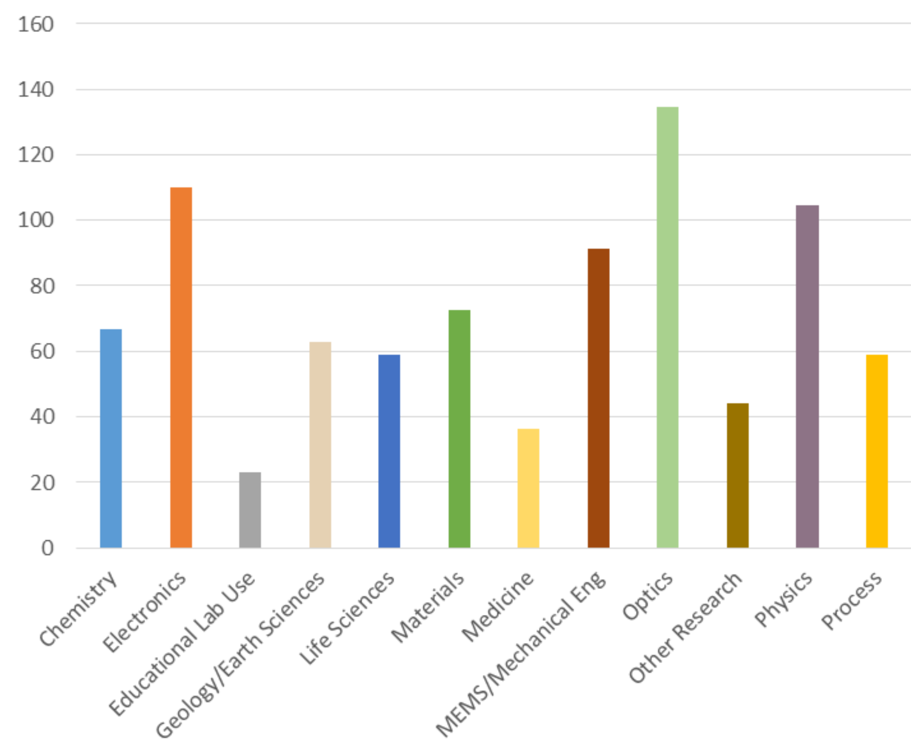



*Figure 17: NNCI Hours/User by Discipline (Year 2)*

As was done for Year 1, if it is assumed that the "traditional" disciplines include the engineering-related electronics, materials, MEMS, and process development disciplines, whereas "non-traditional" is everything else (Educational Lab Use is excluded in this tabulation), than it can be seen that the relative usage breakdown by number of users and hours is given in Table 15 below, comparing Years 1 and 2. While number of users is an even split between traditional and non-traditional, there is a slightly larger number of hours (54%) for the traditional users, as one might expect for typical fabrication-heavy research, compared to the non-traditional users who might be more likely to utilize characterization and imaging tools.

Table 15: Usage by Traditional and Non-Traditional Disciplines

| | Year 1 | Year 2 |
|---|---|---|
| **# of Users** | | |
| **Traditional Users*** | 5386 (51%) | 6063 (50%) |
| **Non-Traditional Users**** | 5262 (49%) | 6044 (50%) |
| | | |
| **Hours of Usage** | | |
| **Traditional Users*** | 495,215 (55%) | 506,393 (54%) |
| **Non-Traditional Users**** | 409,935 (45%) | 424,855 (46%) |

* Electronics, Materials, MEMS/ME, Process

** Chemistry, Physics, Optics, Medicine, Life Sciences, Geo/Earth Sciences, Other

### 10.3. Publications Information

The publications data shown below (Table 16) was collected by sites for the calendar year 2016. Due to the difficulty in getting compliance from users for this requested information, this should be considered a lower limit of the actual publications data. In addition, no attempt was made to remove duplicates, where authors might have been from multiple NNCI sites. This represents a significant increase (22.5%) in total publications from Year 1, with increases in all categories.

Table 16: NNCI 2016 Publications Data

| Publication Type (CY 2016) | |
|---|---|
| **Internal User (Site) Papers** | 2400 |
| **External User Papers** | 466 |
| **Internal User Conference Presentations** | 1088 |
| **External User Conference Presentations** | 120 |
| **Books/Book Chapters** | 38 |
| **Patents/Applications/Invention Disclosures** | 340 |
| **Total** | **4452** |

# 11. NNCI Site Reports

NNCI sites were asked to provide summary information as part of this Year 2 report. Specific information requested included:

1. A brief narrative corresponding to the NNCI Year 2 (Oct. 1, 2016 - Sept. 30, 2017).
    a. Facilities, tools, staff updates during the year
    b. User base – marketing, outreach and support activities, including any specific research strengths or focus of the site
    c. Research highlights – include brief mentions of any significant user accomplishments. Note: Research and education highlights are provided as a separate document.
    d. Education and outreach activities summary
    e. Societal and ethical implications activities (if applicable)
    f. Computation activities (if applicable)
2. A listing of all external user institutions for NNCI Year 2, separated as follows: Academic, Small company (<500 employees), Large company, Government, International, Other. See Appendix 13.3 for the complete listing. Due to disclosure limitations, some external users asked that their information not be shared, and the number of these are indicated in the appendix.
3. The number of publications in each category for calendar year 2016. The list of publications may have been part of each site's Year 2 report to NSF, but the data presented here is only aggregate numbers of publications for the NNCI network. See Table 16 above.
4. A list of site-site or network-wide activity, including proposals, facility operations, education/SEI programs, staff interactions, or other events. This was provided in Section 9 above.

In addition, the user statistics for NNCI Year 2 (Oct. 2016-Sept. 2017) were collected from the sites and used by the Coordinating Office to generate both the aggregate network user activity described in Sections 10.1 and 10.2 above as well as the individual site usage information shown after each site narrative below.

The reports below are presented as provided by the sites, with only minor editing for format.

### 11.1. Center for Nanoscale Systems (CNS)

This has been a very productive second year for the Center for Nanoscale Systems. PI Westervelt and co-PI Wilson, the operational director of the center, have been continuing the assessment, revamping, and augmentation of the tools and instrumentation available at CNS for advancing transformative nanoscience. The specific new tools and techniques added this year will be outlined below. PI Westervelt and co-PI Wilson have also continued cultivating a cooperative, synergetic relationship with the Center for Integrated Quantum Materials (a NSF STC).

This year we enlisted several new participants in the CNS scholars program. This activity is focused on enabling young researchers access to CNS expertise and instrumentation, particularly researchers from underrepresented groups and researchers from minority serving institutions. The new participants were mostly from Howard University and are engaged in activities in Quantum Engineering. In addition to the programs mentioned, we have continued our partnership with Harvard Catalyst, a federally sponsored translational Biosciences initiative to train non-traditional life science researchers in an array of techniques available at CNS. Catalyst Reactor sponsors pilot grants of ~$50,000 for researchers to enabling access nanoscience technologies in the pursuit of life science. The funding is designed to support the innovative application of light and electron microscopy, nanoscale fabrication, and nanoscale analysis technologies for big ideas that will advance clinical healthcare. Projects this past year ranged from *"PNP-Hydrogel Delivers miRNA to 3D-Bioprinted Calcific Aortic Valve Disease Model" and "Optimization of Drug Delivery by Tumor-Targeting layer-by Layer Nanoparticles Using Advanced Microscopic Technologies"*, to *"A Microscopy-Based Platform For Rapid, At-Will Antimicrobial Resistance Testing" ; "Laser-activated plasmonic intracellular delivery: Using micropyramids to deliver CRISPR-Cas9 to hematopoietic stem cells (HSCs)"*. These projects have helped greatly increase the number of *"non-traditional"* users at CNS particularly in the life sciences and in several new emerging areas.

<u>Facility, Tools and Staff Updates</u>

This year we have added two new staff; some allowing us to expand our research capabilities and some re-staffing to back-fill for newly retired or departed staff.

New Staff:

*Dr. Sventla Stoilva-McPhie; Advanced Bio-Imaging Scientist;* Electron Microscopy and CryoTEM; Dr. Stoilva-McPhie was brought in to complement our CryoTEM team a growing area of the lab. Sventla has a wide variety of expertise is Structural Biology. She did postdoctoral study at IGBMC- University Louis Pasteur, Strasbourg, France, in Cryo-electron microscopy (Cryo-EM) and structural biology: specifically studying lipid bound 2D crystals of cholera toxin, Annexin V and coagulation factor V. She also studied at the University of Leeds, UK, Cryo-EM and structural biology center focusing on 2D crystals of Photosystem II and membrane-bound blood coagulation factors VIII, VII, IX, X. as well as Cryo-EM collaborative projects on DNA-protein complexes and membrane proteins (multidrug and ABC transporters). She served as an Assistant Professor in the Department of BioPhysics at the University of Texas. She has extensive experience in the operation and maintenance of electron microscopes, having served as a primary facilitator of the UT Medical Branch's Sealy Center for Structural Biology and Molecular Biophysics.

*Dr. Yi-Ju (Christine) Wang; Nanofabrication Engineer:* Dr. Wang came to us from Advion Inc. with a wide array basic processing expertise. She has a PhD. In Chemical Engineering from the University of Houston. She will become the principle trainer for the fundamentals of optical lithography and will support process design activities.

We have also expanded the capabilities available to the userbase both in the nanofab and other parts of the lab. The new tools and instrumentation include:

Imaging and Analysis additions

- Hitachi NB5000 FIB
- Park NX-10 AFM
- Cary 7000 UMS UV-VIS –NIR
- Neaspec nSNOM / nanoIR system

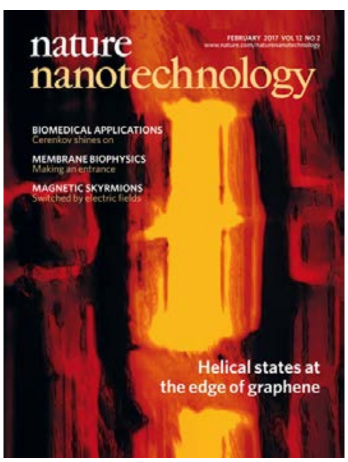
Nanofabrication additions:

- Hitachi 8230 SEM
- ***Intlvac Ion-beam Miller***
- Bruker DekTak Profilometer
- ULVAC Deep Oxide RIE

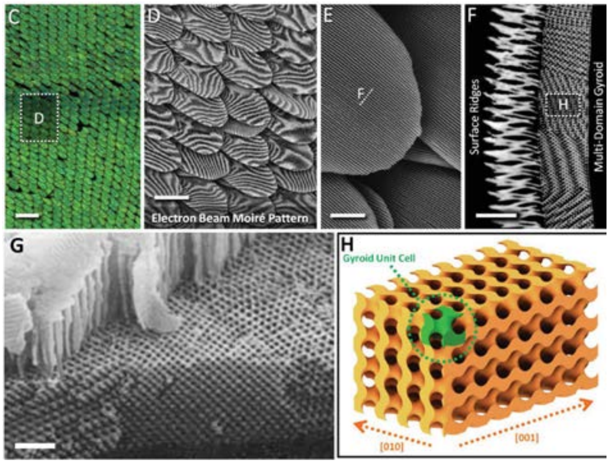
These new tools expand our analysis and processing capabilities. The FIB system, for example, has been instrumental in our rapidly expanding efforts in "slice and view" study of nanoscale structures.

Research Highlights:

**Quantum Engineering:** *Helical edge states and fractional quantum Hall effect in a graphene electron–hole bilayer; Javier D. Sanchez-Yamagishi, Jason Y. Luo, Andrea F. Young, Benjamin M. Hunt,Kenji Watanabe, Takashi Taniguchi, Raymond C. Ashoori and Pablo Jarillo-Herrero: Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA. Department of Physics, University of California Santa Barbara, Santa Barbara, California 93106, USA. Department of Physics, Carnegie Mellon University, Pittsburg, Pennsylvania 15213, USA. Advanced Materials Laboratory, National Institute for Materials Science, Tsukuba, Ibaraki 305-0044, Japan;* Helical 1D electronic systems are a promising route towards realizing circuits of topological quantum states that exhibit non-Abelian statistics. Here, an MIT team demonstrate a versatile platform to realize 1D systems made by combining quantum Hall (QH) edge states of opposite chiralities in a graphene electron–hole bilayer at moderate magnetic fields. Using this approach, they have engineered helical 1D edge conductors where the counterpropagating modes are localized in separate electron and hole layers by a tunable electric field. These helical conductors exhibit strong non-local transport signals and suppressed backscattering due to the opposite spin polarizations of the counterpropagating modes. Unlike other approaches used for realizing helical states, the graphene electron–hole bilayer can be used to build new 1D systems incorporating fractional edge states. Moreover, one can tune the bilayer devices into a regime hosting fractional and integer edge states of opposite chiralities, paving the way towards 1D helical conductors with fractional quantum statistics.



**BioInspired Materials Engineering:** *Characterization of a Mechanically Tunable Gyroid Photonic Crystal Inspired by the Butterfly Parides Sesostris; Johanna Aizenberg et al. Harvard University; School of Physics and Astronomy, University of Exeter*: As a crucial step toward designing photonic crystals with tunable optical and mechanical properties, the Aizenberg group used additive manufacturing to create a flexible macroscale replica of the gyroid photonic structure found in the *Parides sesostris* butterfly wing. This enabled them to systematically analyze both photonic frequency changes and stress fields under various compression modes, revealing not only fine electromagnetic tunability but also the unique mechanical robustness of this geometry.

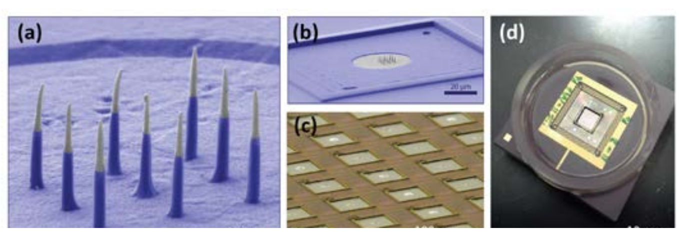



Mechanistic origins of structural color in the neotropical butterfly, P. sesostris. Located on the wings are striking metallic green patches and C–F) high-resolution structural characterizations of their constituent scales reveals a complex composite architecture. G) shows the 3D structure present within wing scales, which can be graphically represented by H) the photonic gyroid structure with an individual unit cell highlighted in green.

The power of 3D printing to rapidly create prototypes with almost any morphology has enabled us to overcome a long-standing limitation in the study of responsive photonic structures, and makes it an indispensable tool as we work toward developing a comprehensive framework for the rational design of dynamically tunable optical materials. Uniquely CNS enables both the study of the nanoscale structure of these natural species with full de-construction using "slice and view" FIB study. As well as the ability to macroscopically render the nanostructure using the techniques of additive manufacturing. (*Reference: Adv. Optical Materials 2016, 4, 99-105*).

**Nanoelectronics:** *CMOS Nanoelectrode Array for all-electrical intracellular electrophysiological imaging: Abbott, J., Ye, T., Qin, L., Jorgolli, M., Gertner, R. S., Ham, D., & Park, H. Department of Chemistry and Chemical Biology and Department of Applied Physics Harvard University*; Developing a new tool capable of high-precision electrophysiological recording of a large network of electrogenic cells has long been an outstanding challenge in neuro-biology and cardiology. Here, the Ham and Park groups combine nanoscale intracellular electrodes with complementary metal-oxide-semiconductor (CMOS) integrated circuits to realize a high-fidelity all-electrical electrophysiological imager for parallel intracellular recording at the network level.

(a-c) False color SEM images of post-fabricated nanoelectrode array on top of the CMOS. (d) packaged device




Their CMOS NanoElectrode Array (CNEA) platform contains 1024 recording/stimulation pixels and intra-cellular recording from over 300 rat neonatal cardiomyocyte have been demonstrated.

CNEA is also able to record delicate changes in membrane potential on a network level during drug perturbation. (*Reference: Nature Nano.* **2017**)

Education & Outreach Activities

This year's REU students were students chosen using a joint Harvard website hosting potential research projects campus wide. The students selected, their institution, and their summer project and Mentor/Mentors are listed in table 1. This was the first year the Harvard site recruited and selected students from the composite University site and we believe the process went well. PI Westervelt and co-PI Wilson used the STC college network and several other vehicles to ensure a diverse candidate pool. PI Wilson recruited both at the NSBE and CARRMS meetings, events geared toward STEM development in the African-American community. We plan expansion of our recruiting activities in future years. Last year we also selected 4 REV interns. Most of these students were selected from a pool at BunkerHill Community College. BHCC has a very vibrant STEM focused directed at VETs. As part of our traditional REU program, this year we solicited summer research projects from the entire CNS user base, (both internal and external). The goal was to foster new strong interactions between staff and research groups. The selected projects are also listed in the table.

**Student interns and projects for FY17**

| # | | PI | Mentor | Co-Mentor | Project Title |
|---|---|---|---|---|---|
| 1 | | Aizenberg & Lewis | Ida Pavlichenko | Nicole Black | Development of an elastomeric material for 3D printable SLIPS---coated medical implants |
| 2 | | Loncar | Cheng Wang | Mian Zhang | Low-loss lithium niobate nanowaveguides |
| 3 | | Mazur | Yang Li | Ling Xie | On-chip zero-index metamaterials consisting of array of core-shell pillars |
| 4 | | Mazur | Daryl Vulis | Yang Li | Fabrication and tunability of CMOS-compatible zero-index metamaterials |
| 5 | | Mazur | Marinna Madrid | Eric Mazur | Fabricating laser-activated nanostructured substrates for intracellular delivery |
| 6 | | Katia Bertoldi | Andrew Gross | | Optimal strength nano-cellular materials |
| 7 | | Aizenberg | Amos Meeks | | Photonic hydrogel actuated microstructures for environmental sensing |
| 8 | | Wilson | Mac Hathaway | | ALD for 2D materials |
| 9 | | Wilson | Ling Xie | Arthur McClelland, Greg Lin | Design, fabrication, and test of microfluidic devices for biochemical analysis |

| | | | | | |
|---|---|---|---|---|---|
| 10 | | Parker | | | Organ on a chip - Microscale soft biological device fabrication |

Our CNS Scholars program offers direct fabrication and instrumentation support for researchers from under-represented groups, small or minority serving institutions. The first submissions have focused on junior faculty and some post-doctoral support. We are only funding use with some materials and supply support. The initial enrollees, institutions and projects are listed in table 2. All submitted brief proposals, which were evaluated by CNS senior staff. In future year we will more extensively advertise these activities. As noted we have initiated a partnership with Harvard Catalyst. Catalyst provides seed support for projects in the translation biosciences. Currently we are not using NNCI funding to support any of these initial researchers but we anticipate possibly inclusion of some of these bioscience teams in CNS Scholars.

**CNS Scholars**

| **Scholar** | **Project** | **Institution** |
|---|---|---|
| Prof. Thomas Searles | *Atomic Layered 2D Materials based Meta surfaces* | Howard University |
| Prof. Renita Horton | *Vasculopathy on a Chip* | Mississippi State University |
| Prof. Katherine Aidala | *Fabrication of Ferromagnetic Nanostructures to Investigate 360 Domain Walls* | Mt. Holyoke College |
| Dr. Tina Brower-Thomas | *"Twistronics" in decorated 2D Materials* | Howard University |

**2017 CNS Scholars / Howard University**

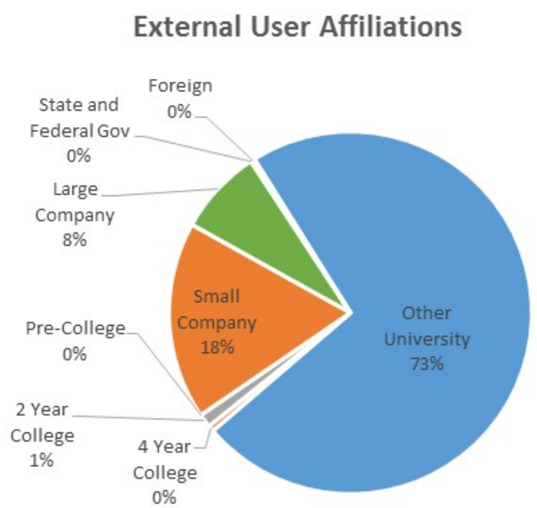
| | |
|---|---|
| Jordan Stroman | *Development of an LED that could electrical excite silicon vacancies in 4H-Silicon Carbide* |
| Tewa Kpulun | *Growth and Transfer of Graphene and Hexagonal Boron Nitride* |
| Mehdi Rezaee | *Decoration of Graphene with Transition Metal* |
| Amirhassan Shams Ansari | *Toward Quantum Wavelength Conversion Using Diamond Nonlinearities* |
| Amber Wingfield | *Investigating incorporation of color centers and boron in HF-CVD diamond* |
| Aaron Jackson, Ph.D. | *Zero Phonon-Line Enhanced Diamond FETs* |
| Pheona Williams | *Terahertz Spectroscopy of Dirac-Plasmons in New Topological Insulators* |

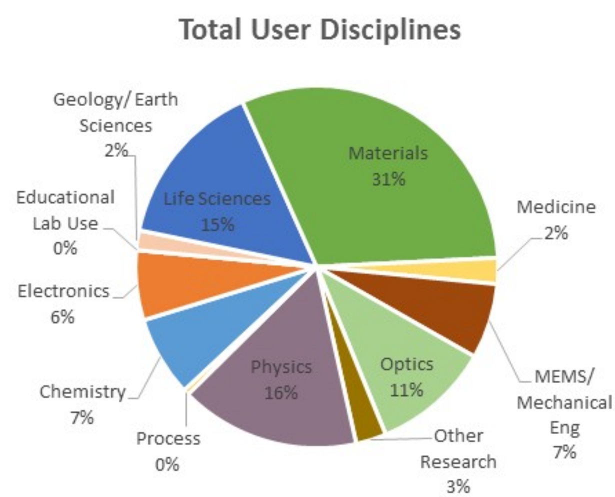
The senior leadership team has also continued visiting current and potential users throughout Northeast and the within the Cambridge area to assess overall user needs community-wide. *One new initiative in development is an assessment of our support to the New England start-up community*. Here in particular, we have reached out to local high-technology incubators to understand their current organizational goals and to gain insight as input as we develop a long-term engagement plan and consider potential partnership activities. The goal for the lab is to align our vision with the broader national nanoscience community.

# CNS Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 1,023 | 1,251 |
| Internal Cumulative Users | 562 | 678 |
| External Cumulative Users | 461 (45%) | 573 (46%) |
| | | |
| Total Hours | 174,710 | 181,826 |
| Internal Hours | 124,256 | 133,020 |
| External Hours | 50,454 (29%) | 48,806 (27%) |
| | | |
| Average Monthly Users | 511 | 514 |
| Average External Monthly Users | 201 (39%) | 196 (38%) |
| | | |
| New Users | 415 | 404 |
| New External Users | 196 (47%) | 200 (50%) |
| | | |
| Hours/User (Internal) | 221 | 196 |
| Hours/User (External) | 109 | 85 |

## Year 2 User Distribution

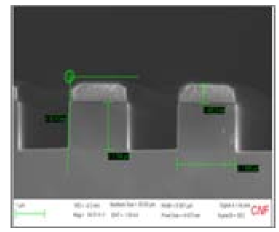


## 11.2. Cornell Nanoscale Science and Technology Facility (CNF)

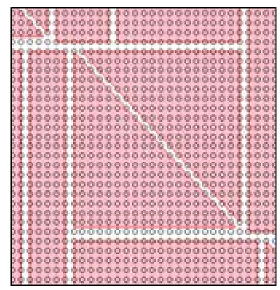
Facility, Tools, and Staff Updates

CNF serves as a nanofabrication-focused open resource to scientists and engineers with emphasis on providing complex integration capabilities. This is made possible by an expertly-staffed user program providing rapid, affordable, hands-on 24/7 open access to advanced nanofabrication tools. The following tools, processes, facilities and software have been acquired or developed over the past year.



- KLA Tencor P7 Stylus Profilometer
- Thermal nanoimprint lithography (TNIL) resist processes for pattern transfer and liftoff
- Improved HBr silicon ICP etch processes for silicon photonics
- Nanocrystalline diamond ICP etch
- Improved Data Fracturing for Nanolithography especially suited to grayscale lithography

User Base



CNF established a set of specific milestones to measure our success in serving users, particularly external users, and marking our other proposed goals. We were successful in meeting all of these benchmarks. CNF hosted 184 external users in the cleanroom who alone clocked over 39,000 hours of cleanroom plus equipment hours. External user fees were $1.61M out of a total of about $2.7M and our median Likert scale score for user satisfaction was 4.5/5. Overall cleanroom hours were over 45,000 (12 months) with 2014 monthly average number of users. Over the twelve month period, a total of 538 different users used CNF. Using the NNCI categories 52% of CNF usage is from non-traditional fields. Remote usage serves as a way to engage future users, achieve higher tool utilization, and enhance the NNCI network value to users. This year 49 remote jobs were completed. We also make use of inter-site capabilities, for example, shipping a user's wafers to U. Penn, Stanford, and Georgia Tech, when a CNF system is down for repairs or a user need is better met. We also performed work for U. Louisville and U. Penn on multiple occasions

Research Highlights

Research reports are published annually as the CNF Research Accomplishments and online at http://www.cnf.cornell.edu/cnf5_research.html. CNF users compiled over 440 publications, conference presentations, and patents. Here we highlight some of the most significant examples of research enabled by CNF in the past year.

