KY Multi-scale Manufacturing and Nano Integration Node

KY MULTISCALE

2017 NSF NNCI Conference
University of Penn
Oct 16-17, 2017

National Nanotechnology Coordinated Infrastructure

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

Outline

1. Overview
2. User Statistics
3. Facility Upgrade and New Tool Capabilities
4. Research Highlights
5. Education and Outreach
6. Network Activity
7. Panel Discussion Slide

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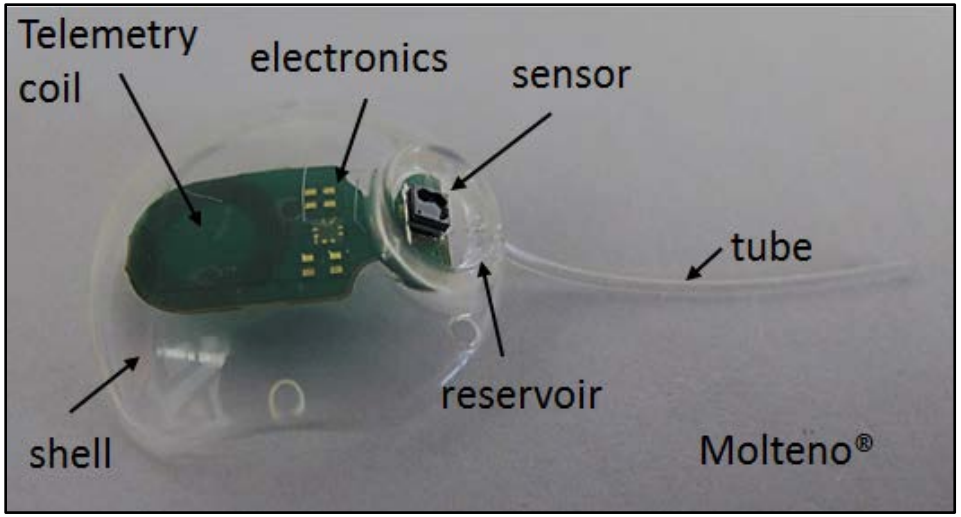
Overview

KY MULTISCALE VISION - The *next generation* of revolutionary products and solutions will require the *combination and effective integration of a diverse set of 3D manufacturing processes*, spanning lengthscales from the nano to meso/macro regimes. Users want *easy access* to these resources to *rapidly and efficiently* fabricate their creative ideas.



Smart ocular shunt prototype

Can we help make multi-scale prototyping less "kludgy"?

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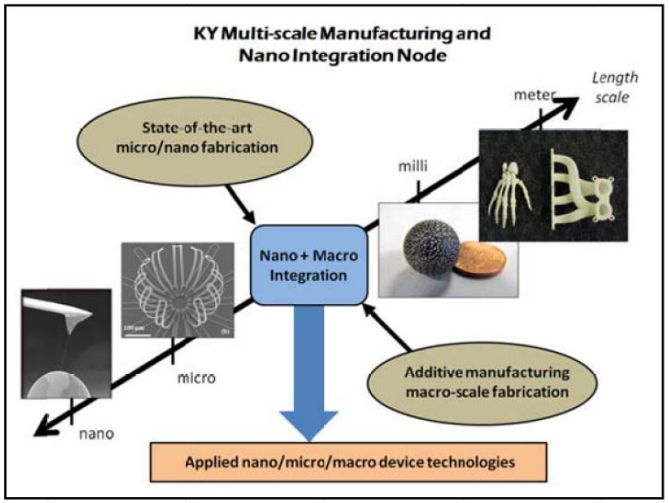
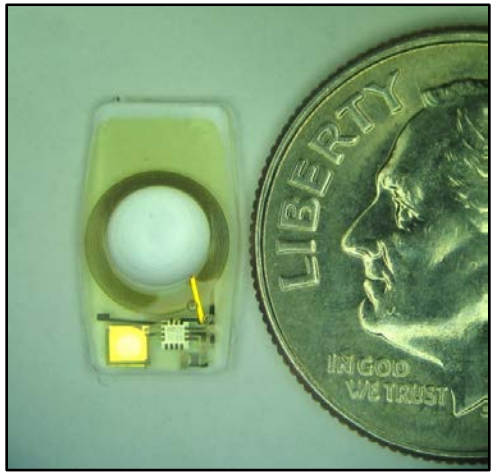
Site Goals

By leveraging over $250M of State and NSF EPSCoR investments in state-of-the-art advanced manufacturing equipment and 25 years of expertise in the fields of micro/nanofabrication and additive manufacturing/3D printing, KY MULTISCALE plans to achieve these goals

1. Be a National Center of Excellence for *current and next generation 3D multi-scale manufacturing and integration*.
2. Offer a comprehensive set of fabrication and characterization capabilities spanning *nano to meso/macro regimes.*
3. Provide *technical expertise* for users to *rapidly and efficiently integrate* these processes.





