NSF Overview of Additive Manufacturing for Health

NSF Workshop on Additive Manufacturing for Health
March 17-18, 2016

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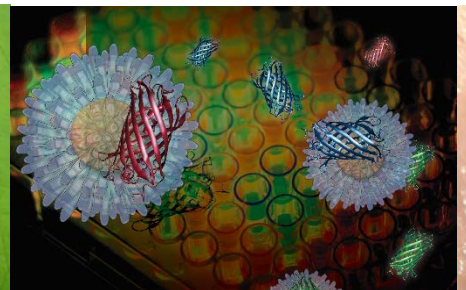


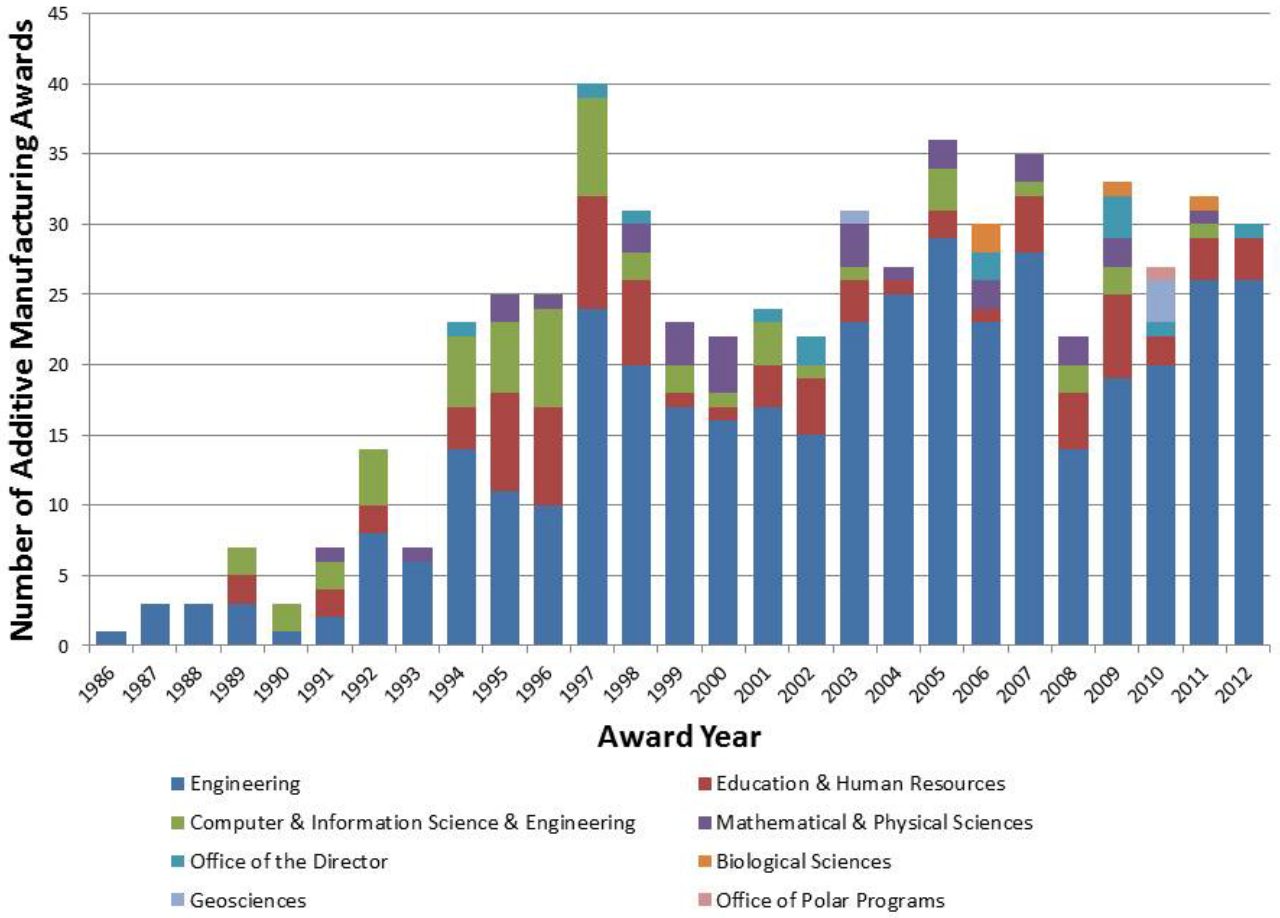

NSF Role in Additive Manufacturing (AM/3DP)