- In **ACS Nano**, the Lin group at Rensselaer Polytechnic Institute in collaboration with researchers at the University of Toronto and National Chiao-Tung University used the CNF to create a teepee-like photonic crystal (PC) structure on crystalline silicon designed to enhance solar energy harvesting.
- In **Science,** the Lammerding group at Cornell University in collaboration with researchers at Radboud University Medical Center, Netherlands, and The University of Texas MD Anderson Cancer Center, Houston, TX, used the CNF to construct microfluidic devices to model cancer cell invasion with precise control over cell confinement.

- In **ACS Photonics**, the Lin group of the University of Rochester used the CNF to demonstrate a silicon nanophotonic chip containing a high-Q silicon microdisk that yields quantum interference visibility for time-energy entangled photons from a micro/nanoscale source used to generate time-energy entangled photon pairs.
- In **Nature Communications**, the Shen group and colleagues at Cornell University in a highly collaborative project with researchers from Duke University, the Johns Hopkins University and the Howard Hughes Medical Institute used the CNF to create a graphene sensor on an abdominal window made from borosilicate glass for surgical implantation.
- In **Nature**, the Peng group of Cornell University working with researchers from Colorado Mesa University, and the University of Michigan used the CNF to produce a device for both wide-field single-molecule fluorescence imaging of photoelectrocatalysis by semiconductor nanorods via two-laser total internal reflection excitation, and for sub-nanorod photocurrent measurements via focused laser excitation, in a three-electrode microfluidic photoelectrochemical cell.
- In **Developmental Cell,** the Sigma group at Rockefeller University used CNF to prepare a microfluidics setup, enabling long-term, high-resolution, time lapse microscopy of up to ten C. Elegans larvae simultaneously.
- In **Nature – Scientific Reports**, Lipson et al. from Columbia with collaborators at Cornell University used CNF to demonstrate a new platform for minimally invasive, light delivery probes, leveraging the maturing field of silicon photonics which enables massively parallel fabrication of photonic structures.
- In **Nature Physics**, Ralph and colleagues from Cornell University used CNF to prepare spin-source/ferromagnet bilayer devices and showed in contrast to most materials that one can change the allowed symmetries of spin–orbit torques by using a spin-source material with low crystalline symmetry in specifically designed devices.
- In **Science**, McEuen and colleagues from Berkeley, NIMS (Japan), Columbia and Lawrence Berkeley Labs showed that excitons, the bound states of an electron and a hole in a solid material, play a key role in the optical properties of insulators and semiconductors. Here, they report the observation of excitons in bilayer graphene (BLG) in a CNF built device using photocurrent spectroscopy.
- Plourde et al. of Syracuse University working with colleagues at Saarland University and the University of Waterloo reported in **Phys. Rev. Applied**, investigation of the transient dynamics of a lumped-element oscillator based on a dc superconducting quantum interference device (SQUID) built at CNF.
- In **Soft Matter**, Stroock et al. at Cornell University investigated the dynamics of capillary-driven flows at the nanoscale, using an original platform made at CNF that combines nanoscale pores (I3 nm in diameter) and microfluidic features. In particular, they show that drying involves a fine coupling between thermodynamics and fluid mechanics that can be used to generate precisely controlled nanoflows driven by extreme stresses – up to 100 MPa of tension.

<u>Education and Outreach Activities</u>

CNF supports a broad range of educational and outreach activities. In 2016-17 CNF hosted 140 individual events with over 2286 direct participants.

**Research Experience for Undergraduates (REU)**: In 2017, CNF hosted five students including 1 women, 2 underrepresented minority student and 3 from non-R1 institutions. We included an

additional 12 interns from other REU funding sources into our cohort for the summer. Research reports are available at http://www.cnf.cornell.edu/cnf_2017reu.html

**International Research Experience for Undergraduates:** CNF coordinated an NNCI signature international research program for undergraduates selected from the prior year REU program and given an opportunity for a 2nd summer advanced research experience with the National Institute of Materials Science in Tsukuba, Japan. Six students from across the 2016 NNCI REU programs were selected for this program in 2017.

**International Research Experience for Graduate Students:** As a reciprocal program to the IRES funded iREU program, Cornell placed selected Japanese graduate students at NNCI sites for the summer. Nine projects were volunteered by five NNCI sites. After a matching process conducted at CNF, four Japanese graduate students came to NNCI sites for summer projects in 2017 at U Kentucky, Arizona State, NC State, and University of Texas. We are pleased with the support that we received from other NNCI sites in support of this program.


**Nanooze:** CNF produces and distributes Nanooze, a children's science magazine relating to nanotechnology. Nanooze (http://www.nanooze.org/) is a both web-based and printed magazine, with kid-friendly text, topics, and navigation. Nanooze is edited by Professor Carl Batt; it is distributed to thousands of classrooms throughout the US. We print 100,000 copies per issue as requests from classroom teachers continue to grow. The newest issue is on the environment is shown at left; the next issue on biomimetics is in production.

**NSF Disney Science Portal:** Working with Prof. Carl Batt, CNF is updating the existing "Take a Nanooze Break" exhibit at Disney EPCOT into a more universal and maintainable "NSF Disney Science Portal" to highlight a range of current NSF nanotechnology research. The interactive exhibit is in the final construction phase and will be installed in January 2018. It is expected to receive hundreds of thousands of visitors each year.

**TCN – Technology and Characterization at the Nanoscale**: CNF offered an introductory short course on nanotechnology (TCN – Technology and Characterization at the Nanoscale) semi-annually during the summer and winter recess, so that interested students from universities and industry can easily participate. Under NNCI we are offering TCN free to grad students from external US colleges and universities. Over forty students and scientists registered for the two courses offered this year. The course includes lectures and laboratory demonstrations as well as hands-on equipment sessions. Participants uniformly recommend the course to others.

**4-H:** CNF is teaming with 4-H to host STEM activities and to use 4-H as a distribution network for demonstration materials and Nanooze science magazines. We hosted a large campus visit of 4-H members for their "Career Explorations" featuring hands-on STEM nanotechnology activities.

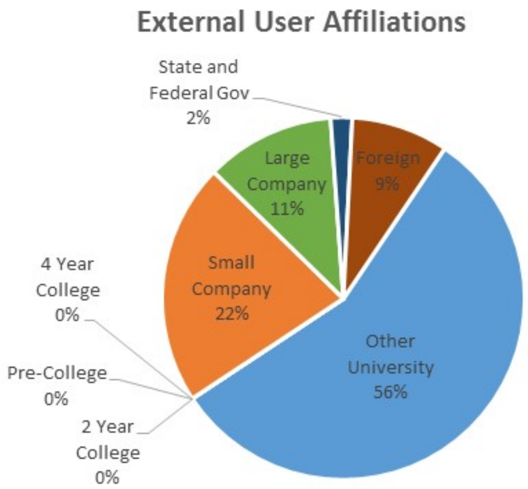
**Other major educational activities**

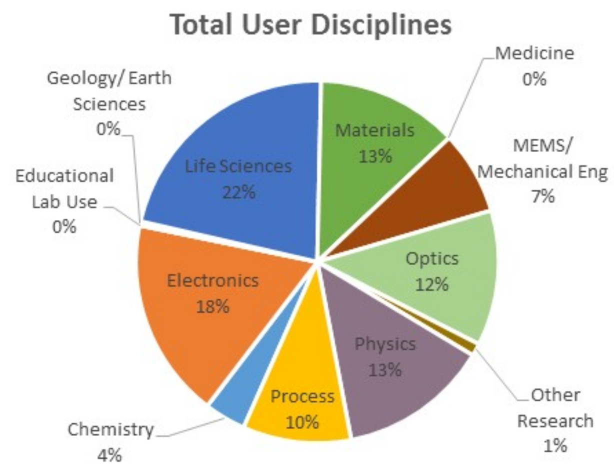
- Annual users meeting featuring keynote speaker George Malliaras (Cambridge University), 12 Invited Talks, 80 Student Posters, and 26 Company Sponsors
- "Future of Nanoscience" Workshop featuring 8 External Panelists and faculty from 11 different science and engineering departments
- Junior FIRST Lego Expo (300 attendees) featuring 23 teams of 6-10 year olds

# CNF Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 548 | 538 |
| Internal Cumulative Users | 325 | 330 |
| External Cumulative Users | 223 (41%) | 208 (39%) |
| | | |
| Total Hours | 40,544 | 45,340 |
| Internal Hours | 22,965 | 25,201 |
| External Hours | 17,579 (43%) | 20,139 (44%) |
| | | |
| Average Monthly Users | 210 | 204 |
| Average External Monthly Users | 67 (32%) | 66 (32%) |
| | | |
| New Users | 131 | 161 |
| New External Users | 46 (35%) | 51 (32%) |
| | | |
| Hours/User (Internal) | 71 | 76 |
| Hours/User (External) | 79 | 97 |

## Year 2 User Distribution



## 11.3. Kentucky Multi-Scale Manufacturing and Nano Integration Node (KY MMNIN)

Facility, Tools, and Staff Updates

Year 2 continued to be a busy and productive period for the new KY MMNIN NNCI site. We enjoyed an expansion of our overall NNCI site when the UofL School of Engineering purchased ownership of the Additive Manufacturing Competency Center (AMCC) and combined it with our existing Rapid Prototyping Center (RPC). This was a logical addition to our NNCI infrastructure as both core facilities specialize in next generation additive manufacturing and advanced 3D printing processes. Included in the expansion was the acquisition of over $1M of additional related tools (3D metal printers, machining equipment, characterization equipment, test equipment, etc).

A major tool was purchased in year 2 for the UofL MicroNanoTechnology Center (MNTC) in the form of a Primaxx Anhydrous HF Etcher. This state-of-the-art tool was sorely needed by our MEMS clients for the dry release of delicate micromachined devices. This acquisition was funded by our NNCI grant, but its installation and characterization financed by the MNTC budget. The MNTC core facility also acquired a Logitec CDP chemical mechanical polishing (CMP) tool through the generous donation of one of our industrial clients. It is capable of polishing both whole wafers (4” and 6”) and pieces/parts.

The UofL RPC core acquired a Stratasys Dimension 1200es FDM 3D printer in year 2. This printer can print 9 colors of ABS in one print at a layer thickness of 254 microns. The build volume of 25.4 x 25.4 x 30.5 cm is enclosed for stable printing temperature and dimensional accuracy. This technology is especially interesting for prototyping micro-fluidic devices.

The UK node acquired a Hellos Dual Beam system for ebeam imaging and Ga-beam patterning funded through EPSCoR and a Trovata 8-source thermal evaporator for OLED research funded through DOE. They are also in the final stages of negotiation with NanoScribe for the purchase of a state-of-the-art two-photon additive nano-manufacturing system.

Two benchtop 3D printers were purchased using NNCI funds and set up in the MNTC UofL Packing core. They are being used for multiscale demonstration projects involving embedded sensors and electronics within 3D printed parts.

Two MRI proposals were submitted in year 2 for a transmission electron microscope for cross-disciplinary research in materials and life sciences (UK) and an in-situ liquid cell electrochemistry system and cathodo luminescence imaging system for electron microscopy studies of novel energy materials (UofL).

In year 2, a part-time staff position was added to help with the implementation of FOM (Facility Online Management) for all of our cores and to assist with the KY Multiscale website and equipment database. The majority of our site administrative and operational duties remain covered by Ana Sanchez (overall site coordinator), Doug Jackson (UofL Integration Engineer), and Brian Wajdyk (UK Integration Engineer) who were all hired in year 1.

User Base

In year 2, we decided to rebrand our site to enhance visibility and marketing. While KY MMNIN (Multiscale Manufacturing and Nano Integration Node) is an abbreviation that captures all the research activities and capabilities of our site, it is challenging to remember. Since our central theme is advanced multi-scale manufacturing, we decided to simplify our site’s name as we promote it to the outside world. We worked closely with a professional graphics design group to develop a revised name and appropriate logo. The figure below shows the results of our effort - a new name, logo and tag line. The array of boxes in the logo section symbolizes the multi-scale nature of our advanced manufacturing capabilities. The red and blue colors represent the two universities. We will market our NNCI site to the outside world as simply ***"KY Multiscale",*** a name easily remembered. The tag line beneath the name associates us with the NSF NNCI network and retains our original NSF name. We also secured the address "kymultiscale.net" for our website in year 2. Along with the rebranding push came a complete revamping of our original website. We gave the website a clean fresh look focusing on our KY Multiscale branding theme, added a new Testimonial section, updated our local Site Equipment Data Base, expanded our Educational/Outreach section, and added an Events Calendar.

KY MULTISCALE
The NSF NNCI Multi-Scale Manufacturing & Nano Integration Node

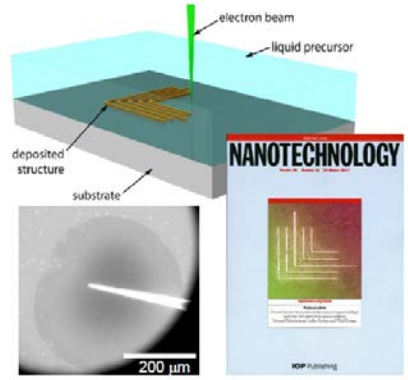
New KY MMNIN logo, name and tag line

In May of 2017, we hosted an advertising booth for our KY Multiscale site at the National SBIR Conference and TechConnect Conference in Washington DC. While the cost for this 3 day event was very high (~$4,500), we hope to attract new external users from both the mature companies and new start-ups who attended the conference. We worked with a professional graphics design group to assist us with our booth design.


Advertising display for booth at TechConnect Conference in DC

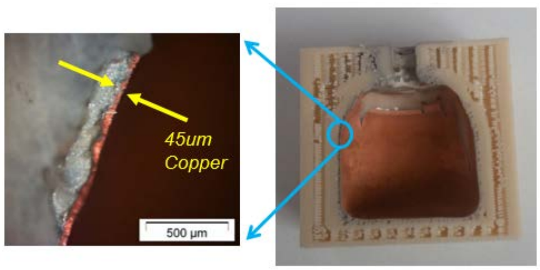
Research Highlights

The vision for KY Multiscale is to be an NNCI site where the next generation of revolutionary products and solutions will be created which require the combination and effective integration of a diverse set of 3D manufacturing processes, spanning lengthscales from the nano to meso/macro regimes. As such our site offers a wide spectrum of tools, manufacturing processes and professional expertise. While numerous research activities over a wide spectrum of disciplines use our core facilities (see Power Point Research Highlights for additional examples), in this section we present a couple of interesting projects unique to our NNCI site and its theme of multiscale additive manufacturing (AM). A research team at the University of Kentucky lead by Prof. T. J. Hastings developed a novel micro/nano AM process called "Focused Electron-Beam Induced Processing" or FEBIP. Using liquid phase reactants in combination with e-bean writing, the team demonstrated that 3D printing of high-purity copper was possible. Figure 3 shows some of their interesting sub-micron nested L-shape patterns fabricated using an aqueous solution of sulfuric acid, copper sulfate, and polyethylene glycol. FEBIP can be used as either an additive or subtractive process, thus addressing the need for nanoscale rapid prototyping, editing, and repair. This research was highlighted on the cover of Nanotechnology.




FEBIP processing for depositing sub-micron patterns of copper.

A second research project related to our site's theme of multiscale additive manufacturing was led by K. M. Walsh's team at the University of Louisville. Using a combination of electroplating and strategically placed channels/reservoirs within conventional 3D-printed parts, they demonstrated it was possible to embed thin conductive films inside plastic components, as shown in Figure 4. This opens up the possibilities of embedding antennas, interconnects, sensors and electronics within additive manufactured products that sense the environment and communicate with the outside world, creating essentially "smart" 3D printed components.




Thin copper films embedded within traditional 3D printed plastic parts.

Education and Outreach Activities

During year 2, we continued to expand our offerings of education and outreach activities for our site. Both UofL and UK ran successful NSF REU programs which used our core facilities. The UofL REU had a theme of advanced multi-scale manufacturing, while the UK REU was focused on nano/bio-active interfaces and devices. All the students from the UofL REU participated in the NNCI network wide REU Convocation hosted by GATech.

The KY MMNIN was once again selected in year 2 to host a doctoral research scholar from the Japanese equivalent of the USA NSF NNCI. This graduate student was an awardee of an internship by the Nanotechnology Platform of Japan to do nano-related research in the United States at our site.

KY MMNIN also participated in National Nanotechnology Day, an annual event featuring a series of community-led events and activities on or around October 9th to help raise awareness of nanotechnology, how it is currently used in products that enrich our daily lives, and the challenges and opportunities it holds for the future. KY MMNIN participated in the NNCI 100 Billion Nanometer Dash, when the UofL mascot "Louie" challenge our cleanroom staff in a 100 billion nanometers run at the university track stadium. The video appears on You Tube. In addition, a member of our staff traveled to our local children's museum, the Kentucky Science Center, and participated in a series of nano education demos.

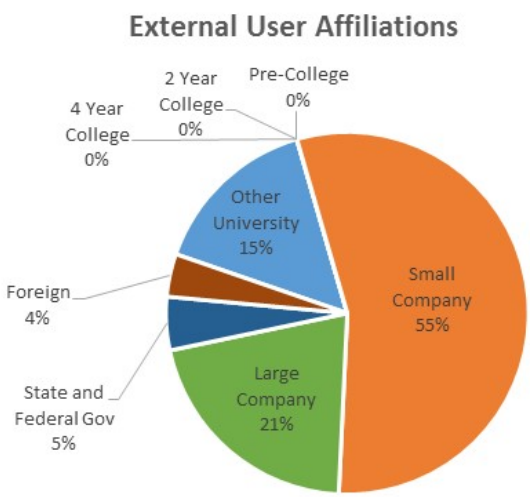
Our 8 cores continued to run summer camps and workshops in year 2, such as UK's Stem Camp for 70 middle school students, the MNTC 2017 Microfabrication Summer Camp, an

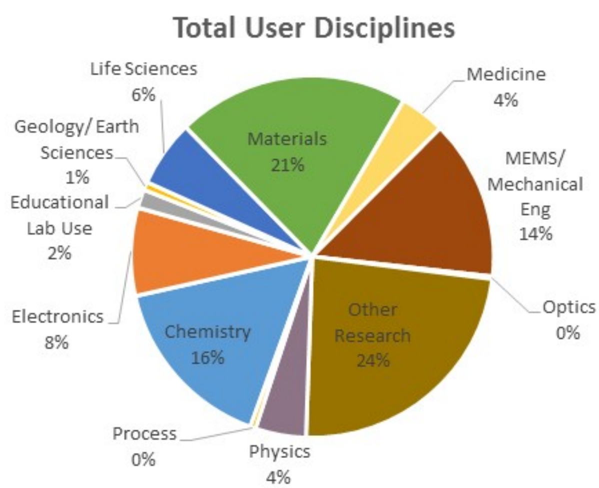
Entrepreneurship Workshop at UK, a Renewable Energy Workshop by the Conn Center, and a 2017 Promise Zone Research Summer Camp. Other educational activities included participation in NSF's "Ask a Nano Expert" and "Generation Nano" Initiatives, creating "Nano-nugget Videos" for the NNCO, participating in Engineer Day at UofL and UK, sponsoring "Pizza with a Scientist" for the KY Science Center at Mellow Mushroom, co-sponsoring seminars, and demonstration classes/tours for surrounding high schools and regional universities (EKU).

# KY MMNIN Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 278 | 420 |
| Internal Cumulative Users | 206 | 315 |
| External Cumulative Users | 72 (26%) | 105 (25%) |
| | | |
| Total Hours | 14,629 | 17,151 |
| Internal Hours | 9,726 | 12,166 |
| External Hours | 4,903 (34%) | 4,986 (29%) |
| | | |
| Average Monthly Users | 104 | 141 |
| Average External Monthly Users | 22 (21%) | 25 (18%) |
| | | |
| New Users | 111 | 251 |
| New External Users | 26 (23%) | 43 (17%) |
| | | |
| Hours/User (Internal) | 47 | 39 |
| Hours/User (External) | 68 | 47 |

## Year 2 User Distribution



### 11.4. Mid-Atlantic Nanotechnology Hub (MANTH)

The Mid-Atlantic Nanotechnology Hub (MANTH) is housed at the Singh Center for Nanotechnology at the University of Pennsylvania (Penn). MANTH provides open access to leading-edge R&D facilities and expertise for academic, government, and industry researchers conducting activities within all disciplines of nanoscale science, engineering, and technology. Users from the mid-Atlantic and beyond have full access to state-of-the-art instrumentation for the fabrication and characterization of nanoscale structures, devices, and materials. Further, MANTH provides a portal for users to access the intellectual expertise of the Penn faculty and staff in the nano-arena as well as other relevant facilities at Penn. MANTH also includes a partnership with the Community College of Philadelphia to investigate approaches to appropriate training of technicians for the nanotechnology industry.

MANTH hosted the October 2017 Year 2 NNCI conference. Over 80 participants from the 16 member sites, the NSF, and the NNCI Advisory Committee attended the one and one half day meeting. The first day included site overviews from their directors, and this year the overviews were presented in the form of short presentations followed by panel discussions. The 4 topics of these panel discussions: Redefining Traditional Roles; Resource Allocation and New Equipment; Future Research Directions; and New Education and Outreach, were chosen to help the sites understand how to best serve our users. The panels invoked lively questions, answers, and comments from the participants.

On the second day of the conference, breakout sessions looked into Facility Management, Diversity, New Business Development Concepts, and Training Programs and Workshops. These sessions were followed by a review of the discussions before all of the attendees. The meeting concluded with an Advisory Board Report. Parallel meetings were held to discuss nanotechnology education and nanotechnology societal and ethical implications. Two technical talks were presented at the conference: Prof. Mehdi Javanmard from Rutgers University described research his group is conducting at MANTH on electro-fluidic nanotechnology, which provided an outside academic user perspective; and Prof. Eric Stach from Penn described the new research avenues we will pursue with the electron microscope suite MANTH plans to install in 2018.

MANTH's NNCI network interactions include the work of a senior staff member who is the chair of the Equipment, Maintenance, and Training (EMT) Working Group. MANTH staff has also played a leading role in making agreements with vendors who supply materials for member fabs. Significant price reductions were negotiated for all of the NNCI sites for materials such as electron beam and photo resists, wipes, gloves, and other consumables. MANTH staff participated in NNCI events that include the Stanford ALD workshop in April, and the Stanford Lithography workshop in June 2017. A post-doctoral researcher at MANTH participated in the weeklong NNCI-ASU Winter School in January 2017 on the Responsible Innovation and Social Studies of Emerging Technologies.

<u>Facility, Tools, and Staff Updates</u>

New equipment in our facility includes:

- **Oxford Instruments PlasmaPro** 100 Cobra load-locked ICP RIE with Chlorine chemistry. It is outfitted with the following gases: $CF_4$, $CHF_3$, $SF_6$, $O_2$, Ar, $Cl_2$, and $BCl_3$, and is expandable to a total capacity of 12 process gases. The wafer chuck is equipped with both a

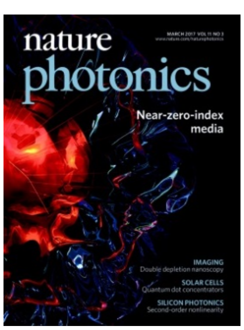

liquid heat exchanger capable of operating between -5 and 80 degrees Celsius and a heater capable of operating up to 350 degrees Celsius.
This system can etch high aspect ratio structures in $SiO_2$, $Si_3N_4$, Si, Al, $Al_2O_3$, W, Ta, Mo, Ti, $TiO_2$, and III-V materials such as GaAs and InP with high selectivity to both photolithography and electron beam lithography resists. The Oxford Cobra tool enhances our center's capability to fabricate new photonic and electronic devices.

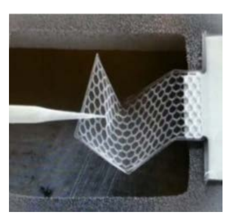
- **MRL Cyclone Atmospheric and LPCVD** furnace stack for oxidation, Si Nitride deposition and annealing
  4-Stack Tube Furnace
  - Thermal Oxidation (wet/dry)
  - LPCVD Silicon Nitride
  - (2) Atmospheric anneal: $N_2$, forming gas
  - Up to 150 mm substrates
  - 50 wafer processing flat zone
- **Scanning Probe Accessories.** Five additions have been made to our existing scanning probe tools in the Scanning Probe Facility to improve their utility or to make them more efficient.
  - An improved cryogenic system has been installed for the high vacuum electrical probe station. Simpler connections reduce wasted $LN_2$.
  - A fluid tip holder has been added to the Bruker Icon AFM.
  - The environmental sample stage for the Asylum AFM was rehabbed and returned into service
  - An improved epi-illumination system has been installed in the TIRF-AFM.
  - A cooling stage has been added to the Pico Plus AFM.

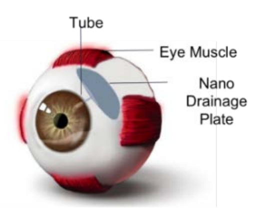
User Base

Nearly 600 researchers made use of the MANTH facility last fiscal year - an increase of 20% over last year. Approximately one quarter of our users are external, approximately equally split between academic and industry. Approximately one quarter of the research conducted here is in the life sciences and medicine, similar to last year. Approximately 100 attended hands-on workshops on microfluidics fabrication and scanning electron beam imaging. In particular, an increased number of potential researchers have participated in the ever-popular MANTH microfluidics workshop, where attendees fabricate and test prototype devices.

