Directorate for Engineering Report

Pramod Khargonekar, NSF Assistant Director for Engineering

NSF Directorate for Engineering Advisory Committee Meeting

October 21, 2015

New ENG Advisory Committee Members

Gilda Barabino
City College of New York, CUNY

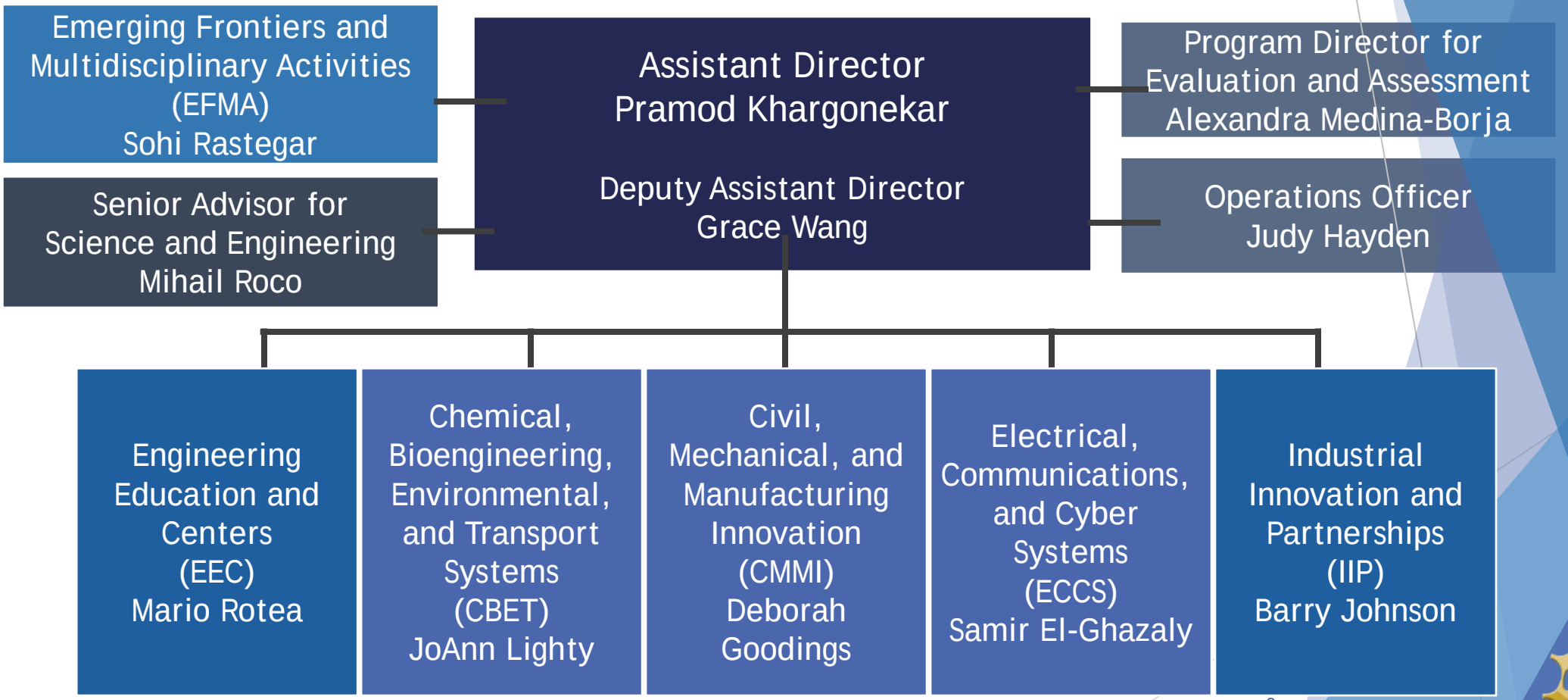
Susan Butts
Consultant, formerly Dow Chemical Company

Reggie DesRoches
Georgia Tech

Hank Foley
University of Missouri

Images courtesy Advisory Committee members

NSF Directorate for Engineering



CBET Staff Changes

- **Jaimie Greene**, STEP student
- **Caroline Hayer**, Program Specialist (formerly IIP)
- **José Lage**, Program Director for Thermal Transport Processes (Southern Methodist University)
- **Carole Read**, Acting Program Director for Chemical and Biological Separations (formerly EEC)
- **Brandi Schottel**, Engineering Analyst (formerly CBET AAAS Fellow)
- **Ariela Zycherman**, AAAS Fellow

CMMI Staff Changes

- **Cherrelle Dike**, Program Specialist
- **Donald Hearn**, Program Director (expert) for Service, Manufacturing and Operations Research (University of Florida)
- **David Mendonça**, Program Director for Infrastructure Management and Extreme Events (Rensselaer Polytechnic Institute)
- **Kara Peters**, Program Director for Mechanics of Materials and Structures (North Carolina State University)

ECCS Staff Changes

- **Dominique Dagenais**, Acting Deputy Division Director
- **Alireza Khaligh**, Program Director (expert) for Energy, Power, Control, and Networks
- **Kerstin Mukerji**, Science Analyst
- **John Zavada**, Program Director (expert) for Electronics, Photonics, and Magnetic Devices

EEC Staff Changes

- **Mario Rotea**, Division Director (University of Texas at Dallas)
- **Elliot Douglas**, Program Director for Engineering Education (University of Florida)
- **Tammie Jennings**, Program Specialist (on detail from CMMI)
- **Pamela Hanson**, AAAS Fellow
- **Marshall Horner**, Acting Operations Specialist
- **Ashley Huderson**, AAAS Fellow
- **James Moore**, Program Director for Broadening Participation in Engineering (Ohio State University)

IIP Staff Changes

- **Carl Anderson**, Program Analyst
- **Eric Keys**, AAAS Fellow
- **Dawn Patterson**, Program Analyst
- **Debasis Majumdar**, Program Director for Industry/University Cooperative Research Centers (Saint-Gobain Performance Plastics)

Open Recruitments

ECCS

- Division Director

CBET

- Program Director for Biomedical Engineering
- Program Director for Biotechnology and Biochemical Engineering
- Program Director for Chemical and Biological Separations
- Program Director for Innovations at the Nexus of Food, Energy and Water Systems

Open Recruitments

CMMI

- Program Director for Manufacturing Machines and Equipment
- Program Director for Materials Engineering and Processing
- Program Director for Mechanics of Materials and Structures
- Program Director for Structural and Architectural Engineering
- Program Director for Systems Science and for Engineering and Systems Design

Open Recruitments

EEC

- Program Directors for Engineering Research Centers

IIP

- Program Director for Innovation Corps

Engineering Directorate Report

ENG Budget

	FY 2014 Actual*	FY 2015 Current Plan	FY 2016 Request	Change over FY 2015 Current Plan	
				Amount	Percent
CBET	$167.76	$177.82	$192.26	$14.44	8.1%
CMMI	195.23	209.52	222.73	13.21	6.3%
ECCS	100.37	110.43	119.24	8.81	8.0%
EEC	119.50	117.49	110.39	-7.10	-6.0%
IIP	205.99	226.98	248.11	21.13	9.3%
SBIR/STTR	*159.99*	*177.11*	*194.36*	*17.25*	*9.7%*
EFMA	44.27	50.07	56.49	6.42	12.8%
ENG TOTAL	$833.12	$892.31	$949.22	$56.91	6.4%

* FY 2014 actuals were adjusted to reflect EFMA reallocations in order to facilitate comparison across fiscal years.

