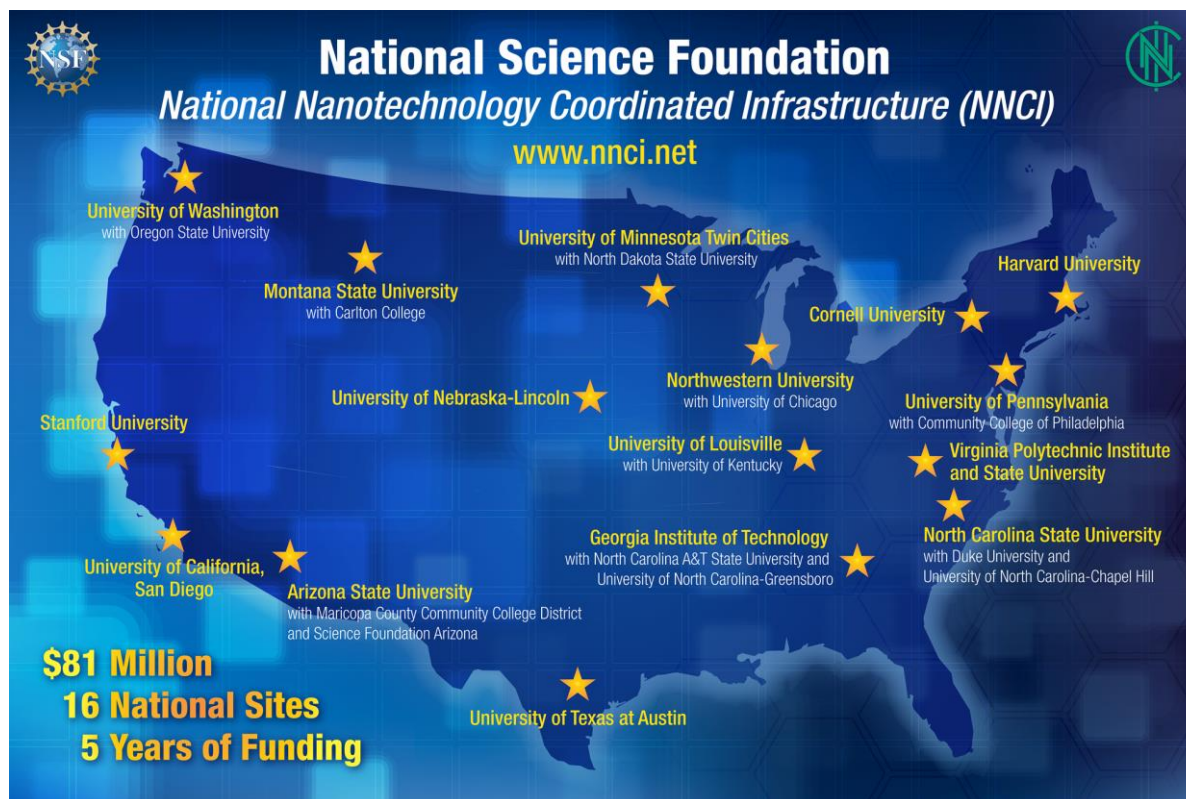




KY MMNIN

(Multi-scale Manufacturing and Nano Integration Node)



<http://www.kymultiscale.net/>

First Google hit for “ky multiscale”

Fifth Google hit for “multiscale manufacturing”

Press Announcement



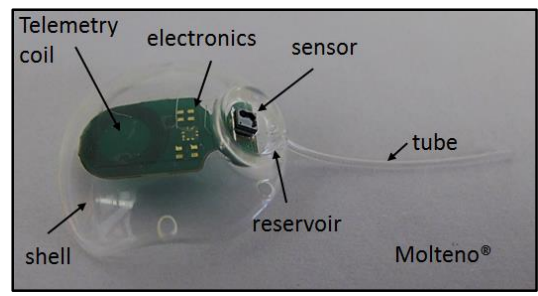
Louisville Mayor Greg Fischer, UofL Acting President Neville Pinto, PI Kevin Walsh of UofL and co-PI Todd Hastings of UK in front of 5 TV stations



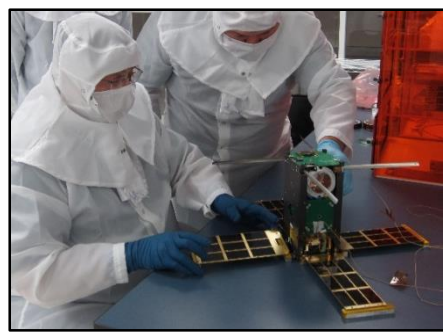
MMNIN Vision

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.

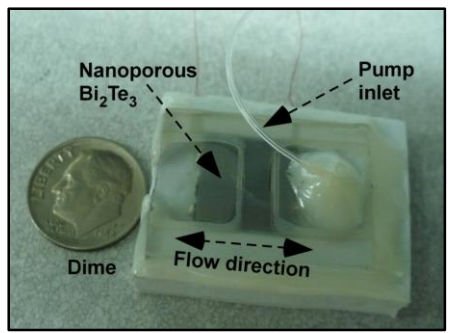
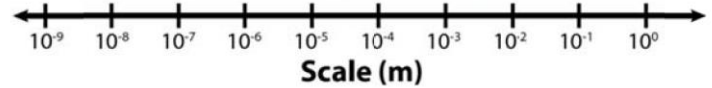
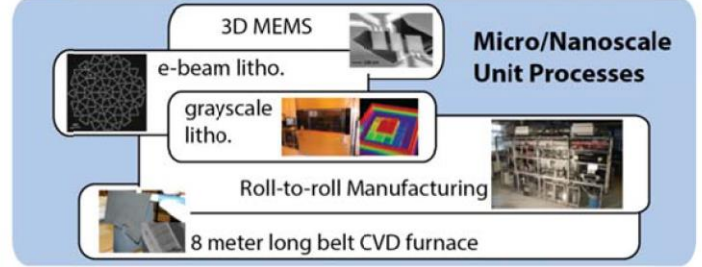
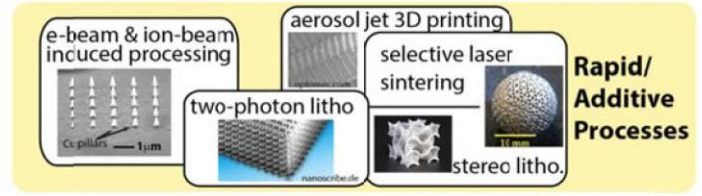
Let's eliminate "kludgy" from the word invention