Research Highlights

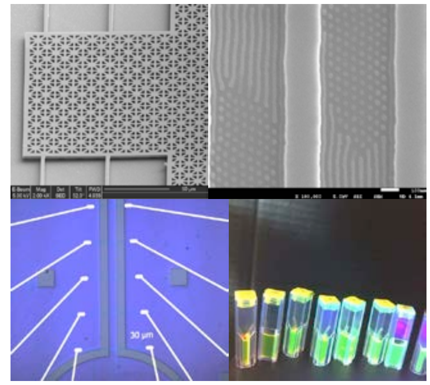





Researchers at MANTH published work in the fields of photonics, materials characterization, and in life sciences. A Penn faculty member and MANTH user, Nader Engheta, co-authored a review of zero-index materials in Nature Photonics in March. Other work includes the research on flexible nanostructured material that may potentially be used to treat glaucoma. This research exemplifies a question widely discussed at the October NNCI conference - how do you categorize these new areas of exploration? This work spans materials research and medical research.

Education and Outreach Activities



**ESE 536 Laboratory course** - A new course in Nanofabrication and Nanocharacterization was developed and offered for the first time in the MANTH facilities in Spring 2017. This course is intended for first year graduate students interested in the experimental practice of nanotechnology. Students gain familiarity with both top-down and bottom-up fabrication and characterization technologies in the context of this hands-on laboratory experience.

**Nano-Technician Program Focus Group** - 12 representatives of industry, foundry, and academic nano programs from around the Mid-Atlantic and New England convened at the Singh Center to discuss the MANTH/CCP Nanotechnology Technician Training Program. The daylong event provided the participants with the opportunity to explore the utility and options of creating a technician program for the greater Philadelphia region.

**Nano Day** - 175 students from 7 Philadelphia schools, and their teachers, learned about nanotechnology at the MANTH site. The daylong event included presentations and hands-on activities. Over 150 Penn graduate and undergraduate students participated as guides and instructors.

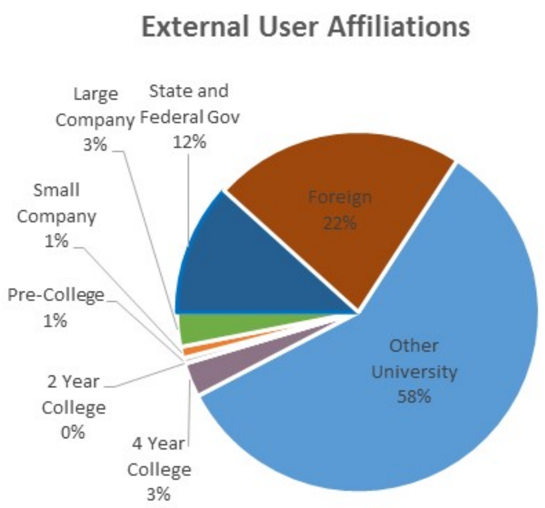
MANTH was host to 6 REU students over the summer. Penn faculty with research topics ranging from Bioengineering to Mechanical Engineering and Nanofabrication. These students participated in the REU Convocation at the GeorgiaTech in August.

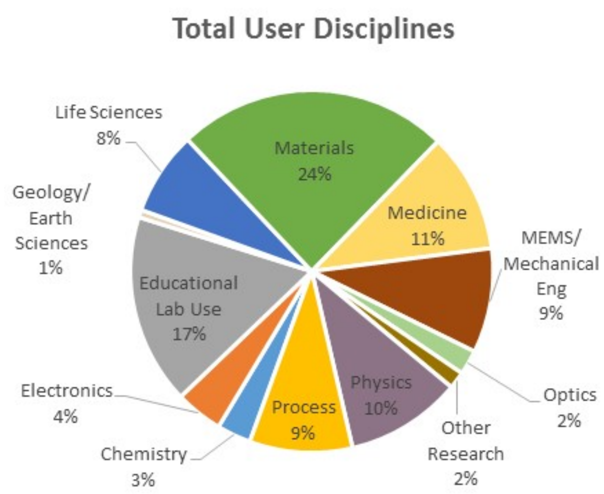
MANTH hosted 54 events that comprised of 771 participants; these events included tours, workshops for students and the general public.

# MANTH Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 482 | 589 |
| Internal Cumulative Users | 368 | 393 |
| External Cumulative Users | 114 (24%) | 196 (33%) |
| | | |
| Total Hours | 36,970 | 37,933 |
| Internal Hours | 34,545 | 31,524 |
| External Hours | 2,425 (7%) | 6,409 (17%) |
| | | |
| Average Monthly Users | 171 | 194 |
| Average External Monthly Users | 29 (17%) | 44 (23%) |
| | | |
| New Users | 270 | 339 |
| New External Users | 73 (27%) | 138 (41%) |
| | | |
| Hours/User (Internal) | 94 | 80 |
| Hours/User (External) | 21 | 33 |

## Year 2 User Distribution

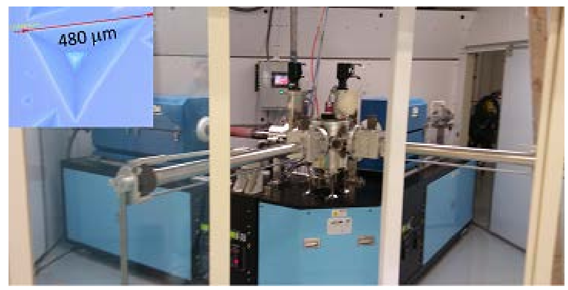


## 11.5. Midwest Nanotechnology Infrastructure Corridor (MINIC)

Facilities, Tools, and Staff Updates

a) The node acquired a qNano Gold nanoparticle analyzer (Izon Scientific Ltd) which measures the size and charge of particles from 50 nm to 10 um using an electrozone technique. The qNano Gold is particularly suited to assaying biologically-derived nanomaterials, such as viruses, proteins, liposomes, and cell organelles to support research involving bionanoparticles. b) An ultrasonicator was acquired from Qsonica, LLC. This powerful (700w) probe-type sonicator has been used for exfoliation of 2D materials from bulk samples and for nanoparticle dispersion. c) Apparatus for gel electrophoresis has been added to the Bio-Nano lab to separate macromolecules, such as DNA and proteins.



Planartech two-tube TMD deposition system. Insert shows a large crystal result.

Cleanroom related tool additions include a dual furnace CVD system from Planartech for the growth of transition-metal dichalcogenide (TMD) films, in particular sulfide and and selenide films for users. The system has dedicated furnace tubes for each type of film, and the tubes are connected by a UHV load-lock mechanism that allows samples to be moved between the tubes without exposure to atmosphere. To date the system has been installed, accepted from the vendor, and has successfully grown 2D films**.** The node has developed large area $MoS_2$ films (> 1mm2) and a novel technique to form extremely large single crystals (~500 μm on a side). State of the art $WSe_2$ crystals (~100 μm on a side) have also been demonstrated. Several researchers have been trained and are using the system. The glovebox with equipment for exfoliation and transfer of 2D fils has been completed and is actively being used. To support our cleanroom users we also upgraded to a Disco DAD 552 dicing saw and a new Westbond 7476 wedge bonder. A new ellipsometer from FilmSense was received that allows rapid measurement of a full wafer using a motorized stage to characterize film thickness and IR. A Parylene deposition system was ordered. Delivery occurred just after the end of this report period.

This year MINIC hosted the second annual 2D Materials workshop. Attendance increased this year hitting 50 attendees. Eight speakers presented tutorial material on topics ranging from basic materials science and growth to processing and devices, and exotic physics demonstrated in these structures. Of the attendees, 27 came from outside the University of Minnesota. Attendees gave the tutorial session 3.4/4.0. This included 12 graduate students who stayed for hands-on training in growing and processing 2D material structures. The attendees scored the hands-on portion of the workshop as 4.7/5.0. Comments for both sessions were overwhelmingly positive.

In July we hired Laura Parmeter as a new technical staff to add to our process support staff. Laura has a background in both biology and physics. This brings the number of process support staff back up to 5. Laura is new to nanofabrication but has made great progress. Her responsibilities are in the photolithography area where she will oversee the equipment and training. She will also be participating in new user orientation. Two part time staff have been hired to support operations in the nanobio focus area.

User Base

The MINIC node supports a broad cross section of nano activities, particularly in the upper Midwest. The node has emphasis in three areas: 2D Materials, Bionano, and Advanced Packaging. Efforts to grow our external user base are described below.

*Marketing to industrial users*: Over the past year, MINIC staff have regularly met with researchers and leadership from local companies, as well as entrepreneurs and those establishing technology-based companies. Examples of these interactions include: a) tours of the Nano Center to 20 medical professionals and industrial researchers attending the Design of Medical Devices Conference in Minneapolis; b) an exhibit at the Minnesota SBIR Road Tour, the local stop on the National SBIR Road Tour. Attended by over 500 industrial researchers and entrepreneurs; c) an exhibit at the annual networking event held at a local technology incubator. This event put us in front of 250 small business owners and industrial researchers; d) Presented tours of Nano Center Facilities to 35 industrial researchers, CEOs of local science and technology firms, and members of the University's Medical Device Fellows program.

*Marketing to external academic users*. Gave presentations on nanotechnology and the work of the MINIC to students and faculty at two local liberal arts colleges (St. Olaf College in Northfield, Macalester College in St. Paul) and a regional university (St. Cloud State University). The talks emphasized opportunities for nanoscience research collaboration, particularly in the areas of 2D materials and bio-nano applications.

Research Highlights

From more than 400 projects, we have selected seven as representative of the impactful work from our node: 2 internal, 2 external academics, and three companies (see Highlights document). Internal work includes the use of graphene ribbons to create the smallest ever nano tweezers to hold single molecules and the development of devices capable of simultaneous measurements of action potential and neurotransmitter levels in the brain. External academics include a novel cancer detector and a method to study oil spill remediation. The industry work includes a revolutionary approach to glaucoma treatment that is now going into human trials, a spin-off that uses state of the art magnetic devices for marker detection, and understanding the mechanisms of surface breakdown in high voltage testing.

Education and Outreach Activities

The Nano Center offers a diverse set of programs for visiting secondary school groups, summer days camps, and regional colleges. Over the past year, about 150 students grades 7 to undergrad were given general overviews of the micro/nanofabrication process, followed by detailed cleanroom tours that gave students the opportunity to observe the tools and unit operations used in lithography. This program is customized for student backgrounds and level; for example, undergrad visitors receive more in-depth explorations into topics such as the material science of silicon and the properties of electron-beam lithography. The popularity of these tours continues to grow with more requests received each year.

Minneapolis high school physics students from the Upward Bound Vision Quest program entering the MINIC cleanroom.

For summer camps hosted at the University, MINIC offers an introduction to nanotechnology that engages middle school students in hands-on activities that demonstrate nanoscale concepts on the macro scale. In the past reporting year, MINIC served a total of 250 students in grades 7 through 10. For older students, we offer a lab-based activity that allows students to replicate the photopatterning step of photolithography. Last year this program was offered to over 150 students grades 10 and up. For several of these summer programs we partnered with local organizations, including Hennepin County 4H club, the YWCA SciGirls project, and Minnesota State U-Mankato.

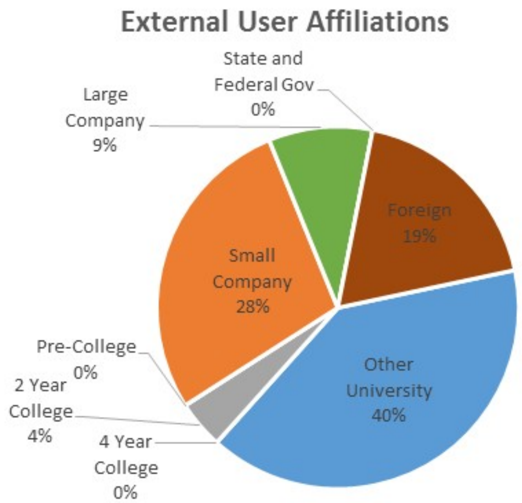
In addition to these one-time educational experiences, MINIC has developed an undergrad internship program, working with second-year undergraduates from a local community college (St. Paul College, or SPC). In the fall of 2016 three SPC students were recruited and trained to work on bionano-related projects at our Nano Center facilities. The interns were supported and mentored on projects related to 1) synthesis and characterization of nanoparticles for bio-imaging; 2) using functionalized nanoparticles to image components of human cells; and 3) measuring the toxicity of hafnia nanoparticles to human skin cells. A paper based on the latter project is in preparation. Two past interns from this program have been accepted into the University's College of Science and Engineering.

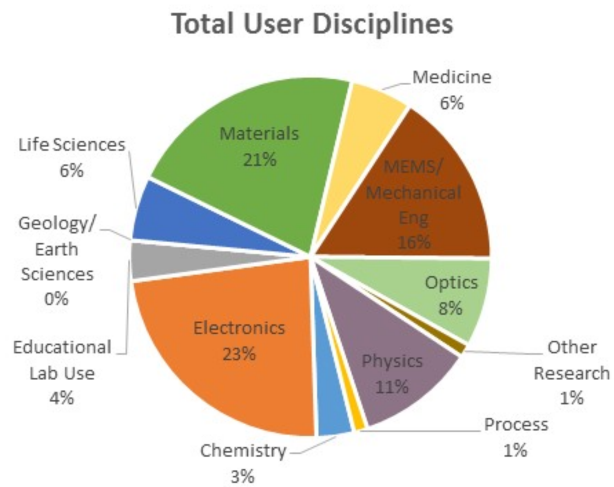
In July 2017 we hosted our second two-day meeting for Northern Nano Lab Alliance (NNLA) members. NNLA was established to better support nano labs at smaller schools throughout the upper Midwest. Attendee representatives from South Dakota State, Iowa State, Michigan Tech, University of Iowa, and Rose-Hulman participated. Each school made a presentation about their facilities, research capabilities, user base, faculty research fields, institutional support, and problems/issues they face. Most sites continue to struggle with inadequate staff support and low user base. As part of the meeting attendees toured MNC facilities and met process and maintenance staff for individual discussions of specific areas of interest regarding equipment operation and maintenance, best practices, training, safety, vendors, and other relevant topics. Charlie Veith from UPenn visited to discuss his program to reduce operating costs for cleanrooms by negotiating with vendors to get better pricing through group buying. These efforts are ongoing. The NNLA training grant program continues with participants from South Dakota State University, Mankato State University, Iowa State University, University of Iowa, Michigan Tech University and Rose-Hulman Institute of Technology.

# MINIC Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 384 | 415 |
| Internal Cumulative Users | 271 | 275 |
| External Cumulative Users | 113 (29%) | 140 (34%) |
| | | |
| Total Hours | 27,002 | 26,443 |
| Internal Hours | 20,495 | 19,733 |
| External Hours | 6,507 (24%) | 6,710 (25%) |
| | | |
| Average Monthly Users | 156 | 156 |
| Average External Monthly Users | 26 (17%) | 33 (21%) |
| | | |
| New Users | 151 | 150 |
| New External Users | 57 (38%) | 59 (39%) |
| | | |
| Hours/User (Internal) | 76 | 72 |
| Hours/User (External) | 58 | 48 |

## Year 2 User Distribution



## 11.6. Montana Nanotechnology Facility (MONT)

MONT Facilities include: Montana Microfabrication Facility (MMF), Imaging and Chemical Anaylsis Lab (ICAL), Center for Biofilm Engineering (CBE) and Mass Spectrometry, Metabolomics, Proteomics, Facility (MSMP); Partner site with the Science Education Resource Center (SERC) at Carleton College.

<u>Facility, Tools, and Staff Updates</u>

**$1M in funding secured for tools and expansion**

MONT Director Dickensheets, working with other MONT user PIs, received a $450,000 grant from the MJ Murdock Charitable Trust to add equipment and expand facilities within MONT. By leveraging matching funds from the MSU Office of Research and Economic Development, MSU College of Engineering and NSF NNCI, the **total investment will be $1M**. The project will enhance MONT's capabilities for **soft-lithography** and **thin films deposition.** Soft lithography capabilities are essential to rapidly prototype and replicate sophisticated microfluidic systems on nano-engineered substrates. A major tool addition for soft lithography and MEMS users will be an aligned wafer bonder. Enhanced thin films capabilities will include a new electron beam evaporator with ion assist for denser, pinhole-free films, and glancing angle deposition for structured films. Renovation to add approximately 250 sq. ft. of cleanroom space will begin in 2018, with new tools installed late in the same year.

**Progress with SUMS facility management software – an example of NNCI Cooperation**

MONT is cooperating with Georgia Tech of SENIC to link its SUMS facility management software to MONT facilities, leveraging the extensive application development that Georgia Tech has already done and applying it to our much smaller installation in Bozeman. If successful, this will save considerable duplication of effort and get MSU instruments online much more quickly and cost effectively than if we were doing this independently. Site staff at the two facilities are working together and with their respective university IT departments to define and solve some issues in linking the software. We hope MONT will be using SUMS in 2018.

**New tools that came online in Y2 of the NNCI project:**

- an electroplating system for thick films of permalloy, an 80/20 nickel/iron alloy
- Raman Confocal Spectro-Microscope. This new tool enables chemical state mapping of heterogeneous surfaces at the nanoscale.
- Thick film resist laminator, for application of dry-film photoresists to wafers

MONT has an outstanding equipment leveraging ratio. MONT has spent about $250,000 of NNCI funds for equipment (years 1+2), but has placed tools valued at around $1.5 million (new tools include PHI Auger Nanoprobe, 10-year-old EVG 610 contact aligner, Filmetrics thin film profiler, electroplating system for ferrous metals); this will continue in Y3 with an additional $1M for expansion and new tools, leveraged with NNCI matching at around 25%.

There were no additions to permanent staff in Y2. Several new student staff members were recruited and trained to work in the various MONT facilities.

<u>User Base</u>

**Marketing and Outreach**

MONT hosted two webinars that were advertised network-wide as well as to a broad number of potential users from local and regional academic and industry affiliates. There were a total of about 70 participants representing 7 universities and 12 companies. The webinars were: “Imaging Microorganisms on Surfaces” on December 7, 2016 (representatives of NNCI sites Virginia Tech and Georgia Tech attended this webinar), and “From Microfluidics to Nano-optics: Building Devices in the Montana Microfabrication Facility” on March 23, 2017.

MONT held its annual User’s Meeting on July 12, 2017. The meeting focused on educating users about MONT’s emerging capabilities and new equipment, and user-lead round table discussions to identify ways MONT can better serve its user base. Fifty-seven people registered for the meeting and evening poster session, more than 60 attended. We sent targeted invites for the poster session to companies from the local nanotech industry. Representative from five companies who are not current users attended the poster session.

**Research strengths of MONT users**

**Nano-systems** engineering strengths include:

- **nanophotonics** for optical imaging, environmental sensing and advanced telecommunications
- **sensors** for self-healing electronics for spaceflight, and for pathogens
- **MEMS active optics** based on shape-changing surfaces are leading to highly miniaturized imaging systems and enhanced microscopy tools for the life sciences

**Energy applications** are enabled by nanostructured ceramic and crystalline materials.

Researchers are using **microfluidics** to explore **life-sciences** questions:

- neural system development and function
- point of care diagnostics
- 3D cell culturing and organoids
- biofilm formation and mineralization

MONT’s imaging and spectroscopy tools are used to address questions in the **geosciences.**

<u>Research Highlights</u>

During Y2, MONT researchers produced 59 publications and 2 patents.

MONT researcher Mark Young published a high impact paper in the **Proceedings of the National Academy of Sciences**: Manrique P, et.al, “Healthy human gut phageome,” Proc Natl Acad Sci 2016 Sep 13;113(37):10400-5. The publication already has 41 citations (in Dec. 2017).

Industrial user **Bridger Technologies, Inc.** moved closer to commercialization of their pathogen sensors that use highly multiplexed nano-gap bridging DNA strands for rapid point-of-care detection. Industrial users **Revibro Optics, Inc.** and **Agile Focus Designs, Inc.** both received NSF SBIR awards to develop active mirror technologies that originated in MONT. Several MONT users took advantage of **other NNCI facilities**, including **UCSD** and **Cornell**. Highlight slides for ten of our user projects are provided separately.

<u>Education and Outreach Activities</u>

We continue to develop a series of web-based modules on characterization of nanomaterials, with primers on Analytical Instrumentation and Methods and additional resources related to nanotechnology. The modules are housed on SERC's website, (our education partner at **Carlton College**) http://serc.carleton.edu/research_education/geochemsheets/index.html. New primers have been recruited on: Transmission Electron Microscopy (including small area electron diffraction and analytical electron microscopy), Laser-induced breakdown spectroscopy (LIBS), and 40Ar-39Ar Mass spectrometry, Auger Electron Spectroscopy, and Confocal Microscopy.

MONT PI Dave Mogk with Mike Hochella (NanoEarth) conducted a pre-meeting workshop in association with the **Goldschmidt 2017 Conference** (an international conference on geochemistry and related subjects) in August. This workshop introduced fundamental principles of nanoscience, with an emphasis on the instrumentation and facilities that are now available for characterization of naturally occurring and incidental nanomaterials. Opportunities to participate in the NNCI were promoted. **Thirty-five people attended the workshop**. Mogk also presented information on MONT's recently acquired PHI 710 Scanning Auger Nanoprobe System to the **Geological Society of America Annual Meeting** in September, touting the auger's capabilities and welcoming collaboration from across the **Earth and environmental sciences**.

During the week of July 10, 2017, seven teachers participated in MONT's Solar Cells for Teachers summer course. Upon course completion, the teachers receive credit toward MSU's Masters in Science Education program. Teachers use the MMF facility (part of MONT) to produce a solar cell that they take home with them. The teachers came from Montana, Minnesota, Germany, Canada, New Mexico, Iowa, and California.

MONT was the major sponsor of "Nano Days," an event that features research in nanotechnology from MSU faculty and students. About 120 5th graders from area schools were enthralled by a talk from MONT co-I Recep Avci, who demonstrated how nanoscience works in cell phone photos. The 5th graders then participated in the hands-on activity stations hosted by MSU students and faculty. MONT hosted Nano Land, and also designed and distributed a small "YOU be the nano scientist" take-home kits with a liquid crystal sheets. Nano Days was open to the public in the evening; about 220 parents and children explored the activities.

On April 20, 2017 MONT sponsored and participated in Community Science Night at Browning Middle School, Blackfeet Reservation, Browning, MT. Families of Browning Middle School students were invited to a science night held in the school gym. Eight Browning Middle School students were trained on to use our "nano kits" and were ambassadors for MONT's nano stations, helping students with demos and sharing nanoscience. The school is 99% Native American.

SEI Activities

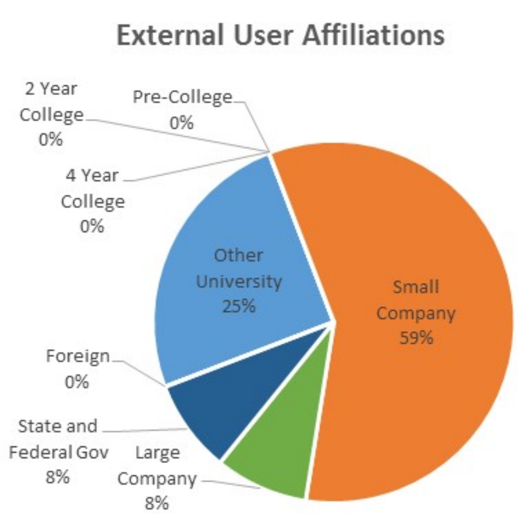
New web-based instructional modules are in preparation to be added to the current Teaching Geoethics Across the Geoscience Curriculum (http://serc.carleton.edu/geoethics/index.html). Specific case studies related to the impacts of nanoparticles on society (e.g., human health) and the environment (e.g., role of nanoparticles in the storage, transport and transformation of hazardous materials in natural and engineered systems) are in development and will be added to our collection of case studies. In addition, our training short courses in the MONT facility explicitly address ethical issues related to the responsible conduct of research (e.g., integrity of data acquisition, reduction and representation; dealing with uncertainty in experimental and analytical results; lab safety; appropriate use and disposal of hazardous materials, etc.). The majority of work in this area this past year has been focused on Professionalism (Responsible

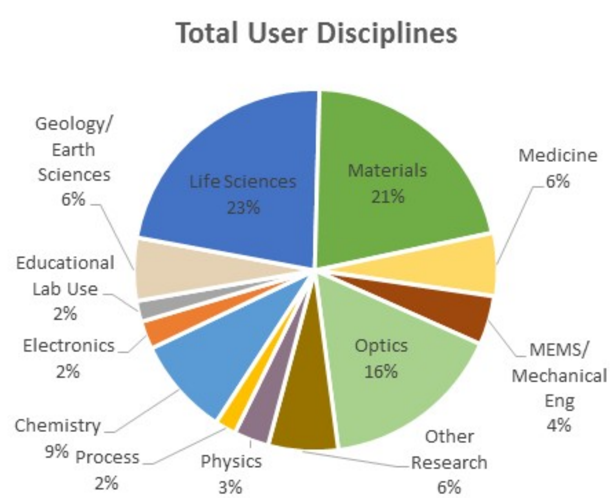
Conduct of Scientists), including topics such as interpersonal relations that involve power structures (e.g., faculty-student, editor-author, administrator-faculty), sexual harassment and bullying, and professional relations that involve trust, responsibility, justice, and fairness. Insuring the integrity of the Science and Scientists related to the MONT facility is a primary concern of this project.

# MONT Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 125 | 160 |
| Internal Cumulative Users | 96 | 124 |
| External Cumulative Users | 29 (23%) | 36 (23%) |
| | | |
| Total Hours | 3,599 | 4,713 |
| Internal Hours | 2,842 | 3,901 |
| External Hours | 747 (21%) | 812 (17%) |
| | | |
| Average Monthly Users | 46 | 51 |
| Average External Monthly Users | 8 (17%) | 10 (20%) |
| | | |
| New Users | 36 | 58 |
| New External Users | 1 (3%) | 9 (16%) |
| | | |
| Hours/User (Internal) | 30 | 31 |
| Hours/User (External) | 26 | 23 |

## Year 2 User Distribution



## 11.7. Nanotechnology Collaborative Infrastructure Southwest (NCI-SW)

Facility, Tools, and Staff Updates

For Year 2 the NCI-SW is pleased to offer the facilities and expertise of the Center for the Life Cycle of Nanomaterials (LCnano) to the wider NNCI community. LCnano allows for the assessment of the risks of nanomaterials to humans and the environment across their life cycle from creation, through use and disposal. The LCnano laboratories are part of the Nano-technology Enabled Water Treatment Engineering Research Center consortium comprising Rice University, ASU, Yale, and the UT El Paso.