ENG FY 2015 by the Numbers

ENG, FY 2015	
Current Plan	$892M
Competitive Research Proposals	9,331
Research Awards	1,851
Funding Rate	20%

Engineering Research

Engineering Programs

- Goal: enable frontier engineering research in core programs
  - Refresh of program descriptions
  - Reorganization of clusters within Divisions

- Goal: engineering to support national priorities
  - Support Foundation-wide Initiatives
  - Position engineering programs for societal needs and grand challenges

Advanced Manufacturing – Key National Priority

- Strategic directions
  - **Advanced biomanufacturing**
  - **Cybermanufacturing**
  - **Scalable nanomanufacturing**
- PCAST Recommendation from AMP 2.0: mechanism for academic-industry input on future manufacturing technologies
  - Joint solicitation by NSF and NIST in 2015
  - Award to University of Michigan at Ann Arbor: MForesight – Alliance for Manufacturing Foresight
- I/UCRC in manufacturing

Advanced Manufacturing

Cellular Biomanufacturing

- FY 2015: $3.7M for 13 high-risk, high-impact research projects on the manufacturing of cells and cell-based products for future healthcare.
- Fundamental research on:
  - Novel cell expansion, differentiation, characterization, monitoring, isolation/separation methodologies
  - Reproducible, robust cellular biomanufacturing processes

Controlling stem cell behavior via novel photo activation of FGF signaling pathway using blue light

Lee, Johns Hopkins

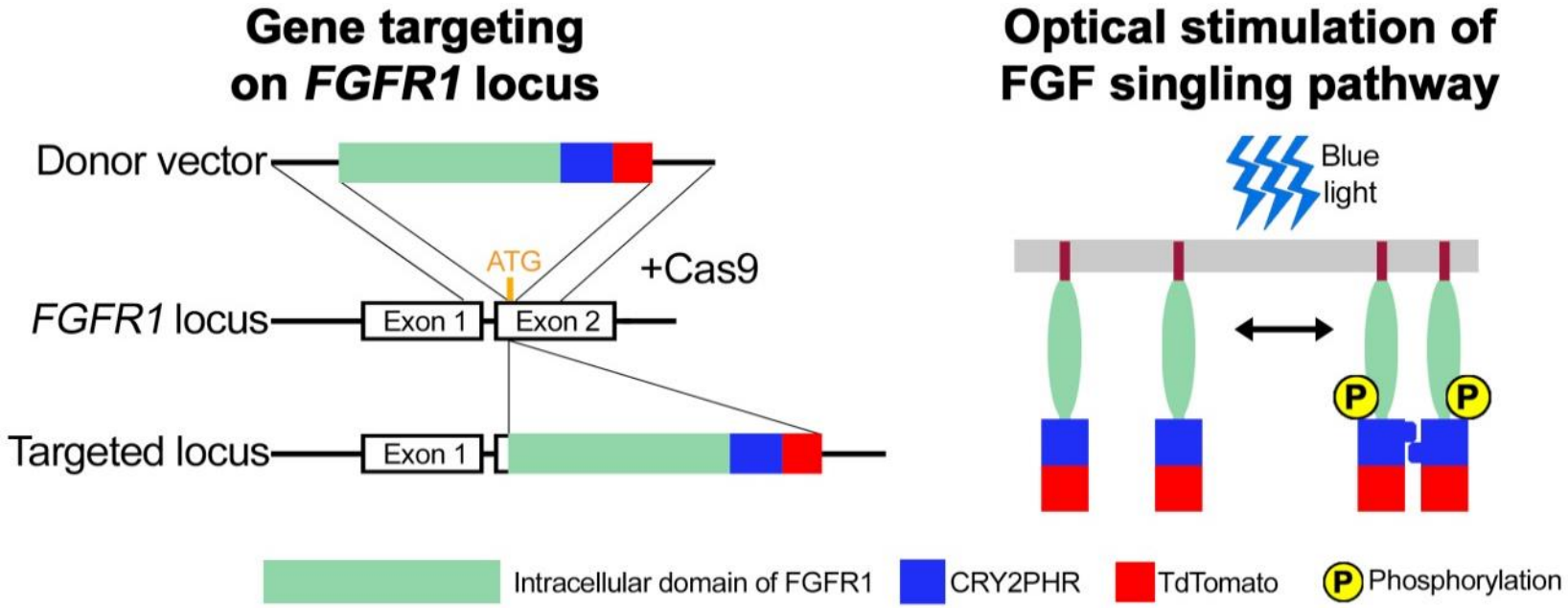


Image credit: Lee, Johns Hopkins

Advanced Manufacturing

Cybermanufacturing

- Context: Factory of the future, Internet of things, supply chains, …
- FY 2015: $6.5M for 30 research projects to explore manufacturing research in the internet age
- Collaboration between ENG and CISE
- Key themes: production-as-a-service, manufacturing apps and operating systems, interoperability, manufacturing exchanges, security, predictive analytics