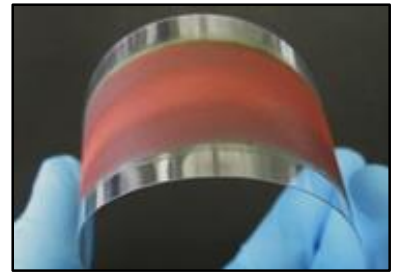
Smart ocular shunt



NASA CubeSAT micro-satellite



Nano-porous gas pump



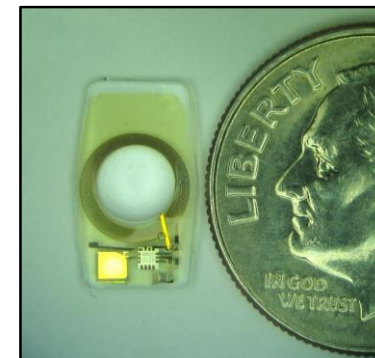
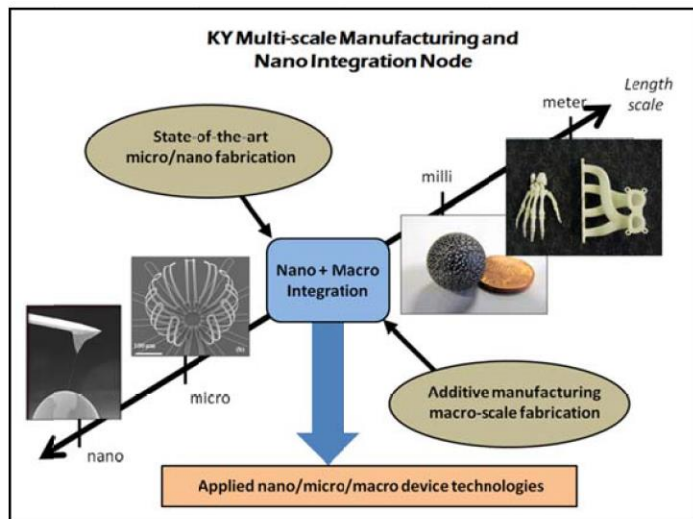
Wearable electronics



MMNIN Goals

Leverages over 25 years of expertise in the fields of micro/nanofabrication and 3D additive manufacturing and over \$250M of State and EPSCoR investments in state-of-the-art advanced manufacturing equipment to ...

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



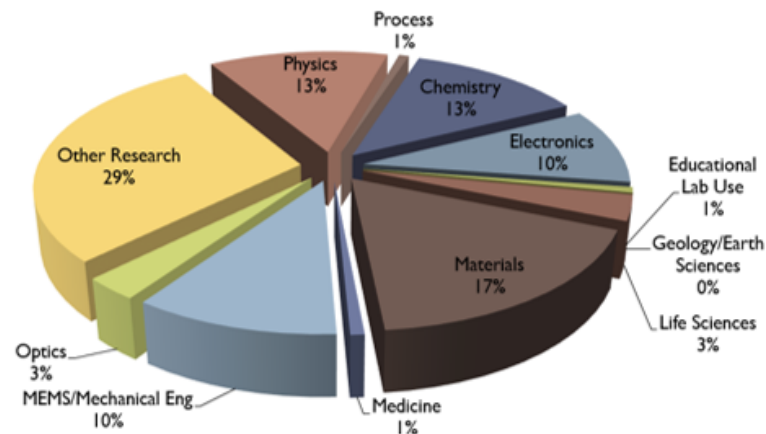
Smart IOP lens



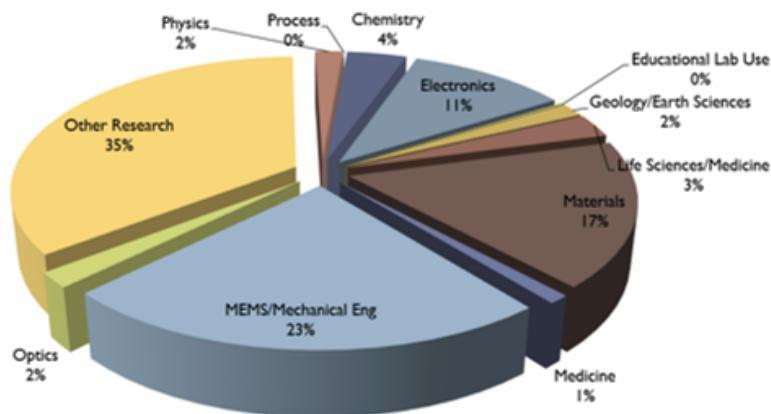
MMNIN User Statistics

TABLE 1. SUMMARY OF USER STATISTICS

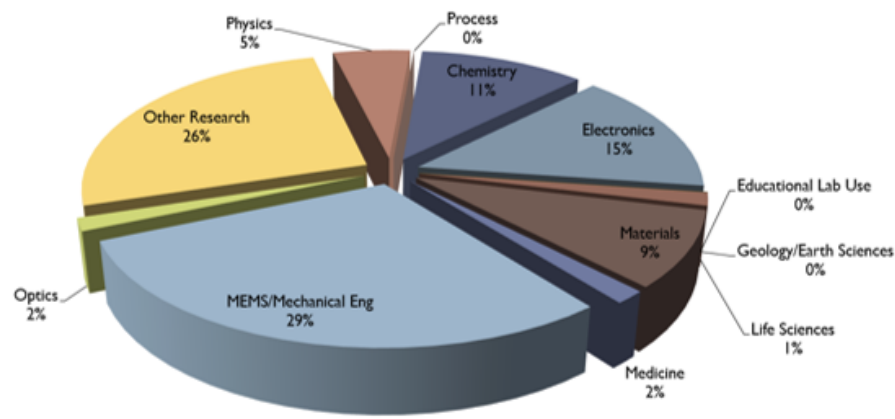
	KY MMNIN (10/2015-09/2016) 12 months
# Total User	278
# Av. Monthly Users	103
# Total External Users	115
# External Academic	8
# External Industry	64
# New Users Trained	111
# Facility Hours	14,629