Smart IOP lens

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Facilities and Personnel

MNTC
Micro and Nano Technology Center

CeNSE
Nanoscale Science and Engineering

RPC
Rapid Prototyping Center

EMC
Electron Microscopy Center

KY MMNIN

CAM
Center for Advanced Materials

HNCF
Huson Nano Core Facility

CAER
Center for Advanced Energy Research

CCRER
Conn Center for Renewable Energy Research

Kevin Walsh,	**Director**
Todd Hastings	**Co-Director**
Ana Sanchez	**Coordinator**

ADMIN STAFF

Mary Watson & Evgeniya Moiseeva	MNTC & HNCF
Eunice Salazar	CCRER
Tereza Rohr	RPC
Alice Marksberry	CAER
Anna Boyanovsky	CENSE
Tanya Floyd	ASTeCC

CORE DIRECTORS

Shamus McNamara	MNTC &HNCF
Mahendra Sunkara	CCRER
Thomas Starr	RPC
Todd Hastings	CENSE
Lance DeLong	CAM
John Balk	EMC
Rodney Andrews	CAER

CORE MANAGERS

Julia Aebersold	MNTC & HNCF
Thad Druffel	CCRER
Tim Gornet	RPC
John Craddock	CAER
Nicholas Briot	EMC
Tanya Floyd	ASTeCC
Brian Wajdyk	CENSE

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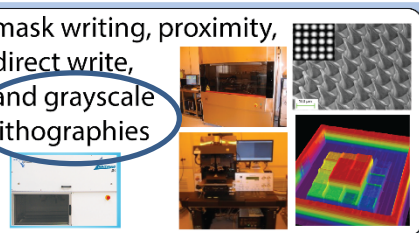
Key Capabilities

Micro- and Nano Fab Unit Processes

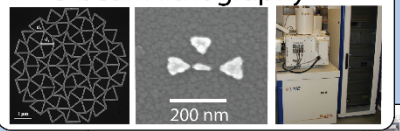
+ Multiple Furnace banks, 2 RTP systems, vacuum ovens

mask writing, proximity, direct write, and grayscale lithographies

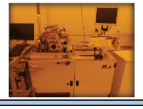


+ Thin films: PECVD, LPCVD, Parylene, MVD, 2x ALD

e-beam lithography



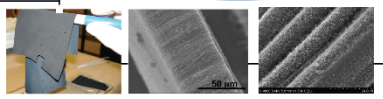
wafer bonding



physical vapor deposition (thermal, e-beam, sputter)

reactive ion etching (deep, corrosive, cryo)

Roll-to-roll Manufacturing



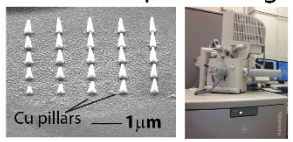
8 meter belt CVD furnace

10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0}

Scale (m)

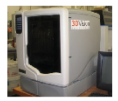
Rapid/Additive Processes

e-beam & ion-beam induced processing

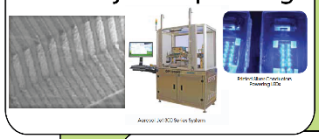


e-beam melting

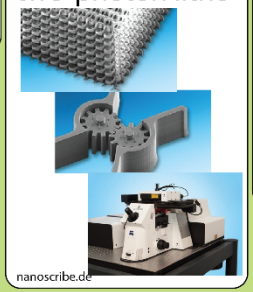
fused deposition modeling



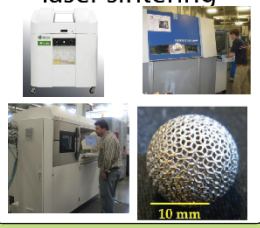
aerosol jet 3D printing



two-photon litho



metal & polymer laser sintering



stereo litho.

10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0}

Scale (m)