Design of an Agile and Smart Manufacturing Exchange

Chakrabbarty, Maggs and Zavlanos, Duke University

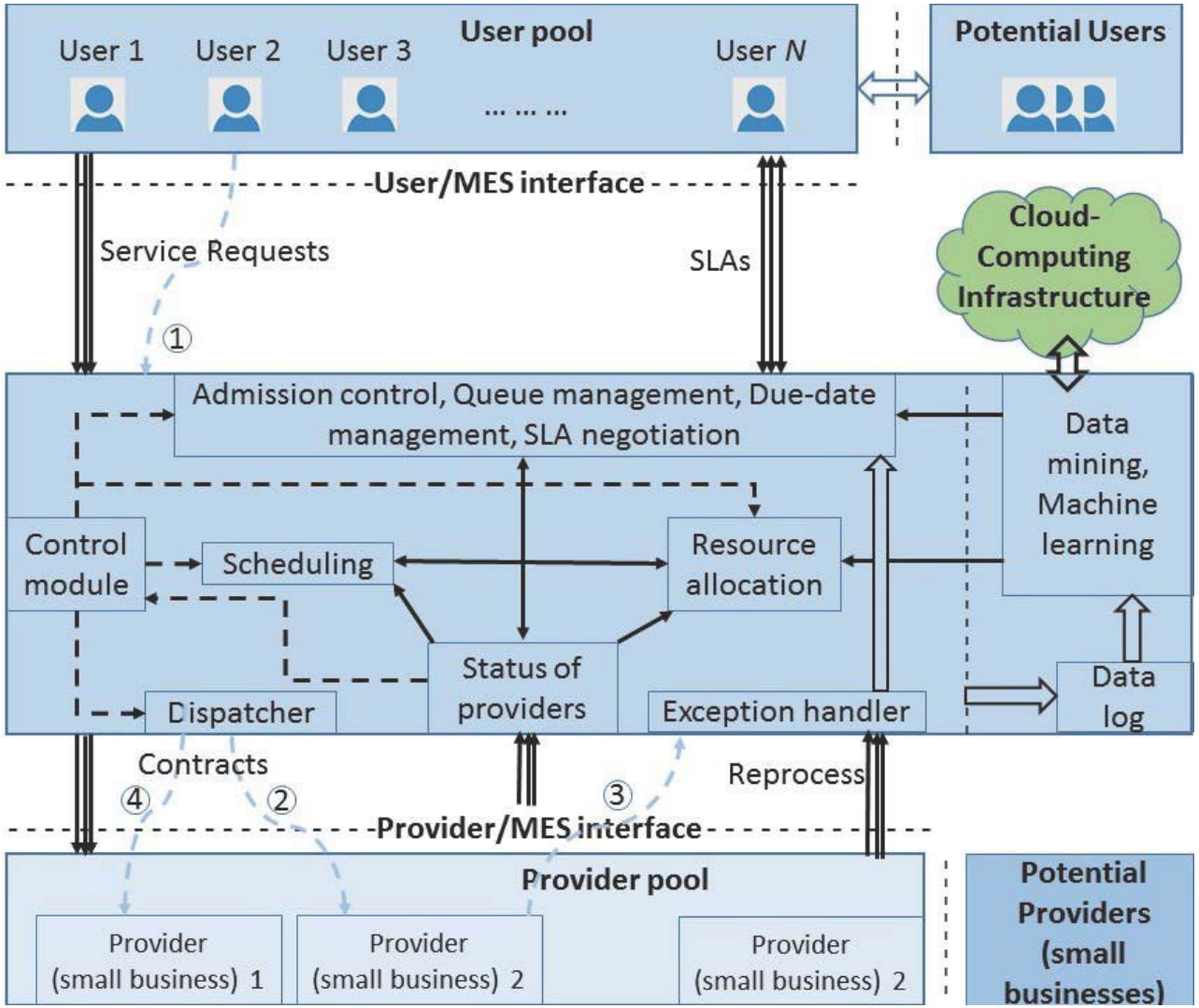
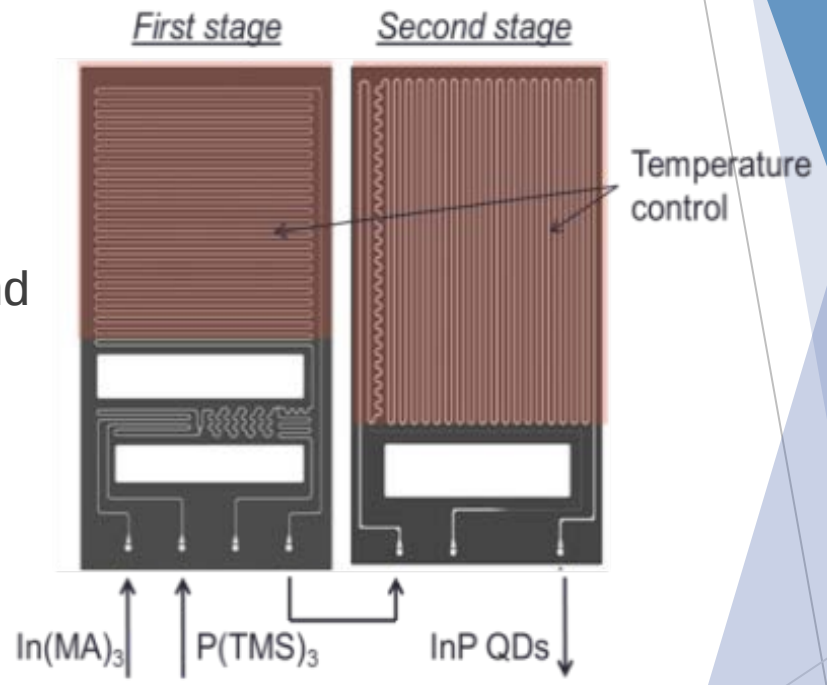


Image credit: Chakrabbarty, Maggs and Zavlanos, Duke University

Advanced Manufacturing

Scalable Nanomanufacturing

- Overcome critical scientific and engineering barriers that prevent the production of useful nanomaterials, nanostructures, devices and systems
- Address scale-up, large-area, continuous, parallel, and roll-to-roll
- Encourage industrial collaboration
- Address nanomanufacturing value chain
- FY 2015: $9.8M for 7 projects
- Collaboration between ENG and MPS



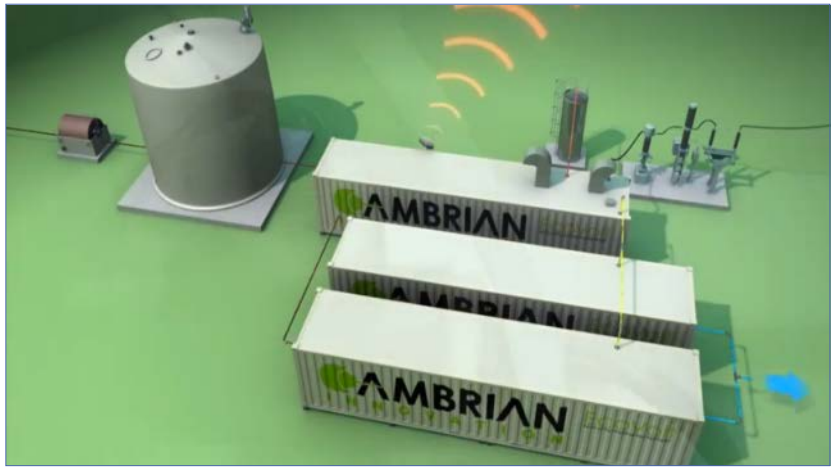
Microreactor for quantum dots. *Image credit: Jensen, MIT*

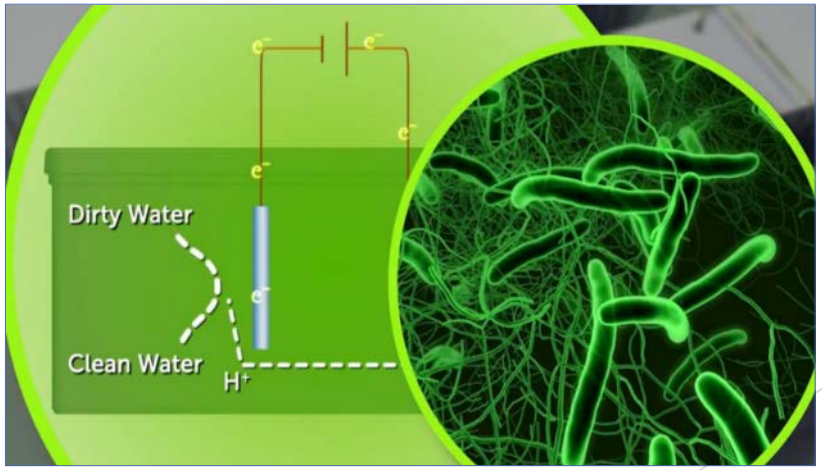
Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS)

- By 2050, world population projected at 9 billion and US population 400 million
- Greater demand for energy, water, and food
- Increased variability in precipitation and temperatures
- Goal: To understand, model, design, and manage the interconnected food-energy-water (FEW) system
  - quantitative and computational modeling
  - real-time, cyber-enabled interfaces
  - basic research for innovative system and technological solutions
  - scientific workforce capable of studying and managing the FEW system

Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS)

- FY 2015: SEES Food-Energy-Water workshops and research supplements
  - 17 workshops and 40 supplemental awards
- FY 2016: Proposed Launch of INFEWS
  - DCL on Nitrogen, Phosphorus, and Water (ENG and MPS)
  - INFEWS as an emphasis area for NSF Research Traineeship (NRT)

