KY Multi-scale Manufacturing and Nano Integration Node (MMNIN)

NNCI Annual Conference
Seattle, WA
Sept, 2018

National Nanotechnology Coordinated Infrastructure

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

Visiting from our Site

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NSF

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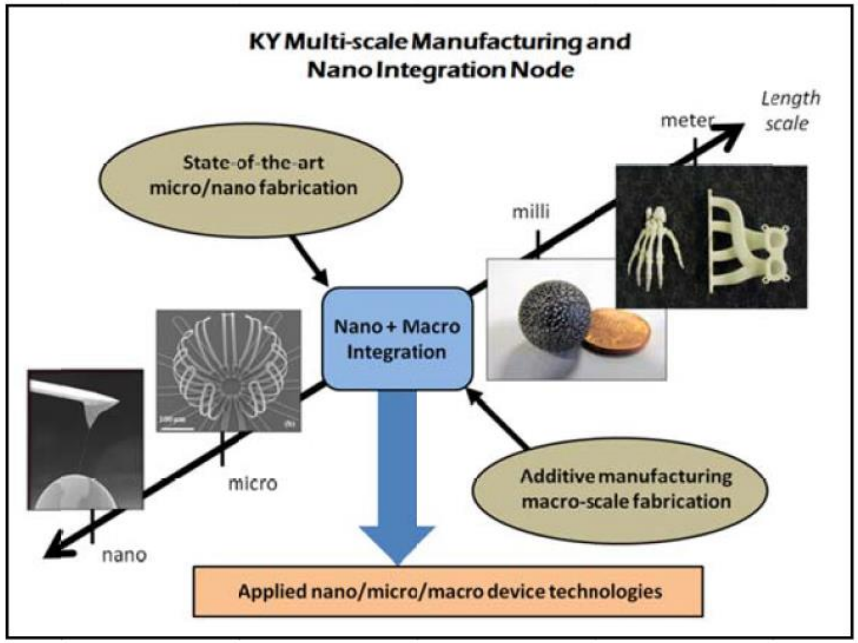
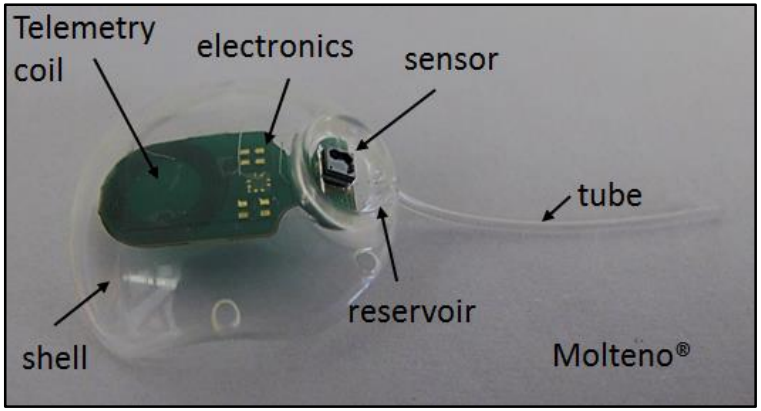
Overview

KY MULTISCALE is a collaboration between the UofL and UK which provides users the unique ability to perform research and build prototypes over various lengthscales and in a variety of materials.

We offer core facilities and expertise for traditional microfabrication, MEMS technology, nanotechnology, imagining/characterization, as well as 20 years of experience in various types of 3D printing technologies (metals, polymers, bio).





Smart ocular shunt prototype

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User Data

Yearly User Data Comparison			
	Year 1	**Year 2**	**Year 3 (6 months)**
Total Users (distinct/cumulative)	278	420	277
Internal Users	206	315	216
External Users	72 (25%)	85 (20%)	61 (22%)
External Academic	8	16	8
External Industry	63	80	53
External Government	1	5	0
External Foreign	0	4	0
Total Hours	14,629	17,150	9,200
Internal Hours	9,726	12,166	5,583
External Hours	4,903 (34%)	4,986 (29%)	3,617 (39%)
Average Monthly Users	104	141	128
Average Ext. Monthly Users	22 (21%)	25 (18%)	25 (18%)
New Users Trained	111	251	80
New External Users Trained	26 (23%)	43 (17%)	14 (18%)

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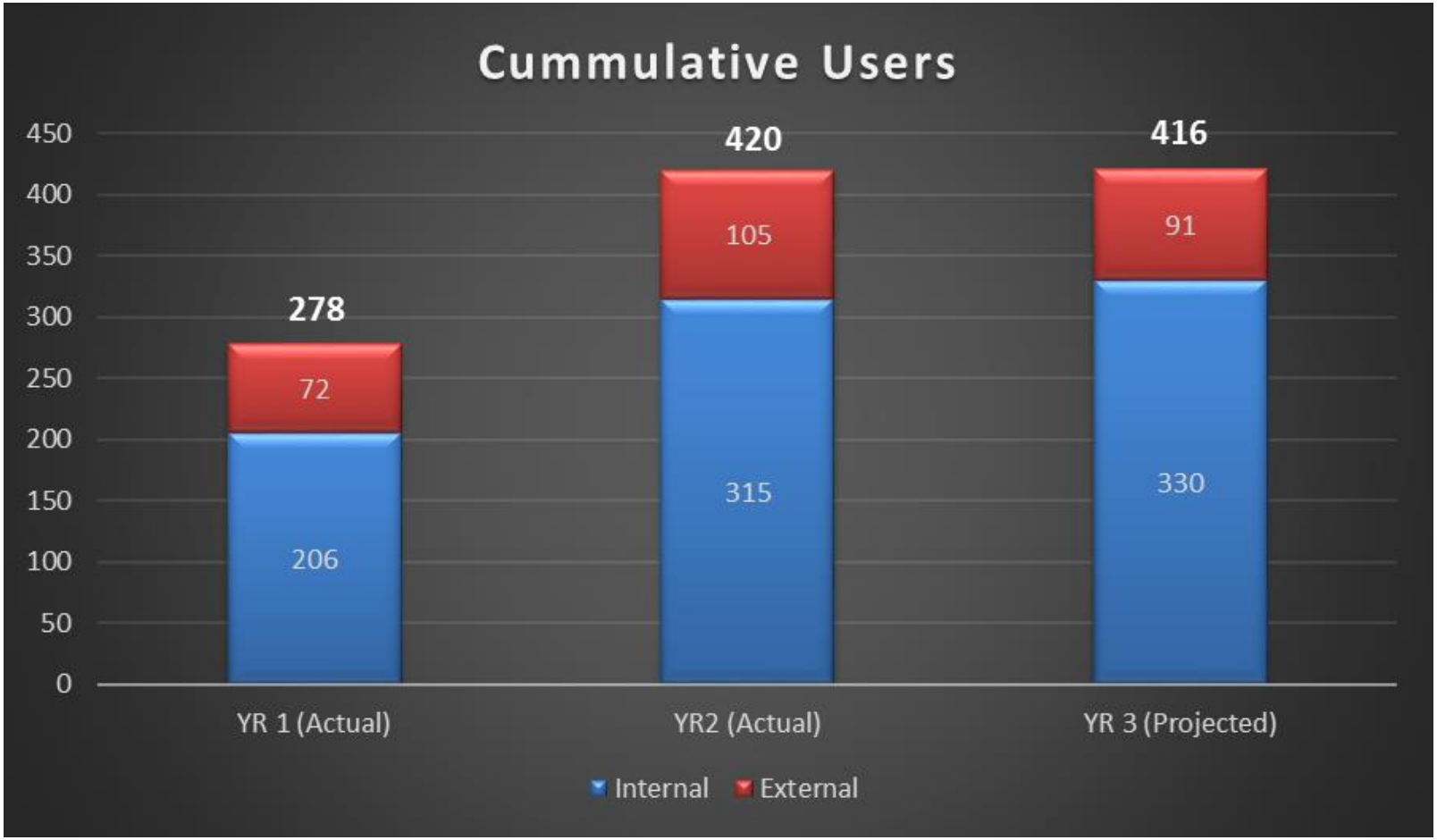
User Data

