



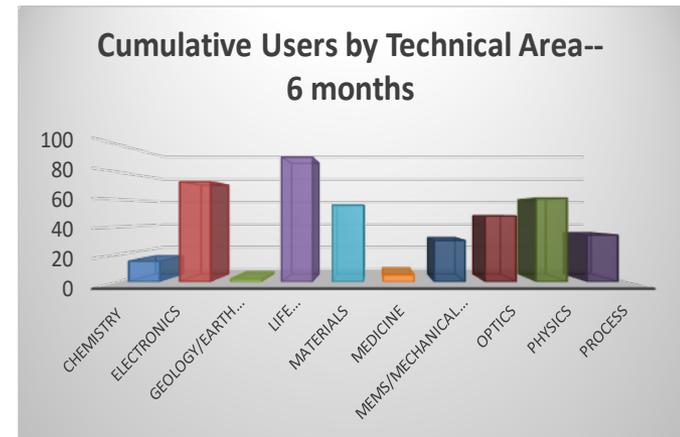
The Cornell NanoScale Facility

Chris Ober, Lester B. Knight Director
Don Tennant, Director of Operations
Lynn Rathbun, Laboratory Manager



CNF Highlights

- 2018 is CNF's 41st Year as an NSF funded User Facility
- Used 40th Anniversary Meeting/Workshop to form Strategic Vision
- 27 (24 FTE) scientific, technical, admin staff
- NBTC merged into CNF – added to biotech strength
- 54% Non-traditional users; 40% external users



CNF User Geography

(under NNCI)



Academics can stay in CNF apartment located within 10 minute walk to facility (\$40/night)

Key Strengths & Differentiation

- Advanced lithography tools (E-beam and DUV) and modeling (Prolith)
- In-House mask making
- Fluidics-> Life Sciences; NanoAg
- Silicon photonics
- Magnetic materials
- MEMS
- 2-D materials
- Proximity to CCMR, PARADIM, CHESS
- >500 years of staff tech experience
- Success commercializing research
- *Other resources (e.g. advanced microscopy) via other Cornell Centers (not counted as our users even if we refer them)*



Foundry Partners to Facilitate Commercialization

- To assist in successful transfer of technology, CNF has undertaken “tool mapping” exercise to relate CNF equipment to available equipment/processes at selected foundry partners. This helps assure that process sequences developed at CNF can be more easily ported to the selected foundry.

- Foundry Partners

- Novati (TX, NC)
 - inactive: sold to Skorpios Technology
- STC (NY)
 - inactive: sold to Akoustis
- Fraunhofer (Dresden, German) (NEW)
 - 200 mm MEMS
 - 300 mm CMOS
- Discussions with SUNY Poly

Additional Key Partnerships:

JEOL - e-beam lithography
GenISys - CAD
Oxford Instruments - Plasma Processing & ALD
SÜSS - Alta Spray, SCIL
PARADIM - NSF funded materials innovation platform, a materials user facility