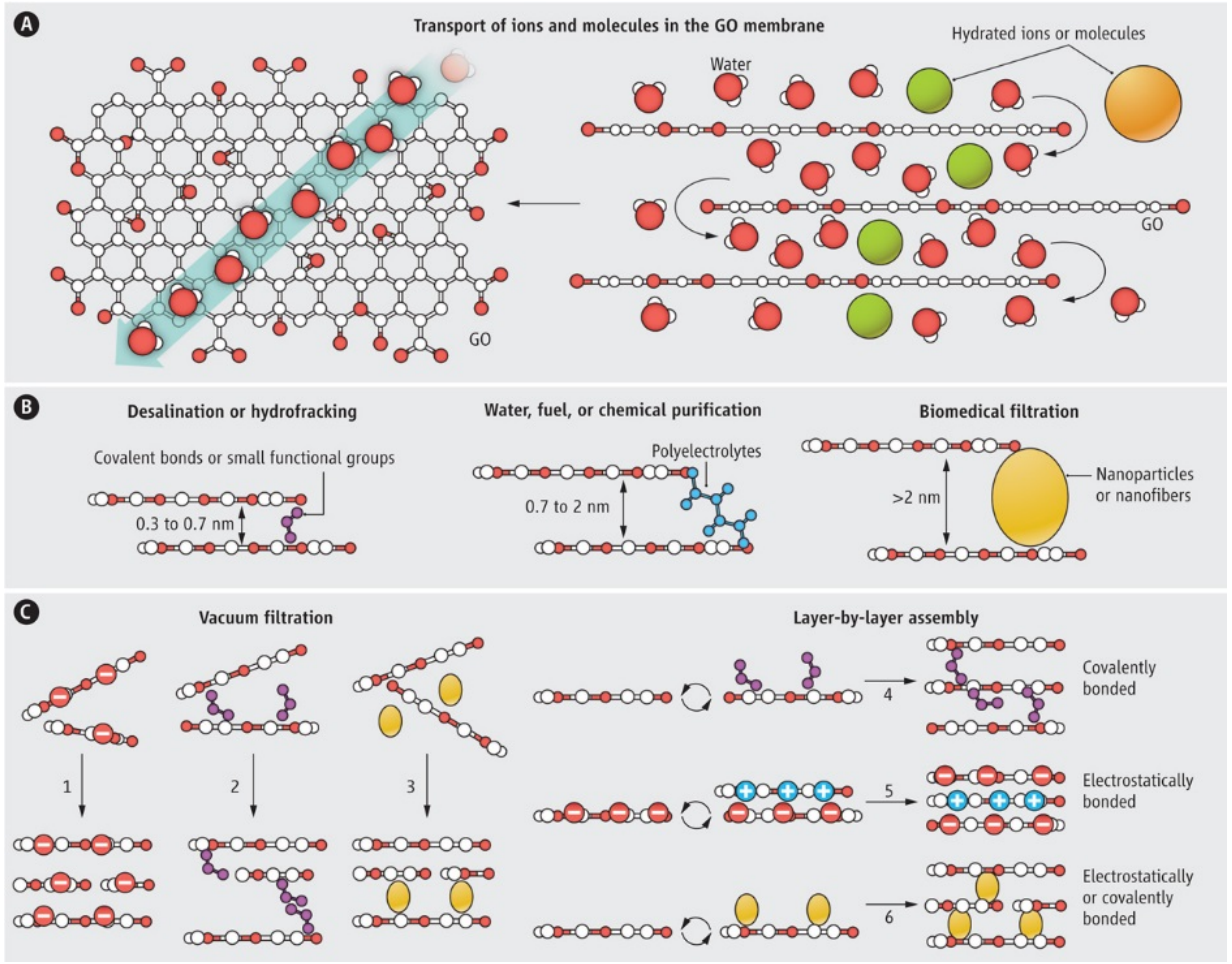




Images courtesy Cambrian Innovation

Graphene Oxide Membranes for Ionic and Molecular Sieving

Baoxia Mi, University of California, Berkeley



- Sieving membranes that enable fast solute separations from aqueous solutions essential for water purification and desalination, sensing, and energy production.
- A fundamentally new class of sieving membranes by stacking graphene oxide (GO) nanosheets.

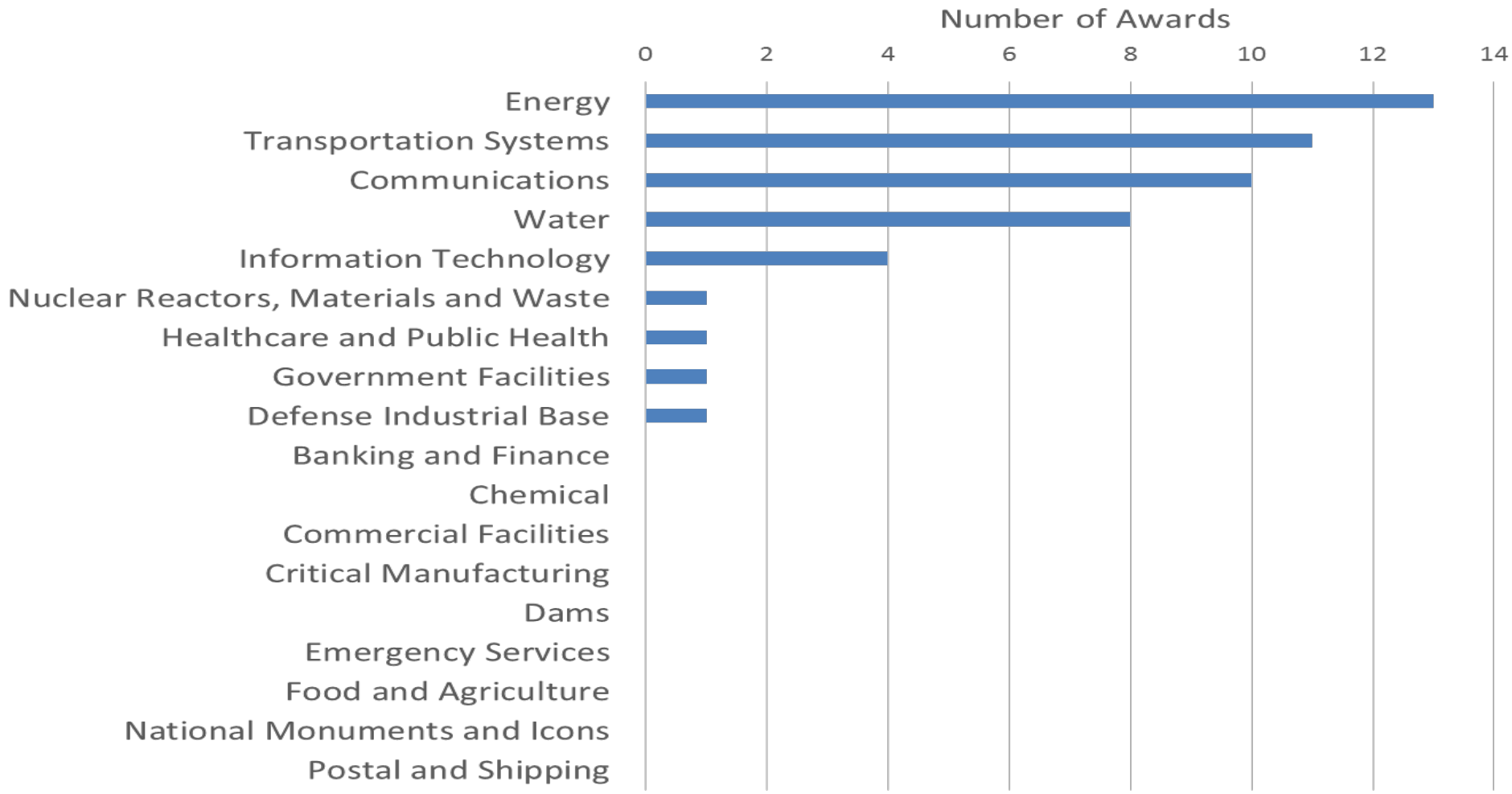
Image credit Baoxia Mi, University of California, Berkeley

Risk and Resilience

Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP)

- Goals:
  - To gain new knowledge that will improve resilience, interoperations, performance and readiness in Interdependent, Critical Infrastructures (ICIs);
  - To understand the variety of societal obstacles to improving ICIs; and
  - To identify technologies and strategies for overcoming these obstacles.
- FY 2015: launched CRISP with $20M in 12 projects
  - Collaboration between ENG, CISE, and SBE