Total Cumulative (distinct) Users



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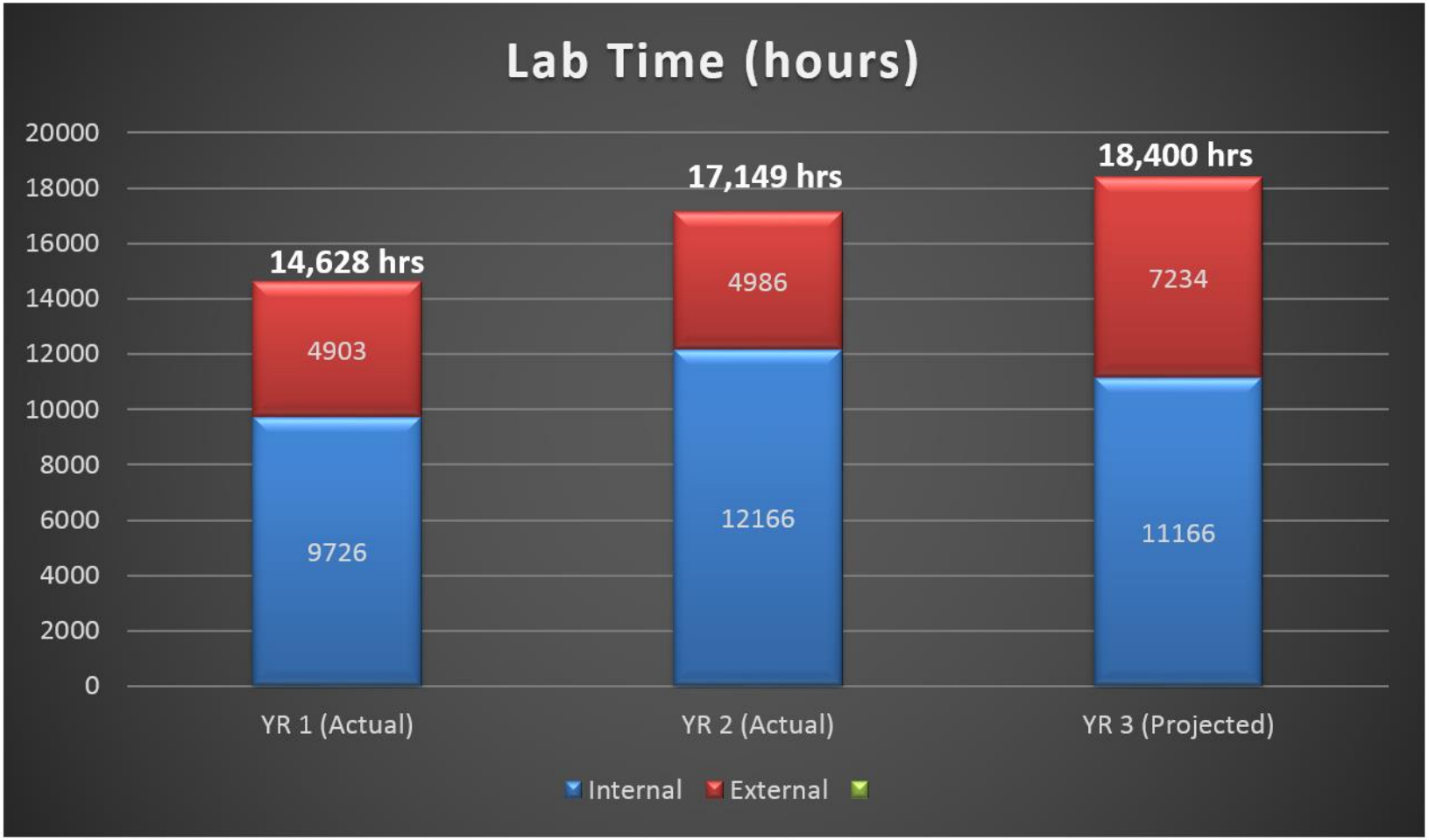
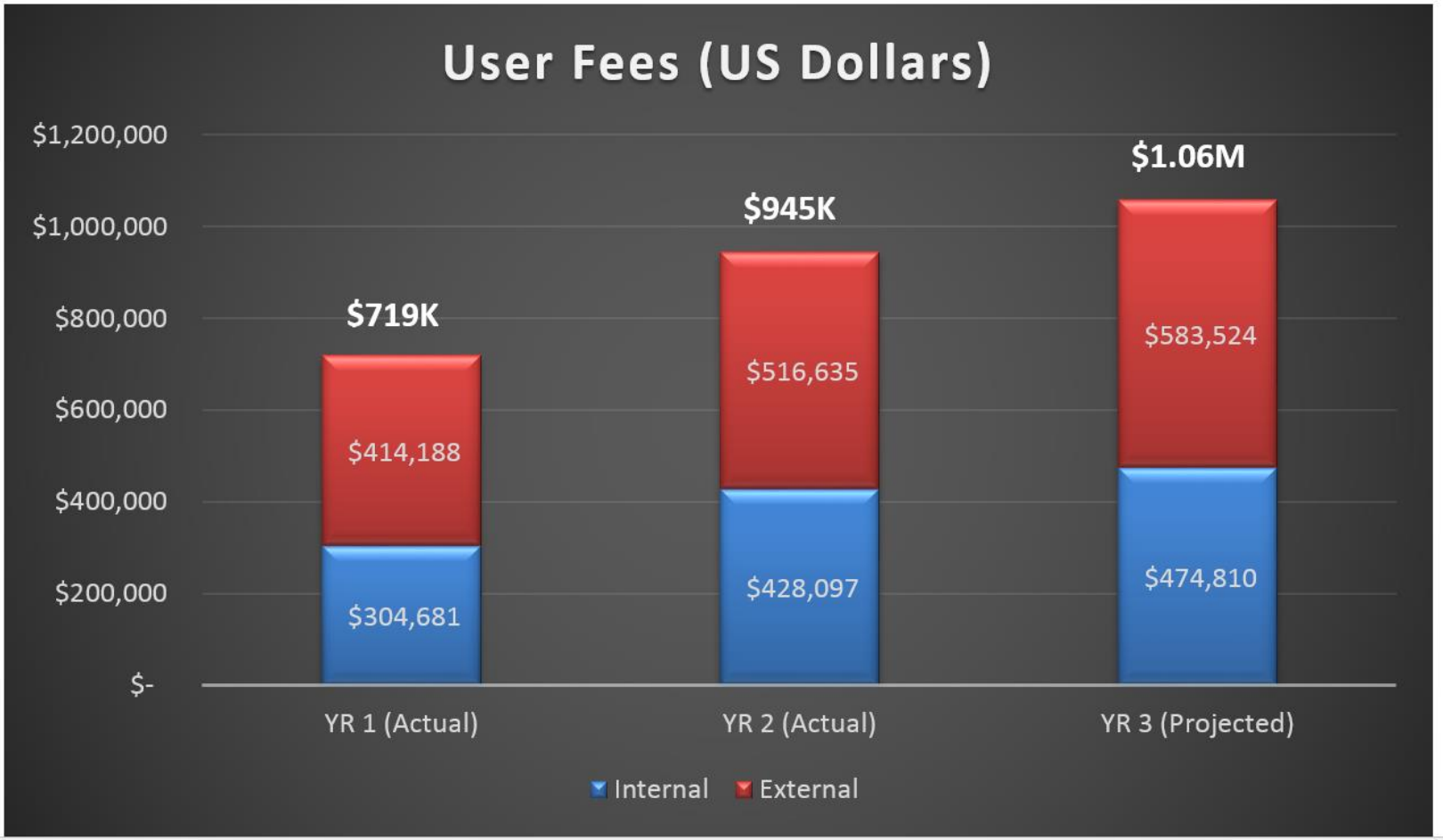
User Data