CNF User Data

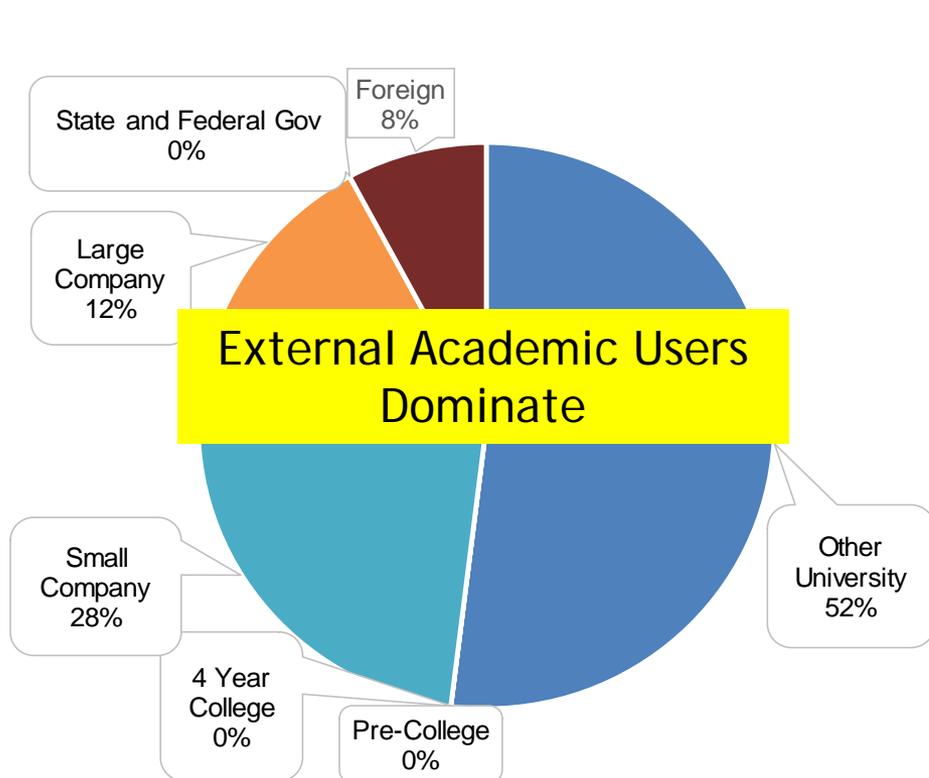
Yearly User Data Comparison			
	Year 1	Year 2	Year 3 (6 months)
Total Users	544	538	408
Internal Users	325	330	281
External Users	219 (40%)	208(39%)	127 (31%)
External Academic			66
External Industry			41
External Government			0
External Foreign			10
Total Hours			25,986
Internal Hours			14,941
External Hours			11,045(42%)
Average Monthly Users			223
Average Ext. Monthly Users	67 (32%)	66 (32%)	68 (30%)
New Users Trained	131	161	85
New External Users Trained	46 (35%)	51(31%)	26 (29%)