Users by discipline



Fees by discipline



Hours by discipline



Overviews of our 8 Cores

MicroNanoTechnology Center (MNTC)

- 10,000 sf micro/nano fab cleanroom
- Semiconductor and adv MEMS processing
- Custom packaging and device modeling

Rapid Prototyping Center (RPC)

- Multiple 3D printing technologies
- Metal, plastic and ceramic
- Advanced 3D design capability

Conn Center for Renewable Energy (CCRE)

- Roll-to-roll platform to integrate micro/nano
- In-situ and Ex characterization
- Scalable nano-material processes

Huson Nanotechnology Core Facility (HNCF)

- Directed nanostructure self assembly
- Interactive nano-manipulation
- Multimodal nano-imaging

Center for Nano Science and Engineering (CeNSE)

- 3,700 sf micro/nano fab cleanroom
- Nano rapid prototyping and adv e-beam litho
- Electronics, Photonics, fluidics and sensors

Electron Microscopy Center (EMC)

- Focused ion beam milling and patterning
- 3D characterization & tomography
- Site-specific sample preparation & analysis

Center for Advanced Materials (CAM)

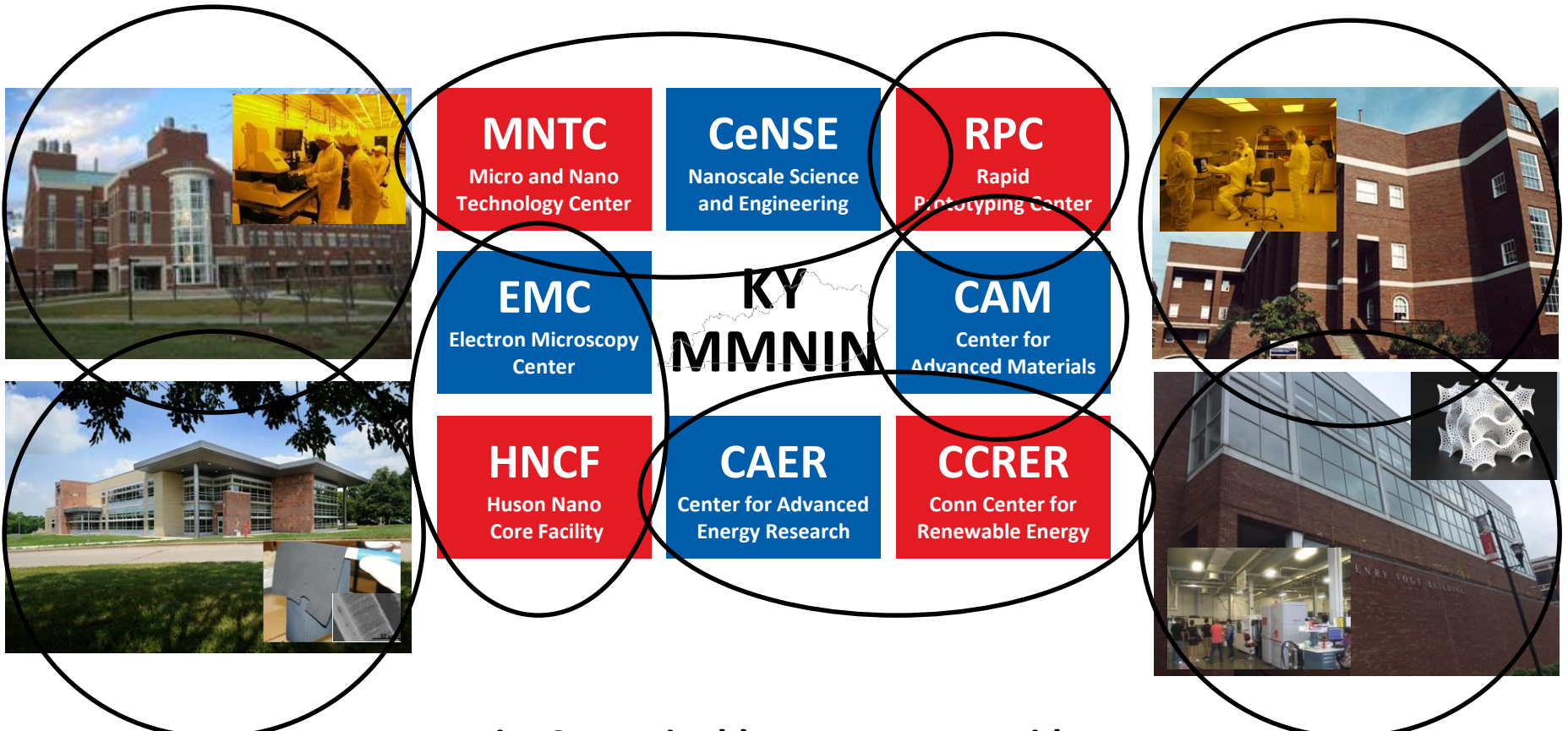
- New materials synthesis
- Materials characterization
- Extreme conditions

Center for Advanced Energy Research (CAER)

- Continuous CNT synthesis pilot facility
- z-aligned, substrate-free CNT array films
- Dispersion and characterization equipment



KY MMNIN: A Collaborative Center



MMNIN: Unite 8 sustainable centers to provide...

- Multiscale and 3D fabrication and characterization
- Multiscale integration research and expertise
- ~50 related faculty and ~30 technical staff
- Seamless interface for users



KY MMNIN 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

Rapid/Additive Processes

e-beam & ion-beam induced processing

e-beam melting

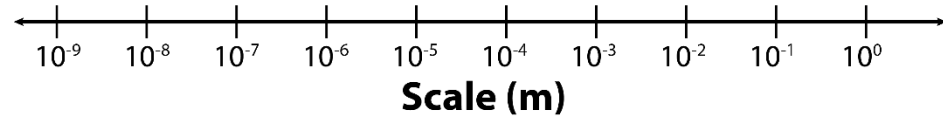
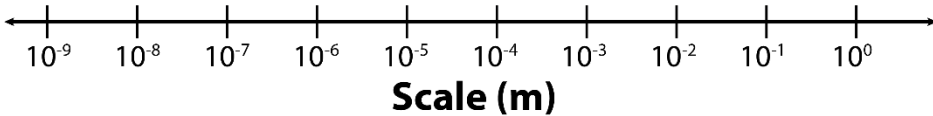
fused deposition modeling

aerosol jet 3D printing

two-photon litho

metal & polymer laser sintering

stereo litho.