Lab Time



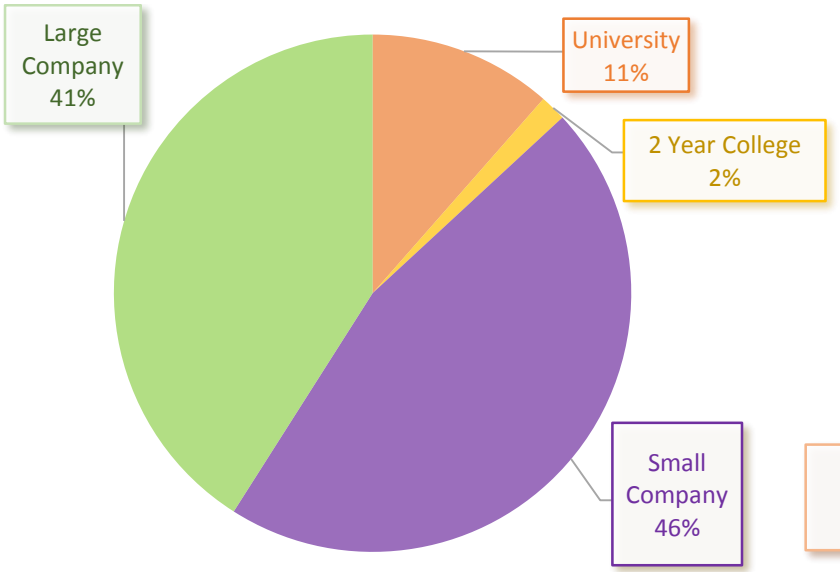
User Data

User Fees Collected

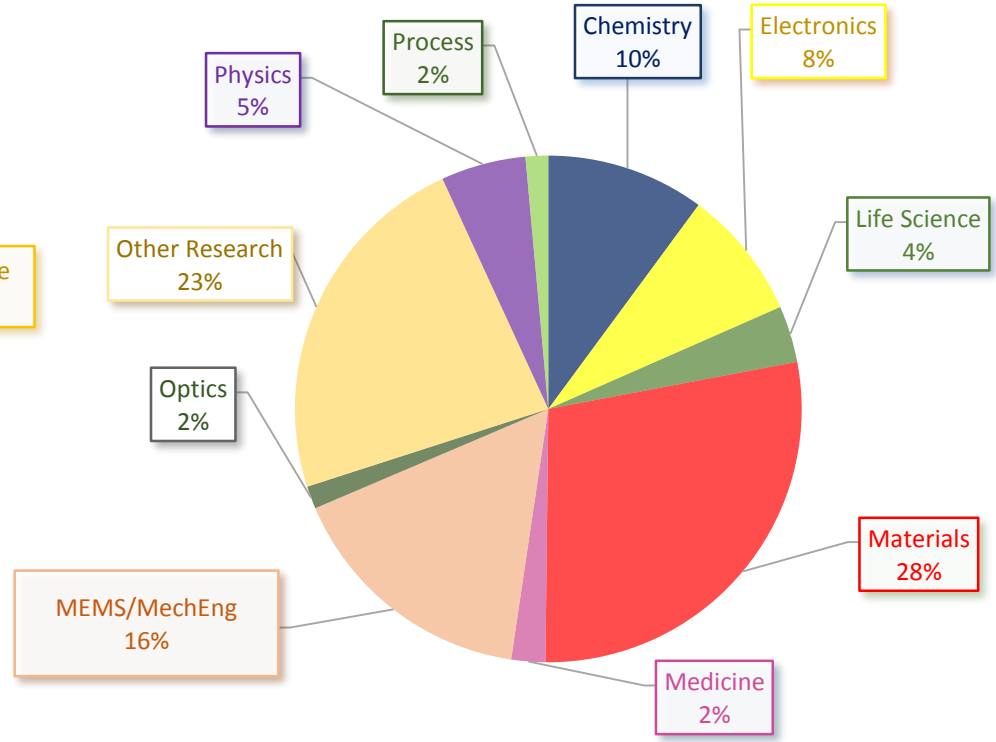


User Data (First 6 Months of YR 3)

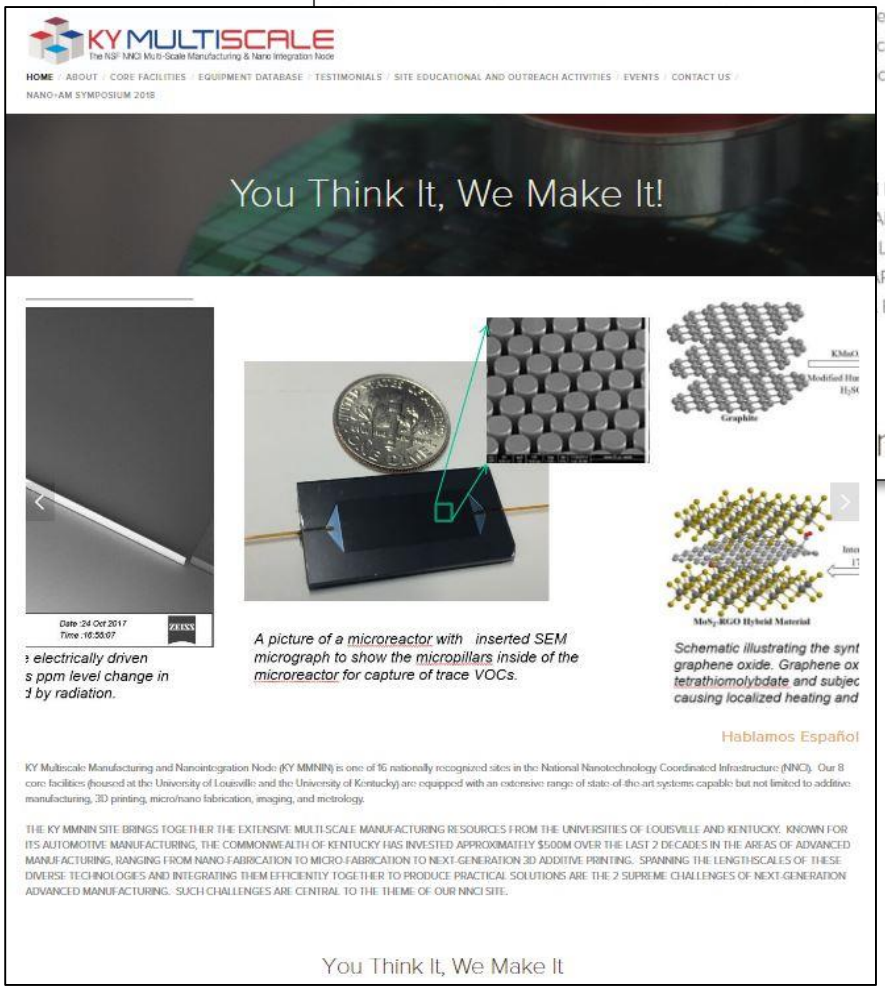
External User Affiliations



All User Disciplines



Facility Upgrades – Website Improvements



- **Updated and expanded content**
- **Added a Spanish version**

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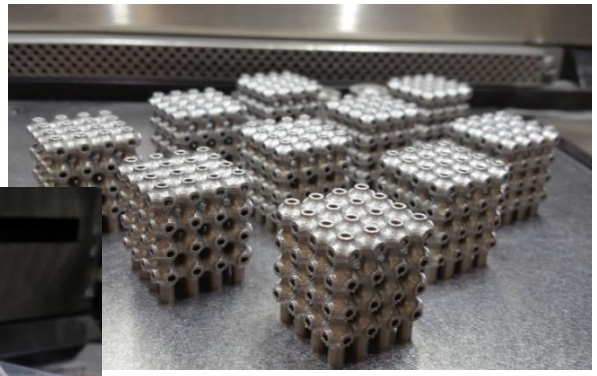
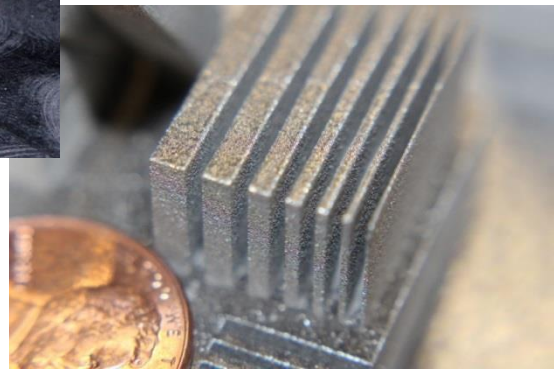