Targeted Infrastructures in CRISP Awards



Smart and Connected Communities

- To intelligently and effectively design, adapt and manage the smart and connected communities of the future
- To enable more livable, workable, sustainable, and connected communities

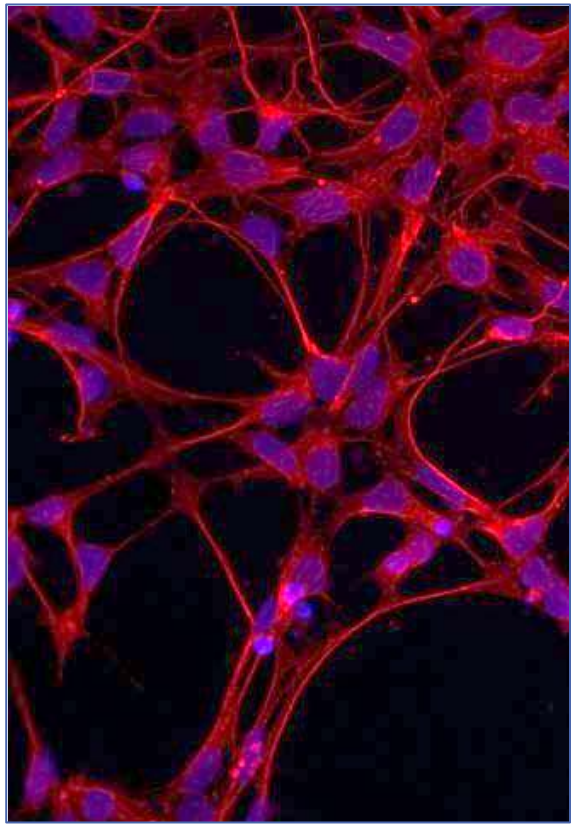
- Builds on Cyber-Physical Systems (CPS), CRISP and Smart Service Systems (under PFI:BIC) programs
- Dear Colleague Letter: Supporting Research Advances in Smart and Connected Communities (NSF 15-120)
  - Collaboration between ENG, CISE, EHR, GEO, and SBE

Large-scale Integration of Renewables into the Power Grid

- Create new foundational knowledge
  - Dear Colleague Letter: Research on Theory and Analytical Tools for Power Networks with High Levels of Renewable Generation (NSF 15-082)
- Provided $4M for 14 EAGER projects
  - System dynamics, stability and control methods
  - Electricity generation and demand scheduling
  - Market design
  - System protection

Solar panels at Arizona State University, home of the NSF ERC for Quantum Energy and Sustainable Solar Technologies (QESST). *Image credit: NSF*

Understanding the Brain (UtB)



Understanding how brain cells form may tell us how the structure of neural networks relates to their function. Shown here are young cells (red) two weeks into their transformation into neurons. *Credit: Arun Mahadevan, Qutub Lab, Department of Bioengineering, Rice University*

- Enable scientific understanding of the full complexity of the brain in action and in context
- ENG: Innovative neurotechnologies and tools, approaches, theories and models
  - Aligns with President's BRAIN Initiative
- Integrative Strategies for Understanding Neural and Cognitive Systems (NCS)
  - Collaboration between ENG, CISE, SBE, and EHR
  - NSF provided $13M in FY 2015 for 14 projects
    - Neuroengineering and brain-inspired concepts and designs
    - Individuality and variation

Engineering Biology

- Context
  - NSF investments in metabolic engineering and synthetic biology
  - NAS Report on Industrialization of Biology
- Engineering Biology: The ability to predict the behavior of and design complex biological systems
- Research needs:
  - Understand the physical, chemical and biological principles that govern life
  - Improve tools, techniques and methodologies for prediction and design
  - Enable scaling-up, usability, interoperation, safety, security, and ethics
  - Develop a future workforce with interdisciplinary education and training
  - Address challenges in advanced manufacturing to ensure future US competitiveness

Optics and Photonics

- Integrated Photonics Institute for Manufacturing Innovation established in New York in July 2015
  - Collaboration between DoD, NIST, DoE, NASA, and NSF
- Dear Colleague Letter: Optics and Photonics (NSF 16-004) published October 2015
  - Collaboration between ENG, BIO, CISE, and MPS
    - Optogenetics, imaging, and diagnostics
    - Novel optoelectronic and photonic devices, ultrafast lasers, and optical communications systems architectures
    - A separate topic area in SBIR/STTR programs

EFRI: Advancing Communication Quantum Information Research in Engineering (ACQUIRE)

- **Key Idea: Address key engineering research challenges to enable secure, scalable quantum communication networks**
  - Room temperature single photon sources, detectors, memories, repeaters and other low-energy photonic components
  - Scalable on-chip integration of quantum photonics with silicon electronics
  - Leveraging novel engineered materials, quantum structures, and devices
  - Potential impact on ultra secure communication network and other capabilities impossible to achieve with classical technology

Related to the National Strategic Computing Initiative

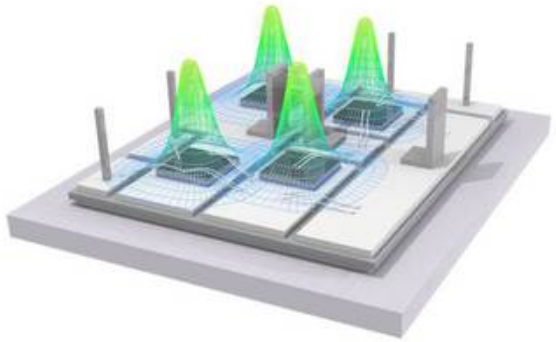
EFRI: New Light & Acoustic Wave Propagation (NewLAW)

- **Key Idea: Breaking symmetries and challenging fundamental laws governing wave motion and field transport**
  - Disruptive approach to design of electronic, photonic and acoustic devices, and enabler of totally new functionalities
  - Acoustic technologies, such as soundproofing and sonar stealth systems, energy absorbing materials, and imaging
  - Integrated nanophotonic elements based on topological insulators, full-duplex wireless communications

Engineering Research Centers (ERCs)

- FY 2015: Launched 3 new ERCs

Compact mobile power

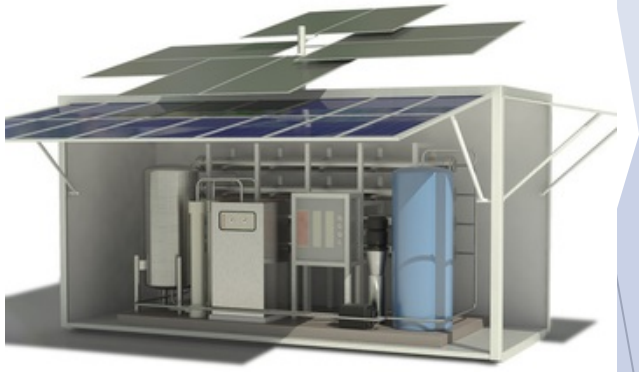


ERC for Power Optimization for Electro-Thermal Systems (POETS), led by the University of Illinois at Urbana-Champaign

Nature-inspired soil engineering

ERC for Bio-mediated and Bio-inspired Geotechnics (CBBG), led by Arizona State University

Off-grid drinking water



Nanosystems ERC for Nanotechnology Enabled Water Treatment Systems (NEWT), led by Rice University

- New ERC Competition launched in August 2015, new awards in 2017

Image credits (L to R): Professor Alan Mantooth at University of Arkansas; CBBG/Arizona State University; NEWT/Rice University.