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NSF

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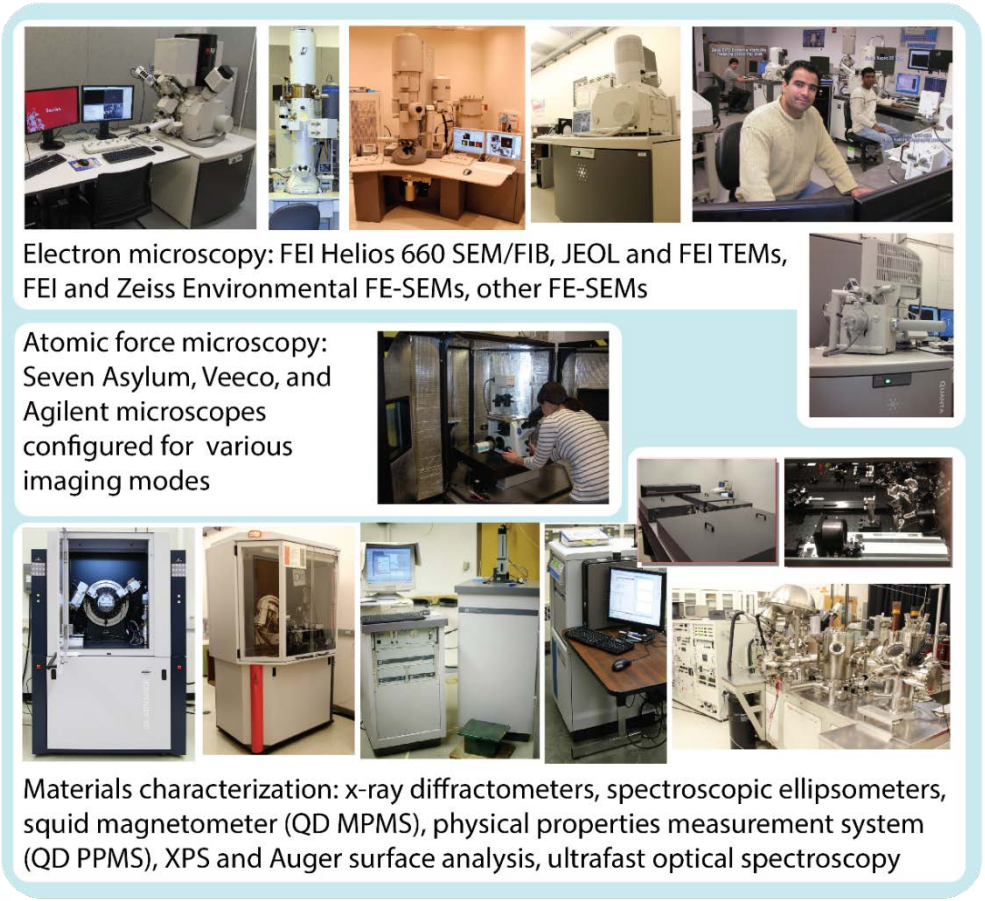
Key Capabilities

Microscopy and Characterization



Electron microscopy: FEI Helios 660 SEM/FIB, JEOL and FEI TEMs, FEI and Zeiss Environmental FE-SEMs, other FE-SEMs

Atomic force microscopy: Seven Asylum, Veeco, and Agilent microscopes configured for various imaging modes

Materials characterization: x-ray diffractometers, spectroscopic ellipsometers, squid magnetometer (QD MPMS), physical properties measurement system (QD PPMS), XPS and Auger surface analysis, ultrafast optical spectroscopy

And…

Full Backend Processing

polishing, lapping, dicing, electroplating, XeF2 release, critical point dry, wafer level bonding, laser cutting, etc

Full Packaging Capabilities

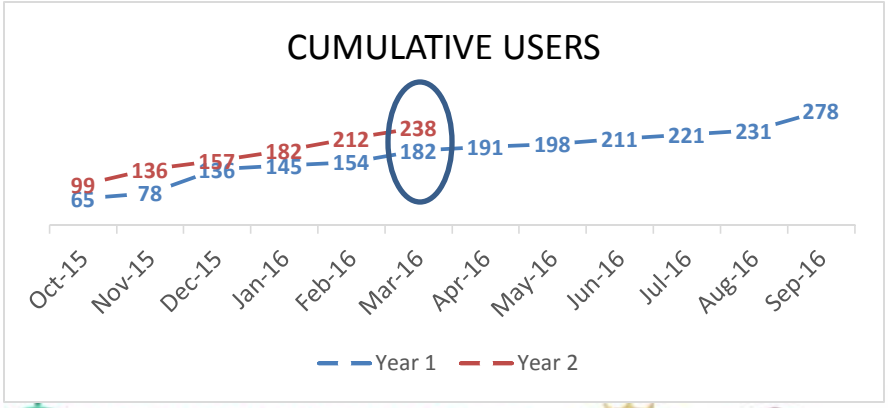
dicing, wire-bonding, flip-chip, die attach, surface mount, custom PCB, etc