Facility Upgrades – AM Expansion





- New Additive Manufacturing Competency Center (AMCC)
- 10,000 sq. ft. core facility managed by Ed Tackett formerly from UC Irvine
- Focused on training and research in 3D printing of functional metals
- **Submitting $7.5M 5 Yr Center Proposal to NSF ATE Program on Oct 15**

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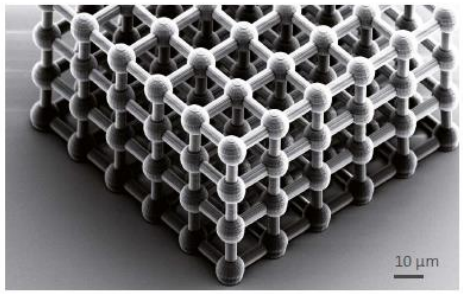
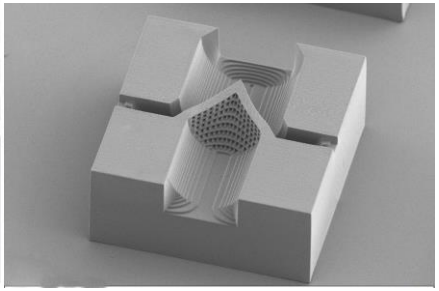
New Tools - Nanoscribe Photonics Professional GT