**Hours increased 12%
Year 1 to Year 2 -
trend continues**

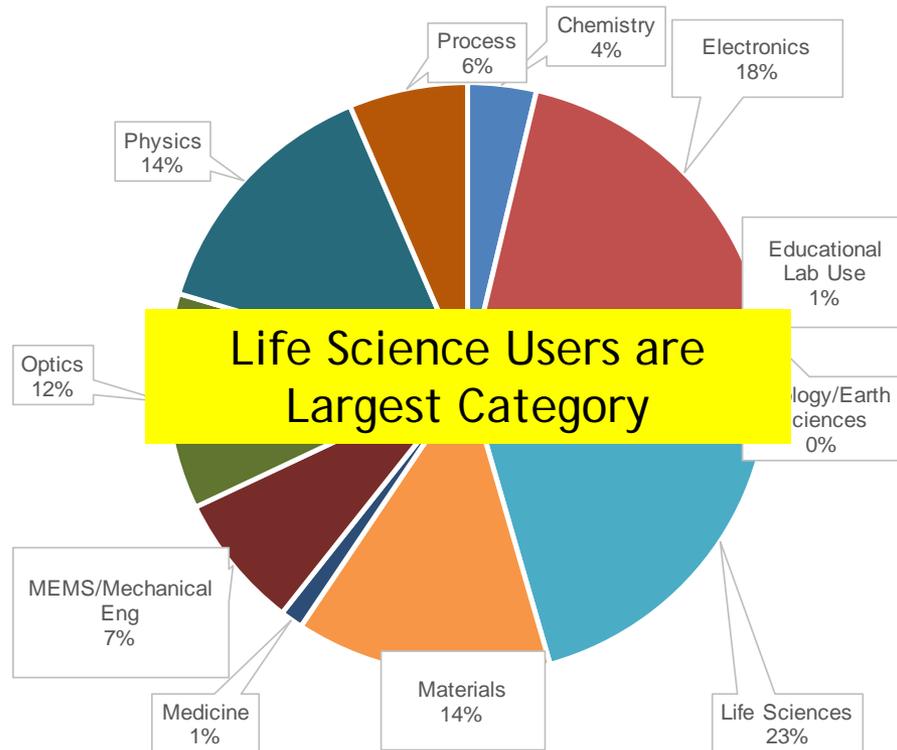
40% External Users

CNF User Data

External User Affiliations



All User Disciplines



CNF Equipment Resources and New Equipment

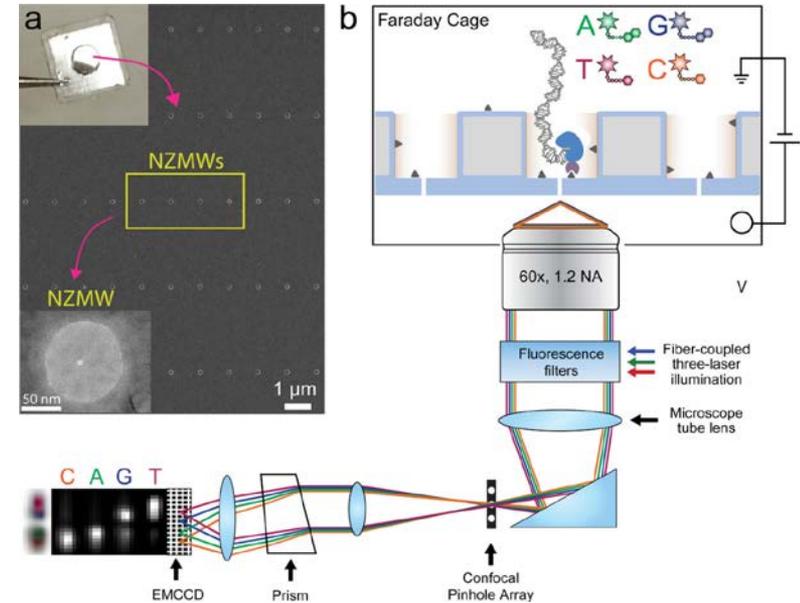
Equipment Highlights (> 120 major tools)

- **VERY NEW:** OEM AIN deposition system & XRD
- Equipment from NBTC:
 - Malvern Nano ZS Zetasizer particle size and zeta potential measurement- uses dynamic light scattering
 - Malvern NS300 NanoSight tracks diffusion of individual particles
 - Accurion EP3 Nanofilm Ellipsometer
 - Olympus IX-71 Inverted Fluorescence Microscope
 - Balzers Critical Point Dryer , Samco UV Ozone Tool , Rame-Hart 500 Contact Angle Goniometer
 - Viscometer, Labcoater Parylene Coater
 - Dektak 6M Contact Profilometer
 - CHA Mark-50 E-beam Evaporator
- Two state-of the-art electron-beam lithography systems
- ASML DUV stepper, i-line, g-line, contact and proximity photolithography
- In-house mask making capabilities
- 5 hot-process banks (20 tubes) for growth and deposition
- Comprehensive set of etching tools (~16) including DSE, ICP etchers
- Plasma enhanced deposition & graphene/CNT



User Research: Length-independent DNA packing into nanopore zero-mode waveguides

In Nature Nanotechnology, Wanunu and his group (Northeastern) and scientists from Pacific BioSciences use the Cornell Nanoscale Facility to show that the efficiency of voltage-induced DNA loading into waveguides equipped with nanopores at their floors is five orders of magnitude greater than existing methods. Compared to conventional methods, single molecule, real-time (SMRT) DNA sequencing exhibits longer read lengths than conventional methods, less GC per cent bias, and the ability to read DNA base modifications. However, reading DNA sequence from sub-ng quantities is impractical due to inefficient delivery of DNA molecules into the confines of zero-mode waveguides, zeptolitre optical cavities in which DNA sequencing proceeds. In addition, they find that DNA loading is nearly length-independent, unlike diffusive loading, which is biased towards shorter fragments. The authors demonstrate here loading and proof-of-principle four-colour sequence readout of a polymerase-bound 20,000 bp long DNA template within seconds from a sub-ng input quantity, a step towards low-input DNA sequencing and mammalian epigenomic mapping of native DNA samples. We should note that Pacific Biosciences was a CNF startup that is now a \$500,000,000 company.