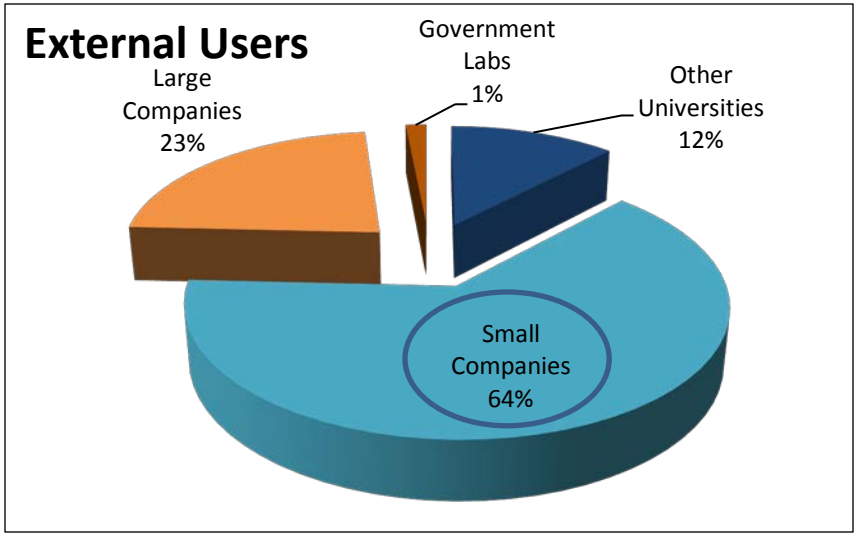
Full Testing

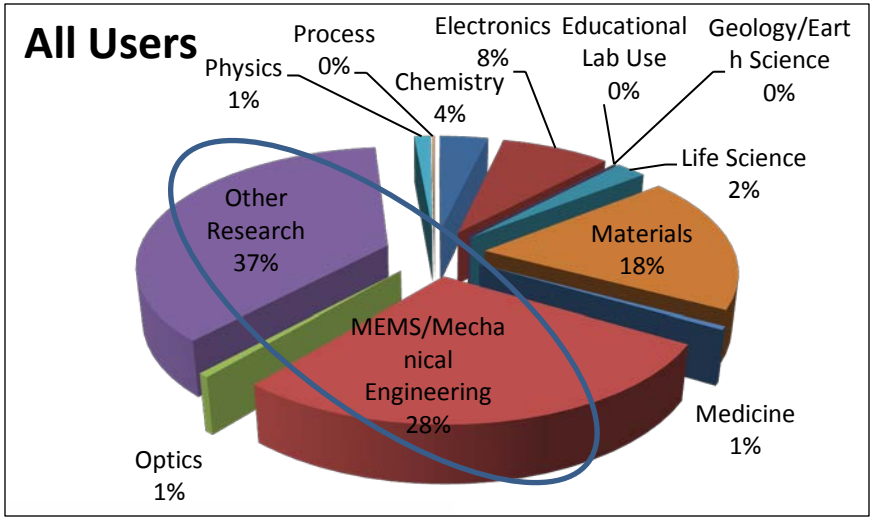
ellipsometry, stress measurement, thermal imaging, contact and non-contact profilometry, 4 point probe, CV, high speed imaging, etc

KY MMNIN User Data

Yearly User Data Comparison		
	Year 1 (12 months)	Year 2 (6 months)
Total Users	278	238
Internal Users	163	181
External Users	115 (41%)	57 (24%)
Total Hours	14629	8289
Internal Hours	10384	5892
External Hours	4244 (29%)	2396 (29%)
Average Monthly Users	104	141
Average External Monthly Users	24 (23%)	20 (14%)
New Users	111	136
New External Users	26 (23%)	23 (17%)







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KY MMNIN User Revenue

	Year 1	Year 2 (6 months)	Year 2 (Projected)
Internal	$305K	$219K	$438K
External	$414K	$219K	$438K
Total	$719K	$438K	$976K

$1M milestone

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Facility Upgrades and New Tool Capabilities

1. Primax Vapor HF Release System (NNCI)
2. Zortrax M200, Desktop 3D Printer (NNCI)
3. MakerGear M2, Desktop 3D Printer (NNCI)
4. Nanoscribe 2 Photon 3D Lithography System (pending NNCI purchase)
5. Optomec Aerosol Jet System (pending NNCI purchase)
6. Acquisition of 10,000 sq ft of AMCC (Additive Manufacturing Competency Center) Space and $1M of 3D Metal Printers (from UofL Foundation)
7. Loan of a Voxel 8 combination metal/plastic 3D Printer (GE First Build)
8. CMP System (donated)
9. Dual beam FIB/SEM FEI Helios 660 (NSF EPSCOR support)
10. Ultra high temperature (1500 C) hot stage upgrade for FEI Quanta FEG
11. Leica CPD300 Critical Point Dryer
12. Revised and rebranded KY MMNIN NNCI Website – KY MULTISCALE
13. FOM Integration among our cores

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You Think It, We Make It!