Two photon lithography →

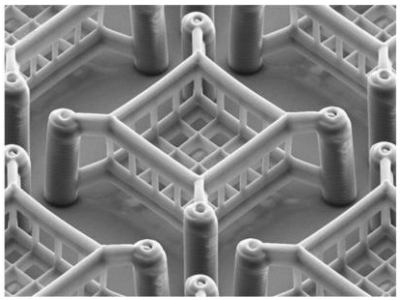
- 3D printing with < 200 nm features
- Convert to functional materials using ALD, CVD, electro– and electroless deposition, or melt infiltration
- Bridges nm-scale electron- and ion- beam induced processes to 10 micron scale aerosol jet printing



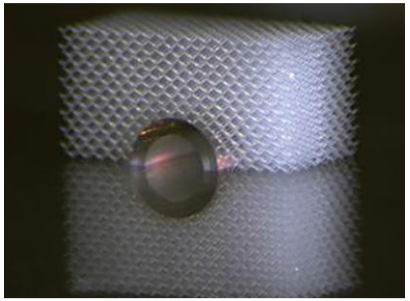
Photonics



Microfluidics



Cell scaffolds



Mechanical metamaterials

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New Tools – Vapor HF System and Nexus Instrument

SPTS Vapor HF System

Excited User with the new Vapor HF System

Robotic Flexible Multi-scale Manufacturing System

R1 – 4DOF 10 micron precision industrial SCARA robot for process tool positioning
R2 – 6 DOF 20 micron precision industrial Robot for coarse part transport
R6–Custom MEMS fixtures for microparts (microfabricated).
R3 – 6-DOF sub micron precision positioning tools for microassembly.
R5 – Rotary Indexing Table
Other components (not shown)
1) Quick change tool racks for:
- Process stations (laser cutter, adhesive dispensing, 3D printer …)
- Modular microgrippers, probers, stages
2) Testing and metrology tools:
- Pull tester, mini environmental enclosures.
3) Additive manufacturing process stations
- Fiber loom, ultrasonic printer, IPL

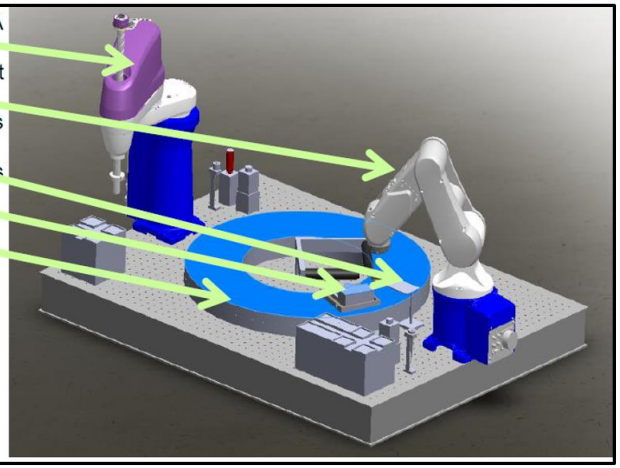

Figure 6. Cartoon of the proposed configuration for the Nexus multi-robot instrument.

$1.5M NSF MRI by Dan Popa funded last month

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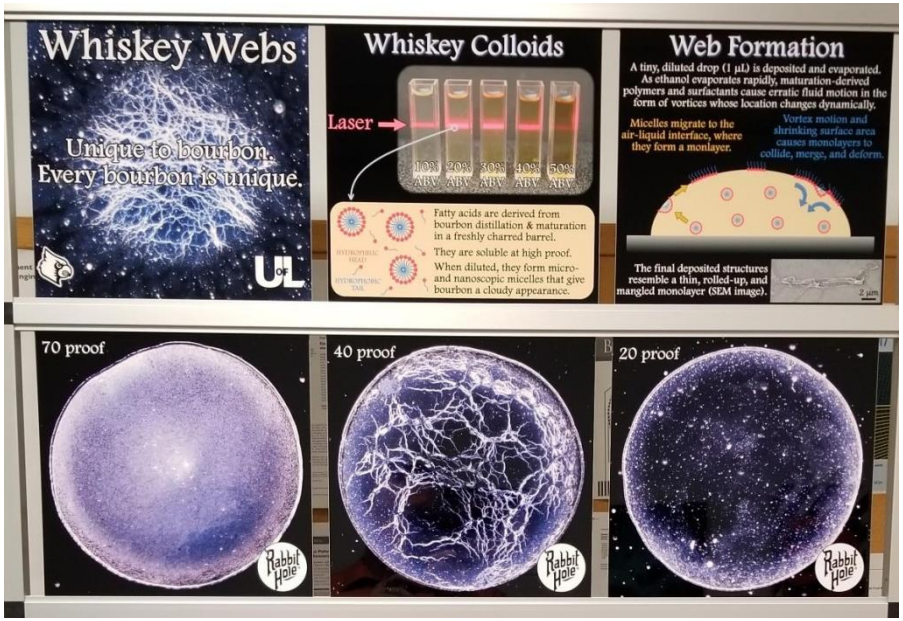
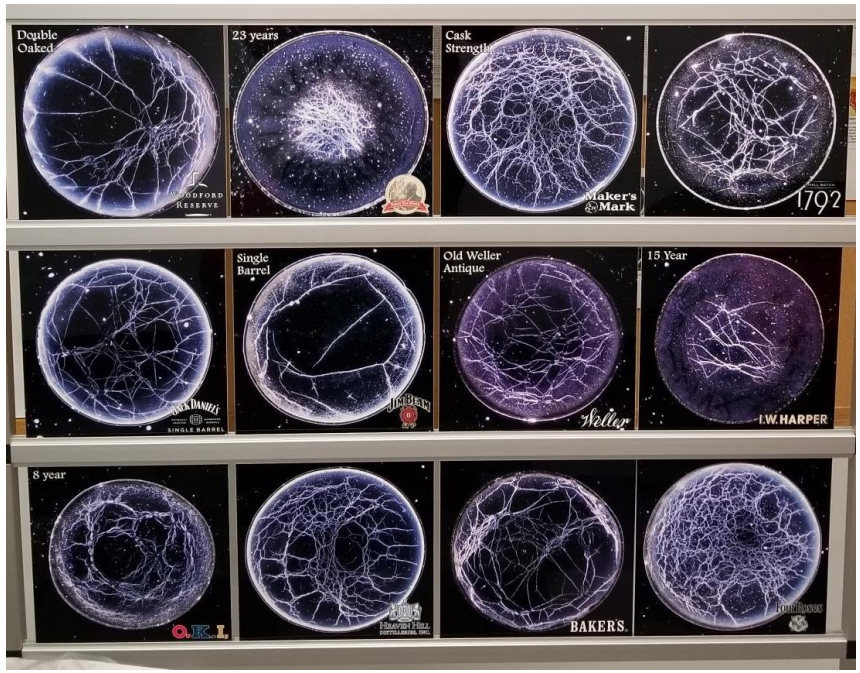
Research Highlights