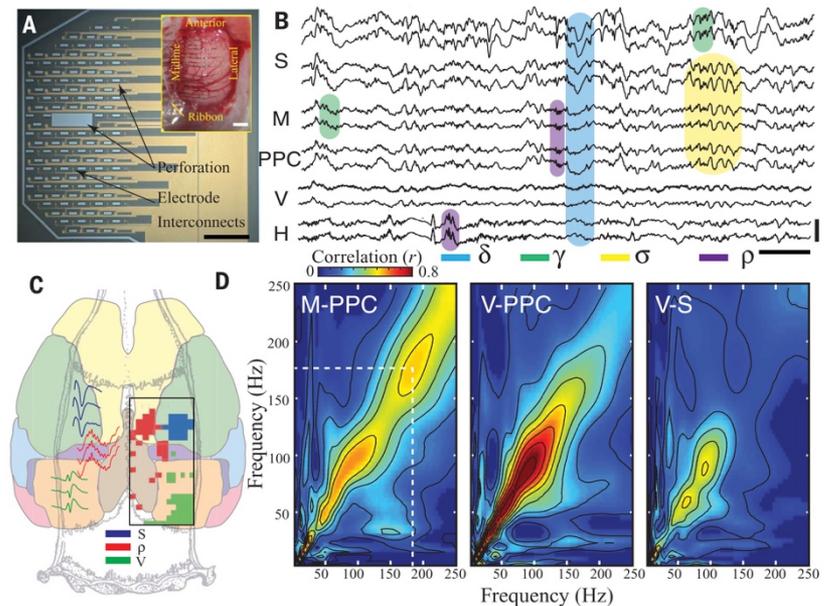


Nat Nanotechnol. 2017 December ; 12(12): 1169-1175.

Support: NIH (HG006873 and HG009186), NNCI ECCS-1542081.

User Research: Learning-enhanced coupling between ripple oscillations in the brain

In **Science**, Khodagholy et al. (NYU) and colleagues at Columbia used the Cornell Nanoscale Facility to produce a conducting polymer-based conformable microelectrode array (NeuroGrid) and used it to record local field potentials and neural spiking across the dorsal cortical surface of the rat brain, and combined with silicon probe recordings in the hippocampus, to identify candidate physiological patterns. Consolidation of declarative memories requires hippocampal-neocortical communication. Although experimental evidence supports the role of sharp-wave ripples in transferring hippocampal information to the neocortex, the exact cortical destinations and the physiological mechanisms of such transfer are not known. Parietal, midline, and prefrontal, but not primary cortical areas, displayed localized ripple (100 to 150 hertz) oscillations during sleep, concurrent with hippocampal ripples. Coupling between hippocampal and neocortical ripples was strengthened during sleep following learning. These findings suggest that ripple-ripple coupling supports hippocampal-association cortical transfer of memory traces.



Khodagholy et al., *Science* 358, 369–372 (2017)

Support: NIH grants UO1NS099705, U01NS090583, and MH107396 and DARPA N66001-17-C-4002. (NNCI grant ECCS-1542081).

User Research : Measuring and Manipulating the Adhesion of Graphene

In *Nanoletters*, McEuen and colleagues at Cornell and Northwestern used the Cornell Nanoscale Facility to characterize the delamination of single-layer graphene from monolayers of pyrene tethered to glass in water and maximize the work of separation between these surfaces by varying the density of pyrene groups in the monolayer. They present a technique to precisely measure the surface energies between two-dimensional materials and substrates that is simple to implement and allows exploration of spatial and chemical control of adhesion at the nanoscale. Control of this energy scale enables high-fidelity graphene-transfer protocols that can resist failure under sonication. Additionally, they find that the work required for graphene peeling and readhesion exhibits a dramatic rate-independent hysteresis, differing by a factor of 100. This work establishes a rational means to control the adhesion of 2D materials and enables a systematic approach to engineer stimuli-responsive adhesives and mechanical technologies at the nanoscale.

Nano Lett. 2018, 18, 449–454

Support: CCMR NSF DMR-1719875)
and the Kavli Institute at Cornell.
NNCI Grant ECCS-1542081.