The Future of Center-Based, Multidisciplinary Engineering Research

- New award to NAS to study the future of center-scale research in engineering
- Key Questions:
  - What models might most effectively enable breakthrough engineering research and discoveries that require center-scale investment considering the convergence of physical science, engineering and life science?
  - What educational models of center-based engineering research programs are best suited to creating a more diverse, internationally aware, and flexible engineering talent pool that is capable of addressing complex, real-world problems?
  - What academic-industry partnership models might most effectively promote advances in use-inspired basic and translational research, accelerate technology commercialization, and strengthen the broader innovation ecosystem?
  - What metrics can be used to define successes and risks of such center programs?

Education and Career Development

INCLUDES: Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science

- Aims to achieve scale for inclusion in STEM
- Collective impacts and collaborative networks
- Director's Workshop, June 3, 2015
  - Learn from and build on existing successes
  - Wide ranging partnerships involving "more than the usual suspects"
  - Shared measurements and systematic networked coordination, collaboration and leveraging
  - National agenda with sensitivity to local differences
  - Connect research and practice of "science of broadening participation"

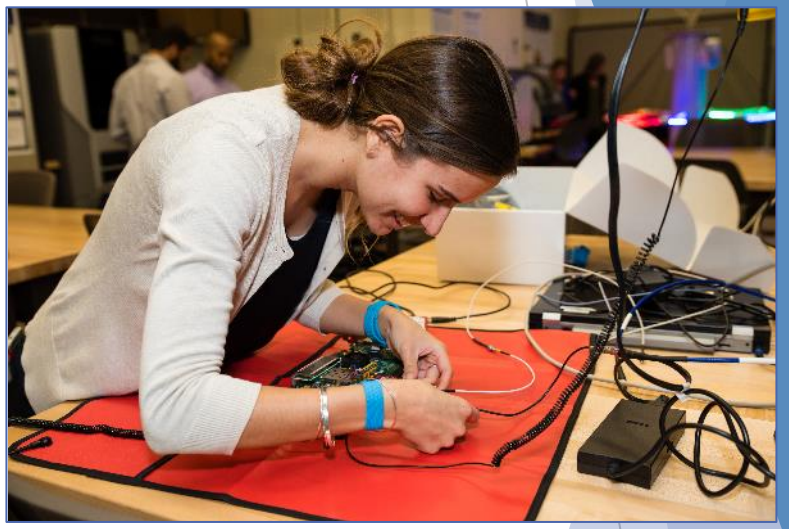
INCLUDES: Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science

- FY 2015
  - Stakeholders convened
  - Research synthesized
- FY 2016 Request: $15M
  - Launch Pilots
  - Ideas Labs and workshops

Engineering Education
Professional Formation of Engineers

Strategically create and support an innovative and inclusive engineering profession for the 21st Century

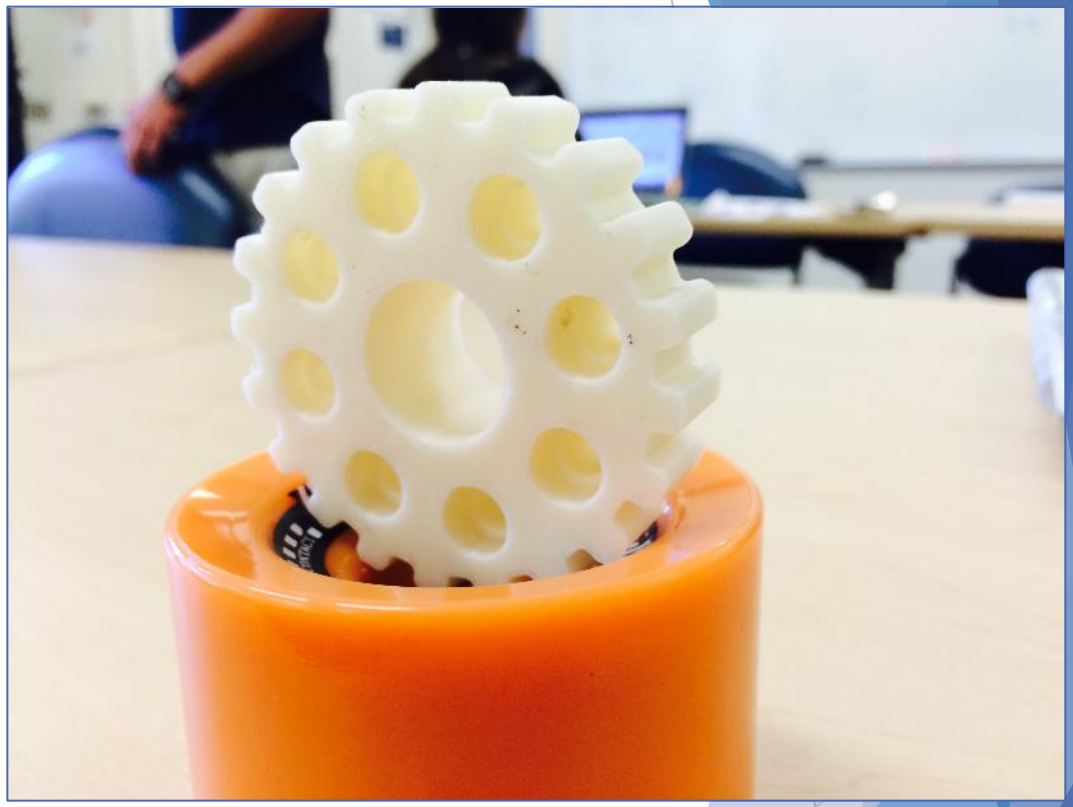
- IUSE/REvolutionizing engineering and computer science Departments (RED)
  - Collaboration between ENG, CISE, and EHR
- Research in the Formation of Engineers
  - Evolution from Research in Engineering Education
- Research Initiation in Engineering Formation (RIEF)



A student works on circuit board project at the University of San Diego, chosen as one of six engineering departments chosen for a RED award. *Credit: University of San Diego*

Engineering and Making

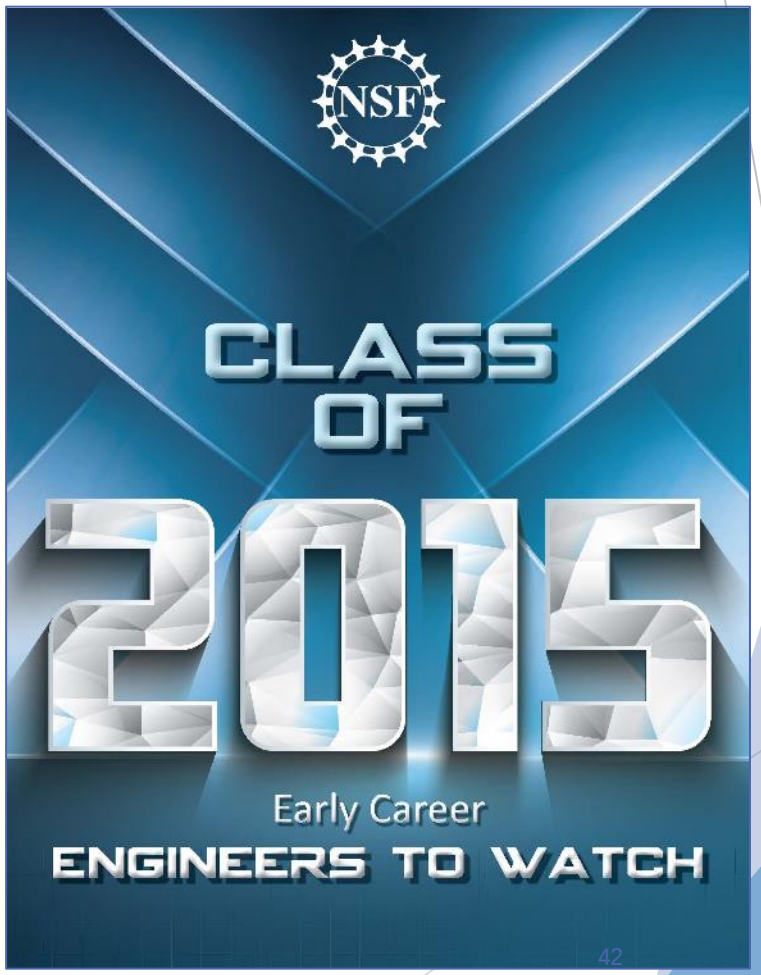
- Dear Colleague Letter (NSF 15-086): Call for EAGER proposals to advance knowledge with respect to STEM learning and design thinking
  - ENG, CISE and EHR collaboration
- Maker Summit, November 2-3, 2015