Plus a full set of Metrology and Material Characterization Tools

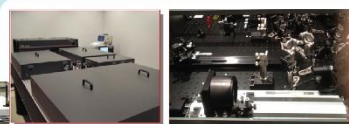
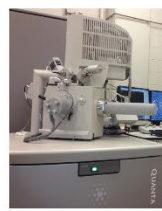
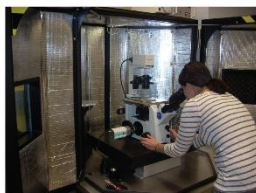


Microscopy and Characterization



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

MMNIN: Design, Build, Characterize, Test

All in the same node!



Site Research Themes

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)

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**
- **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

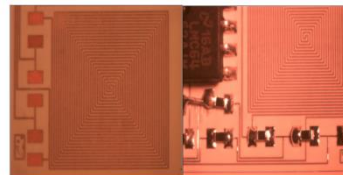
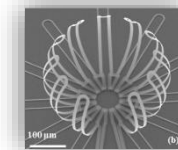
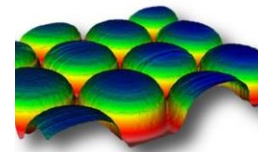


Figure 3. Maskless Lithographic generated Cu/LCP temperature sensor.

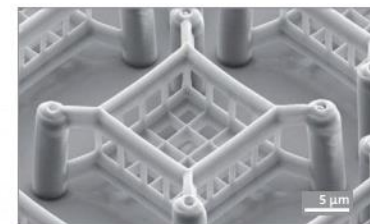


Silver lines printed over a 3D substrate.