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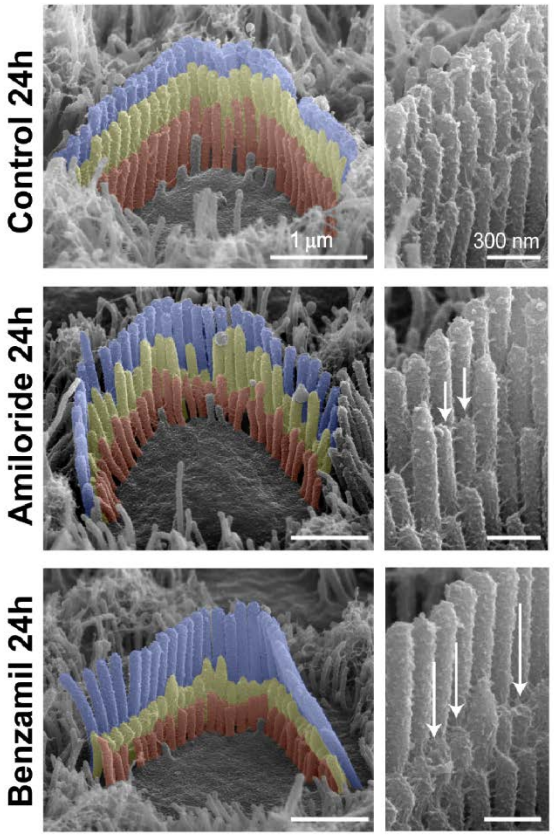
Research Highlights

Research Highlights

- Stereocilia of the inner ear hair cells were imaged using dual-beam FIB/SEM in slice-and-view mode.
- Tension between linked tips in “staircase” essential for normal hearing.
- Tension also produces a continuous influx of calcium (potentially harmful)
- However, Ca^{2+} blocking drugs disrupt the staircase structure $\rightarrow$ Ca^{2+} influx is essential to preserve structure and thus hearing (Vélez-Ortega et al. eLife 2017)
- Calcium binding proteins are critical for auditory transduction. (Giese et al., Nature Comm. 2017)



Stereocilia staircase imaged with dual-beam FIB/SEM by G. Frolenkov’s group at U.K.

Education and Outreach Activities

1. UofL and UK NSF REU Programs
2. NanoDay Celebration at KY Science Center
3. Participated in NSF "Ask a Nano Expert" and "Generation Nano" Initiatives
4. Created Nano-nugget videos for NNCO
5. Eng Day at UK and UofL
6. Summer camps at CeNSE, Conn Center, & MNTC
7. Hands on cleanroom demonstrations with students from China University of Mining and Technology
8. Women in Engineering workshop for HS students
9. Demonstrations for chemistry students from EKU
10. Co-sponsored monthly seminars
11. Co-sponsored KY Science Center Scientific Proofs gatherings at Mellow Mushroom (*pizza with a scientist*)
12. Entrepreneurship Workshop at UK in Prototyping Capabilities
13. Renewable Energy Workshops at Conn Center

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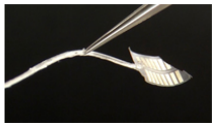
Network Activities

1. Joint NSF RET Proposal with ASU, GaTech, UofL, Minn and Nebraska
2. Sent 10 students to GaTech for NNCI REU Convocation.
3. NNCO NanoDay 100B nm Mascot Run
4. Several Subcommittees and Working Groups
    1. Building the User Base
    2. E-beam Lithography Group
    3. New Equipment and Research Opportunities
    4. Workforce Development
    5. International Relations
    6. Entrepreneurship and Development
    7. MEMS/Sensors Research Area
    8. Vendor Relations and Outreach/Education
    9. Additive Manufacturing Technical Working Group
    10. Lithography Technical Working Group
5. Japanese NNCI/NIMS Graduate Exchange Program
6. Staff attended Dry Etch Workshops at Cornell
7. Advertising Booth at TechConnect in DC; helped man the NNCI booth.
8. NSF/NBC Learn “Science of Innovation” Videos

Episode 5. Micro-Fabrication for Cochlear Implants

Angelique Johnson is the CEO of MEMStim, a company that is innovating how electrode arrays in cochlear implants are manufactured. Using automated micro-fabrication, instead of costly hand-made manufacturing, Johnson is able to lower the cost of production, allowing more people in need of implants to afford them.

View video (5:02 min.)