Students learn technical skills through making-related activities. Credit: Tasha Kawamata, University of Hawaii, and Jacob Tyler, Kapiolani Community College

Engineering CAREER by the Numbers, FY 2015

FY 2015	
Total Funding	$73M
CAREER Proposals	856
CAREER Awards	146
CAREER Funding Rate	17%



Graduate Education in Engineering

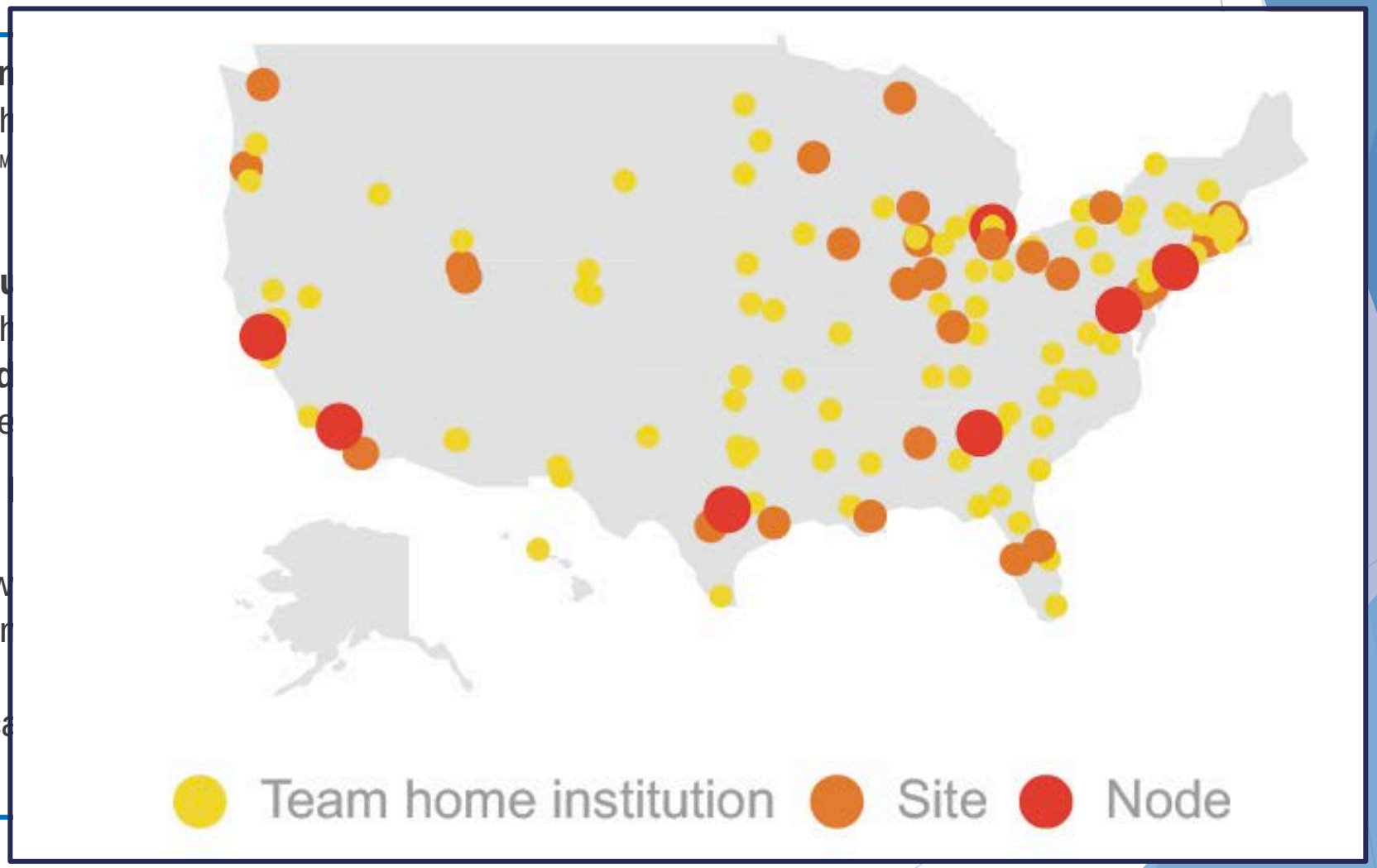
- Great interest at NSF and across agencies in graduate education in science and engineering
- NSF investments:
  - Graduate research fellowships program (GRFP)
  - NSF Research Traineeships (NRT)
  - Graduate research assistantships on research grants
- **What are the most critical issues in graduate engineering education?**
- **What role should NSF ENG play?**

Innovation

7 Nodes provide entrepreneurial learning environments and curriculum development

36 Sites leverage existing entrepreneurial activities

- More than **500 tean** and **1,600 people** h completed I-Corps™ training
- **261 I-Corps™ startu** have raised more th **$49 million in fund** from outside source
- **176 teams** to date reported new collaborations betw their universities ar industry, investors, and/or state or loca governments



I/UCRC Challenge Clusters

- **Advanced materials manufacturing**
  - Partnership of three I/UCRCs with one ERC
  - Embedding self-powered sensors into rubber and plastics in vehicles
- **Energy efficiency in data centers**
  - Partnership of two I/UCRCs, Lawrence Berkeley National Laboratory, and additional universities
  - Managing DC-powered data centers holistically and efficiently
- **Water quality**
  - Partnership of two I/UCRCs with one ERC and additional industry partners
  - Focusing on the development and manufacturing of nanomaterial water filters, sensors, and intelligent maintenance for reliable water quality

Research and Education Facilities

National Nanotechnology Coordinated Infrastructure (NNCI)

FY 2015 – FY 2025 Investment

- FY 2015: $81M initial investment for university user facilities with fabrication and characterization tools, instrumentation, and expertise in nanoscale research
  - 16 sites awarded
  - Serves academia, government, and companies large and small
  - Builds upon National Nanotechnology Infrastructure Network (NNIN)
- FY 2016: Coordination award to be selected