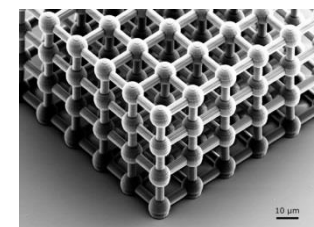


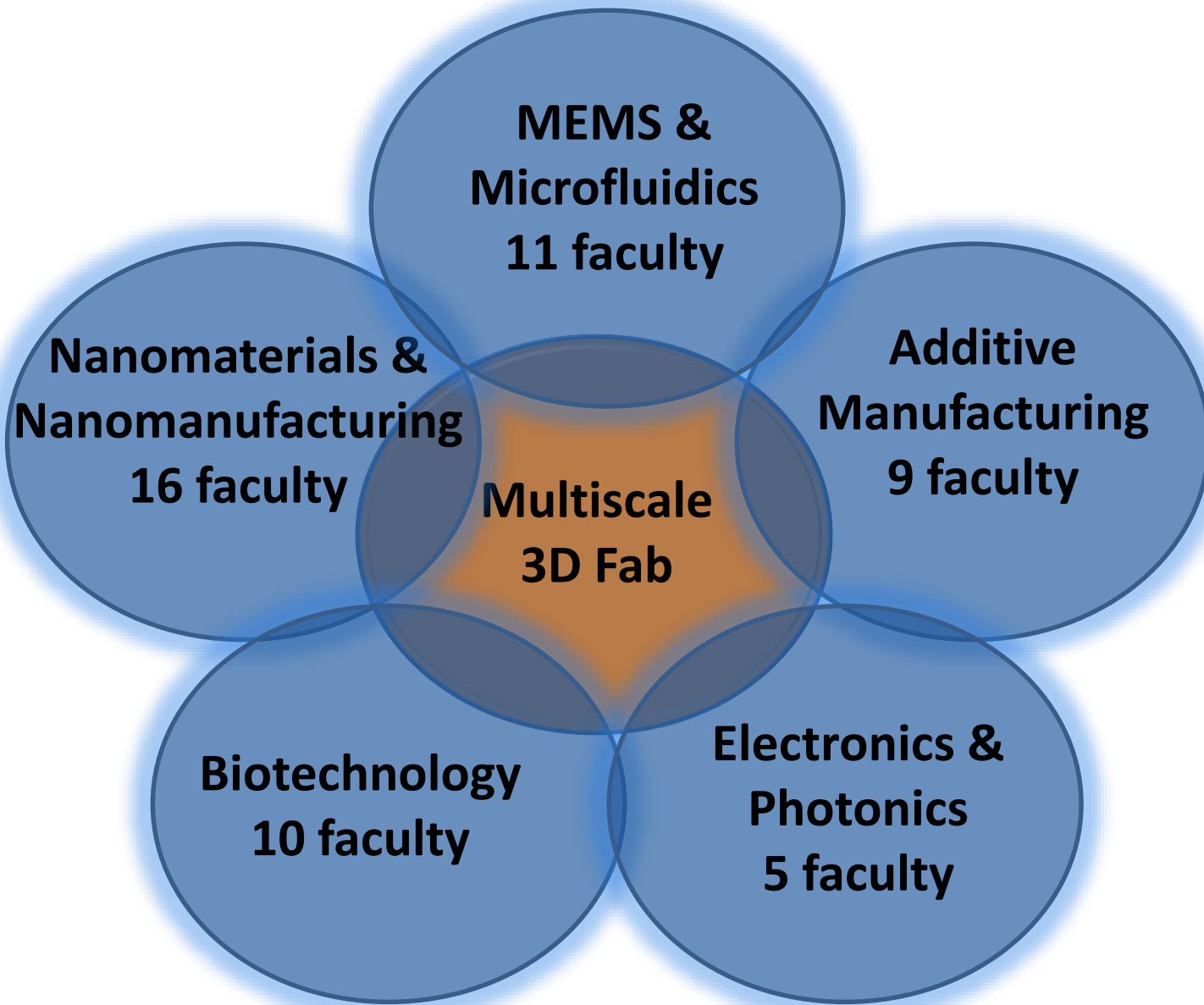
Materials and Software Challenges

- **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



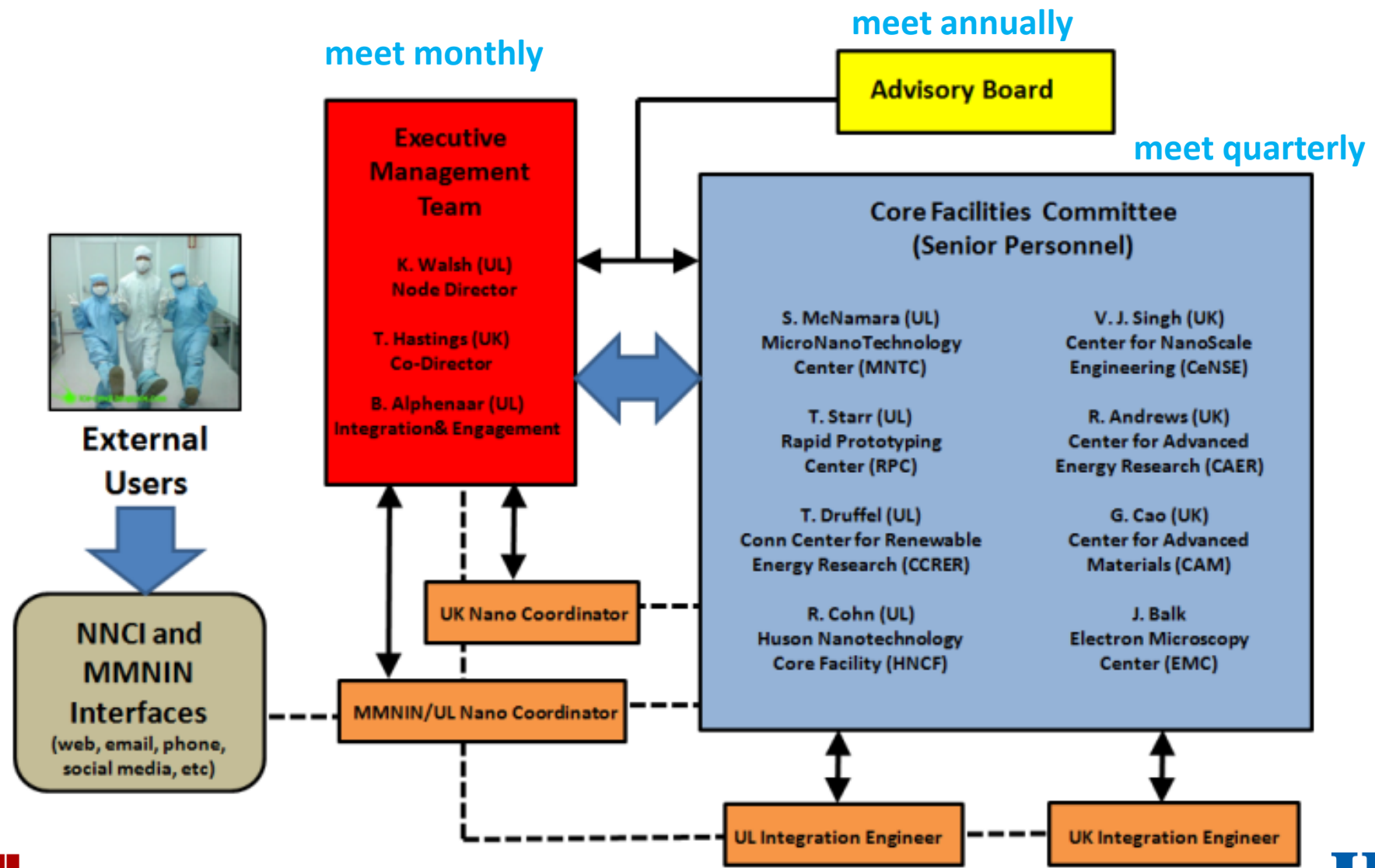
Biocompatible cell scaffold. Courtesy of T. Striebel, M. Bastmeyer, CFN, KIT (Germany).







KY MMNIN Organization



Accomplishments to Date

- Set up the KY MMNIN website
- Implemented FOM for facility management
- Developed an on-line Equipment Data Base for our site
- Hired 2 nano-coordinators and 2 integration engineers
- Established the KY MMNIN Advisory Board
- Made several equipment purchases
- Developed some multi-scale demonstration projects
- Increased industrial client usage
- Hired 3 Endowed Chairs in Advanced Manufacturing and Nano-integration
- Chair of NNCI Equipment and Research Sub-committee
- Several E&O activities

KY MMNIN

"You Think It, We Make It"



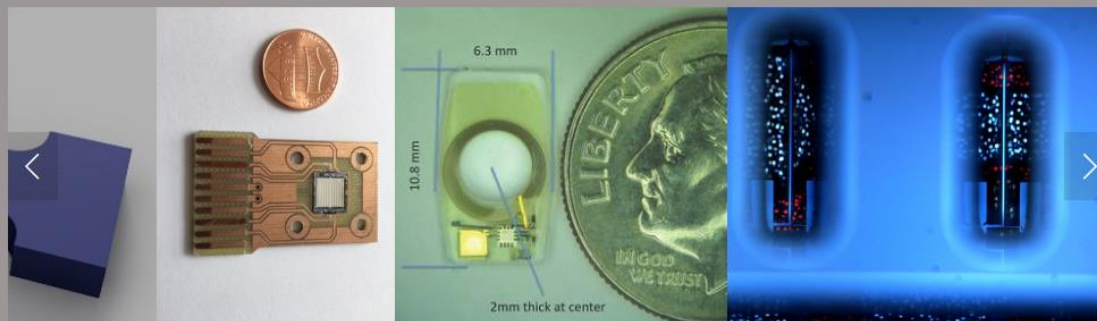
**KY MULTI-SCALE MANUFACTURING AND
NANO INTEGRATION NODE**



THE NNCI'S ONE-STOP SITE FOR "MULTI-SCALE" MANUFACTURING FROM NANO-FABRICATION TO MICRO-FABRICATION TO CUSTOM 3D ADDITIVE PRINTING!