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PANEL SLIDE

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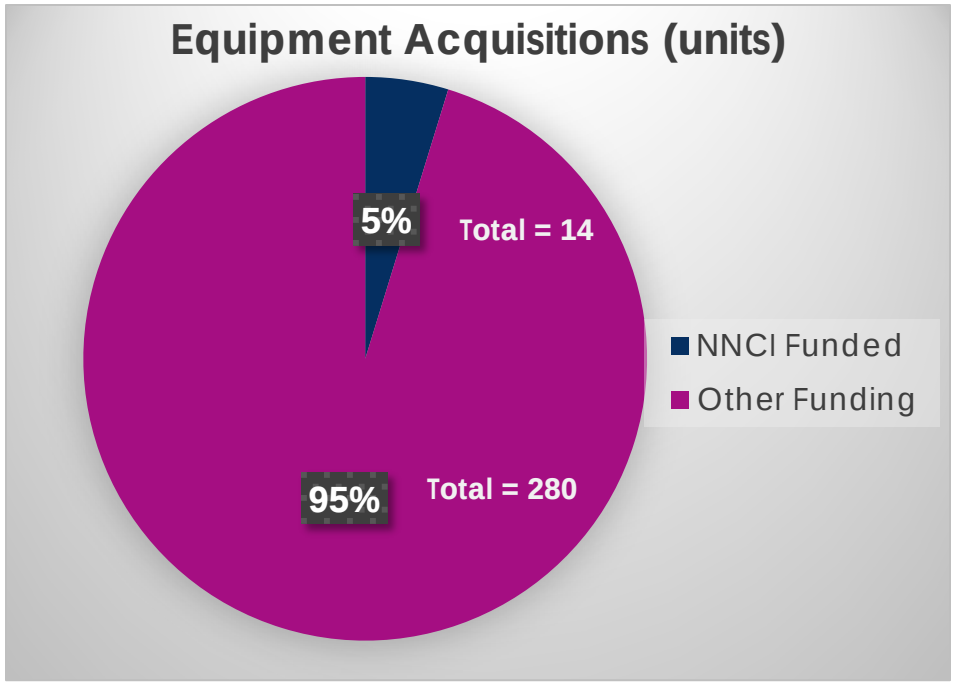
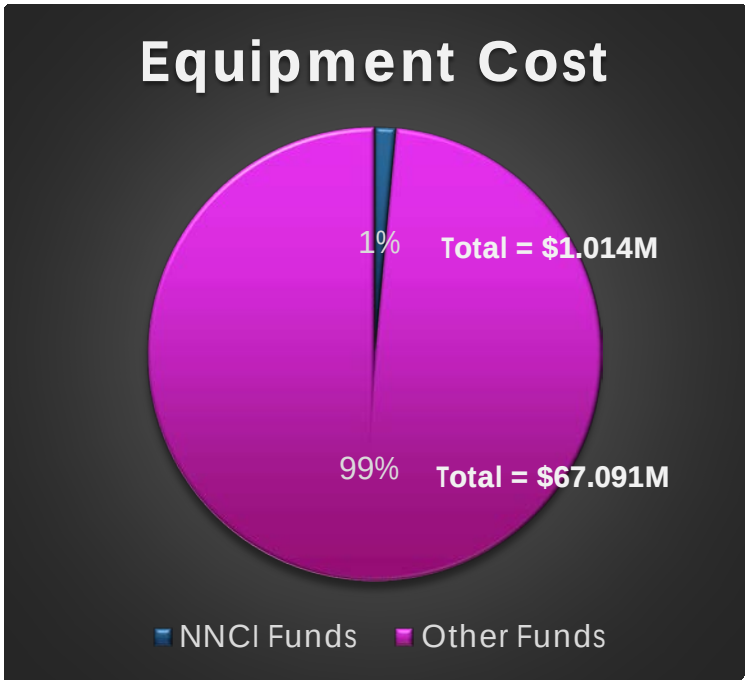
Panel Discussion Topic

Resource Allocation and New Equipment Acquisition – How do new and established user facilities plan for long-term replacement and for new acquisitions?