CNF Impact (CY 2017)

- Total 450 PPPs (underreported) for 2017
 - 201 Publications (25% High impact journals)
 - 136 Conference Papers
 - 113 Patent (Disclosures, Applications, Issued)
- 30 small companies, 10 large Companies
- Leverage estimated \$40M in grant funding per year
- 6 StartUps in first 3 Years (Xallent, Esper Biosciences, FloraPulse, Ultramend, Jan BioTech, Heat Inverse)



Diversity – Pervades all we do

- NNCI Diversity sub-committee
- A key part of REU program since inception
- Recruiting diverse student and faculty body to Cornell and to nanoscience
- Work closely with Cornell Diversity Programs in Engineering
 - Reaching out to HBCU schools for cooperation (Morgan State)
 - Outreach to schools – inner city
 - Participation in engineering diversity open house
 - Support to send students to NSBE and SHPE
 - LSAMP program activities with DPE
- **Nellie Whetten Award** – given to outstanding young women whose research was conducted in CNF, and whose lives exemplify Nellie's commitment to scientific excellence, interdisciplinary collaboration, professional and personal courtesy and exuberance for life (since 1989)



External Advisory Board



Chuck Black, BNL
(Chair)



Stefano
Cabrini, LBL



Michael
Spencer,
Morgan State



Steve Turner
Pacific
Biosciences



Alice White,
Boston
University

The Board “recognizes the important role CNF has played in advancing science during its 40-year history”; “CNF has built a reputation that provides it credibility to take a leadership role in defining new directions”

- Define and articulate a vision for CNF’s next 20 years
 - Engage community in planning workshop and develop strategic plan
- Evolve user community
 - Explore partnerships with SUNY Poly and IBM
 - Build CNF User Alumni Community
 - Reach out to new industrial and academic users

Impact of Education & Outreach Activities

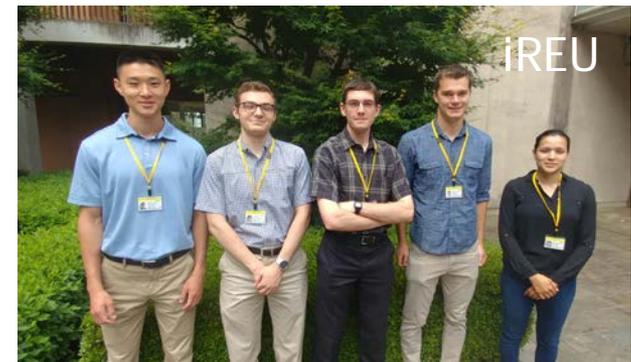
Major CNF Activities	# Participants (annual)
Nanooze	>100,000
Nanooze Disney	>250,000
CNF Research Accomplishments	1000
Nanometer	2000
4H	100
REU	5
IREU	6
Annual Meeting/Symposium	300
K12 other	2000
TCN Short course	40
Total CNF	>350,000

• Assessments

- Nanooze
- TCN Short Course
- REU
- REU Longitudinal
- iREU

• Case Study: Nanooze Assessment

- Sent to all subscribers (> 1100), 137 respondents
- Most survey respondents were teachers (92%)
- Distribution is geographically diverse
- Used mostly for formal lessons (94%)
- 123 Teachers shared Nanooze with up to 11,000 others (large multiplier)
- Readers spanned K-12 but largest group (43%) were middle schoolers
- Many age groups reported to learn about careers in Nano (66% showed increased awareness, asked to learn more)
- Nanooze also used as fun way to improve reading and literacy
- Nanooze content was retained and used in other lessons



Nanooze: Website, in Print and at DisneyWorld

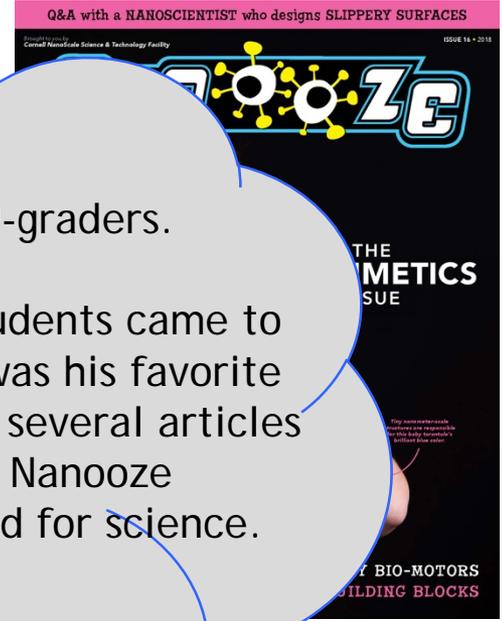
- Science magazine for kids
- New print issue each year
- 15 back issues in circulation
- >1.15M copies in print
 - ~100,000 copies/ issue
 - Distributed to classroom
 - Large array of “second”
- Editorial, design, and
- Could expand with
- Impact Survey Con
- “Take a Nanooze B

www.nanooze.org

Years ago, I shared Nanooze with my 5th-graders.