During year 2 three new staff members have been hired to support users working with the ASU NanoFab and the LeRoy Eyring Center for Solid State Science (LE-CSSS), the two largest centers under the NCI-SW umbrella. Scott Agnew joined the staff of the ASU NanoFab as a process engineer, specializing in etch development. Scott has an MS degree and over 30 years' prior experience in the semiconductor industry. Joining LE-CSSS are Dewight Williams and Dr. Katia March. Katia is an expert in electron energy loss spectroscopy and scanning transmission electron microscopy (STEM). She will be the external user contact for advanced STEM applications. Dewight is an expert in cryo-transmission electron microscopy (cryo-TEM) and will establish the cryo-TEM laboratory based around the FEI Titan Krios Cryo-TEM.

Significant investments by ASU and external funding agencies have resulted in the acquisition of two new tools for users of the NCI-SW. The LE-CSSS has installed a new FEI Titan Krios Cryo-TEM. The cryo-TEM is designed to image rapidly frozen molecules with 2-3Å resolution. The ASU NanoFab has acquired a new AnnealSys rapid thermal processor under the Defense University Research Instrumentation Program (DURIP). The new tool is operational in the NanoFab cleanroom and allows precise control of annealing in a variety of atmospheres.

User Base

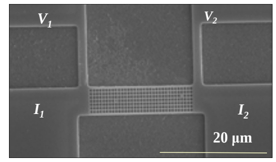
The NCI-SW supports a traditional nanotechnology user base as well as users working in the areas of renewable energy, health sciences, environmental nanoscience, and the SEI of nanotechnology. We support non-traditional users in the medical and geoscience communities. Outreach activities include quarterly newsletters and archived webinars. The webinars last one hour and included topics as diverse as nanomaterials in the environment, the limits of solar cell efficiency and advanced scanning transmission electron microscopy. Participants sign up for the webinars in advance and have a choice to watch a live stream or review it later. We track the demographics of the participants with Google Analytics. For the first five webinars a total of 287 people registered in advance, with 151 watching the live stream and a further 282 viewing the recording. The newsletter is distributed to more than 5,000 email addresses, and >17% of the recipients opened the link to review the newsletter on-line.

Research Highlights

Laser Components DG (LCDG) is an external user success story. They began in 2004 as a start-up company, engaged with the ASU NanoFab on a small scale with one employee (Dragan Grubisic). They started with the idea to develop a highly sensitive silicon avalanche photodiode. It took them several years of development work to make progress, but now in 2017 they have grown to 22 employees at their facility at the ASU Research Park. They still have two employees using the NanoFab on a regular basis for their development work. Their R&D

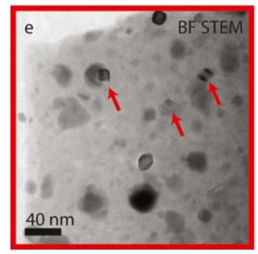
activities have expanded to include Ge, III-V, and II-VI materials. They are currently developing both IR emitters and detectors.

Dr. Hao, Professor of Mechanical Engineering at the University of Arizona in Tucson, generously credits his work at the ASU NanoFab as enabling his 2017 NSF CAREER Award # CBET1651840 entitled "Study of Nanoporous and Nanograined Materials for Thermoelectric Applications". His research focuses on how nanostructured films can optimize the characteristics of thermoelectric devices.



*A nanoporous Si film.*

The NCI-SW aims to support non-traditional users in the fields of geology and geochemistry. An international collaboration between the University of Arizona and the University of Toronto is using the LE-CSSS transmission electron microscopy laboratory to study the in-situ growth and formation of Fe nanoparticles and vesicles in lunar soil. Electron energy loss spectroscopy measurements indicate the Fe nanoparticles are composed entirely of $Fe_0$, suggesting this simulation accurately mimics micrometeorite space-weathering processes occurring on airless body surfaces.



*Images of a soil grain with Fe nanoparticles*

Education and Outreach Activities: More than a dozen lab tours were conducted during Year 2. The tours visited facilities within LE-CSSS and the ASU NanoFab. In total, over 1,000 students went on these tours and participated in hands-on science activities in LE-CSSS. The NCI-SW continued to provide remote access (RA) to a scanning electron microscope to Grade 4-12 classrooms and in public outreach events. Nine sessions were held, including signature events of Night of Open Door (2/25/17) and Geeks' Night Out (3/4/17) during which over 500 people saw exhibits related to nanotechnology. Two of the sessions were parts of nationwide RA events, on 10/12/16 in celebration of National Nano-technology Day and on 7/19/17 at the High Impact Technology Exchange Conference. For National Nanotechnology Day, students from Madison Park Middle School contributed a Nano Nugget video mentioned in a White House blog.

Students from Madison Park Middle School explain nanotechnology as a Nano Nugget developed for National Nano-technology Day on 10-9, 2016.

The NCI-SW hosted four students from community colleges and one international student from Japan in our REU program as well as one RET participant. All the students participated in the NNCI Convocation. We also provided hands-on lab experiences for students in the nano-technology AAS program at Rio Salado College. Our partner, Science Foundation Arizona, hosted an Introduction to Nanoscience Activities mini-workshop for K-14 schools on 4/18/17.

Arizona State University was the lead in an RET site proposal with NNCI partners at GA Tech, Louisville, Nebraska, and Minnesota. The program objectives are: 1) grow a national cohort of educators with experiences that reflect broad educational, industrial, and societal nanoscience and engineering (NSE) activities; 2) build and disseminate a library of NSE educational materials; 3) highlight the work of RET teachers/CCF at Professional Development Workshops; and 4) encourage RET participants to present at professional society meetings.

SEI Activities

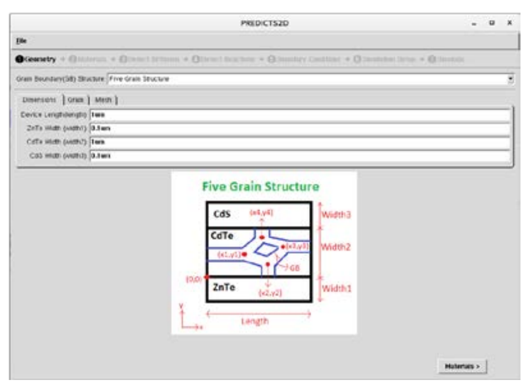
Participants in the community engagement workshop hosted by the SEI User Facility

Dr. Jameson Wetmore and his colleagues Ira Bennett, Erik Fisher, David Guston, and Cynthia Selin, run the NCI-SW SEI User Facility, which works one-on-one with visiting scholars and also facilitates workshops to do in-depth training with a number of people at a time. Examples include Kim Stolk, a graduate student studying at TU Delft who spent two weeks in Arizona in the Fall learning more about the Socio-Technical Integration Research protocol and developing practical guidelines and support documents to make it more accessible to others. During March 2017 the SEI User Facility hosted a community engagement workshop to give engineers aspiring to help the developing world basic training in how to prepare for such endeavors.

In June of 2017 the SEI team supported the second NCI-SW Science Outside the Lab session in Washington DC. The 14 students that participated came from NNCI sites from across the country including; University of Washington, University of Illinois, Northwestern University, North Carolina State University, University of Pennsylvania, and University of Nebraska-Lincoln. The participants were graduate level scientists or engineers and spent the week learning from practitioners in the science policy field with particular attention paid to nanotechnology policy. They visited with NGOs focusing on health and safety, the National Nanotechnology Coordination Office, the NSF and the EPA to name a few. The response by the students was extremely positive and it is anticipated that we will continue to pull graduate participants from the NNCI sites in 2018.

The NCI-SW SEI User Facility hosted the Winter School on Responsible Innovation and Emerging Technologies, held from 3-10 January at Saguaro Lake Ranch. Thirteen students from four countries participated. Four of those participants were from NNCI sites; North Carolina State University, University of Pennsylvania and two from University of Virginia.

Computation Activities




Example of the PREDICTS2D graphical user interface released to the nanohub in 2017.

Prof. Vasileska at ASU coordinates the computational activity for the NCI-SW. Dr. Vasileska has been a long time contributor and user of the NCN's nanoHUB and she has tallied 4,500 new simulation users on nanoHUB for calendar year 2016. Her most recent contribution has been the release of the 1D and the 2D versions of the unified solver, PREDICTS2D, as shown in the figure below. The 2D graphical user interface of PREDICTS2D allows users to establish geometric parameters of the simulation mesh and grain boundaries to simulate point defect diffusion reactions as well as grain boundary diffusion.

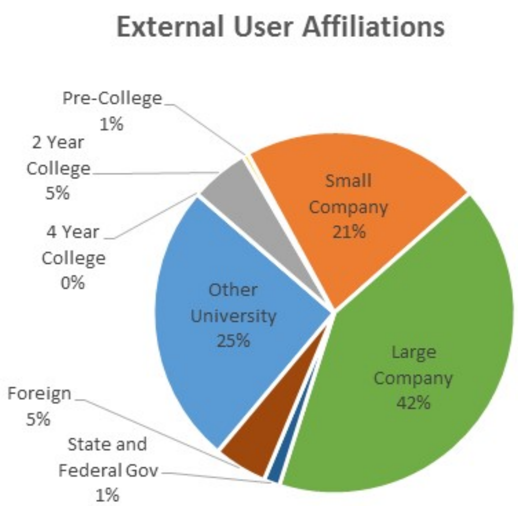
Dr. Vasileska's group and researchers at First Solar Inc. have used these tools to study the important problem of copper diffusion in thin films of CdHgTe. As described in the Highlights slides they were able to demonstrate good agreement between the measured and simulated copper doping profiles confirming that most of Cu species are engaged in neutral donor-acceptor pairs.

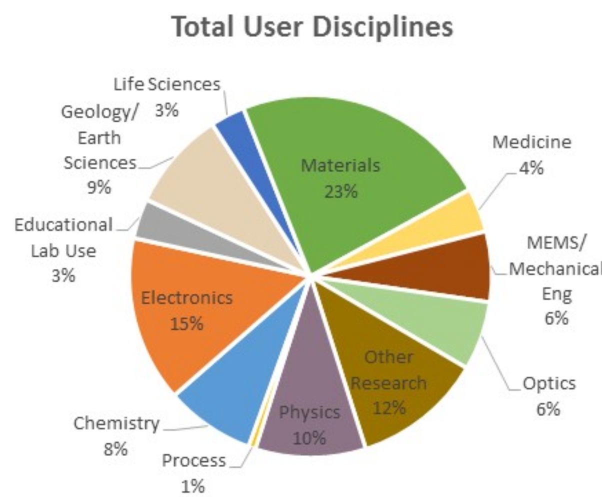
In addition to developing new computational user tools Dr. Vasileska is converting the EEE533 Semiconductor Device & Process Simulation class that she teaches at ASU into a nanoHUB course.

# NCI-SW Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 705 | 810 |
| Internal Cumulative Users | 536 | 600 |
| External Cumulative Users | 169 (24%) | 210 (26%) |
| | | |
| Total Hours | 43,098 | 49,370 |
| Internal Hours | 32,883 | 38,270 |
| External Hours | 10,215 (24%) | 11,100 (22%) |
| | | |
| Average Monthly Users | 271 | 313 |
| Average External Monthly Users | 43 (16%) | 49 (16%) |
| | | |
| New Users | 275 | 333 |
| New External Users | 47 (17%) | 53 (16%) |
| | | |
| Hours/User (Internal) | 61 | 64 |
| Hours/User (External) | 60 | 53 |

## Year 2 User Distribution



## 11.8. Nebraska Nanoscale Facility (NNF)

Facility, Tools, and Staff Updates

The enhancement of our NNF facilities has proceeded in the last year through funds received from the University of Nebraska, U.S. Army Research Office and NSF-NNCI. Following is a list of major acquisitions. A Bruker Quantax Micro-XRF high-performance micro-spot x-ray source for our FEI SEM has been purchased for the Electron Nanoscopy Instrumentation Facility. The Nanoengineering Facility recently installed an Anasys nanoIR2-sTM system. This system provides high resolution localized IR spectroscopy and imaging, along with atomic force microscopy (AFM) imaging and metrology. The Facility also purchased an Optomec Laser Engineered Net Shaping (LENS) 3D Metal printer. The Nanoengineering Facility has also purchased a bio 3D printer for tissue engineering. A cell-culture laboratory also has been added to the Facility. This lab is equipped with $CO_2$ incubator, bio-safety cabinet, plant-growth incubator, centrifuge, refrigerator/freezer, pH meter, microbalance which enables the investigation of normal physiology and biochemistry of cells and the effects of drugs and toxic compounds on the cells. The Surface and Materials Characterization Facility purchased a High Magnetic Field (4.5T) Annealing System and an advanced X-Ray Photoelectron Spectrometer (XPS/UPS) with UV Photoelectron Spectroscopy option. A new bench top X-Ray Fluorescence Spectrometer (XRF) has been added to the X-Ray Characterization Facility. NNF Shared Laboratory Facilities – The NNF has made more capabilities available for external users through a shared-laboratory mechanism that will provide NNF users access to certain capabilities on the campus that are not part of the NNF/Central Facilities. Through the Shared Facility mechanism, we added Raman Microscope/Spectrometer, Dynamic Mechanical Analyzer (DMA), and several Material Test Systems (MTS) for mechanical properties measurements to the current NNF capabilities. The strategy was adapted as a part of adding specific capabilities that are relevant to the manufacturing sector in our region to attract more industrial users to the NNF.

New staff members supported by NNF and the University of Nebraska include: Program Associate: Samone Behrendt, NNF Coordinator and User Contact: Jacob John, Research Technologists: Anand Sarella and Andrei Sokolov, and Engineering Associate: Zach Sun.

User Base

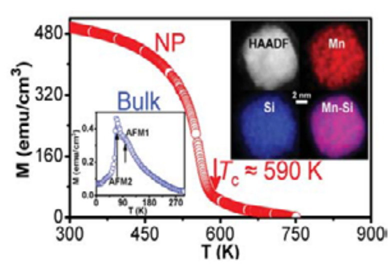
The expansion of the external user base from academia and industry relies in large part on newly hired, NNF-supported technical staff: Drs. Jacob John, Anand Sarella and Andrei Sokolov. The Facility Coordinator-User Contact coordinates our efforts to reach out to potential new users from industry and academia. Two Research Technologists work with the Coordinator and the Facility Managers in providing technical services and scientific expertise to the external and internal users. The Coordinator prepared outreach materials such as brochures, fliers and promotional slides for promoting and creating awareness about the NNF capabilities throughout the region. The Coordinator also initiates communications with potential users, arranges meetings and discussions, schedules facility tours, and makes frequent trips for meetings and presentations in order to expand the external user base. Since the inception of NNF, the external user base has expanded from 12 to 36 annually, and the external hours from 120 to 840 annually.

***Outreach to New Regional Users:*** The Facility Coordinator has organized outreach to more than 70 companies, of which more than 45 companies have requested materials describing the capabilities of the NNF in the last 1 year. Due to these outreach efforts, around 25 companies visited the NNF for tours and discussions so far and 16 of them have already started using NNF. The facility tours and discussions with potential users about the capabilities and procedures help to generate new users and we plan to continue doing the same. The twenty-five companies who visited us for tours and discussions are: 1. Taft Technologies, NJ (start-up); 2. Monolith Materials, CA; 3. Intellifarm; 4. Lincoln Industries; 5. Crosslink Technologies; 6. Trial Fastener; 7. Addax Rexnord; 8. Lester Electrical 9. Celerion; 10. Somrubioscience; 11. Benchmark Biolabs; and 12. Bosch Security System; 13. Bruckman Rubber; 14. Geist; 15. Lester Electrical; 16. Meat Probes; 17. Majors Plastics; 18. Yasufuku; 19. ContiTech; 20. MFS/York; 21. Schneider Electric; 22. Centennial Plastics; 23. Vishay Dale Electrics; 24. Valmont Industries; 25. Dynetics. The Facility Coordinator also reaches out to colleges and universities in the region. The activities include giving presentations about the NNF capabilities and services, one-on-one meetings with deans, department chairs, faculty members, post docs and students as well as distributing user-targeted NNF promotional materials on their respective campuses. The interested potential users are invited for a tour of the NNF and discussion with the expert staff scientists in our site. The NNF also provides remote services for users who are either located far away from our facility or have difficulty in making frequent trips to our site. The NNF also conducts several events in the campus to expand our user-base in ways described below.

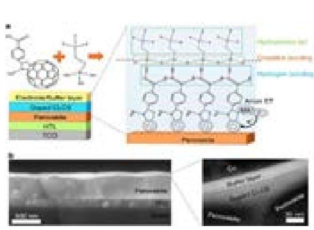
***Annual Academic and Industry User Workshop and Minicourses:*** Our second User Workshop, held on May 10, 2017, was a successful event with 50 attendees, mostly from regional industry. The User Workshop enables scientists/engineers from industries to know more about the NNF capabilities and potential benefits of becoming new users and provide opportunities for one-on-one discussions with NNF staff scientists that will eventually result in a plan for usage of NNF services by the industry. We are currently working on organizing next year's User Workshop on April 13, 2018. The Nanotech Minicourse was held during June 20-22, 2017. The attendance was 20, a number that was limited to enable each researcher to have both lecture and hands-on experience with our Facility Specialists. We also have created Facility Training Videos for several of our instruments. These are useful for both internal and external first-time users. We are currently working on organizing next year's Nanotech Minicourse from June 19-21, 2018.

<u>Research Highlights</u>

***Nano Letters:*** Synthesis of $Mn_5Si_3$ nanoparticles and size-induced ferro-magnetism was discovered by the Sellmyer group. Low-temperature antiferromagnetism in the bulk was converted into high-temperature ferromagnetism ($T_c$ = 590 K) by low-dimensional and quantum-confinement effects, evident from first-principle density-functional theory calculations. Several facilities in NNF were used to fabricate and characterize the nanomagnets.



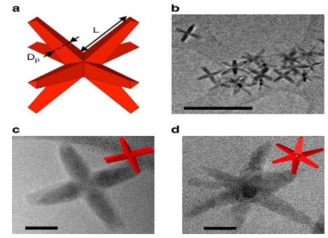

M(T) in bulk and nanoparticle (NP) $Mn_5Si_3$, and TEM.



Schematics of per-ovskite solar cell and cross section images.

***Nature Communications:*** Jinsong Huang and co-workers used NNF to develop a strategy to overcome the water and moisture related stability issues of high efficiency perovskite solar cells. Water-resistant silane molecules with hydrophobic groups were attached to fullerene thereby making it highly water-resistant and resulted in enhanced stability of p–i–n planar heterojunction-structure perovskite devices. With crosslinkable silane-functionalized and doped fullerene electron transport layer, the perovskite devices delivered an efficiency of 19.5% with a high fill factor of 80.6%.

***Nature Communications:*** E. Sutter and co-workers used NNF to study the real-time in situ imaging by liquid-cell electron microscopy to elucidate the nucleation and growth mechanism and properties of linear chains of octapod-shaped nanocrystals in their native solution environment. Their results suggest that monomer-resolved in situ imaging combined with modelling can provide unprecedented quantitative insight into the microscopic processes and interactions that govern nanocrystal self-assembly in solution.




(**a**) CdSe/CdS nanocrystal. (**b**) TEM image of CdSe/CdS octapods. (**c**,**d**) TEM images of octapods.

Education and Outreach Activities

***Research Experience for Undergraduates (REU):*** NNF supported three individual students and four professor-student pairs who worked on research projects in nanoscale-science research labs for 10 weeks during the summer under faculty supervision. Also NNF provided state of the art instrumentation to undergraduate students associated with other REU programs on Campus

***High School Intern Program:*** NNF hosted a STEM summer program for 15 high school interns this year. Faculty from Chemistry, Physics, and Engineering. provided opportunities for high school students to work in their research labs for 10 weeks with the help of a Ph.D student mentor.

***K-16 Diversity Programs to Title 1 Schools****:* The programs focused on Title 1 schools and included:

a. After-School and Summer Nano Camps to diverse middle school student populations and first-generation, college-bound high-school students (120 students). Part of this camp included hands-on activities and tours of nano-related research in NNF faculty labs and facility tours of NNF equipment.

b. Teacher Conferences and Workshops where NNF provided free conference registration scholarships and Nano/STEM activity kits for Native American and Title 1 teachers.

***Teacher Conferences/Workshops:*** NNF had the opportunity to train and resource hundreds of K-12 teachers with STEM/Nano-related information at teacher science fairs and conferences, teacher workshops, and through online educational videos, lesson plans, and other materials.

***New User Outreach and Education:*** Education for new users included our annual Workshop and Minicourse, but also Nanotech Courses where regional and local university students attended classes designed to promote nanoscience understanding through use of NNF equipment. Development of equipment-training videos supported new user learning needed to work in NNF labs.

***NNF Special Events:*** NNF sponsored a variety of events throughout the year such as:

a. Junior/Senior High Tours to interested junior and senior high students, teachers, and parents

b. NanoDays, a nationwide festival of educational programs about nanoscale science and engineering which was held at our local mall and attended by 400 students and general public.

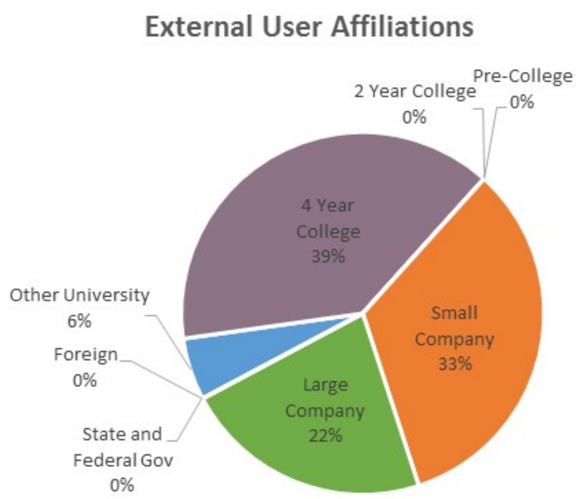
c. Student Conferences that brought together outstanding Physics student researchers from across the US for the WoPhyS conference, the Nebraska Women in Science Conference, and Nebraska Math Day where we had the opportunity to talk with 1700 high school students.

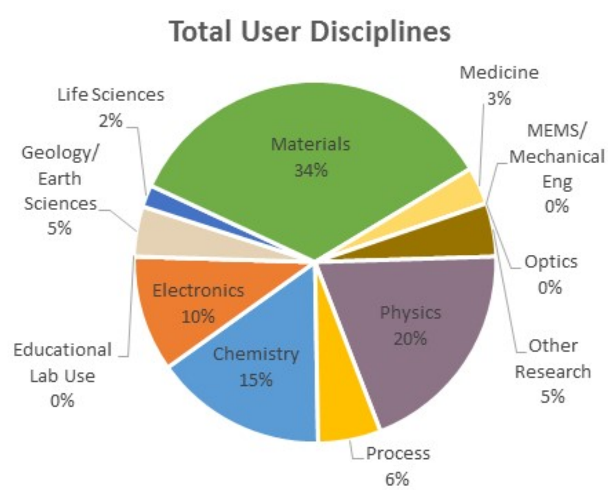
***Traveling Nanoscience Exhibit:*** Our 400-sq.-ft. hands-on exhibit was viewed in three Nebraska museums this past year by over 52,000 people. These museums partnered with NNF to reach thousands of underserved populations in Nebraska with the Nano mini-exhibit, including both rural populations and the growing number of ethnic minorities in those communities.

# NNF Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 314 | 357 |
| Internal Cumulative Users | 295 | 321 |
| External Cumulative Users | 19 (6%) | 36 (10%) |
| | | |
| Total Hours | 23,445 | 20,102 |
| Internal Hours | 23,123 | 19,278 |
| External Hours | 322 (1%) | 824 (4%) |
| | | |
| Average Monthly Users | 40 | 120 |
| Average External Monthly Users | 3 (8%) | 7 (6%) |
| | | |
| New Users | 47 | 54 |
| New External Users | 0 (0%) | 1 (2%) |
| | | |
| Hours/User (Internal) | 78 | 60 |
| Hours/User (External) | 17 | 23 |

## Year 2 User Distribution

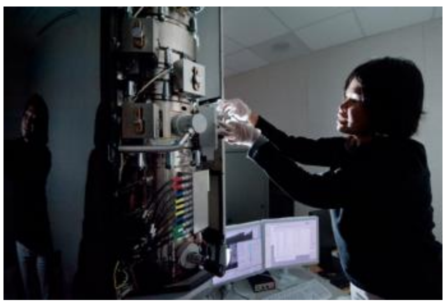


### 11.9. NNCI Site @ Stanford (nano@stanford)

Facility, Tools, and Staff Updates

The NNCI Site @ Stanford University provides ***access to world-leading facilities and expertise in nanoscale science and engineering for internal users and for external users*** from academic, industrial, and government labs. Furthermore, we seek to develop and ***propagate a national model for educational practices*** that will help students and visitors become knowledgeable and proficient users of the facilities.