[ABOUT](#) [BECOME NEW USER](#) [CORE FACILITIES](#) [EQUIPMENT DATABASE](#) [OUTREACH](#) [EVENTS](#) [NEWS](#)
[NETWORK FORUM](#) [CONTACT US](#) [FOLLOW US ON FACEBOOK](#)

The KY MMNIN site brings together the extensive multi-scale manufacturing resources from the Universities of Louisville and Kentucky. Known for its automotive manufacturing, the Commonwealth of Kentucky has invested approximately \$500M over the last 2 decades in the areas of advanced manufacturing, ranging from nano-fabrication to micro-fabrication to next-generation 3D additive printing. Spanning the lengthscales of these diverse technologies and integrating them efficiently together to produce practical solutions are the 2 supreme challenges of next-generation advanced manufacturing. Such challenges are central to the theme of our NNCI site. Below we highlight a few of our successful multi-scale manufactured projects. These examples demonstrate the diverse set of micro & nano processes available at our NNCI site. Allow us to work with you to help solve your multi-scale manufacturing needs.






Statewide Facility Integration

- **Single point-of-entry, statewide system for equipment reservation/interlocking, reporting and communications (uses Facility Online Manager, FOM)**

Kentucky Multi-Scale - FOM - Welcome



Time on server
Friday Jan. 13
15 : 53 : 53

Welcome to **Kentucky Multi-Scale Facility Online Manager (FOM©)**

[Click here for University of Louisville / FOM Account Login](#)

Or

[Click here for University of Kentucky Login \(Link Blue\)](#)

FOM© is an online accounting and equipment management software.

FOM© is FREE for small research group use (online scheduler only, with a minimal installation fee).

FOM© supports unlimited number of equipments, unlimited number of facilities, and unlimited number of users.

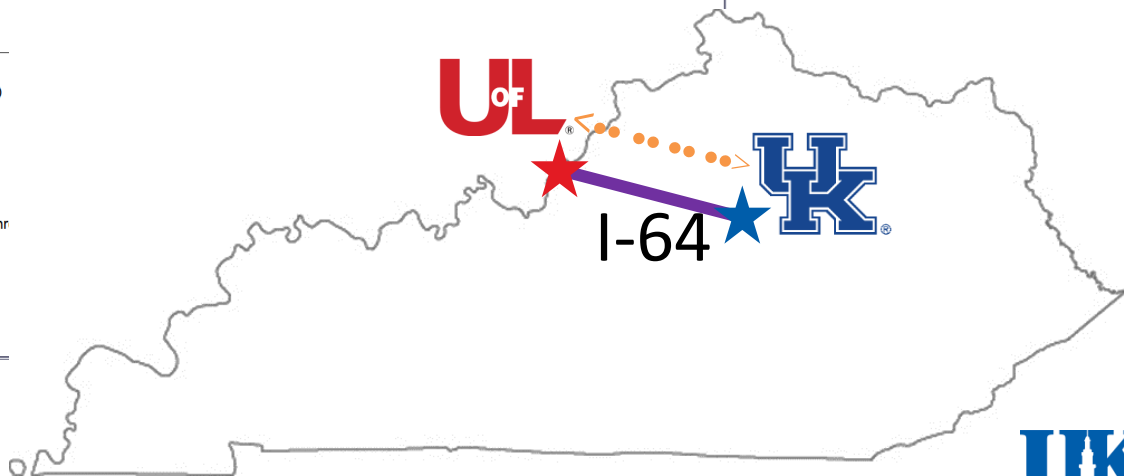
FOM© can be used as a simple scheduler or as a complicated management system. It can be used in a single laboratory, or used to host all the facilities on campus.

If you are interested in using FOM©, please contact FOM Networks at info@FOMNetworks.com.

Visit <http://www.FOMNetworks.com/> to see the features of FOM©

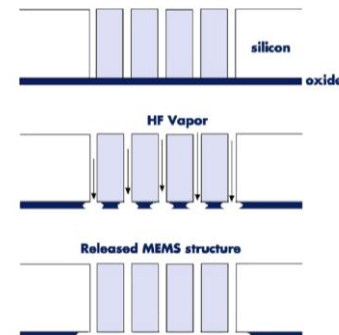
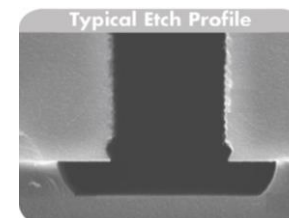
The following facilities are currently hosted on this FOM© server:
(Facility names are linked to facility websites. To use the facility, please login first.)

- [ASTeCC](#) Shared resources for internal and external customers.
- [Huson Nanotechnology Core Facility](#) SEMs, AFM, Ellipsometer
- [RPC](#) Rapid Prototyping Center
- [Uof_MNTC](#) This facility includes access and instruments to the Cleanr
- [VPR Light Microscopy Core](#) Confocal and electron microscopes

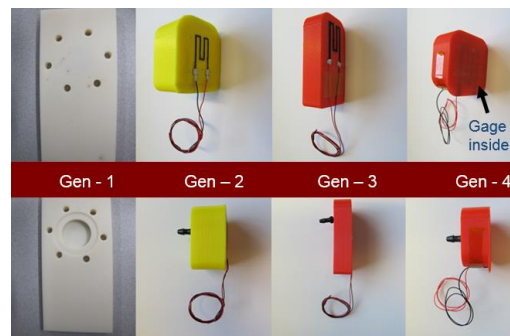


Recent Equipment Additions

- Ordered SPTS Primaxx HF Vapor Etch System
- Purchased 2 Benchtop 3D Printers
 - FDM and SLA
 - For Embedded Sensors
- Purchased Helios Dual Beam System
 - NSF EPSCoR
 - ebeam for imaging
 - Ga beam for patterning
- Pending purchase of NanoScribe System
- 2 MRI Proposals Submitted
 - UK - Transmission Electron Microscope for Cross-Disciplinary Research in Materials and Life Sciences
 - UofL - In-situ Liquid Cell Electrochemistry System and Cathodoluminescence Imaging System for Electron Microscopy Studies of Novel Energy Materials



Schematic illustration of HF vapor release etch

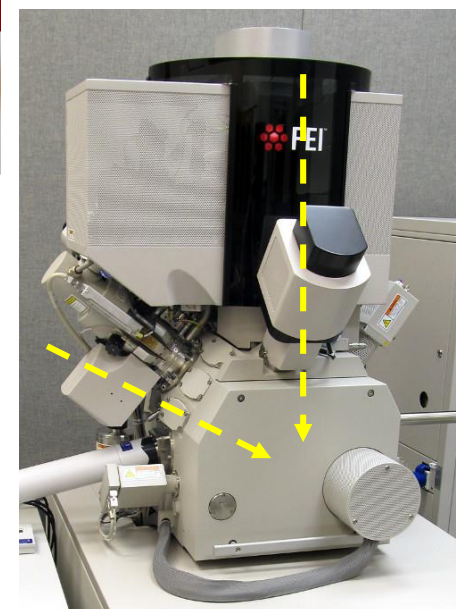


Initial Design
2-piece
leaky

1-piece
design
Low
leakage

1-piece
Optimized
cavity making
sensor thinner

1-piece
design with
internal
gage



Education and Outreach (E&O) Activities



NanoDays at the KY Science Center

NanoDays is an event introducing a variety of STEM careers and activities to our next-generation scientists and provides them the opportunity to interact with nanotechnology professionals. This career-focused science celebration features extra interactive micro/nano experiences, local professionals from or KY Multiscale-Manufacturing site (MMNIN), hands-on activities, and powerful demonstrations regarding micro-nanotechnology. This event is hosted annually at the Kentucky Science Center in partnership with MMNIN.