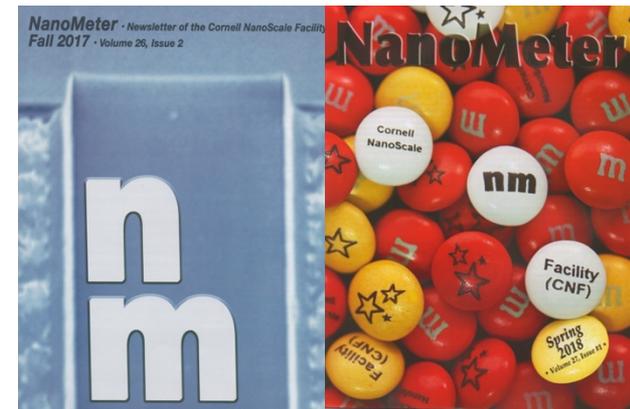
As a junior in high school, one of my students came to see me. He said that reading Nanooze was his favorite thing that we had done. He mentioned several articles that we had read. He said that reading Nanooze helped re-awaken his love for school and for science.

He hoped that I still use the magazine (which I do) because it was the best part of his entire 5th grade.



Outreach & Workforce Training

- CNF Fellows and Ambassadors
- Technology and Characterization at the NanoScale Short Course
 - June 2017
 - January 2018.
- NNCI Intra-network Plasma Processing Web Workshop (Dec 2017)
- Two Photon 3D Printing Workshop for users & staff
- Annual Symposium and User Meeting held in September 2017 + Planning Workshop
- REU program – 5 interns, 10 weeks; mini convocation held jointly with PARADIM interns; NNCI convocation
- Recently printed and distributed 2 “Nanometer” Newsletters, Promotional Brochures



NNCI Cooperative Network Activities

Network Wide

- NNCI Annual Conference; volunteered to host 2019 conference
- Purchase and service synergy
- Sent Staff and 5 REUs to the REU Convocation
- Participated in NanoDays events on Cornell Campus; Ithaca Sciencenter; Mascot Run
- Working group participation (16 staff members in 9 different groups)
 - REU Working Group - Chaired by Rathbun (CNF); Mallison (CNF)
 - Reactive Ion Etching/Plasma Processing Working Group - Chaired by Genova (CNF);
 - ALD Working Group – Chaired by Genova
 - E-beam Lithography Working Group –Bleier (CNF); Banerjee
- Sub-committee participation
 - Global and Regional Interactions (GRI) Subcommittee
 - CNF organizes NNCI international student activities
 - Ober and Tennant visiting NYS university to communicate capabilities of NNCI
 - Diversity Subcommittee
 - Sharing best practices
 - Report presented during NNCI monthly Directors call



Multi-Site

- Conference Exhibit Booths at MRS, AVS, EIPBN, CLEO
- Exhibit at the USA Science and Engineering Festival in Wash DC
- Initiated ALD and SEM analysis software workshops and took part in those from other sites
- Planning Nano Day for Congress – more info at this meeting

On Behalf of Network

- Nanooze Disney Exhibit
- Nanooze Magazine
- Nanooze Impact Study

Workshop Discussion: The Future of Nanoscience

- CNF Planning workshop held fall 2017
- Discussion Groups: 1) Future of NanoScience; 2) Engaging Bioscientists; 3) Future tools and Technologies
 - Democratization of information – how do we handle and use massive amounts of data
 - Communication everywhere - sensors and signal transduction
 - Autonomous transportation
 - Digital Ag
 - Biomolecular technology and tissue engineering - C is the new Si
 - Biology and soft matter integrated with hard electronics
 - Neurotech
 - Neuromorphic computing, AI and quantum computing
 - 3D vs 2D
 - Cheaper and not as small