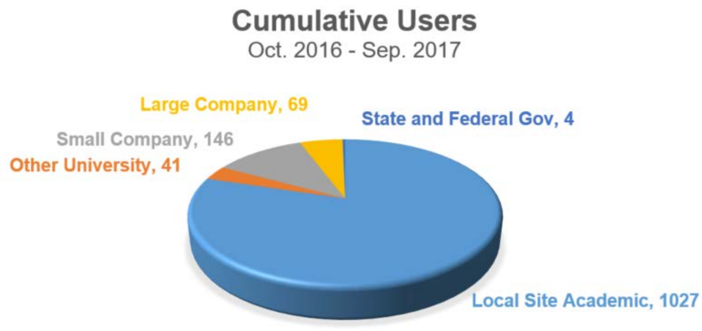
Stanford's facilities offer a comprehensive array of advanced nanofabrication and nanocharacterization tools, including resources that are not routinely available at shared nanofacilities, such as an MOCVD laboratory that can deposit films of GaAs or GaN; a JEOL e-beam lithography tool that can inscribe sub-10-nm features over 8-inch wafers; a Cameca NanoSIMS that combines the high mass resolution, isotopic identification, and sub-ppm sensitivity of conventional SIMS with 50-nm spatial resolution; and a unique scanning SQUID microscope with world-leading spin sensitivity. The facilities occupy ~30,000 sqft of space including 16,000 sqft of cleanrooms. They offer state-of-the-art equipment as well as processes developed by scientists who work at the cutting edge of nanoscience. Close to forty expert staff members maintain the instruments, teach users to operate them, and consult with users to optimize processes for their applications. The NNCI Site @ Stanford provides access to the ***Stanford Nano Shared Facilities*** **(SNSF)**, the ***Stanford Nanofabrication Facility*** **(SNF)**, the ***Stanford Mineral Analysis Facility*** **(MAF)** and the ***Stanford Environmental Measurements Facility*** **(EMF)**.

***New capabilities***: During this reporting period we added several new capabilities to our offerings, including a Heidelberg MLA150 high-speed, direct write, optical lithography tool, a Nanoscribe two-photon, 3D printing system capable of feature sizes down to 100 nm, a flip-chip bonder, a Nagase micromist coater, a Keyence VK-X Series 3D Laser Scanning Confocal Microscope, an Oerlikon Leybold Univex 400 RF/DC Sputter Station which can be used for the deposition of both metal and dielectric films, and a DENS Solutions Climate S3+ in-situ TEM Gas & Heating holder which enables atomic resolution imaging of gas-solid interactions and sample dynamics in research areas such as catalysis, nanomaterials growth and corrosion studies.

***Personnel***: Professor Kam Moler, PI of the NNCI Site @ Stanford and Faculty Director of SNSF, moved into her new role as the Senior Associate Dean for Natural Sciences. Following this, Professor Bruce Clemens took over the leadership of the NNCI Site as well as SNSF. Dr. Shivakumar Bhaskaran who started in his position as technical liaison to external users on June 27, 2016 advises external users of capabilities, provides background information about a nanofabrication or nanocharacterization techniques. Our new Program Manager for Education and Outreach, Dr. Angela Hwang started in her position in February 2017. The main focus of the position is to develop, implement and administer educational and outreach programs in support of the NNCI Site @ Stanford. Dr. Swaroop Kommera joined SNF as Senior R&D Engineer and Jana Krchnava joined SNF as a financial accountant.

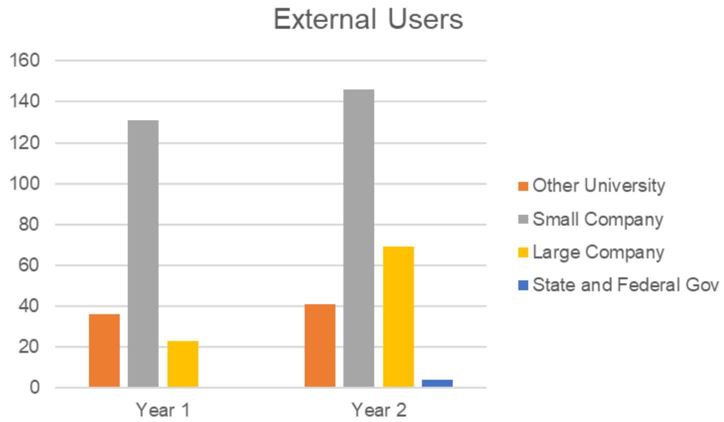
User Base

Between October 2016 and September 2017, SNSF and SNF served a total of ***1,287 users: 1,027 internal users, 215 industrial users, 4 government users, and 41 external academic users. Billed user fees during this time accumulated to about $6.5M of which about $2.3M was collected from external users.***




Cumulative users between October 2016 and September 2017.

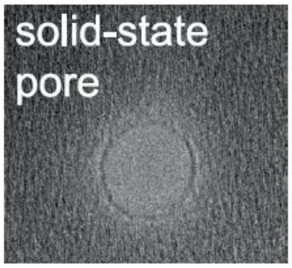
During calendar year 2016 we captured 235 journal publications, 39 conference publications, 4 books and book chapters, and 3 issued patents. We note here that these publications are all self-reported and that while we almost doubled the reported number of publications over the previous reporting period, we estimate the total number of publications to be about three times higher.




Growth of the external user base between NNCI Year 1 and 2.

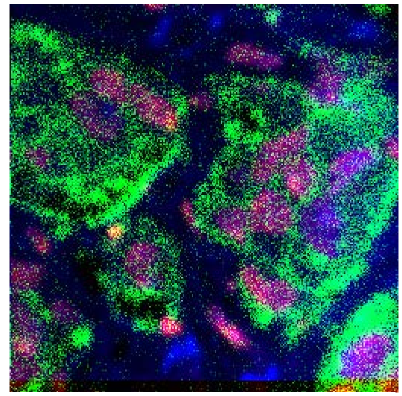
Research Highlights

Our facilities support about 700 ongoing research projects during any given year. We give two examples of projects from our external users to highlight the range of industrial companies as well as a focus on non-traditional areas. ***Two Pore Guys*** is developing a handheld molecular sensor based on solid-state nanopores, will have application in diagnostics, agriculture, food safety and environmental monitoring. Currently the company is working on is HIV antibody detection. At the NNCI Site @ Stanford, Two Pore Guys researchers use nano-, micro-fabrication facilities at to facilitate fast prototyping of their device designs (figure at left). One of the main reasons for coming to Stanford is the availability of a full suite of fabrication and characterization capabilities.




Single-molecule sensing with a 27 nm diameter nanopore device.

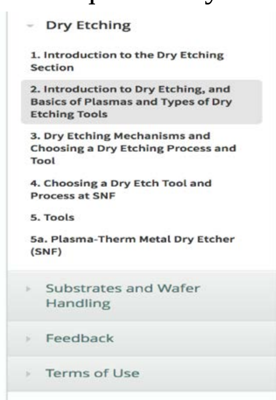
Dr. Scot Liu's team belongs to the ***Pathology department at Genentech, a member of the Roche company***. The team is interested in developing technologies for tissue section-based diagnostics. They are evaluating SIMS technology using the Cameca NanoSIMS 50L as a possible method to interrogate the expression level and prevalence of multiple biomarkers on tissue sections. Tissue section based diagnostics are used to determine the eligibility of cancer patients to receive certain targeted therapies (figure at right). "***Stanford is the only facility that has instruments capable of performing these experiments open to the general public***", says Dr. Scot Liu about why they have set up their research program at Stanford (Rost *et al., in press* (2017)).



NanoSIMS image of a breast cancer tissue sample (Green: HER2, red: DNA, blue: hematoxylin. Field of view: 100 um x 100 um

<u>Education and Outreach Activities</u>

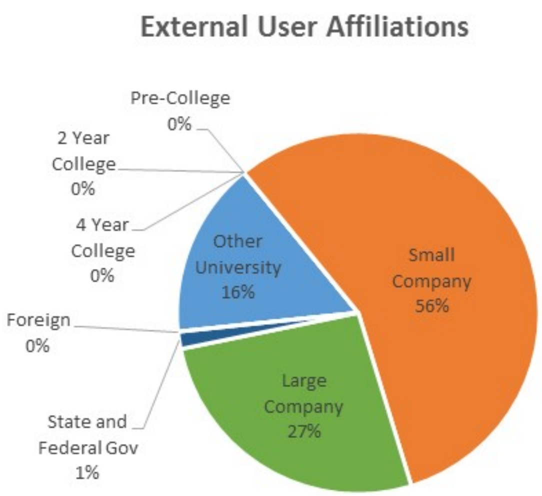
All users of shared nanofacilities must understand the basic concepts of nanoscience, the properties of materials, and the physical principles that underlie fabrication and characterization techniques. They must learn to operate sophisticated tools and to design and implement complex fabrication processes. *The knowledge of the users, rather than the availability of the instruments, is the rate-limiting factor that controls scientific and technological progress in shared nanofacilities.* Our vision is that Stanford will accelerate progress in nanofacilities nationwide by providing open access to critical information. The Stanford Site is currently leading a NNCI working group to ***coordinate the creation, curation and evaluation of the technical content and learning progress of facility users***. A first pilot program was recently released to cover etching. Within the first 6 months of being live, the module has been accessed about 2,500 times by users all over the world. The NNCI Site @ Stanford is dedicated to ***developing and implementing activities targeted at youth, school teachers, and the general public that will increase their interest, understanding, and involvement in STEM***. These initiatives range from volunteer participation in outreach events to more in-depth workshops that span multiple days. During the reporting period, over 1,000 people were involved in these type of activities with the NNCI Site @ Stanford. During June 2017, we held our first ***Summer Institute for Middle School Teachers*** (SIMST) program that enables middle school teachers in the local bay area community to learn about nanoscience and how to incorporate the content into their classroom. 12 teachers participated in SIMST. One of the criteria for accepting teachers into the program was their school background. 7 of the teachers are currently serving high-needs (Title 1) schools. Selected partner institutions serving diverse audiences are being supported by Stanford. In our second year partnering with ***California State University, East Bay (CSUEB)***, a group of students visited in October 2016 and April 2017. CSUEB's facility capability is limited and students were unable to perform a procedure necessary for their fabrication process.

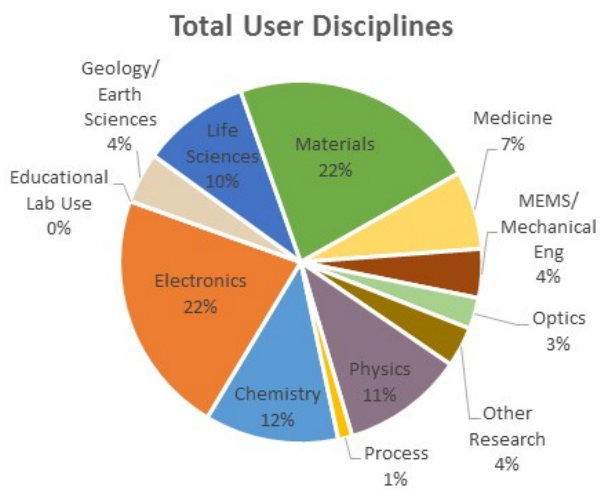



# nano@Stanford Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 1,142 | 1,287 |
| Internal Cumulative Users | 952 | 1,027 |
| External Cumulative Users | 190 (17%) | 260 (20%) |
| | | |
| Total Hours | 113,089 | 113,193 |
| Internal Hours | 94,996 | 91,248 |
| External Hours | 18,093 (16%) | 21,944 (19%) |
| | | |
| Average Monthly Users | 520 | 572 |
| Average External Monthly Users | 74 (14%) | 92 (16%) |
| | | |
| New Users | 550 | 579 |
| New External Users | 97 (18%) | 143 (25%) |
| | | |
| Hours/User (Internal) | 100 | 89 |
| Hours/User (External) | 95 | 84 |

## Year 2 User Distribution



## 11.10. Northwest Nanotechnology Infrastructure (NNI)

Facility, Tools, and Staff Updates

In 2017, the nanotechnology infrastructure at the University of Washington flourished with the completion two major projects. December 4, 2017 marked the ribbon-cutting of the new Institute for Nano-Engineered Systems (NanoES). NanoES is an $87.8 million building providing approximately 43,000 assignable square feet (sf) of flexible research space and 8,300 assignable sf of learning space. The ground floor will accommodate vibration-sensitive instrumentation and connect with the NNCI Molecular Analysis Facility (MAF) in the adjacent Molecular Engineering & Sciences (MolES) building.

In an almost simultaneous launch, the $37.5 million renovation and expansion of the NNCI Washington Nanofabrication Facility (WNF) in Fluke Hall was completed. The October 2017 expansion completion has created 15,000 sf of ISO Class 5, 6, and 7 spaces for fabrication that will work in conjunction with NanoES, MAF, the UW College of Engineering as well as a growing cadre of commercial users.

For 2017, new WNF lab capabilities include the development of xenon difluoride ($XeF_2$) and vapor hydrogen fluoride (VHF) etching. This new etching capability in conjunction with the lab's new wet-process track for coating and developing will increase and improve the lab's fabrication capability.

The Molecular Analysis Facility (MAF) complements the WNF cleanroom with resources for microscopy, spectroscopy, surface science, and biophysics tools. In addition to the profilometer, Bruker Icon AFM, and Asylum Cypher AFM systems, the MAF now has a Molecular Vista Photoinduced Force Microscope (PiFM). The PIFM detects photo-induced molecular polarizability of feature sizes down to the molecular level. A new Nanoindenter has just been ordered and will arrive in early 2018. Funding for the nanoindenter is from an NSF MRI grant. A new Bruker D8 Discover with IµS 2-D x-ray diffractometer was installed in the past year and is already heavily used. The MAF has also incorporated the Biophysics Tools previously housed in the UW cost center 'Analytical Biopharma Core' along with a new staff member. These tools will provide characterization related to biophysics research. The easy-to-use wide field (EVOS) microscope with fluorescence as well as white light imaging has been added as well. The MAF is now expanding into the NanoES side of the building with new space for the current MAF TEM as well as incorporating a FEI Tecnai Cryo TEM that is being transferred from the UW Biostructures Department into the MAF facility.

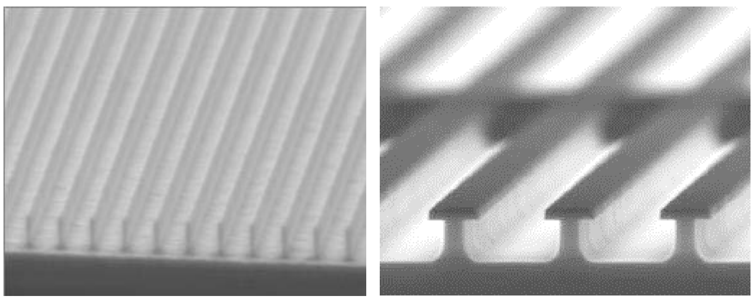
The NanoES building is also home to the new Beckman microscopy facility, which was kick-started with the acquisition of two advanced cryo electron microscopes and the hire of a full-time technical staff member. The FEI Titan Krios was purchased with support from the Beckman, Murdock, and Washington Research Foundations and internal funds and installed in summer/autumn 2017. The FEI Arctica was purchased with NIH funding and is expected to be operational by spring 2018. Both tools will allow the automated 3D imaging of biological structures with unprecedented precision. While managed in a separate cost center based in the Department of Biochemistry, these tools will be on our CORAL system and available to NNCI researchers.

User Base

The Northwest sites continued to see steady growth, with the NNI logging a total of 46,563 user hours combined. The University of Washington logged 39,531 user hours during the 2016-2017 academic year (27,842 UW; 11,239 industrial; 387 outside academic) generating a NNI user revenue of $2.68 million ($860k UW; $1.71M industrial, $19k other academic). During this period 153 new users were trained at UW (all statistics from Oct.'16-Sep.'17).

Research Highlights

Our site is emphasizing three focus areas, which are aligned with major research efforts at UW and OSU: Integrated Photonics, Advanced Energy Materials and Devices, and Bio-nano Interfaces and Systems. Included as one of the over 100 industrial clients at NNI is Modern Electron, an energy technology startup that is working on the development of advanced thermionic energy converters for electricity production, shown in the figure above.



*SEM image showing 50 nm wide metallic lines isolated from electron collector plate by dielectric fins (left) and electrostatic "T-shaped grid" comprised of metal grid lines on dielectric support and electron collector plate (right).*

The 2017 work by NNI academic users is included as a research summary that highlights work from The University of Washington's WNF and MAF as well as Oregon State University's Materials Synthesis and Characterization Facility and the Oregon Process Innovation Center.

Education and Outreach Activities

The NSF NNCI Northwest Nanotechnology Infrastructure site has continued to expand upon our portfolio of educational and outreach activities with the goal of impacting K through gray audiences throughout the Pacific Northwest Region, with a particular emphasis on K-12 outreach, girls in nanotechnology, nanotechnology education through educators-in-residence network, workforce development, and partnership with Regional First Nation Tribes to recruit students to our respective programs at UW and OSU.

(1) **Workforce Development** - In the second year of the NNCI program, approximately 20 paid internships for undergraduates were supported within NNCI-supported facilities. Community college students and 4-year undergraduates engaged in real-world exposure to cutting-edge nanotechnology solutions through participation in NNCI-NNI cleanroom labs that provided hands-on nanofabrication and characterization experiences, including professional skills development in project management, fabrication techniques, instrument operation and maintenance, and interdisciplinary working teams with members from government, industry, academy, and international partners. Our 20-student internship program drew from a diverse group, including 6 women, 3 URM/EOP student (Native Hawaiian/Pacific Islander and 2 Native Americans), and students from across the engineering and STEM majors at the UW and our partner community colleges.

(2) **Pre-college Outreach** - Our NNCI site has been active in both local and regional STEM K-12 and community STEM outreach events. In addition to a variety of local K-12 school outreach events, typically attended by 250-1000 students and parents, NNI staff, faculty, and students presented at a regional STEM career fair hosted by the Federal Way Schools and Central Puget Sound School districts. In addition, NNI participated in UW's Engineering Discovery Days (April 21-22, 2017), attended by at least 7,477 students and 2,636 chaperones. In Autumn 2017 we hosted our first annual Introduce a Girl to Nano event, with 277 girls attending an on-campus event on October 14, 2017. At these events, NNCI site staff and faculty presented both hands-on nanofabrication demos and engaging research highlights, in addition to participating in moderated panel sessions encouraging students to pursue their studies within STEM disciplines.

*Pre-college outreach remains a hallmark of NNI's E&O activities, reaching 10,000-12,000 Northwest community members each year. Seen here, an NNI staff member interacts with the community at the 2017 Sammamish High School Science and Technology Night.*

(3) **National Nanotechnology Day** – In October 2017 NNI hosted our first annual National Nanotechnology Day in partnership with the Pacific Science Center, an independent, non-profit interactive learning experience located in downtown Seattle. Working with the Pacific Science Center's staff to regionally advertise the event, dozens of NNI faculty and students and boasted ticket-sales to 2,057 guests (K-gray) throughout the day with over a dozen hands-on demonstrations of nanotechnology.

*In October 2017, NNI partnered with the Pacific Science Center to host over 2,000 guests in a hands-on nanotechnology fair, including demonstrations of some of the latest technology to come out of NNI.*

(4) **First Nations Engagement** - For the first two years of the program, NNI supported Ms. Laurel James (member of the Yakama Nation) to serve part-time as a program manager and liaison with the American Indian Science and Engineering Society (AISES). Ms. James has since completed her interdisciplinary Doctor of Philosophy (Ph.D.) in both the School of Environmental and Forest Sciences as well as the Department of Anthropology and over the past year we have moved our recruitment efforts to focus on local tribal nations to identify candidates for our cleanroom internship program. **NNI recently successfully recruited and employed two students from the Puyallup Indian Tribe who joined the 2017 NNI Summer internship program.** We plan to continue and expand our outreach efforts to support students from local and regional tribes.

(5) **Educators-in-Residence** - NNI co-PI Ratner has been partnering with reginal districts to establish a K-12 educators network to partner with NNI laboratories and the WNF to develop curricular and co-curricular materials on nanotechnology education to bring back to their classrooms and to disseminate to their peers. Ratner continues to recruit teachers from across

the region, with an emphasis on schools in rural and underserved communities. Priority is being given initially to teachers at schools that serve a high percentage of students who qualify for free and reduced lunch, and to cities outside of a 50-mile driving radius from the Seattle metropolitan area.

(6) **<u>REU and Undergraduate Research Symposium</u>** - In collaboration with NNI-affiliated investigators and the UW Molecular Engineering and Sciences Institute, we partnered with the new Clean Energy Bridge to Research REU (Christine Luscombe, PI) to host an inaugural Summer Undergraduate Research Symposium on the University of Washington campus to bring together undergraduate researchers from across the region to participate in a nanotechnology-focused symposium. The program's goals are to foster enthusiasm for molecular and nanotechnology research, enhance communication skills and critical thinking, and to prevent the siloing of neighboring undergraduate research programs.

(7) **<u>Professional Master's Program Evening Courses</u>**

The University of Washington offers a comprehensive curriculum with evening classes for professional master's students. Currently, two courses utilize the NNCI facilities at UW:

- Spring 2017: EE527 Solid-State Laboratory Techniques (Microfabrication), taught by NNI Senior Personnel Dr. Michael Khbeis and WNF staff with extensive cleanroom sessions.
- Summer 2017: EE502 Introduction to Microelectromechanical Systems (MEMS), established by PI Böhringer, offers microfabrication lab demos at WNF.

(8) **<u>Short Courses</u>**

- WNF and MAF occasionally offer short courses presented by experts from academia or industry, such, e.g., the most recent event "Introduction to Vacuum Technology", a 2.5-hour session by Velibor Mandic from the Kurt J. Lesker company.
- On July 31- August 2, 2017 the NESAC/BIO center held its annual Surface Characterization Workshop. The workshop includes lectures and surface analysis demonstrations. Demonstrations on surface analytical instruments provide application examples for the material covered in the work shop lectures. Attendees learn the capabilities of surface analysis methods and how to intelligently review data received from surface analysis laboratories. The workshop is taught by Prof. Dave Castner, Prof. Lara Gamble, and key MAF staff as well as Prof. Buddy Ratner from Bioengineering.

(9) **Introduce a Girl to Nano** - NNI-associated students from Chemical Engineering launched the inaugural 2017 'Introduce a Girl to Nano' event, hosted on the University of Washington Campus in the Student Union Building on Saturday, October 14, 2017. 277 K-12 students attended the event, experiencing hands-on demonstrations in nanotechnology, including modules in drug delivery, colloidal nanoparticles, and the role of nanotechnology in everyday life. Surveys were collected from participating organizations to help build upon the experience for future years. Event organizers coordinated with NNI staff and the National Nanotechnology Coordination Office to advertise the event and distribute educational materials for teachers and students to bring back to the classroom.

*NNI students hosted the first annual Introduce a Girl to Nano event on the UW campus, introducing nanotechnology to 277 girls from across the region.*

(10) **Womxn in Nanoscience (WINS)** - The Washington Research Foundation sponsored a new seminar series called Womxn in Nanoscience (WINS) that seeks to promote increased gender diversity in the nanosciences. Led by undergraduate students that are employed by WNF, the students identified a need by undergrads to have more insight to what real-world careers and experiences are like. The first two guest speakers were former WNF undergraduate Evgenia Yuferova (IM-Flash) and former Ph.D. student Nicole Thomas (Intel Research).

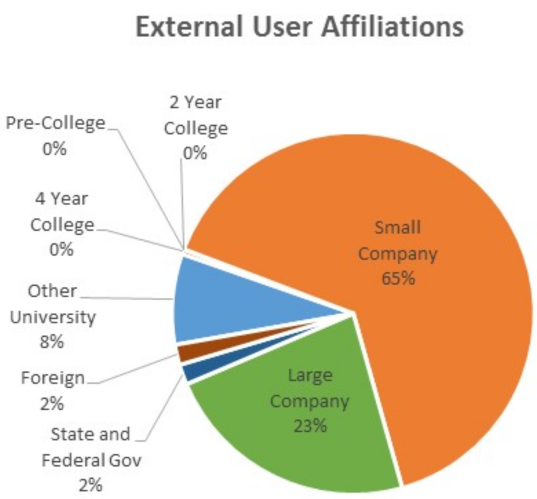
SEI Activities

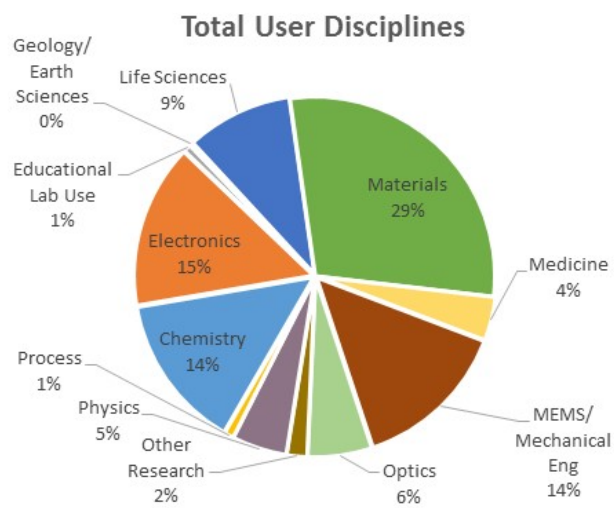
The NNI site does not have a formal SEI program supported by NNCI. However, co-PI and MENTOR lead Ratner has joined the NNCI SEI Coordinators Group and is working with NNCI partners to grow the SEI activities for NNI. This fall the SEI Coordinators Group begins testing an educational video on Ethics in Nanotechnology to standardize ethics training across the NNCI.