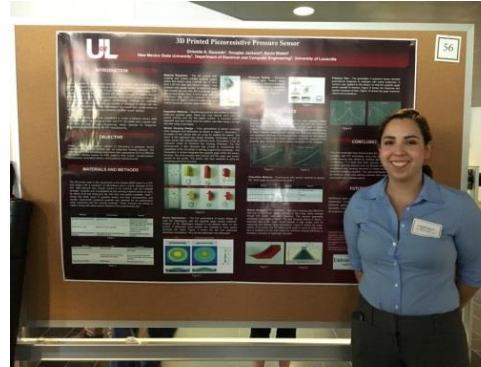


New REU Program in Micro/Nanotechnology

IMPACT

(Interdisciplinary Micro/nanotechnology Program Addressing Challenges Today)

Our student group includes several first generation college students from our Kentucky feeder colleges, 3 females, 1 Native American and 2 Hispanic students. Represented schools include Cornell, Virginia Tech, South Dakota School of Mines and Technology, New Mexico State, Furman, Morehead, Centre, Berea, and Bellarmine. All students receive a unique NNCI-related hands-on cleanroom experience where they each fabricate and test a photovoltaic device. In addition to that, all of the individual faculty-mentored research projects involve some aspect of micro/nanotechnology.



New Mexico State student at National REU Symposium in DC

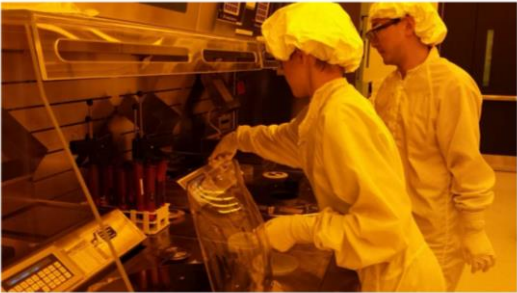


Research Experiences for Undergraduates

- Home
- Internship Application 2017 >
- Program Schedule >
- Program Activities >
- Research Projects >
- Housing >
- Faculty Mentors >
- City Attractions >
- Contact Us >
- Blog >
- Flyer REU 2017 >

Research Experiences for Undergraduates - Micro/Nano Manufacturing - Summer 2017

University of Louisville - Summer 2017 Research Experience for Undergraduates (REU) Program in Micro/Nano Technology Manufacturing and Engineering



Micro/Nano Technology Center - Photoresist Coating

Summer 2017 Application NOW Open! [Click here to apply](#)

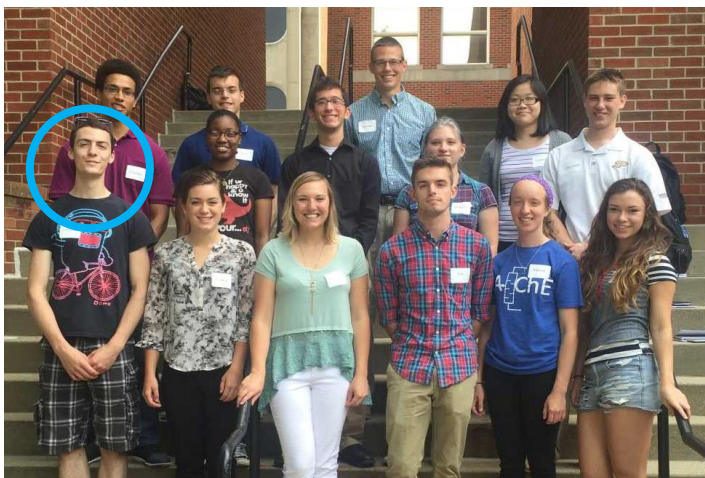
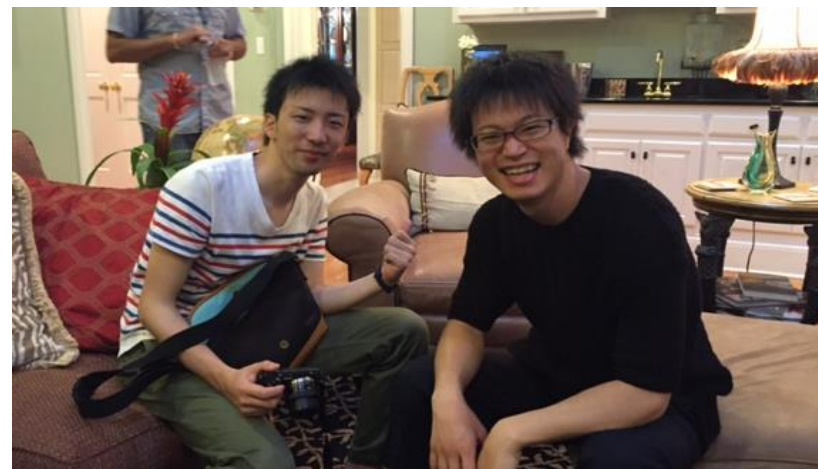




Japanese NIMS Graduate Exchange Program



Two graduate students were awardees of an internship by the Nanotechnology Platform of Japan for nanotechnology research in the United States during the summer of 2016. This program is administered by the National Institute of Materials Science in Japan (NIMS), and in the US by the National Nanotechnology Coordinated Infrastructure site at Cornell (NNCI-CNF) as a student exchange program between the Nanotechnology Platform and NNCI.