“Whiskey Webs”





Prof. Stuart Williams
Mechanical Engineering

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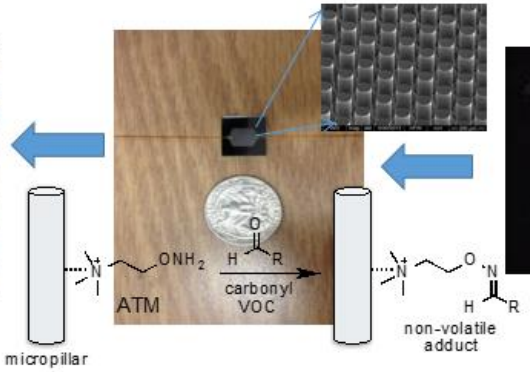
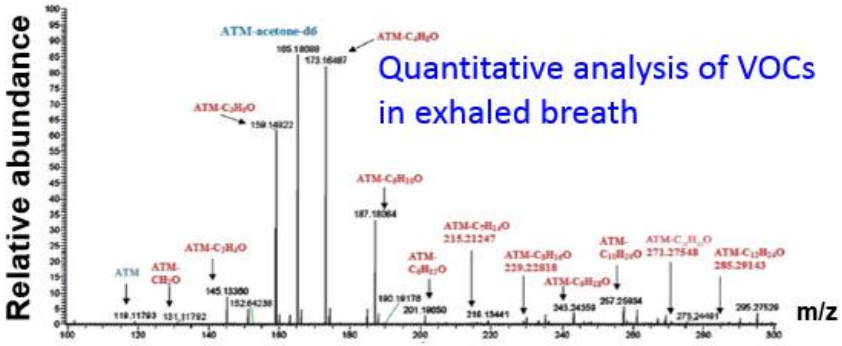
Research Highlights

Microreactor Chip for Breath Analysis to Detect Early Stage Lung Cancer

Prof. Xiao-An (Sean) Fu
Chemical Engineering





- Startup company - Breath Diagnostics Inc
- Chemistry and ChE collaboration
- Cancer detection using breath analysis
- SBIR Phase 1 and Angel Investors
- Used 3 core facilities for MEMS chip fabrication and assembly

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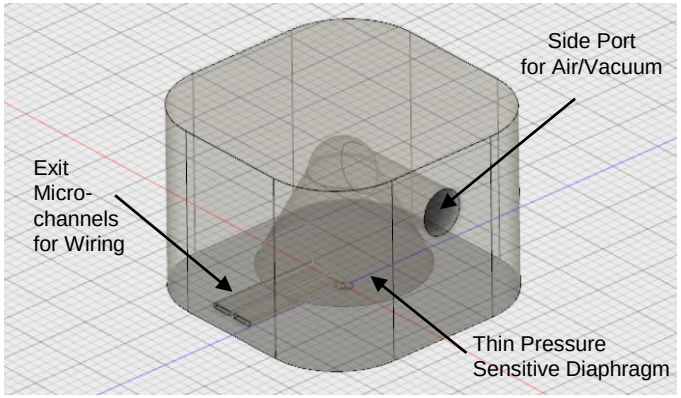
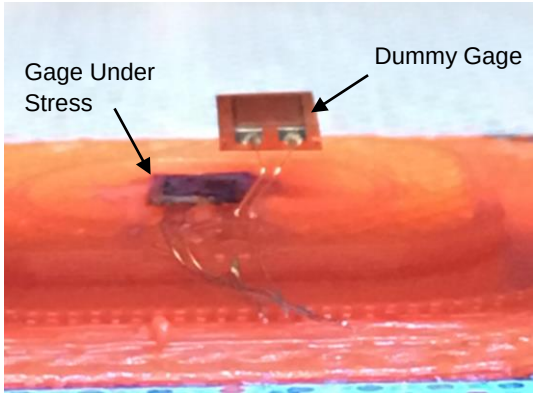
Research Highlights

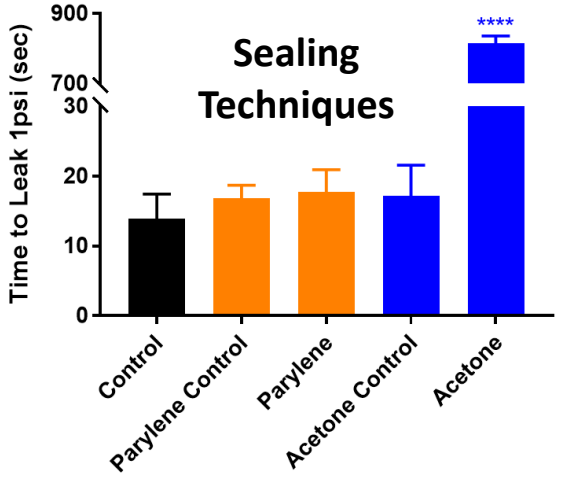
Embedded Strain Gauge within an FDM-Printed Pressure Sensor