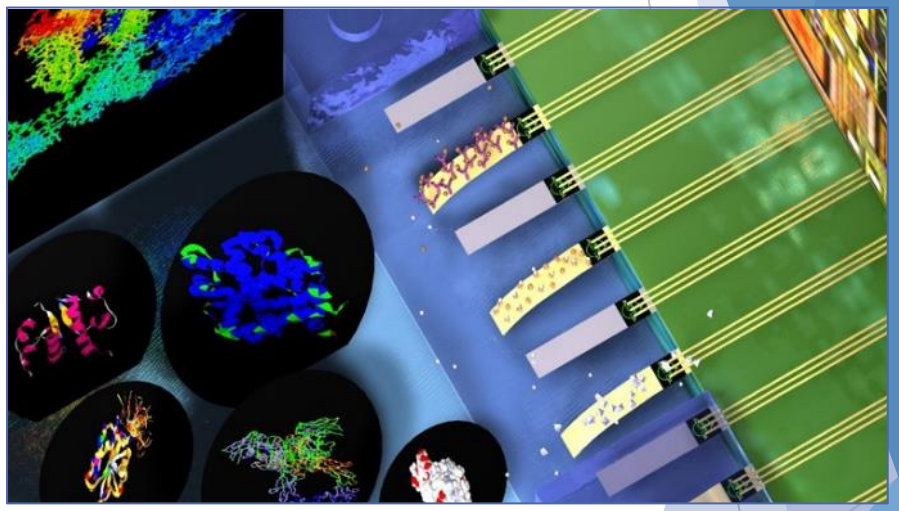
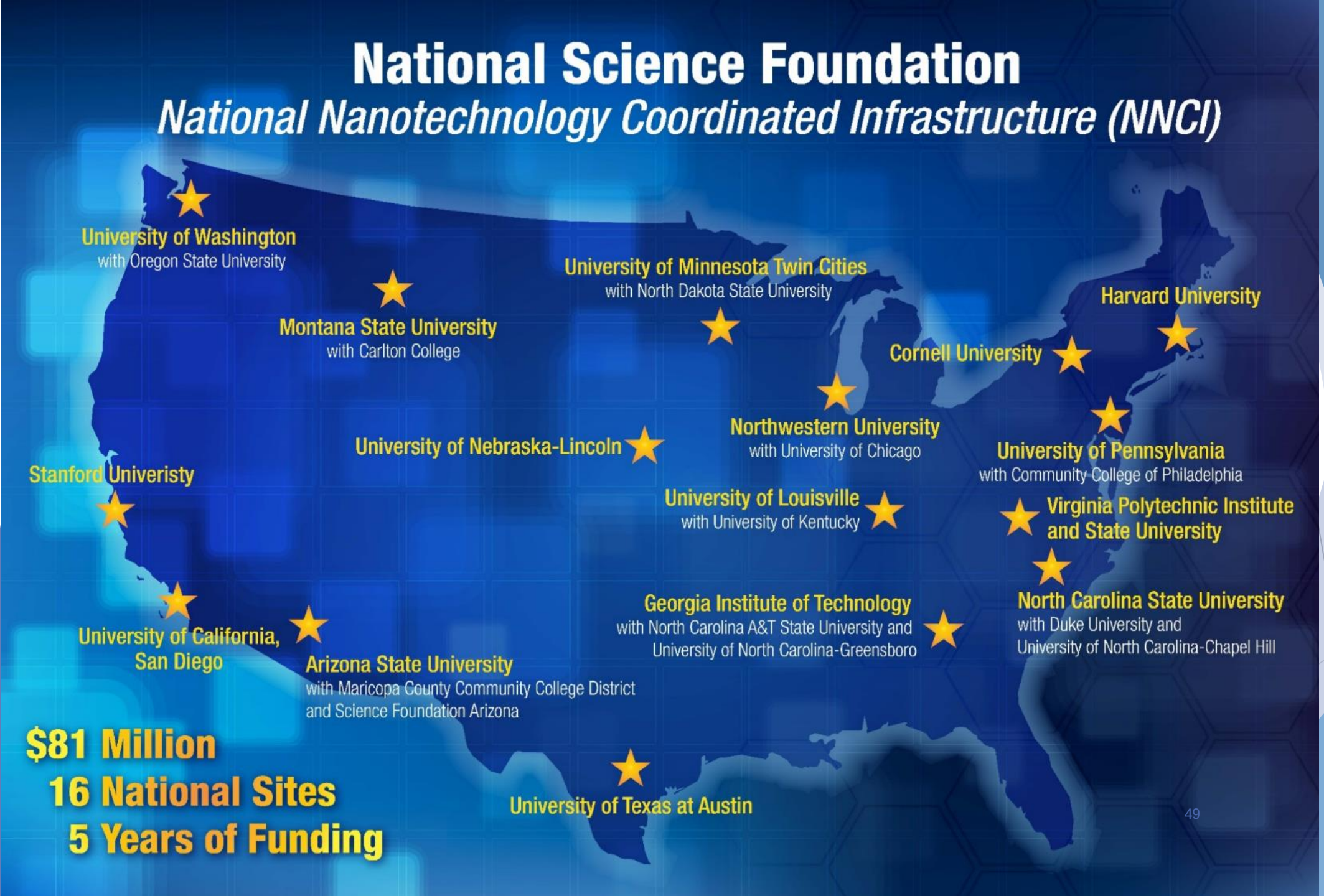


Illustration of nanotechnology for biomolecular sensing. Image Credit: Northwestern University Atomic and Nanoscale Characterization Experimental Center.

National Science Foundation

National Nanotechnology Coordinated Infrastructure (NNCI)



$81 Million
16 National Sites
5 Years of Funding

Natural Hazards Engineering Research Infrastructure (NHERI)

FY 2015 – FY 2025 Investment

Boundary layer wind tunnel. Image Credit: John Jernigan, University of Florida.

- $40M initial investment in multi-hazards research facilities, cyberinfrastructure and tools to address the national need for resilience
  - FY 2015: One cyberinfrastructure and seven experimental facilities awarded
  - FY 2016: Competition for coordination office, simulation center, and rapid-response research capability

Operations

Broader Impacts

- Merit review has two criteria:
  - Intellectual merit
  - Broader impacts
- COV feedback on broader impacts indicates need for clarity
  - Initial plan: community workshops in CMMI and ECCS
- **What should NSF ENG do to achieve greater broader impacts?**

Compliance Checking

- ENG effort to standardize compliance checking criteria and streamline process
  - Complements automated compliance checking improvements in FastLane
  - Provided training to ensure consistency in compliance checking practice
  - Released a DCL on July 14, 2015 to increase PI awareness
- Early indications
  - RWR rate dramatically decreased
  - Compliance checking time significantly reduced
  - Administrative professionals and program directors report high confidence in quality control

Compliance Checking Challenges

Interpretation of GPG language

Inconsistency in practice

Heavy NSF administrative burden

Confusion and frustration among Principal Investigators

Reproducibility of Engineering Research

- NSF Director's Symposium on Robust and Reliable Science: The Path Forward, held September 2015
- Initiating a review of Data Management Plan among Program Directors to seek discipline-appropriate approaches for open access of data
- Supports the development of infrastructure for the sharing and curation of data, samples, specimens, methods, or analytical tools
  - through Natural Hazards Engineering Research Infrastructure, Network for Computational Nanotechnology, and other activities

- **What is the nature of reproducibility/reliability problem in engineering research?**
- **What should NSF ENG do in this regard?**

Expanding Public Access to the Results of Federally Funded Research

Within six months agencies will develop plans to increase public access to scientific publications and scientific data in digital formats…

OSTP, 02/22/2013

Access to publications

- Applies to journal articles and juried conference papers funded from proposals submitted after January 2016 (PAPPG)
- Requires public access no later than 1 year after publication
  - Shared via the NSF Public Access Repository, hosted by DOE/OSTI
  - Integrated into annual and final report process
  - Reported with a persistent identifier

Access to data

- Retains current Data Management Plan (DMP) requirement
- Plan to have baseline data to support revisions of DMP guidelines in 2016
- Main question for ENG: **What constitutes data in ENG research?**

Discussion Questions

- Graduate education
- Broader impacts
- Reproducibility/reliability of research
- Public access to data

Thank you