294 tools acquired by the 16 sites since the start of NNCI



Total = $68,104,620

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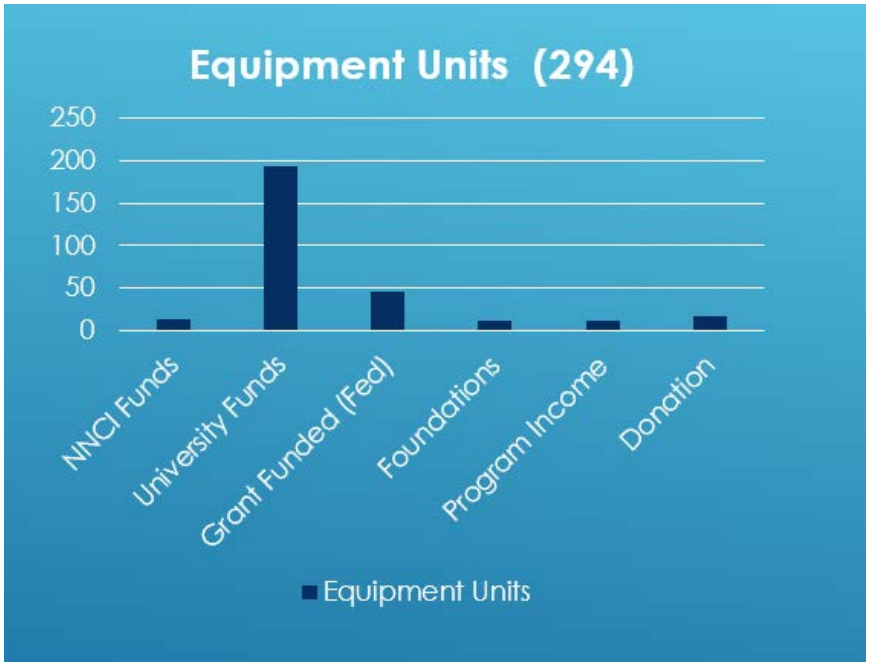
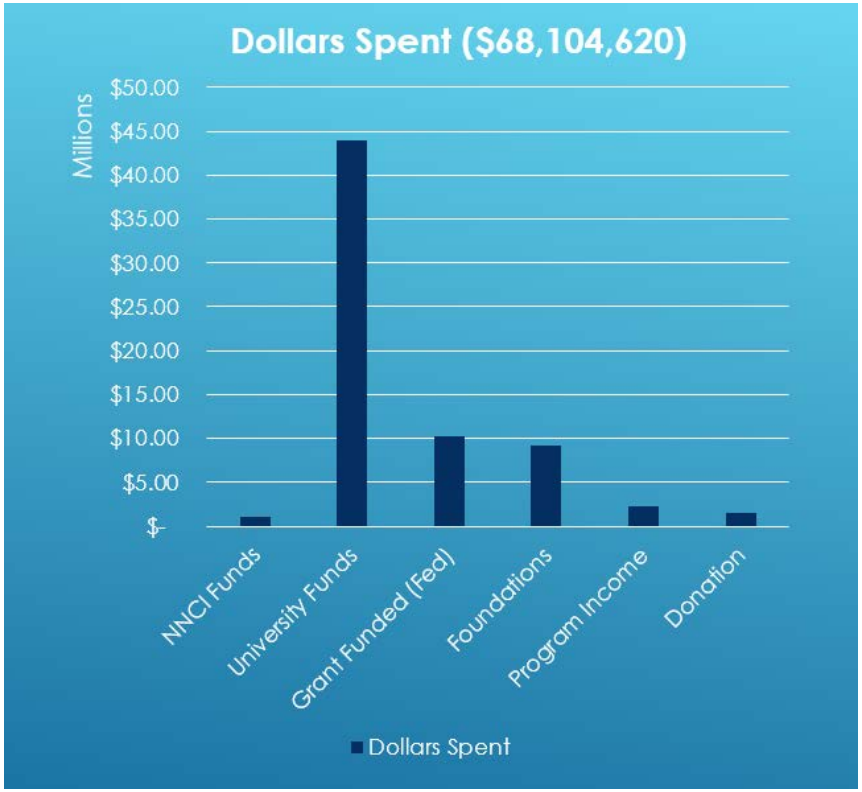
Panel Discussion Topic

294 Tools for a Total of $68,104,620





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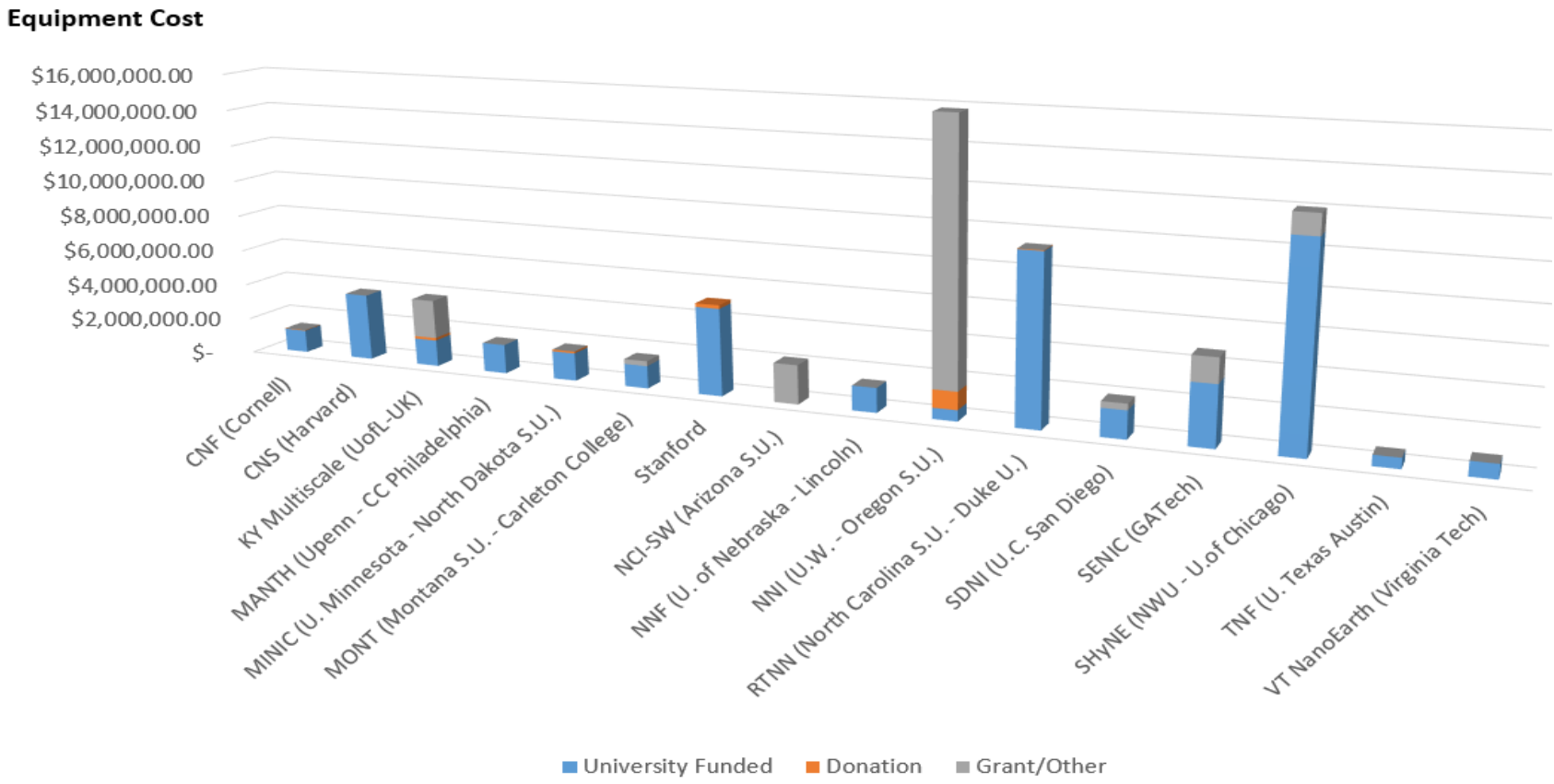
Panel Discussion Topic