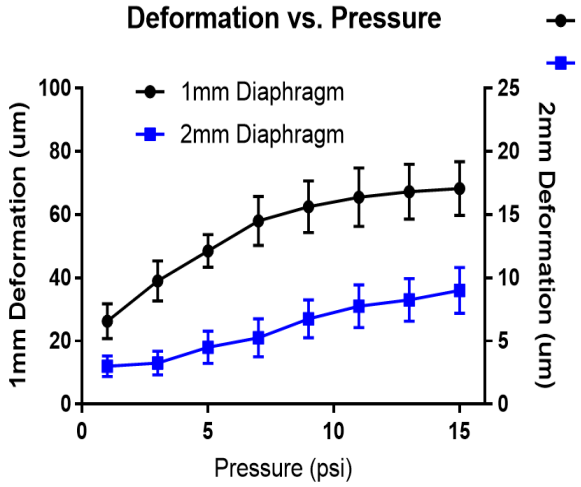
Garrett McGrady and Neel Jain

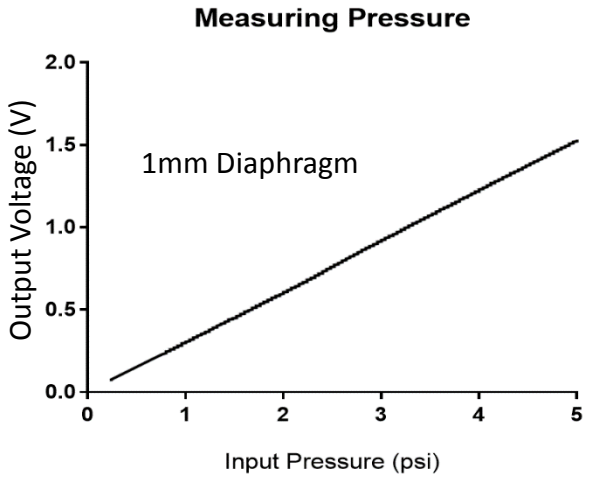
Skepticism surrounds fused-deposition modeling as a method for non-static prototyping due to the perceived structural inhomogeneity of printed ABS. Our exploitation of the elastic properties of ABS has shown that FDM printing can be used to create individually calibrated pressure sensors, which yield repeatable results with minimal elastic hysteresis, air leakage, and no delamination of diaphragm layers.











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Publications

CY2017	TOTAL
Journal Publications	163
Conference Proceedings/Presentations	37
Books and Book Chapters	0
Awarded Patents	8
Patent Applications (i.e. Provisional Patents)	15
Patent Disclosures	29

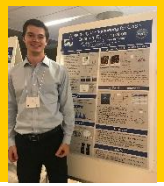
	CY2015	CY2016	CY2017
Journal Publications	**116**	**139**	**163**
Conference Proceedings/Presentations	27	99	37
Awarded Patents	4	2	8

Impact of Education & Outreach Activities

KY MMNIN 2017-2018 Education & Outreach Events		
Event	**#s**	**%**
KY NANO + AM Symposium	140	3%
UofL IMPACT REU Program	9	<1%
UK REU Program	14	<1%
Youth Science Summit	35	1%
National Nanotechnology Day	1000	23%
MNTC Eng Expo	100	2%
UK's Engineering Day	3000	69%
CCRER Summer Camps	30	1%
AM Workshop	34	1%
Public Science Interest Groups Presentations	50	1%
Visiting Faculty and Students from China University of Mining and Technology	9	<1%
UK's Women in Engineering Workshop	40	1%
TOTAL	**4461**	100%

KY Nano + 3D Symposium Survey Responses

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
There is a need for an annual symposium targeting researchers and industry members.	**17**	12	2		
2 days is an appropriate length for this conference	12	**15**	4		
The conference talks and presentations were of high quality and informative	11	**18**	3		
The symposium was well organized	**20**	11	1		
I am likely to attend or recommend a colleague to attend in the future	14	14	2	1	



How did the IMPACT REU…
(Q1) …improve students' learning of micro/nanotechnology research skills and content?
(Q2) …improve students' learning how to prepare and professionally communicate research?
(Q3) …stimulate students' career goals and interests?

Category Topic (Between 6-13 questions per category)	Sample Question (5-point scale)	Overall Mean
Gains in thinking & working like a scientist	Gains in understanding theory & concepts guiding my research	3.9
Personal gains related to research work	Gains in understanding everyday research work	4.1
Gains in skills	Gains in defending an argument when asked questions	3.7
Questions about overall research	How much did you engage in real-world science research?	4.2
Rate your research experience	Rate your research experience overall	3.9
Importance of the cleanroom experience	90% rated the cleanroom experience as "*important*" or "*very important*"	N/A

(GAIN QUESTIONS: 1=no gain, 2=little gain, 3=moderate gain, 4=good gain, 5=great gain)
(HOW MUCH QUESTIONS: 1=none, 2=little, 3=some, 4=a fair amount, 5=a great deal)
(RATE QUESTIONS: 1=NA, 2=poor, 3=fair, 4=good, 5=excellent)

GAINS IN MICRO/NANO RESEARCH SKILLS AND CONTENT (Q1)

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NNCI Cooperative Network Activities

Network-Wide

- **Lead the Equipment and new Research Sub-committee** (some surprising findings)
- **Attended the NNCI REU convocation at NCSU (sent 9 students)** and the NNCI Annual Conference at UW in Seattle
- Participated in National NanoDay and the 100 Billion Nanometer Mascot Race
- Attended the 2017 NSF Nanoscale Science and Eng Grantees Conf in DC and provided material for NNCI presentation
- Participated in the RSV at NSF and the monthly NNCI Directors' Meetings

Multi-Site

- **Submitted a Joint NSF RET proposal** (NCI-SW, SENIC, MINIC, KY MMNIN, NNF) – not funded
- Hosted a PhD student as part of the **NNCI Japanese NIMS Graduate Exchange Program**
- Manned the NNCI booth at the 2017 TechConnect World Innovation Conference in DC on May 14-17

On Behalf of the Network

- **Collected the following data for Dr. Goldberg**
  - **List of NNCI-submitted equipment grants (MRIs and DURIPs)**
  - **Table of NNCI "Workhorse" Equipment needs**
- Initiated discussion of a possible NNCI-lead national Nano Education Proposal using Desktop SEMs
- **2018 KY Multiscale Nano+AM Symposium**
- UofL Graphics Dept designed an NNCI USA map
- Host the UGIM website and member of UGIM Steering Committee (many NNCI members participate in UGIM)

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2018 KY Nano+AM Symposium

- Aug 1-2, 2018 at the newly renovated Speed Museum in Louisville KY
- Goal 1A - Bring together academia and industry in the converging fields of micro/nano and additive manufacturing (3D printing)
- Goal 1B - Promote KY Multiscale core facilities
- Mayor, University President and Invited Keynote Speakers
- 54 Talks, 23 Posters, and 2 Expert Panel Sessions
- > 140 attendees
- Advisory Board Breakout Session