# NNI Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 638 | 708 |
| Internal Cumulative Users | 396 | 486 |
| External Cumulative Users | 242 (38%) | 222 (31%) |
| | | |
| Total Hours | 38,350 | 46,562 |
| Internal Hours | 21,822 | 30,600 |
| External Hours | 16,528 (43%) | 15,962 (34%) |
| | | |
| Average Monthly Users | 267 | 277 |
| Average External Monthly Users | 103 (39%) | 98 (35%) |
| | | |
| New Users | 126 | 159 |
| New External Users | 41 (33%) | 37 (23%) |
| | | |
| Hours/User (Internal) | 55 | 63 |
| Hours/User (External) | 68 | 72 |

## Year 2 User Distribution



### 11.11. Research Triangle Nanotechnology Network (RTNN)

Facility, Tools, and Staff Updates

**Staff:** In Year 2, a new Director of Operations for the NC State Nanofabrication Facility (NNF) was hired. We also brought on one full-time hardware engineer, one photolithography engineer, one electronics technician, one SEI staff member, as well as 12 undergraduate and graduate students to assist in RTNN activities. **Tools:** Through university support and by leveraging external funding (such as NSF's MRI program), we have acquired new equipment and upgraded existing equipment to expand RTNN capabilities including two new cryo-transmission electron microscopes, three atomic layer deposition tools, an atomic force microscope, a Raman confocal microscope, e-beam and maskless lithography systems, a reactive ion etcher, a rapid thermal processor, and several new detectors for existing scanning electron microscope (SEMs). **Techniques:** We have developed new techniques for voltage contrast imaging, measuring elastic moduli of soft materials, and performing X-ray/ultraviolet photoelectron spectroscopy measurements on air-sensitive materials. **Facilities:** The NNF underwent a $6M renovation project to upgrade its infrastructure. In addition, a new core facility, Chemical Analysis and Spectroscopy Laboratory, in NC State's College of Natural Resources was brought within the RTNN. Its unique capabilities in chromatography and spectroscopy complement RTNN's existing analytical tools.

User Base

The RTNN is committed to bringing in new, non-traditional users. Currently, we bring in greater than 50% of our users from non-traditional disciplines, such as textiles, biology, and agriculture. Core technical capabilities and specialized expertise in the RTNN span the following areas: interfaces, metamaterials, fluidics and heterogeneous integration; nanomaterials for biology and environmental assessment; organic and inorganic 1-D and 2-D nanomaterials; and textile nanoscience and flexible integrated systems.

The overarching goal of the RTNN is to build the user base. We make a concerted effort to reach out to users from underrepresented demographic populations, rural areas without access to Research 1 institutions, non-Research 1 (non-R1) institutions, and industry. As identified in our proposal, three barriers to engaging new users are: awareness of the facilities and how to access them, distance to travel to the facilities, and cost to utilize the facilities. To address these barriers, we have implemented targeted, innovative new programs and activities and strengthened existing ones to attract and retain new and current users.

**RTNN Kickstarter Program:** This program supports use of the facilities by new, non-traditional users by providing initial access for free. In Year 2, 18 projects were selected (>400 hours in facility use). The majority of participants are from non-R1 colleges/universities (50%), start-ups (22%), and K-12 students and classrooms (11%). Several participants in this program have continued work with their own financial support, demonstrating that this is a pathway to bringing in new users.

**Online Coursera Course: "Nanotechnology, A Maker's Course,"** introduces nanotechnology tools and techniques and shows demonstrations within RTNN facilities. Over 30 diverse faculty, staff, and students across the three RTNN institutions were involved in the development of this course. The course targets students who have a high school or higher science background and limited exposure to these facilities. It includes 8 modules, each focused on a different fabrication or characterization concept. Students first learn the science behind a specific technique or instrument. In-lab demonstrations of the equipment follow each lecture with simple explanations of each step in the process. The course launched in September 2017 and to date has over 5,700 course views and >2,100 enrolled learners. Several participants have reached out to engage with us outside the course (e.g. facility tour, subscription to newsletter, research).

**Workshops, short courses, symposia:** In Year 2, RTNN held 31 technical workshops and short courses (>100 participants) on engaging and relevant topics such as non-ambient X-ray diffraction, *in situ* atomic force microscopy, and microfluidic devices. We were also able to take one of our successful short courses on vacuum technology on the road for several days.

**Communication**: One of our main methods to disseminate information to stakeholders is via the RTNN website (www.rtnn.org). The website describes RTNN events, programs, and opportunities (e.g. nanotechnology jobs board). It also highlights recent nano-related news and provides an overview of research being pursued by principal faculty. The website has over 400 unique visits monthly.

We also maintain two subscription lists to share RTNN information and opportunities: one to principal faculty (over 100 faculty members across all three RTNN institutions) and one to other stakeholders (>1,000 subscribers). We have worked diligently to broaden our reach by adding new contacts to our subscribers list and have increased the number by over 100% since July. As a result of feedback from our advisory board, we established a strategic email campaign. Newsletters are sent monthly using a formal, visually appealing design through Bronto's platform. Bronto manages our subscriber lists and analyzes the effectiveness of our email communications. When subscribers click on an embedded link, they are directed to the RTNN site where they can learn about facility capabilities and other opportunities. Consistently, the most clicked link relates to "job opportunities." Moving forward we will utilize the analytics to improve newsletter content and design.

Early in Year 2, we launched our social media campaign. We are active on multiple platforms including Twitter, Facebook, and LinkedIn. Through these forums, we can promote our activities, events, and opportunities to reach a broad audience, many of whom are not connected through our website or subscription lists. These platforms are a great way for our education and outreach participants to share their experiences and spread the word about new opportunities.

**Industry Engagement:** We have developed a focused strategy to engage with local industry. We first contacted our current industry users to get feedback on their needs and expectations for the facilities. One result was a workshop on non-ambient XRD that served many industrial users. We also met with members of on-campus partnership and development offices to get their feedback on best practices for strengthening relationships and partnerships with industry. These meetings culminated in the establishment of the Corporate Affiliates Program at NC State's Analytical Instrumentation Facility (AIF). We are currently in talks with officials at UNC-CH and Duke to implement similar programs with their nanotechnology facilities.

Research Highlights

A**ssessment**: Unique surveys were created for collecting demographic and user satisfaction data from participants of our programs. The assessment is approved by IRB at all three RTNN institutions. **Satisfaction:** Overall, facility users who responded to the survey were very satisfied with their experiences in the facility they used (6.04 ± 0.74, 7=very satisfied). Greater than 98%

of users indicated that they would return to the lab if further work was necessary. **Kickstarter Program:** Semi-structured interviews were conducted with seven participants. Respondents were happy with the program and indicated they will return to the facilities. A common theme from respondents was gratitude for and awe of RTNN staff. **Tours:** Surveys are sent to teachers, camp counselors, and/or school group leaders. 71.3% of respondents noted that they were very likely to return/recommend RTNN for a tour, and 24% noted that they were likely to return/recommend. **User research:** Work performed in the RTNN led to 191 publications by our users. One of our Kickstarter participants (Stephen Furst, Smart Material Solutions) used results from his work to win a Phase II SBIR grant. He has since grown his business, enabling him to dedicate one employee to work in RTNN facilities several hours weekly.

Education and Outreach Activities

**Outreach to K-12 Students: Immersive Lab Experiences**: In Year 2, we reached over 3,300 students through our outreach programs with >50% of participants from underrepresented groups in STEM. Our goal is to move beyond passive experiences such as tours and equipment demonstrations to more engaging activities. Thus, we have created experiences for G6-12 students where students actively work in the facilities. Thus far, we have designed four user experiences: microcomputed tomography, SEM, photolithography, and nanoparticle synthesis. **Visits to Schools**: RTNN staff have also traveled to many K-12 schools, interacting with over 1,000 students. These visits are paired with hands-on activities to engage students. For example, before the visit, students collect samples and send them to the facility. RTNN staff then analyze the samples and bring their results to the classrooms. One of our exciting new additions this year is a portable, desktop SEM that we take into classrooms, allowing students to use it without traveling and eliminating complex and lengthy training sessions. **Science Kits:** We worked with Morehead Planetarium and Science Center to include a nanotechnology activity, "Sticky Sand," into Science Night kits that were provided for free to 150 schools across the state. These kits enabled schools to host an evening event at their schools to promote science. The kits included different science activities with instructions and supplies. Through the Science Nights, we were able to reach over 30,000 people across NC. **Other:** We developed detailed lesson plans for teachers that incorporate the facilities, participated in numerous North Carolina Science Festival activities, and hosted tour groups in the facility and remotely.

**Community College and Teacher Workshops:** We hosted our second two-day workshop for community college and small college educators in August 2017. At the event, faculty used the facilities to analyze samples from our university research labs. Time was also devoted to developing curricula that incorporates nanotechnology. We also held short workshops for local K-12 educators introducing the facilities, describing our programs, and explaining how to engage with the RTNN.

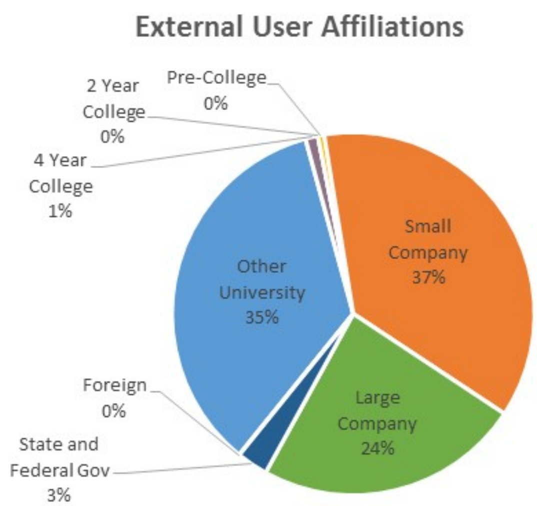
SEI Activities

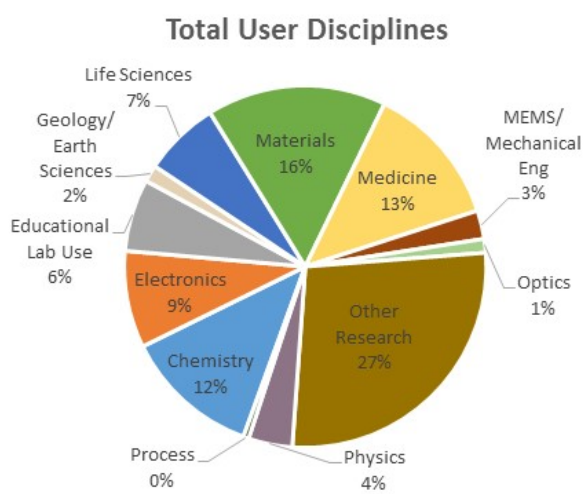
**Assessment:** Surveys were designed for specific activities: facility users, Kickstarter participants, symposia, workshops, and tours. We created and implemented an assessment survey for the Coursera course for program participants under the age of 18. **Social Media:** Through the cross-platform approach for developing a social media presence, we were able to establish an impactful footprint on Twitter, Facebook, and LinkedIn. **Team Science:** We have started the project by comparing and contrasting assessment data among the facilities, especially when it comes to staff-related satisfaction. We have collected comments from users and are using these to profile lab dynamics. This benchmark will allow us to evaluate the effectiveness of cross-disciplinary cooperation. **Advancing Informal Stem Learning (AISL) proposal**: We wrote and submitted a program to develop augmented and virtual reality tours of RTNN facilities. **RTP Industry Database:** In response to feedback from the advisory board, we developed a database of relevant companies in the Research Triangle Park to network in the future. The intent of this database is to strategically reach potential new users of RTNN facilities.

# RTNN Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | Year 1 | Year 2 |
| Total Cumulative Users | 1,177 | 1,454 |
| Internal Cumulative Users | 975 | 1,096 |
| External Cumulative Users | 202 (17%) | 358 (25%) |
| | | |
| Total Hours | 53,044 | 51,747 |
| Internal Hours | 46,908 | 43,053 |
| External Hours | 6,136 (12%) | 8,694 (17%) |
| | | |
| Average Monthly Users | 395 | 422 |
| Average External Monthly Users | 50 (13%) | 63 (15%) |
| | | |
| New Users | 433 | 527 |
| New External Users | 71 (16%) | 69 (13%) |
| | | |
| Hours/User (Internal) | 48 | 39 |
| Hours/User (External) | 30 | 24 |

## Year 2 User Distribution



## 11.12. San Diego Nanotechnology Infrastructure (SDNI)

Facility, Tools, and Staff Updates

Facility: Major effort was spent on setting up a laboratory equipment management system for the SDNI Facility. We chose the commercial Facility Online Manager (FOM) system, made by FOM Networks, and built the interfacing hardware to integrate our tools into the system. The system is now fully operational.

Tool acquisitions and upgrades: We have made investments in a number of purchases/installations of tools and tool upgrades, including two state-of-the-art FEI SEMs (Quanta FEG250 and Apreo) to strengthen our material characterization and imaging capabilities. We have upgraded the Vistec EBPG5200 E-beam lithography system by acquiring an auto aperture module, which greatly enhances throughput by allowing electron-beam writing of devices with widely differing feature dimensions without staff intervention. Other tool acquisitions and upgrades include two units of electron beam induced current (EBIC) imaging installed in our Zeiss Sigma 500 SEM and FEI Scios DualBeamto systems to allow imaging of depletion regions at junctions, defects, and crystal domains, two rapid thermal processors (Allwin21, Model AW610) to permit faster ramp rates and longer annealing times, a plasma etch system (Plasma Etch, Model PE-100), a semi-automatic wire bonder (TPT HB16) with wedge/wedge, ball/wedge and bump bonding mode capabilities, and MeiVac sputter cathodes following recommendations made by Georgia Tech to greatly simplify target change operations and reduce bottle-necking for our users (a clear benefit from the site interactions).

User Base

From October 1, 2016 to September 30, 2017, SDNI has served totally 110 academic groups, 69 companies, 2 national laboratories, and 2 international laboratories. The 110 academic groups include 101 local PI groups and 9 outside academic groups across the country. This represents about 8% growth compared to year 1. Out of 69 companies, 51 of them are small business and 18 are large, multinational companies. Compared to Year 1, we observed a rapid growth of 46% in small company usage while the number of large company users has shown a slight decline in hours of usage. The result indicates that SDNI has been considered as an important resource for supporting the growth of small high-tech business. In fact several small companies have used SDNI's facilities and worked with SDNI technical staff to achieve major milestones to secure investment funding, winning government contracts, and launching their products. There are also late stage startup companies of more than 100 employees and over $10M product revenues used the SDNI facility to advance their technology and product roadmap to enter IPO.

Overall, the SDNI facility has produced 50,343 hours of usage, which is 5% higher than the previous year. The facility has obtained over 100% growth for "remote use" via direct service. One of the highest growth areas is usage by small companies, registering 7144 hours in total (~14% total usage hours). Regarding scientific areas, SDNI observed 45% growth in life sciences areas, which is the fastest growth area and a result of the unique strength and ecosystem of San Diego area. The facility has trained 210 new users, about 15% increase compared to the previous year.

Research Highlights

In the past 12 months, the SDNI has supported numerous cutting edge research and development activities using nanotechnologies. Most prominently, SDNI's advanced E-beam lithography and dry etching and patterning capabilities, supported by our PhD level staff, have enabled Professor Boubacar Kante's group to make two major breakthroughs in nanophotonics. Within 4 months, Professor Boubacar's group published a paper in *Nature* on the world's first bound-state-in-the-continuum (BIC) laser and another paper in *Science* on the world's first topological photonic crystal laser. The latter was selected to be one of the "***Physics World Top Ten Breakthroughs of 2017"***. [http://physicsworld.com/cws/article/news/2017/oct/27/physicists-create-first-topological-laser](http://physicsworld.com/cws/article/news/2017/oct/27/physicists-create-first-topological-laser). Both works relied on advanced electron-beam lithography and patterning techniques conducted by our staff scientists. The works have led to major grants from Department of Defense and Department of Energy.

Other noticeable scientific and engineering breakthroughs supported by SDNI include (a) publication in Nano Letters about "neuron-reading' nanowires to accelerate development of drugs to treat neurological diseases" that led to the award of NSF Scalable Nanomanufacturing for Integrated Systems (SNM-IS) program by Professor Shadi Dayeh, (b) supporting startup company Nanovision Biosciences for their breakthrough development in nanowire-based retinal prosthesis for vision restoration, and (c) supporting startup company NanoCellect Biomedical to commercialize its ground breaking microfluidics technology for biomedical instruments promised to transform the research and clinical practices of medicine. The NanoCellect work has resulted in over $10M grant from NIH and over $10M investment from private sectors, with its unique systems deployed internationally for precision medicine. All these transformative and translative research has taken advantage of SDNI's strengths in nanophotonics and nanobiomedicine.

<u>Education and Outreach Activities</u>

Research Experience for Undergraduates (REU): SDNI (REU) Program funded 12 students in 2017. Students were paired up with a graduate student mentor and faculty research mentor. The goals of the REU program are to expand student participation and interest in nanotechnologies, to develop a diverse and competitive pool of undergraduates on nanotechnology research, and to encourage undergraduate students to pursue graduate studies and professional careers in science and engineering.

Student recruitment was in coordination with the NNCI CO and the Society of Hispanic Professional Engineers (SHPE), the Society for Advancement of Chicanos and Native Americans in Science (SACNAS), the Society of Women Engineers (SWE), the National Society of Black Engineers (NSBE), and NanoEngineering & Technology Society (NETS at UCSD).

Research Experience for Teachers (RET): SDNI funded 4 teachers from San Diego County. The goals of the program are to advance precollege students' interest in science and engineering careers through the compelling and informative lessons developed by RET teachers, to establish long-term collaborative relationships between K-14 STEM teachers and SDNI's research community, and to develop novel and exciting science and engineering curricula to share with the community of precollege educators.

Outreach: SDNI partnered with the Center for Research on Educational Equity, Assessment and Teaching Excellence (CREATE) and the Reuben H. Fleet Center in their pilot community outreach project: 52 weeks of science. This is a year-long celebration of science in Spanish/English at Logan Heights community, \with the goal of bringing accessible science learning to the community every week of the year, highlighting the importance of bringing informal STEM education to this underserved community. SDNI collaborated with the Boys and

Girls Club of Logan Heights Branch to bring a week of nanoscience to elementary and middle school students. This one week camp included activities and workshops in nanoscience and nanoengineering to students, followed by a visit at UC San Diego SDNI facilities.

Other outreach events include: Comienza Con un Sueno STEM for Hispanic Families (60 high school and parent participants), STEM in your back yard at Logan Heights Library (100 participants), presenting at National Librarian Conference- collaborating with libraries in STEM outreach efforts (80 participants), Lab tour for college students from Cybernetics Electronics Engineering Baja California (30 international college students), COSMOS lab tour (25 high school participants), Talented Youth Program with Johns Hopkins (30 participants), and 52 Weeks of Science at Barrio Logan (200 participants).

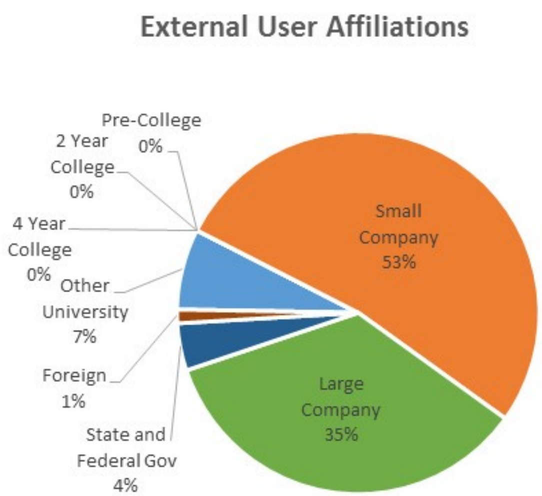
Computation Activities

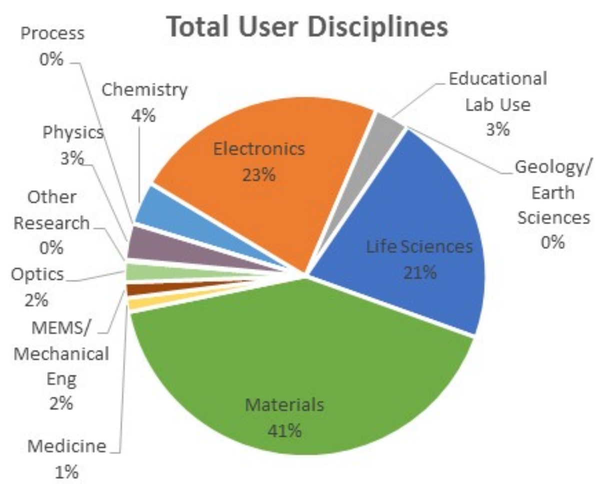
SDNI offers users two custom simulation software programs (OOMMF and FastMag) for nanomagnetics. We had multiple requests from users in terms of updating some features of OOMMF, and we are working on the issues related to our recent releases of the CUDA environment. We also changed the code structure to accommodate requests from NIST for making the OOMMF adoption easier. We started implementing an additional module for accelerated computation of Spin Transfer Torque effects, used in Magnetic Random Access Memories (MRAM). In FastMag, we worked on a module for including the Spin Hall Effect in the computations and updating the code for making it more user friendly. We also had a significant effort on coupling the micromagnetic FastMag code with an integral equation solver for accounting for eddy currents.

# SDNI Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 650 | 644 |
| Internal Cumulative Users | 495 | 478 |
| External Cumulative Users | 155 (24%) | 166 (26%) |
| | | |
| Total Hours | 47,893 | 50,497 |
| Internal Hours | 40,890 | 38,890 |
| External Hours | 7,003 (15%) | 11,607 (23%) |
| | | |
| Average Monthly Users | 290 | 385 |
| Average External Monthly Users | 49 (17%) | 56 (20%) |
| | | |
| New Users | 183 | 210 |
| New External Users | 34 (19%) | 50 (24%) |
| | | |
| Hours/User (Internal) | 83 | 81 |
| Hours/User (External) | 45 | 70 |

## Year 2 User Distribution

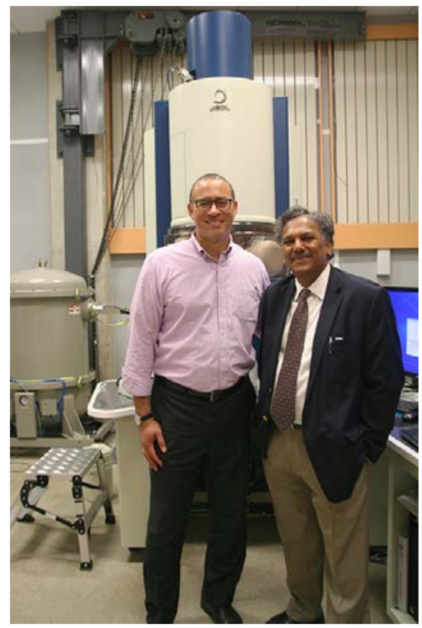


## 11.13. Soft and Hybrid Nanotechnology Experimental (SHyNE) Resource

Facility, Tools, and Staff Updates

The Soft and Hybrid Nanotechnology Experimental (SHyNE) Resource is a joint venture between Northwestern University and University of Chicago. SHyNE Resource provides researchers from academia, government, and companies large and small with access to user facilities with leading-edge fabrication and characterization tools, instrumentation, and expertise within all disciplines of nanoscale science, engineering and technology. Northwestern University, under the leadership of site director, Professor Vinayak Dravid, partnered with University of Chicago and co-director Professor Andrew Cleland to represent the Midwest within the NNCI. SHyNE Resource coordinates the integration of a diverse group of open-access nanoscale fabrication and characterization facilities across Northwestern University (NU*ANCE*, SQI, NUFAB, IMSERC, NUCAPT, JB Cohen XRD) and the University of Chicago (PNF).



SHyNE Director, Vinayak Dravid with NU Provost Jonathan Holloway in front of the recently installed JEOL ARM200CF. S/TEM.

SHyNE facilities are actively engaged in acquiring, updating or replacing key equipment within the facilities through a combination of internal and external funding mechanisms. In total, more than **30 new instruments** and numerous tool upgrades were installed in Year 2. In terms of fabrication equipment, Year 2 was the first full year of operation for the new PNF cleanroom and additional equipment continues to be installed including back-end tools and additional deposition equipment. NUFAB is expanding capabilities to include polyimide processing for flexible devices among other equipment and a 1000 sq. ft. clean room expansion is underway. Highlights on the characterization side include two state-of-the-art S/TEM instruments (JEOL ARM200CF and ARM300CF) under installation in the NU*ANCE* Center, polymer characterization equipment in IMSERC and the addition of pulsed laser deposition to JB Cohen XRD facility, now the X-ray and Materials Deposition Facility. Maintaining an active and engaged user base for SHyNE facilities is contingent upon the successful recruitment and retention of high quality staff. **Six new technical staff** joined the SHyNE team in Year 2, five of whom are in newly created positions and many receive partial funding through NNCI.