294 Tools for a Total of $68,104,620



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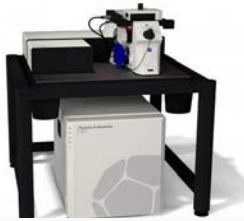
EXTRA

Research Focus Areas

Top Down 3D Integration Challenges (macro/meso to micro – next gen AM)

- New 3D multi-scale manufacturing ***techniques and integration*** (3D MSMI) strategies
- Printing ***conductive interconnects*** on ***highly non-planar AM surfaces***
- Integrating ***micro-fluidics*** with AM and 3D printing
- Strategies for ***embedding*** sensors, electronics and components inside AM products
- 3D printed ***electronic, optical, biological, and sensing*** materials
- 3D MSMI ***design for manufacturability (DFM)***

Printed Biologics Micro-Arrays
(20 micron spots)



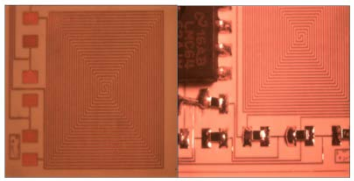
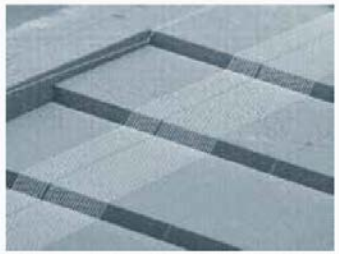


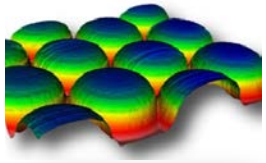
Figure 3. Maskless Lithographic generated Cu/LCP temperature sensor.

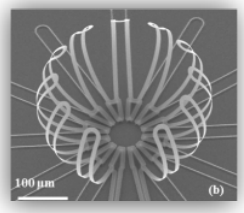


Silver lines printed over a 3D substrate.

Bottom Up 3D Integration Challenges (nano/micro to meso)

- Self-assembly and ***3D patterning at the nano-level***
- Focused e-beam induced ***processing in liquids***
- Two-photon ***additive manufacturing***
- ***Grayscale*** for generating 3D topologies
- ***2D to 3D self-assembly*** using released stress-engineered films
- Strategies for fabricating ***3D MEMS bistable elements*** (no-power MEMS)
- ***Custom characterization tools*** for the nano/micro regime

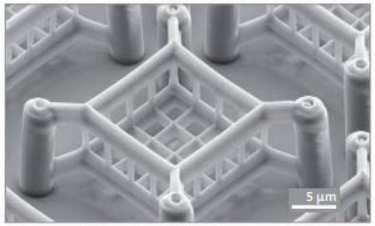




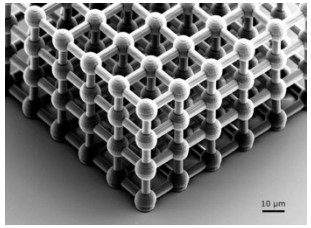
Aerosol Jet 300 Series System

Materials, Design and Integration Challenges

- ***New materials*** for additive manufacturing (AM) and 3D printing
- ***Integrated and mixed AM layers*** for achieving specific functionality
- ***Smart materials***
- AM strategies to ***improve resolution***
- ***Software*** development for AM and MSMI



Biocompatible cell scaffold. Courtesy of T. Striebel, M. Bastmeyer, CFN, KIT (Germany).



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