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Equipment Acquisition Challenges

- **Last year, 13 NNCI sites submitted…**
- **26 proposals to the NSF MRI and DOD DURIP programs for…**
- **26 tools totaling $20.2M**
- **EXAMPLES - 2 FIBs, 2 eBLs, 2 ICP-MSs, 2 AFMs, 2 CT Scanners, 1 Nanoscribe, 1 DRIE, 1 CVD System, and many advanced characterization tools (How many were funded?)**
- **Summary – It is difficult to replace traditional "workhorse" tools, especially for ufab**

	SITE NAME	UNIVERSITY	AGENCY PR	EQUIPMENT REQUESTED	DOLLAR AMOUNT	BRIEF DESCRIPTION OF EQUIPMENT	STATUS
2					$ 20,149,557		
3	TNF	University of Texas - Austin	DURIP	Optically-Accessible Chemical Vapor Deposition (OACVD)	$ 500,000	Equipment for Transitional Metal Dichalcogenide Synthesis	Rejected
4	TNF	University of Texas - Austin	DURIP	Advanced Electron Beam Lithography System	$ 750,000	For the fabrication of nanoscale optoelectronics	Rejected
5	KY MMNIN	U. of Louisville	NSF MRI	Deep Reactive Ion Etcher	$ 412,636	Tool used to etch patterns in silicon (will replace our failing 20yr old DRIE system)	Pending
6	KY MMNIN	U. of Louisville	NSF MRI	Multiscale Additive Manufacturing Instrument with Integrated 3D P	$ 1,530,219	Development of an instrument for flexible multi-scale manufacturing of Micro/Nano	Pending
7	NCI-SW	Arizona State U.	NSF MRI	Inductively coupled plasma, time of flight mass spectrometer	$ 697,595	ICP-TOF-MS for single nano-particle analysis	In preparation
8	NNF	University of Nebraska - Lincoln	NSF MRI	Attocube	$ 550,000	Low-T, high field scanning probe system	Pending
9	MANTH	U. of Pennsylcania	NSF MRI	TESCAN S8000G focused ion beam / scanning electron microsc	$ 923,077	Equipped with a cryogenic transfer system and a time-of-flight mass spectrometer (To	Pending
10	RTNN	North Carolina State University	NSF MRI	X-ray nanoCT system (e.g. Xradia 520 Versa High-Res 3D XRM	$ 695,668	The equipment uses high-energy X-rays for nondestructive, quantitative, three-dimensi	Pending
11	RTNN	North Carolina State University	NSF MRI	Anasys Instruments, NanoIR2-FS	$ 553,875	The equipment uses atomic force microscopy coupled with infrared tip-enhanced exc	Pending
12	CNF	Cornell University	NSF MRI	Nanoscribe Photonic Professional GT	$ 385,304	It would enable the rapid prototyping of nano-, micro- and mesostructures with mir	Pending
13	Stanford	Stanford University	NSF MRI	Empyrean X-ray Diffractometer from PANalytical	$ 654,089	For Nondestructive Characterization of Energy Materials in Cross-Disciplinary Researc	Pending
14	SHyNE	Northwestern University	NSF MRI	eBL System	$ 994,000	Dedicated Electron-Beam Lithography	Pending
15	SHyNE	Northwestern University	DURIP	Infrared AFM	$ 376,000	AFM integrated nano-FTIR and sSNOM	Pending
16	SHyNE	Northwestern University	NSF MRI	High energy Single Crystal XRD	$ 669,620	Single Crystal X-Ray Diffractometer	Pending
17	SENIC	Joint School of Nanoscience and N	NSF MRI	Illumina NextSeq 550	$ 498,929	High throughput DNA sequencing system	Pending
18	SENIC	Joint School of Nanoscience and N	NSF MRI	Zeiss Xradia 510 Versa	$ 1,108,126	3D X-ray Microscope for digital material design and engineering	Pending
19	SENIC	Georgia Institute of Technology	NSF MRI	Hitachi Focused Ion Beam Instrument	$ 967,940	Focused Ion Beam Instrument for Nanoscale Machining and Manipulation of Diverse I	Pending
20	CNS	Harvard University	NSF MRI	Aberration Corrected Low Energy Electron Microscope (AC-LEEM	$ 1,380,679	To explore surface states and surface interfaces, by imaging (LEEM), diffraction (LEE	Pending
21	MONT	Montana State U.	NSF MRI	200 kV cryo-electron microscope (Talos Arctica)	$ 639,325	Structural biology atomic models for macromolecular assemblies in mulitple confom	Pending
22	MONT	Montana State U.	NSF MRI	Inductively Coupled Plasma-Mass Spectrometer (ICP-MS)	$ 2,421,477	For characterization of microbial communities, elemental cycling, biocorrosion	Pending
23	NNI	U. of Washington	NSF MRI	Nanoindenter	$ 454,179	Acquisition of an advanced nanoindentation system for multidisciplinary research and I	funded
24	NNI	U. of Washington	NSF MRI	Development of a Big Data Atomic Force Microscopy System	$ 999,999	The proposal seeks to develop a unique and powerful Big Data AFM to excite, acquire	pending
25	NNI	U. of Washington	NSF MRI	Quantum matter at low temperatures	$ 665,000	Development of an instrument combining optics, transport and strain for studying quan	funded
26	NNI	U. of Washington	NSF	Biophysical imager	$ 390,785	Instrument Development: A nanoscale, unbleachable orientation and postiion sensor f	funded
27	NNI	U. of Washington	NSF MRI	SQUID Magnetometer	$ 333,879	MRI: Acquisition of a Cryogen-Free MPMS3 SQUID (Semi-Conducting Quantum Inter	pending
28	NNI	Oregon State University	NSF MRI	Probe Corrector for G2-200 Titan TEM	$ 597,156	The bolt on probe corrector will will re enable STEM (scanning transmission electron	Pending
29	NanoEarth	Virginia Tech					No submissions of DURIP or NSF MRI
30	MINIC	U.of Minnesota					No submissions of DURIP or NSF MRI
31	SDNI	U.of California - San Diego					No submissions of DURIP or NSF MRI

END

National Nanotechnology Coordinated Infrastructure

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