Cameron Spitzfaden (Alma College) presented his research entitled "Surface Plasmon Resonance Imager Using a Coded-Aperture Sensor" at the NSF Research Experiences for Undergraduates Symposium, October 2016.

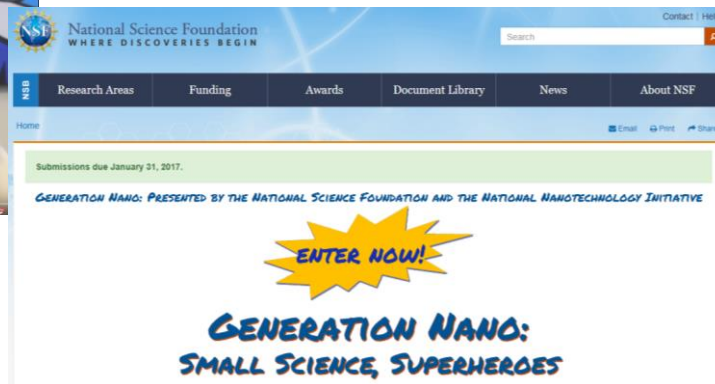
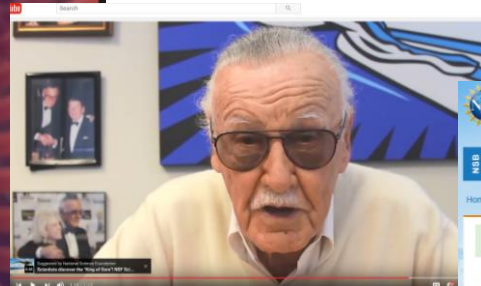
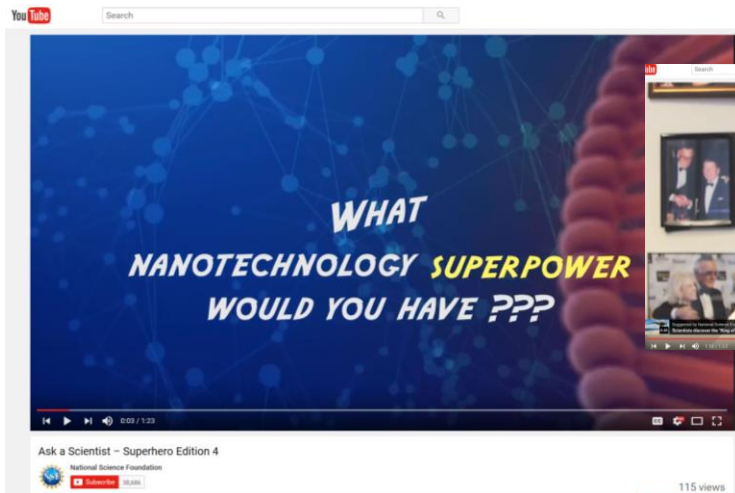


UK REU Program in Engineering Bioactive Interfaces and Devices

UK currently has a REU program in Engineered Bioactive Interfaces and Devices directed by Professor Kim Anderson. During the first week of the REU program, all students participate in a one day introduction to CeNSE and EMC capabilities and research goals. A number of these students are trained on the centers' instrumentation and continue as users throughout the course of the summer. Before the start of the NNCI award CeNSE and the EMC supported the research of several members of the 2015 cohort.



NSF "Ask a Nano Expert" and "Generation Nano" Initiatives



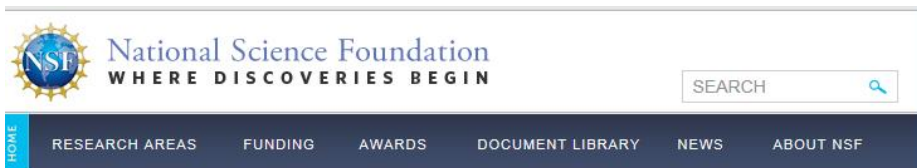
Participant and Judge

GENERATION NANO

Competition opens October 5, 2016. Entries are due by midnight, January 31, 2017. Entries should include a written piece, a 2-3 page comic and a short video.



NSF and NBC Learn “Science of Innovation” Videos



Science of Innovation (2016)



From 3-D bioprinting that could one day generate heart tissue to origami-inspired structures built for medicine and space exploration, a new set of educational videos continues an exploration begun [three years ago](#) inside the creative process that leads to innovation. Six new stories in the "Science of Innovation" video series highlight how innovation can turn fundamental science and engineering ideas into significant societal and economic impacts.

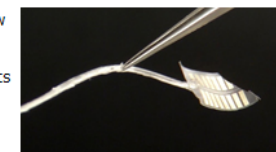
"Science of Innovation" is produced by NBC Learn in partnership with the National Science Foundation and the United States Patent and Trademark Office.

Dr. Angelique Johnson and MEMStim

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 \(5:02 min.\)](#)



One of 6 NBC Learn 5-min Videos



OUTREACH DATA SUMMARY	Middle School	High School	Undergrad Students	Graduate Students	Professional /Post Grad.	All ages
2016 Nanodays @ the Kentucky Science Center						~2000
UofL Summer REU Program			10			
Japanese NIMS Graduate Exchange Program				2		
MNTC Summer Camps		12				
Idea Festival Aerospace Conference						NA
Engineering Expo (UofL) / Engineering Day (UK)						~3000
CCRER Summer Camps		25				
CCRER High School Fair Mentoring		10				
CCRER Visiting Research Scholars					5	
CCRER Wastestock Challenge					15	
WaterStep				1		
RPC Prototyping ME capstone, rocket team, and 3D printing programs				~25		
University Innovation Fellow Program			4			
CeNSE and EMC UK REU Program training support			2			
UK's president's Summer Youth Program for outstanding minority students		2				
CeNSE and EMC nano-fabrication demonstrations	70					



Suggestions and Comments for the Future

John Shott of our Advisory Board

1. Diversity of User Population – It is often difficult to identify a “discipline” for each project since many projects these days are so interdisciplinary. The NSF might consider replacing “disciplines” with an agreed upon list of “application areas” based upon the NSF grand challenges.
2. Not penalize the smaller EPSCoR sites (Montana, Nebraska, Kentucky) for increasing their number of internal users when collecting site statistics. When evaluating the ratio of external users to internal users, perhaps use a constant baseline (year 1 for example) for the number of internal users in all calculations.

THE END