New technical staff in Year 2:

1. Wuk Jun Nam, Process Engineer, Pritzker Nanofabrication Facility
2. Sam Kaehler, Equipment Engineer, Pritzker Nanofabrication Facility
3. Tirzah Abbott, Senior Microscopy and Imaging Specialist, NU*ANCE* Center
4. Charlene Wilke, BioCryo Electron Microscopy Imaging Specialist, NU*ANCE* Center
5. Hee Joon Jung, Postdoctoral Fellow in Electron Microscopy, NU*ANCE* Center
6. Yaobin Xu, Postdoctoral Fellow in Electron Microscopy, NU*ANCE* Center
7. Dr. D. Bruce Buccholz, PLD Facility Manager, X-ray and Materials Deposition Facility
8. Arsen Gaisin, Mass Spectrometry Specialist, IMSERC

9. Shaoning Lu, Research Engineer, NUFAB

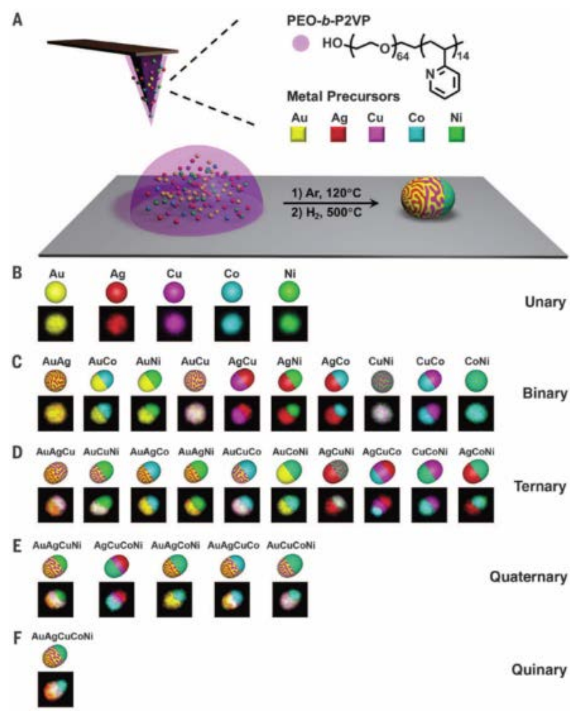
User Base

For Year 2, SHyNE facilities had **1620 unique users** (18% increase over Year 1) who logged over **132,000 hours** of instrument time generating $4.2M in revenue. External users represented 13% of total users and 11% of revenue. We continue to work toward increasing external usage, and to this end we will be rolling out a new seed funding initiative for new external users in Year 3. SHyNE actively engages local and regional companies, colleges, universities, non-profit organizations and governmental agencies to recruit new users. This is accomplished by a number of marketing strategies including: exhibitions at conferences and trade shows, production of a web portal, a marketing video and promotional materials, networking with alumni, coordination with university-wide corporate engagement and media relations offices, and an active social media presence. In particular, SHyNE exhibited at PittCon 2017 (Analytical Chemistry and Applied Spectroscopy) in Chicago and made nearly 50 connections with potential users; we also began tracking another 50 connections via our web portal. In Year 3, we continue to focus on connecting with users from non-traditional industries which predominate the Chicago region, including food and beverage, agriculture, pharmaceutical and biomedical industries.

SHyNE staff engaging a potential user at PittCon 2017.

Research Highlights

The research output facilitated by SHyNE facilities is substantial, including more than **250 publications**, which *specifically cite* the NNCI grant and/or one of the facilities funded through SHyNE. We expect the actual output is much higher and are actively working with University administration to find strategies to approach total compliance with facility acknowledgement. Similarly, we are working with our intellectual property groups to determine better methods to capture patents which were supported through SHyNE Resource facilities. Research activities resulted in many high-profile publications in journals such as *Science*, *Science Translational Medicine*, *Nature Photonics*, *Nature Materials*



The SPBCL-mediated synthesis of multimetallic nanoparticles (NPs) and a five-element library of unary and multimetallic NPs made via this technique. (A) Scheme of the process; (B) – (F) Unary, binary, ternary, quaternary, and quinary NP systems consisting of various element combinations of five metals.

and *Nature Chemistry*. In particular, the Mirkin group at Northwestern demonstrated the fabrication of polyelemental nanoparticles libraries by a polymer pen lithography technique, available to SHyNE users (*Chen, et al. Science*). The Shah group at Northwestern developed a 3-D printed hyperelastic bone for regenerative medicine and utilized SHyNE facilities for peptide synthesis and materials characterization (*Jakus, et al. Science Translational Medicine*). External users from the University of Illinois at Chicago utilized SHyNE facilities to characterize 2D materials for electrocatalytic $CO_2$ reduction (*Asadi, et al. Science*).

Education and Outreach Activities

Education and outreach activities are a critical part of SHyNE's mission and include academic courses with laboratory components, an REU program, hands-on workshops, seminars, vendor symposia/demos, facility tours/demos (K-12, higher education and public). We provide facility tours for more than **900 visitors** in Year 2. Nearly **1400 students** participated in courses utilizing SHyNE facilities in Year 2. SHyNE facilities hosted workshops and seminars reaching more than **500 participants**. SHyNE sponsored **four REU students** in a unique, facilities-focused REU program that exposed undergraduates to advanced instrumentation as a key component of their projects.

Key workshops and seminars:

1. "AFM-Raman-TERS Workshop & Demo Session", hosted by NU*ANCE* and co-sponsored by HORIBA Scientific, AIST-NT, NU-MRSEC.
2. "Advanced "Hyperspectral Imaging Techniques for Elemental and Molecular Applications Workshop", hosted by NU*ANCE*, and co-sponsored by Middleton Spectral Vision, Bruker AXIS, NU-MRSEC
3. "American Crystallography Association summer school" hosted by IMSERC in partnership with Notre Dame.
4. "BEAMER Basic Training", hosted by PNF and GenISys

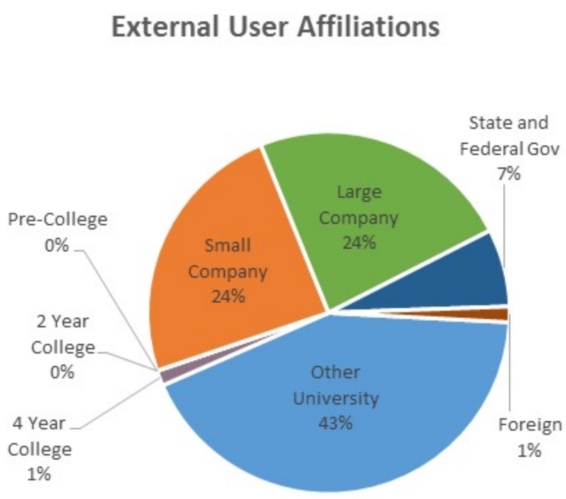
SEI Activities

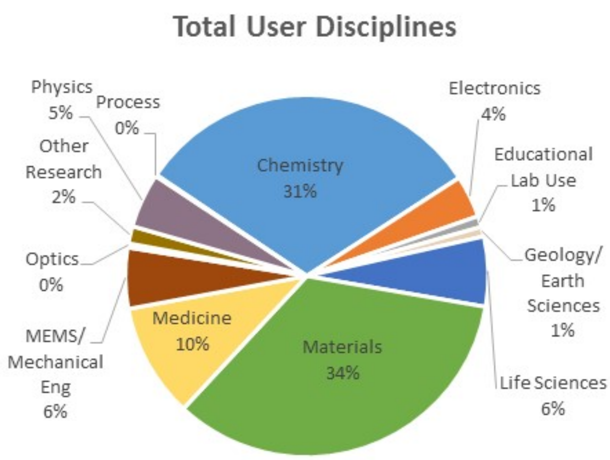
SHyNE continues to grow and develop our novel NanoJournalism program in collaboration with Northwestern's Medill School of Journalism. In Year 2, we hired a NanoJournalism intern who shadowed facility staff and users and wrote several articles about research going on in the facilities. SHyNE also hosted the Medill students for a series of facility tours and presentations about nanotechnology. Looking forward to the next year, we are planning science communications workshops with Medill Professor Abigail Foerstner and will grow the NanoJournalism program with a dedicated web-page and increased social media presence.

# SHyNE Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 1,446 | 1,620 |
| Internal Cumulative Users | 1,230 | 1,404 |
| External Cumulative Users | 216 (15%) | 216 (13%) |
| | | |
| Total Hours | 138,000 | 132,673 |
| Internal Hours | 128,838 | 127,127 |
| External Hours | 9,162 (7%) | 5,545 (4%) |
| | | |
| Average Monthly Users | 679 | 802 |
| Average External Monthly Users | 54 (8%) | 54 (7%) |
| | | |
| New Users | 699 | 698 |
| New External Users | 152 (22%) | 140 (20%) |
| | | |
| Hours/User (Internal) | 105 | 91 |
| Hours/User (External) | 42 | 26 |

## Year 2 User Distribution



## 11.14. Southeastern Nanotechnology Infrastructure Corridor (SENIC)

Facility, Tools, and Staff Updates

SENIC has continued to build upon the "one facility, two locations" approach to the partnership, with IEN and JSNN meeting remotely when common equipment and facilities issues arise. The two sites have also continued to exchange best practice techniques for installing and maintaining common toolsets.

Further build-out of Georgia Tech's Marcus Nanotechnology Building continued this year with the onset of construction of the 3,000 SF Marcus Center for Therapeutic Cell Characterization and Manufacturing (MC3M), with project completion in January 2018. A Heidelberg MLA-150 maskless aligner and an Elionix ELS-G100 e-beam lithography system were ordered, with delivery and installation in early 2018. A piezoelectric aluminum nitride thin film reactive sputtering process was developed on a home-made CtrlLayer SDS sputtering system, and a germanium selenide RF sputtering system, converted from a plasma etching tool, was installed. The IEN cleanroom has added a tin oxide precursor to the Cambridge NanoTech ALD system and magnesium sputtering capability to the CVC DC sputtering system. A chemical mechanical polishing (CMP) process for silicon was established. In the organic cleanroom, a Nanoscribe 3D-DLW system was installed, and the data collection and evaluation software for the Biacore T200 SPR was upgraded.

In 2017, the IEN Software Development Group added additional features to the Shared User Management System (SUMS) including real-time interfacing with the GT Environmental Health and Safety Radiation/Laser Safety as well as the campus Right-To-Know (RTK) databases to assure that researchers are qualified to use tools at each login. SUMS has public facing pages which now allow anyone to view tools and services available at IEN. The software is also currently in use at the NNCI site at Montana State University. SUMS currently has over 1800 active researchers, 45 equipment groups offering 733 tools or services and 536 individual research groups. IEN has hired 2 FTE cleanroom staff members (Process Equipment Engineer II and Laboratory Technician I) to support its lithography, plasma systems, and high-temperature furnace operations.

SENIC partner JSNN completed several installations, as well as operational and process improvements, in its core facilities, including in the Micro and Nanofabrication Core, Analytical Chemistry Core, Advanced Microscopy, Nanobiology Core and Material Test Center. These include a 200-mm Kurt Lesker RF/DC Sputtering System with reactive sputtering capabilities, a 200-mm Wet/Dry Oxidation and Annealing Furnace, a custom-modified Vapor Phase Deposition System for large area deposition of two-dimensional transition metal dichalcogenide monolayers, a large substrate vacuum furnace (up to 1600 ˚C) for large-scale nanofiber manufacturing, a Stratasys J750 multi-material 3D printer, a Next-Generation Sequencing (NGS) capabilities for the Soft Matter and Nanobiology Core, a Varian 820-MS ICP Mass Spectrometer, a new 532 laser for the Horiba XploRA One Raman Confocal Microscope, a CytoViva Hyperspectral/Dark Field Microscope, and a glovebox-integrated Arradiance GEMStar XT-DP Thermal/Plasma Enhanced Atomic Layer Deposition System for high aspect ratio particles. JSNN has also placed orders for a Thermal Atomic Layer Deposition tool (Veeco/Cambridge Nanotech) and an ESCALAB™ Xi+ X-ray Photoelectron Spectrometer (Thermo Scientific). These tools will be operational in early 2018 as part of the JSNN Nanofabrication and Analytical Chemistry Cores respectively. JSNN recently hired a full-time staff for user outreach, marketing and to collect and analyze tool usage statistics. Based on the positive experiences of the IEN support team, during the past year JSNN also formed a Technical Support team whose responsibilities include user consultation, training, process and characterization support, remote jobs and data analysis, if requested by the user.

User Base

Marketing of SENIC continued through our website (http://senic.gatech.edu/), as well as additional promotion and communication efforts through social media. Collateral marketing materials, such as SENIC-branded bookmarks, brochures, and banners, are distributed at conferences and other promotional/marketing events. In addition, JSNN created several marketing materials and brochures for their 6 core facilities (Micro and Nanofabrication Core, Advanced Microscopy Core, Analytical Chemistry Core, Nanobiology Core, Gateway Material Test Center, Computational Modeling Core), and IEN is currently revising its major marketing materials and working to create a SENIC brochure that will highlight the combined IEN and JSNN tool capabilities.

Following the recommendations of the SENIC advisory board, promotional events such as SENIC webinars and presentations at various university sites in the southeastern region were held. IEN hosted two SENIC webinars, one on the general SENIC program and another on Nanoscribe 3D lithography. SENIC Ambassadors hosted outreach representatives for presentations at their respective universities: University of North Carolina @ Charlotte, Kennesaw State University, and University of South Carolina, Greenville. These events were well attended by the faculty and students from the host universities and by local industry representatives. SENIC representatives also visited industries in the vicinity such as Michelin (Greenville, SC), Sealed Air (Charlotte, NC), and TensTech (Charlotte, NC) and discussed the availability of SENIC resources to industry research staff. In addition, SENIC continued to interact with county economic development officials.

In May 2017, IEN held its annual User Science and Engineering Review (USER) Day in conjunction with IEN's first Technical Exchange Conference at which facility users presented research posters. JSNN hosted its 5$^{th}$ Annual Nanomanufacturing Conference (Sept. 2017) with over 150 attendees. Both IEN and JSNN also attended or exhibited at local and regional conferences and events to help recruit new users, including IEEE Sensors (Oct 30- Nov 2, 2016), AVS-63 (Nov 7-9, 2016), IEEE Southeastern Conference (March 2017), Core Day Conference at Emory University (April 28, 2017), and Industry-Academic Intersection Conference (May 10, 2017).

Since 2013, IEN has held a biannual seed grant competition that seeks to provide no-cost facility access to beginning graduate students so that they can begin their cleanroom training without regard to financial concerns. Four to five awards are made each submission cycle for a six-month grant period. While this program had been restricted to Georgia Tech projects, with the advent of SENIC the program is now open to any academic researcher in the southeastern US, and the first external user (from VCU) was awarded a grant for the period Dec. 2016-May 2017, and a second user (from Louisiana Tech) began work in Sept. 2017.

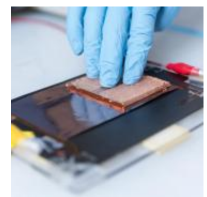
During this year of the NNCI program (Oct. 2016 - Sept. 2017), the SENIC facilities have served nearly 1200 individual users (12% increase over year 1), including more than 220 external users (35% increase) representing 94 companies and 28 colleges and universities. Within this time, we have contracted with more than 50 new external entities at Georgia Tech and within the JSNN consortium. A reciprocal billing agreement has helped users access capabilities at both SENIC locations with minimal difficulty. The majority of users access the facilities on-site, although 183 users obtained services remotely, and some users operated in both on-site and remote fashions. Monthly users averaged 498 (11% increase), and 26 new users were trained each month on average (313 total during the reporting period).

As part of a network-wide NNCI effort, SENIC participated in the first annual user satisfaction survey. The online survey was emailed to all IEN and JSNN users and received 118 responses (as of 1/22/18). Overall, the results are positive: 93% of respondents were able to complete their work on-time, and 98% would refer SENIC to a colleague. The average facility rating was 4.4/5 and overall site rating was 4.3/5.

Research Highlights

Notable *new* users came to SENIC from Kennesaw State University, University of South Carolina, Emory Univ. School of Medicine, Michelin Global Research Center, Lubrizol, VerAvanti, Alacrity, MagAssemble, Goulston Technologies, Ecolab, Becton Dickenson and Company, Midwest MicroDevices, USDA, and Air Force Research Lab. Example research highlights include:

**Triboelectric Nanogenerators Boost Mass Spectrometry Performance (Facundo Fernandez, Georgia Tech)**

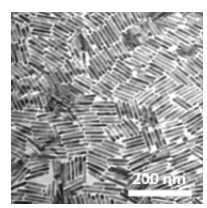


Triboelectric nanogenerators (TENG) convert mechanical energy harvested from the environment to electricity. Researchers have shown that replacing conventional power supplies with TENG devices for charging the molecules being analyzed by mass spectrometry can boost the sensitivity. The research was supported by the NSF, NASA Astrobiology Program and the Department of Energy and reported in the journal ***Nature Nanotechnology***.

**Low-Cost Technique to Convert Bulk Alloys to Oxide Nanowires (Gleb Yushin, Georgia Tech)**

A simple technique for producing oxide nanowires directly from bulk materials could dramatically lower the cost of producing these one-dimensional (1D) nanostructures, providing materials for use in lightweight structural composites, advanced sensors, electronic devices, and battery membranes. The research was supported by the NSF and Sila Nanotechnologies and reported in the journal ***Science***.

**Uniform "Hairy" Nanorods with Energy and Biomedical Applications (Zhiqun Lin, Georgia Tech)**




Materials science researchers developed a new strategy for crafting one-dimensional nanorods from a wide range of precursor materials. The research was supported by the Air Force Office of Scientific Research and reported in the journal ***Science***.

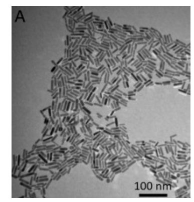
**Protein Trapping in Plasmonic Nanoslit and Nanoledge Cavities: The Behavior and Sensing (Jianjun Wei, UNCG)**

A novel plasmonic nanoledge device was developed to explore the geometry-induced trapping of nanoscale biomolecules and examine generation of surface plasmon resonance (SPR) for plasmonic sensing. This work was reported in ***Analytical Chemistry***.

**Brain-Mimicking Nanomaterials for A.I. Retina Receive $7 Million Research Grant (Alan Doolittle, Georgia Tech)**

A team of Georgia Tech and Binghampton University researchers were funded by the DoD to expand work on new metal oxide materials to emulate the way human neural networks buzz with electric potential on a cellular level and provide neuristers for practical use in brain-like computing.

**Thwarting Metastasis by Breaking Cancer's Legs with Gold Rods (Mostafa El-Sayed, Georgia Tech)**



Now, a research team led by Georgia Tech has developed a new photothermal gold nanorod therapy to thwart cancer's spread through the body. The research was funded by the NSF and NIH and published in **Proceedings of the National Academy of Sciences**.

Education and Outreach Activities

SENIC's vision for education and outreach is focused on the development of a strong workforce capable of meeting the needs of a growing nanotechnology-enabled economy. Through our programs, we reached ~9,000 individuals from young children through adults. In 2017, SENIC (GT) had four summer undergraduate interns participating in 10 weeks of research and hosted the first annual NNCI REU convocation August 6-8, 2017. JSNN has collaborated with Forsyth Technical Community College's Nanotechnology and Biotechnology programs over the past five years and provided four research internships in 2017. The community college students received up to 160 hours of on-site and paid workforce training in one of the JSNN core labs. A Forsyth Technical Community College Nanotechnology student team was selected as first place winners in the NSF 2016 Community College Innovation Challenge (CCIC) for their project "Energy Efficient Solar Greenhouse Utilizing Nanotechnology Project." Five of the six students on the team interned at the JSNN core labs during the past two years. GT submitted an REU proposal to NSF (pending) and was also part of a five-site NNCI RET proposal to NSF (pending).

IEN hosts 15 Nano@Tech seminars each academic year with speakers primarily from the local community, which includes Georgia Tech faculty, as well as faculty from neighboring universities and researchers at companies in the region. JSNN also holds at least 12 seminars per year with speakers primarily from colleges, universities and industries in North Carolina. Both of these are live-streamed and archived. IEN's NanoFANS Forum, a biannual symposium at the intersection of life sciences and nanotechnology was held in May 2017 ("Nanobiomaterials in Healthcare") with more than 100 attendees. JSNN also held a Translational Collaborations Workshop and Facility Tour (April 2017) with over 50 life science experts and medical professionals from University of North Carolina School of Medicine and RTI International attending. Vendor-supported and sponsored workshops were also held at both SENIC locations.

IEN short courses were conducted with a special focus on hands-on experiences for the participants: "Soft Lithography for Microfluidics" (Oct 2016, April 2017, and Sept 2017), "Microfabrication" (March 2017 and August 2017), and "Practical Surface Characterization of Materials" (August 2017).

SENIC has been active in providing outreach to K-12 students, teachers and the general public. Unique to JSNN is the NanoBus, an after-school mobile hands-on laboratory which includes an

STM, 3-D printer and a variety of lab activities. Staffed by JSNN students, the NanoBus visited 13 schools between September and May 2017 reaching over 2200 students. In addition, JSNN has hosted 24 field trips (lab tours, demos and/or talks) for local middle and high schools, boys' and girls' scouts, Rotary and Kiwanis clubs, STEM-focused clubs, professional societies, and other southeastern US universities including predominately undergraduate-serving institutions. Lastly, JSNN has continued to host local high school students and the Canterbury Summer Science Academy for a week-long summer science camp on hydroponics, 3D printing, thin-film deposition and microscopy. GT reaches K-12 students with school visits both on and offsite with visits occurring each month of the year. We have established a relationship with GT's Office of Government and Community Relations and participate each semester in its Middle School STEM program. IEN also has a strong relationship with Atlanta Public School's Gifted and Talented program, providing spring research internships for high school students, and annually hosting their kickoff event for 150 students.

Both SENIC sites supported their local science festivals – NC Science Festival and Atlanta Science Festival. JSNN hosted the Annual Gateway to Science event during the NC Science Festival which included demos, tours, and videos on careers in nanotechnology. GT held an open house where the community could image materials with an SEM and the images are posted online for downloading (http://ien.gatech.edu/asf2017). For reaching K-12 teachers, GT exhibited at the Georgia STEM Forum and Georgia Science Teachers Association and SENIC (GT & JSNN) exhibited at the North Carolina Science Teachers Association. GT also provided a workshop for teachers at Albany State University and at the National Science Teachers Association annual meeting.

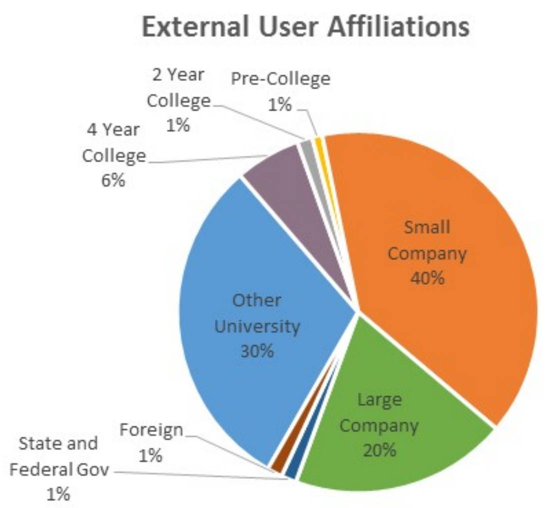
SEI Activities

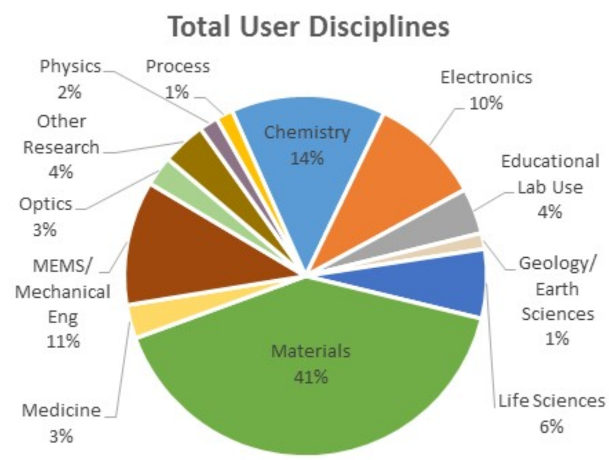
The aim of the SEI work at SENIC is to increase attention to application of nanotechnology, while still attending to social and ethical implications. We continue to work toward development of a model which incorporates societal impacts in a pragmatic manner that parallels elements of the I-Corps program. We provided a synoptic description of this model at the NNCI SEI half-day workshop in Philadelphia on October 17, 2017 and are scheduled to present this model in greater depth at the NNCI SEI phone meeting in January 2018. We developed an exercise from this model, which we are scheduled to pilot at the 2018 NNCI Winter School in January of 2018. In addition, we have been working on a measure of technological emergence to provide guidance to SENIC concerning emerging areas of nanotechnology R&D. The indicator is based on growth of terms from titles, abstracts, and/or keywords plus networked relationships over at least a 10-year period.

# SENIC Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | Year 1 | Year 2 |
| Total Cumulative Users | 1,067 | 1,196 |
| Internal Cumulative Users | 903 | 975 |
| External Cumulative Users | 164 (15%) | 221 (18%) |
| | | |
| Total Hours | 79,581 | 85,275 |
| Internal Hours | 71,659 | 73,499 |
| External Hours | 7,922 (10%) | 11,773 (14%) |
| | | |
| Average Monthly Users | 447 | 498 |
| Average External Monthly Users | 60 (13%) | 63 (13%) |
| | | |
| New Users | 313 | 313 |
| New External Users | 67 (21%) | 110 (35%) |
| | | |
| Hours/User (Internal) | 79 | 75 |
| Hours/User (External) | 48 | 53 |

## Year 2 User Distribution



### 11.15. Texas Nanofabrication Facility (TNF)

Facility, Tools, and Staff Updates

NSF NNCI Texas Nanofabrication Facilities (TNF) is a partnership between three Centers at the University of Texas. TNF comprised the Microelectronics Research Center (MRC), the Texas Materials Institute (TMI), and the NASCENT Nanosystems ERC.

- MRC, former NNIN site, core focus is Micro and Nanofabrication in a 12,000 $ft^2$ 100 shared cleanroom lab.
- TMI core focus is imaging and spectroscopic characterizations such as TOF-SIMS, XPS, SEM, TEM, AFM, ... TMI's equipment will be relocated and centralized in the new home of the Department of Electrical and Computer Engineering: the Engineering Education and Research Center (EERC), $310M building of the Cockrell School of Engineering. EERC will serve education and research through discoveries and innovations.
- NASCENT **N**anodevice **M**anufacturability **Fab** (nm-Fab) has 5,000 $ft^2$ cleanroom space dedicated to Roll-to-Roll and flex wafer-scale nanomanufacturing systems. Multimillions plasma etcher and film deposition system had been brought in the lab in March 2017 and are under the installation phase. NASCENT –ERC has a strong education and outreach programs that increase the broader impact of the MRC education program (see Education Activities). NASCENT-ERC mission is also to seek industrial partnership to accelerate the design, development and commercial deployment of the center's nanomanufacturing systems. That effort attracts new external users to the TNF shared facilities.

Bottom lines, each of the three UT Centers of TNF are unique by their vison, goals and strategies however their strongly serve and enhance the NSF NNCI program at TNF.

TNF offers over 130 state-of-the-art tools necessary for micro and nanofabrication, as well as an extended suite of characterization tools, crystal growth and nano-manufacturing systems. TNF acquired new capital investment worth $2M that complements its existing strengths.

- Raith eLine Plus SEM/E-beam lithography, to upgrade the decade old micro-nano fabrication at UT. To be delivered in Dec 2017. Sponsored by UT
- Rigaku X-ray Diffraction System Smartlabs. Facilitated in Aug 2017 at MRC. Training of new users on going. Funded by UT ECE.
- Replacement of the energy-dispersive X-ray spectrometer (EDS) on the SEM: Bruker QUANTAX Compact to quantify light elements in materials at specific locations (Installed Sep 2017). Funded by UT ECE.
- Small Angle X-ray Scattering Instrument with In Situ Capabilities from SAXSLAB. To be installed in Engineering Education and Research Center (EERC). NSF MRI Acquisition.
- Swagelok Orbital M200 Welder utilized by the technical staff to make and repair gas delivery lines to all of the MRC equipment. This type of service is very expensive if sub-

contracted and has always been done "in house" in an effort to save the University money and time. Funded by UT ECE.

TNF is a network of 24 professionals (student workers, technicians, engineers, administrative staff) dedicated to their user base: research associates, professors, start-ups, small and large company users.

TNF is collaborating with the other NNCI sites on different fronts: Technical, Education and Societal and Ethical Implications (SEI). Technical Network Interactions: TNF staff are still harvesting from technical workshops that were organized under NNIN (ALD- Harvard and Stanford, Etch- Cornell, EBL-Georgia Tech, Soft Lithography- Harvard). TNF staff built up strong personal relationships with their counterpart across the network during those in person meetings. This leads to interactions allowing frank and trustworthy discussions in the network to enable quick implementation of solutions:

- Technical manuals or equipment software drives are exchanged (ASU, Cornell).
- Bulk prices are negotiated (EBL photoresist GaTech).
- Process recipes and safety practices are shared (PDMS mask fusion Harvard, GaTech).
- Preferable providers for ALD precursors are named (ALDs NNCI group).

Education Network Interactions: Even with no central REU coordinating office, the best practices set up by Cornell (L Rathbun, MC Mallison) and Georgia Tech (N Healy) are invaluable guides to advertise the program, collect applications, recruit interns, select mentors and advisers, coordinate the summer effort towards quality deliverables: poster, oral presentations, extended abstract. The REU convocation at one NNCI site (2017 GaTech at Atlanta, 2018 Research Triangle Nanotechnology Network at Raleigh - North Carolina) is the climax of this program. During those two full days' meeting, education coordinators share experiences to ultimately improve their own program outcomes. SEI Network Interactions Prof. Lee Ann Kahlor, TNF SEI Director has extended collaboration across the network (see SEI paragraph).

User Base

A proven way to increase the user base is to organize technical workshops. In the past year TNF in collaboration with vendors offered lectures and equipment demonstration sessions:

- AFM- Park System (Oct 2016): long term demo agreement on NX10 AFM system (~$200k)
- LitesizerTM 500 dynamic light scattering (DLS) by Anton Paar (Nov 2016)
- Polymer Pen Lithography (PPL)- TERA-print, (Dec 2016)
- Woollam Ellipsometer M-2000DI: Case studies on user samples (Aug 2017). 30 undergraduate and graduate students attended the lectures by Dr. Ron Synowicki and demo on two UT owned ellipsometers.

Research Highlights

We are listing five research projects that are using the facilities available at the TNF centers. For details see the vignettes included in the highlights report.

- Prof Ray Chen UT Faculty and Omega Optics founder: ***Silicon Nanophotonic Biosensor Chip for Lung Cancer Detection***
- Prof Neal Hall UT Faculty and Silicon Audio founder: ***Sensors for drag measurements at hypersonic speeds***
- Steve Savoy, Nanohmics founder: ***Multiplexed Metal-Oxide Gas and Fluid Sensor Arrays***
- Burt Fowler and Harry Chou GraphAudio Researchers at TNF: ***Graphene Enabled Acoustics***
- Prof. A Heltzel UT Faculty and PC Krause and Associates researcher: ***Fabrication of metamaterials for efficient passive cooling***

Education and Outreach Activities

NASCENT-ERC education director and program evaluator (R Hartman and D Yañez) and MRC education coordinator (M Palard) are working closely to offer a uniform and cohesive Research Experience for Undergraduates (REU) program. NASCENT ERC REUs are recruited at a state level toward the goal of feeding the UT graduate schools. The TNF NNCI REUs are recruited nationwide to foster research interests and enable science awareness. A cohort of 10 REUs is hosted by TNF in between the 2 programs each summer for 9 weeks. In addition of the REU program, NASCENT-ERC offers during the summer, pre-college activities: paid one (1) week Nano Camp -30 high schoolers-, 7 weeks NASCENT Young Scholars -15 women and URMs high schoolers, Teacher internship -7 RETs-. NASCENT–ERC is also a strong partner for K-12 scientific outreach activities such as *Explore UT* (one Sat in March), *NanoDays* at the Thinkery Children's museum and "*Introduce a Girl to Engineering Day*" (one Sat in the Spring). MRC shared facilities are leveraging the NASCENT ERC education and outreach activities by offering cleanroom tour (over 6 per year), seminars, equipment hands-on demonstration time, equipment training staff expertise, and interactions with faculty and grad students,

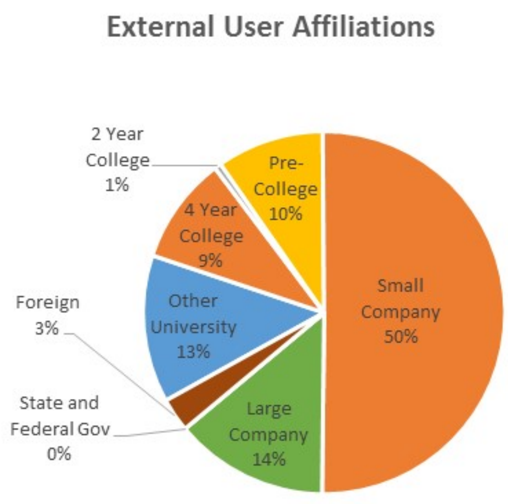
SEI Activities

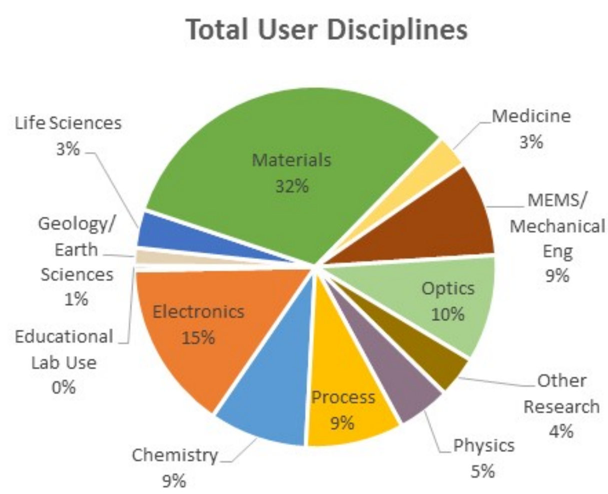
We have continued our focus on finding ways to integrate SEI into TNF daily operations. Years one and two were spent on research analysis and content development, as well as training an MA student in SEI. In that work, our team drafted and tested on various audiences multiple iterations of a training video focused on SEI. We ended with a 15 min. professional quality video. In the last 12 months, the video has been shared with Jamey Wettmore and the other SEI representatives from the NNCI nodes. We met in person at Penn in Nov 2017 and again via phone conference in Dec 2017. Next steps are to submit a case study of this process to the *Journal of Responsible Innovation*. We also are working with the TNF to integrate the video into safety training beginning in Feb 2018. The video will be embedded in a survey so that we can collect brief pre- and post-viewing data. There is interest in then working to integrate the video in trainings across the nodes. Finally, we are moderating a panel on SEI at the NSE Grantees conference in Dec 2017.

# TNF Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 653 | 696 |
| Internal Cumulative Users | 500 | 529 |
| External Cumulative Users | 153 (23%) | 167 (24%) |
| | | |
| Total Hours | 67,570 | 58,354 |
| Internal Hours | 53,484 | 45,952 |
| External Hours | 14,084 (21%) | 12,402 (21%) |
| | | |
| Average Monthly Users | 244 | 272 |
| Average External Monthly Users | 45 (18%) | 50 (19%) |
| | | |
| New Users | 99 | 193 |
| New External Users | 48 (48%) | 45 (23%) |
| | | |
| Hours/User (Internal) | 107 | 87 |
| Hours/User (External) | 92 | 74 |

## Year 2 User Distribution



## 11.16. Virginia Tech National Center for Earth and Environmental Nanotechnology Infrastructure (NanoEarth)

Facility, Tools, and Staff Updates

**Facility –** A portion of the Nanoscale Characterization and Fabrication Laboratory (NCFL) has been remodeled to better accommodate NanoEarth visitors by providing semi-private work space and a group meeting area. Additionally, a NanoEarth data analysis lab with specialized software has been created.

**Tools –** NanoEarth acquired funding for a new TEM sample cleaner to replace a 10+ year old system and allow users to significantly reduce hydrocarbon contamination and also dehumidify nanomaterials, especially those that are naturally occuring.

**Staff –** Leveraging non-NNCI funding, Dr. Matthew Chan has been hired as NanoEarth's associate director for diversity initiatives as well as the associate director for the Virginia Tech Center for Sustainable Nanotechnology (VTSuN) which is part of NanoEarth. His addition has greatly supported NanoEarth's Multicultural and Underrepresented Nanoscience Initiative (MUNI) and other education and outreach activities mentioned below.

Additionally, we hired an undergraduate research assistant, Joshua Kling, to assist with routine lab duties in our VTSuN lab and to develop user protocols for new instrumentation.

User Base

NanoEarth is designed for users in the Earth and environmental sciences and engineering fields, but many other scientists and engineers accomplish important research in related fields using the labs and instrumentation. In the case of NanoEarth, Earth and environmental science and engineering related users have included those in the fields of chemistry, mechanical engineering, medicine, materials, electronics, and physics.

NanoEarth hosted Jones-Dilworth, a technology branding/marketing consultancy firm based in Austin, TX, to lead a "messaging bootcamp" with NanoEarth team members. The goal of this exercise was to develop a communication strategy that expands NanoEarth's traditional and non-traditional user bases. The bootcamp was widely regarded as a success and NanoEarth implemented some of the resulting messaging strategies.

In addition to making personal connections with researchers, NanoEarth has recruited users at several targeted conferences including Goldschmidt2017 and the National Association of Black Geoscientists Annual Technical Conference. We have also hosted a booth in collaboration with other NNCI sites at the Southeastern Regional Meeting of the American Chemical Society (SERMACS).

We also attract underrepresented and non-traditional users through MUNI (Multicultural and Underrepresented Nanoscience Initiative) which provides financial support for underrepresented individuals and groups to visit our facilities for both research and educational purposes. In our second year, we organized and paid for the research and educational visits of 33 underrepresented individuals from 11 different colleges and universities.

Research Highlights

**Highlight #1** (from a team of external and internal users), *Discovery of incidental Magnéli phase generation and release from industrial coal-burning*: This work shows for the first time that burning coal produces large quantities of otherwise rare titanium suboxide nanoparticles from $TiO_2$ minerals naturally present in coal. Toxicity testing in fish and mice suggest that chronic exposure in human will be problematic. Published in *Nature Communications*.

**Highlight #2** (from a team of external and internal users), *Transformation of $CeO_2$ nanoparticles in diesel engine fuel and exhaust, and plant toxicity*: Nanoscale cerium oxide is used as a highly promising eco-friendly diesel fuel additive, but its fate in the environment has not been established. In this study, transformation of the nanoparticles during engine combustion was established, and toxicity in soils at expected concentrations to plants was shown to be not detectable. Published in *Environmental Science and Technology*.

**Highlight #3** (from a team of external and internal users), *Outdoor urban nanomaterials: The emergence of a new, integrated, and critical field of study*: Engineered nanomaterials (ENMs) are widely incorporated in the outdoor urban environment. This is the first compilation, review, and case study in the literature devoted to this field. Engineered and incidental nanomaterials are included in this study. Published in *Science of the Total Environment*.

**Highlight #4** (from a team of external and internal users), *Nanoparticles in road dust from impervious urban surfaces: identification, environmental implications*: Sixty-six road dust samples were collected throughout the mega-city of Shanghai (China). Results show that metals are generally enriched in aerosolized samples relative to the bulk dust, clearly a human health hazard. Published in *Environmental Science: Nano*, and was awarded the journal cover.

**Highlight #5** (from a team of external and internal users), *In-situ straining and time-resolved electron tomography data acquisition in a TEM*: An international academia-industry collaboration team designed an integrated system using a uniquely developed sample holder and image-acquisition software suite for in-situ deformation and time-resolved electron tomography data acquisition. The project was supported by a Japanese government fund specialized for advanced characterization instruments development. It also demonstrates an inter-network collaboration between NNCI (NanoEarth) and Japan's Nanotechnology Platform (Kyushu University node). Published in the journal *Microscopy*.

**Highlight #6** (from a team of internal users), *Stable oligonucleotide-functionalized gold nanosensors for enviro-biocontaminant monitoring*: The global propagation of environmental biocontaminants such as antibiotic resistant pathogens and their antibiotic resistance genes (ARGs) is a public health concern that highlights the need for improved monitoring strategies. The mecA ARG was targeted as a model biocontaminant. mecA-specific nanosensors were successfully tested for antibiotic resistance gene (ARG) detection in ARG-spiked effluent from four wastewater treatment plants (WWTPs). Published in the *Journal of Environmental Sciences*.

Education and Outreach Activities

NanoEarth has a very active and robust Education and Outreach (E&O) program. A few highlights are included below.

- Pulse of the Planet: Syndicated radio producer Jim Metzer (multiple radio media major-award winner, plus multiple NSF, Grammy Foundation, and Fulbright grants) has already produced a total of 22 NanoEarth-sponsored Pulse of the Planet radio shows related to Earth and environmental nanotechnology. Over a million people have been reached via the live national listening audience and podcast streams/downloads.

- In coordination with Nancy Healy of the NNCO, NanoEarth sent a *Welcome to Nanoscience* textbook and related lab supplies (e.g. drinking water test kits, pH papers, dissolved oxygen & visible light probes, etc.) to Dr. S. Krishnannair, a professor at the University of Zululand in South Africa. Dr. S. Krishnannair is working to introduce nanoscience into the local education system via environmental science to provide 8th and 9th grade students with an exposure to a variety of STEM related topics.
- Through MUNI, NanoEarth organized and paid for the visit of three undergraduate students to attend the Virginia Tech HBCU Research Summit. The students also met with NanoEarth faculty and learned more about graduate school.
- The NanoHU Pioneers of Hampton University (a leading HBCU) visited NanoEarth to participate in several hands-on activities and discussions related to nanoparticle synthesis, dynamic light scattering (DLS), transmission electron microscopy (TEM), and focused ion beam (FIB). Students also had the opportunity to experience a bit of campus life and eat lunch in an award-winning Virginia Tech dining hall. The Pioneers program is an NSF-funded summer research program for high school students.
- NanoEarth launched new programs specifically targeting engagement of new industry users and student-led entrepreneurship. A new NanoEarth Industry Seminar Series featured three invited speakers who shared their unique industry perspectives with NanoEarth team members.
- The NanoEarth NanoTechnology Entrepreneurship Challenge (NTEC) was launched and three student-led/faculty-mentored teams were awarded seed funding to pursue entrepreneurial ventures related to the application of nanoscale science and engineering for global sustainability solutions. Funded projects included start-up concepts based on customizable nanocellulose-based packaging foam and 3D-printed sensors for monitoring lead in drinking water.
- The NanoEarth Entrepreneur-in-Residence (EiR) program was initiated to provide in-house consultation support to entrepreneurial faculty, staff, and students.

<u>SEI Activities</u>

NanoEarth participates in Societal and Ethical Implications (SEI) of nanotechnology activities that are coordinated across participating NNCI nodes under the direction of Professor Jamey Wetmore of the Nanotechnology Collaborative Infrastructure Southwest (NCI-SW) node. SEI activities initiated within NanoEarth include: 1) engagement with diverse and underrepresented groups, 2) empowerment of individuals and social change through nanotechnology entrepreneurship, and 3) earth and environmental nanoscience in the service of society. These activities were shared with representatives from other NNCI nodes during the NNCI annual meeting at UPenn, and will help form the basis of inter-node SEI activities in the future.

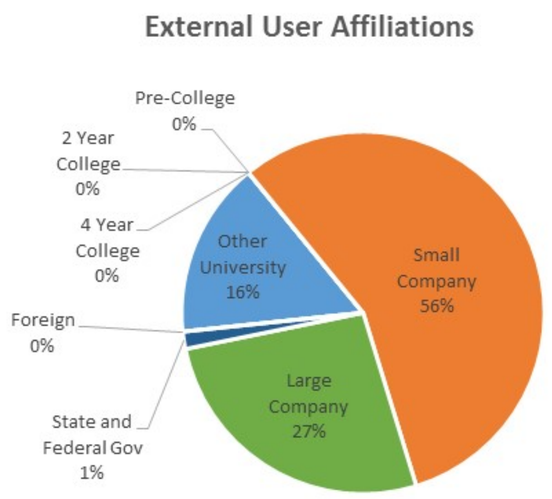
<u>Computation Activities</u>

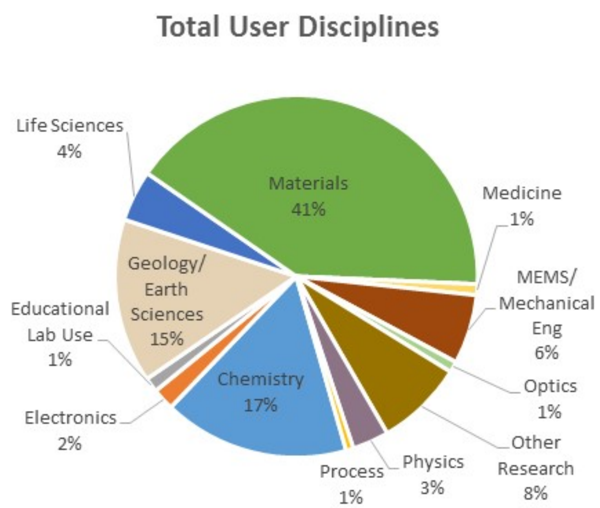
NanoEarth continues to manage access requests for users of the Nanotechnology Consumer Products Inventory (CPI). While the inventory no longer receives funding support from the Pew Charitable Trusts, NanoEarth faculty, staff, and students have played a vital role in sustaining this critical nanoinformatics resource.

# NanoEarth Site Statistics

| Yearly User Data Comparison | | |
|---|---|---|
| | **Year 1** | **Year 2** |
| Total Cumulative Users | 277 | 307 |
| Internal Cumulative Users | 232 | 245 |
| External Cumulative Users | 45 (16%) | 62 (20%) |
| | | |
| Total Hours | 7,627 | 18,056 |
| Internal Hours | 6,196 | 14,277 |
| External Hours | 1,431 (19%) | 3,779 (21%) |
| | | |
| Average Monthly Users | 78 | 90 |
| Average External Monthly Users | 9 (12%) | 14 (15%) |
| | | |
| New Users | 277 | 134 |
| New External Users | 45 (16%) | 27 (20%) |
| | | |
| Hours/User (Internal) | 27 | 58 |
| Hours/User (External) | 32 | 61 |

## Year 2 User Distribution



## 12. Program Plans for Year 3

Many of the program aspects for the Coordinating Office (see Section 2 for details) will remain the same as we go into Year 3. The role of the Coordinating Office will continue to be to (1) promote and market the NNCI and its sites, (2) assist users in finding appropriate resources across the network and beyond, (3) coordinate site activities and share best practices across the network and beyond, (4) assist the sites wherever possible, and (5) serve as the main interface with the NSF. Thereby, the goal is to ***make the network greater than the sum of its parts***.

As highlighted in the Charter Letter provided to the NNCI Advisory Board, the initial roles of the Coordinating Office (CO) were defined as follows in the NSF program solicitation:

- "The Coordinating Office will be responsible for establishing a comprehensive web portal to ensure close linkage among the individual facility websites such that they present a unified face to the user community of overall capabilities, tools, and instrumentation."
- The Coordinating Office "will also work with all sites in ways to guide users regarding which site or sites, which instruments, and which processes would enable users to complete their projects most successfully."
- "The Office will help to coordinate and disseminate best practices for national-level education and outreach programs across sites, as well as the instruction and study of social and ethical implications of nanotechnology."
- The CO "will seek to harmonize capabilities for modeling and simulation in nanoscale fabrication and characterization across sites, and provide effective coordination with the NSF-supported Network for Computational Nanotechnology (NCN)."
- "The Office will work with the individual sites to establish uniform methods for assessment and quantifiable metrics of overall site performance and impact, including those for educational and outreach activities."
- The CO "will help to share best practices and laboratory safety and training procedures across all sites. It will engage all sites in a planning process to explore emerging areas of nanoscale science, engineering, and technology that can lead to future growth of the external user base."
- The CO "will coordinate the acquisition needs for specialized instrumentation across all sites to enhance new areas of research growth."
- "The Office will also coordinate data management across all sites"
- The CO will coordinate "the dissemination of shared knowledge to research, education, and technology communities"
- The CO will enhance "connections with other nationally funded academic centers or networks and facilities supported by government, the private sector, and international partners."

To achieve these goals, the three Associate Directors of the Coordinating Office will continue to coordinate activities in Education & Outreach, Societal and Ethical Implications, and Computation across the network. Moreover, the Coordinating Office will continue its support of the Subcommittees and Working Groups, as well the NNCI website development and the NNCI

Annual Conference. In prioritizing its programs in view of the limited resources, the Coordinating Office considers recommendations from the NSF, the NNCI Advisory Board, the NNCI Executive Committee, as well as the NNCI Subcommittees and Working Groups. However, the Coordinating Office cannot do it alone and certainly needs the support of all sites, their leadership and staff to be successful.

A number of specific activities planned for Year 3 are highlighted below:

- *NNCI Website*: Highlights of the NNCI website development include public/private pages for working groups, new content on nanoscale applications, and updates to the current tools and experts databases. More details are contained in Section 7.2 above.
- *NNCI Annual Conference:* The 3rd NNCI Annual Conference will be hosted by NNI and will be held at the University of Washington in Seattle September 13-14, 2018. The program will be adjusted slightly based on feedback from the Advisory Board and the survey conducted at the 2nd NNCI Annual Conference.
- *REU Convocation*: The 2nd annual REU Convocation will take place at the RTNN site August 5-8, 2018.
- *Subcommittees and Working Groups*: The Coordinating Office will continue to emphasize the importance of the subcommittees and working groups to coordinate network activities and develop/share best practices. Subcommittees and working groups will be encouraged to report outcomes of their work, including recommendations and particular programs, via the NNCI webpage, at conference calls with the NNCI Executive Committee, and at the NNCI Annual Conference. Formation of additional working groups will be encouraged and supported.
- *NNCI Staff Awards:* The Coordinating Office plans to initiate NNCI-wide staff awards to promote staff and recognize excellence in areas of user support, technical activity, and education and outreach.
- *Workshops*: The Coordinating Office will continue incentivizing sites to collaborate via symposia and workshops. A budget has been established to financially support workshops that involve and benefit multiple NNCI sites.
- *Marketing:* The Coordinating Office, with assistance from all of the NNCI sites, will continue to market the NNCI at conferences and trade shows and through printed and electronic collateral. Moreover, marketing efforts targeting specific groups, such as start-up companies receiving SBIR/STTR funding (as suggested in Section 5), will be coordinated across the network. A new NNCI promotional video, begun in late 2017, will be ready for distribution in 2018.
- *User Survey:* The Coordinating Office will refine the user satisfaction survey and will administer this survey in September/October 2018.
- *Data Collection and Reporting:* The Coordinating Office will continue to collect statistical data on network usage and report these data to the NSF as part of the annual reporting.
- *NNCI Emerging Areas:* The Coordinating Office will work with the NNCI sites and appropriate subcommittees to identify emerging areas of nanoscale science, engineering,

and technology that could further grow the user base and will identify acquisition needs for specialized instrumentation needed to support these emerging areas.

- *NNCI Connections:* The Coordinating Office will work with NNCI sites and the Regional and Global and Regional Interactions Subcommittee to connect with other nationally-funded academic centers or networks and facilities supported by government, the private sector, and international partners.