- Identify and support cutting-edge fundamental research in engineering and science

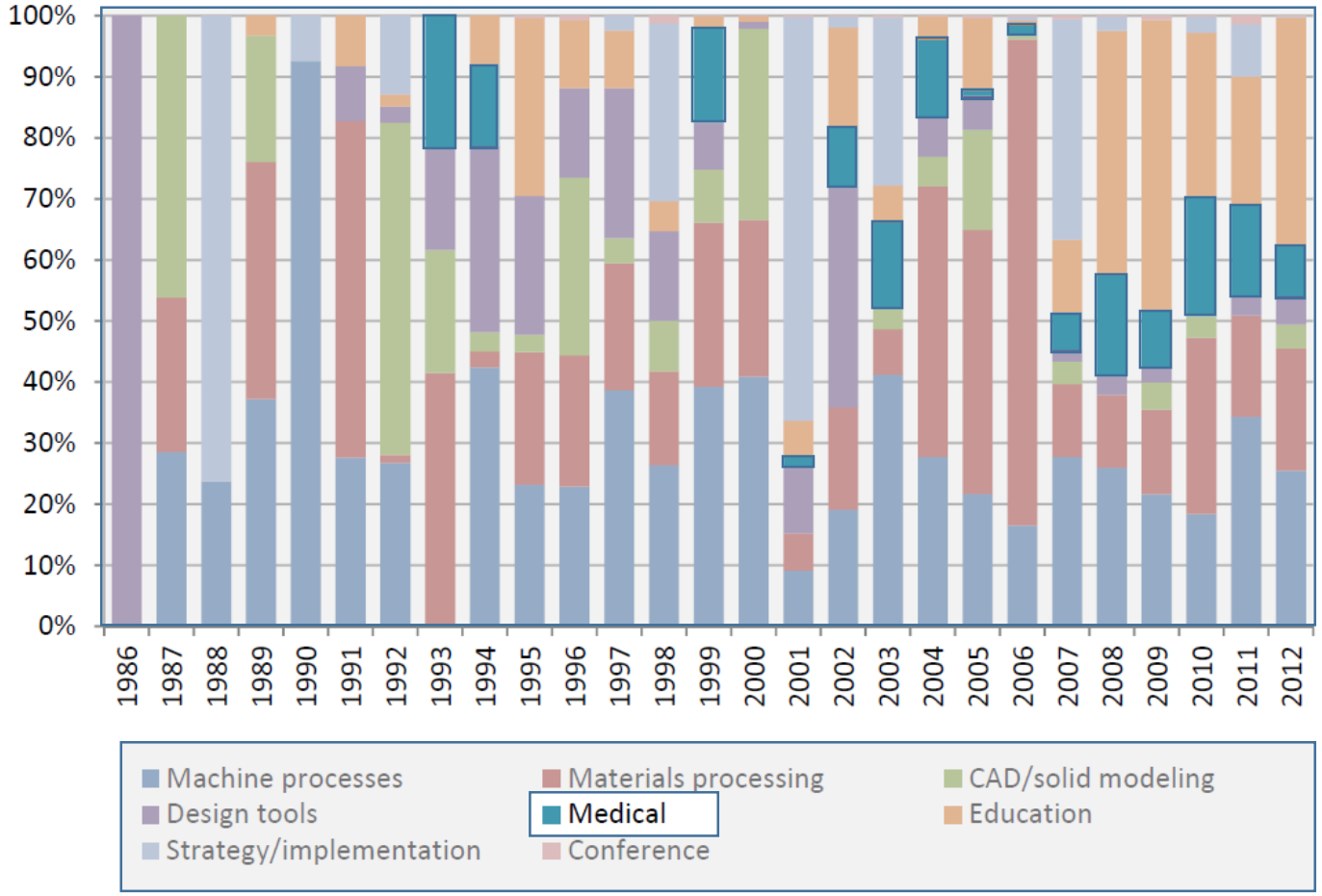
- Educate the next generation of engineers and scientists for manufacturing innovations and workforce development

History of NSF Support for AM/3DP

- NSF laid the foundations of Additive Manufacturing in the 1980s
- 2014 & 2015 - ~$56.3M in new awards to support AM/3DP research

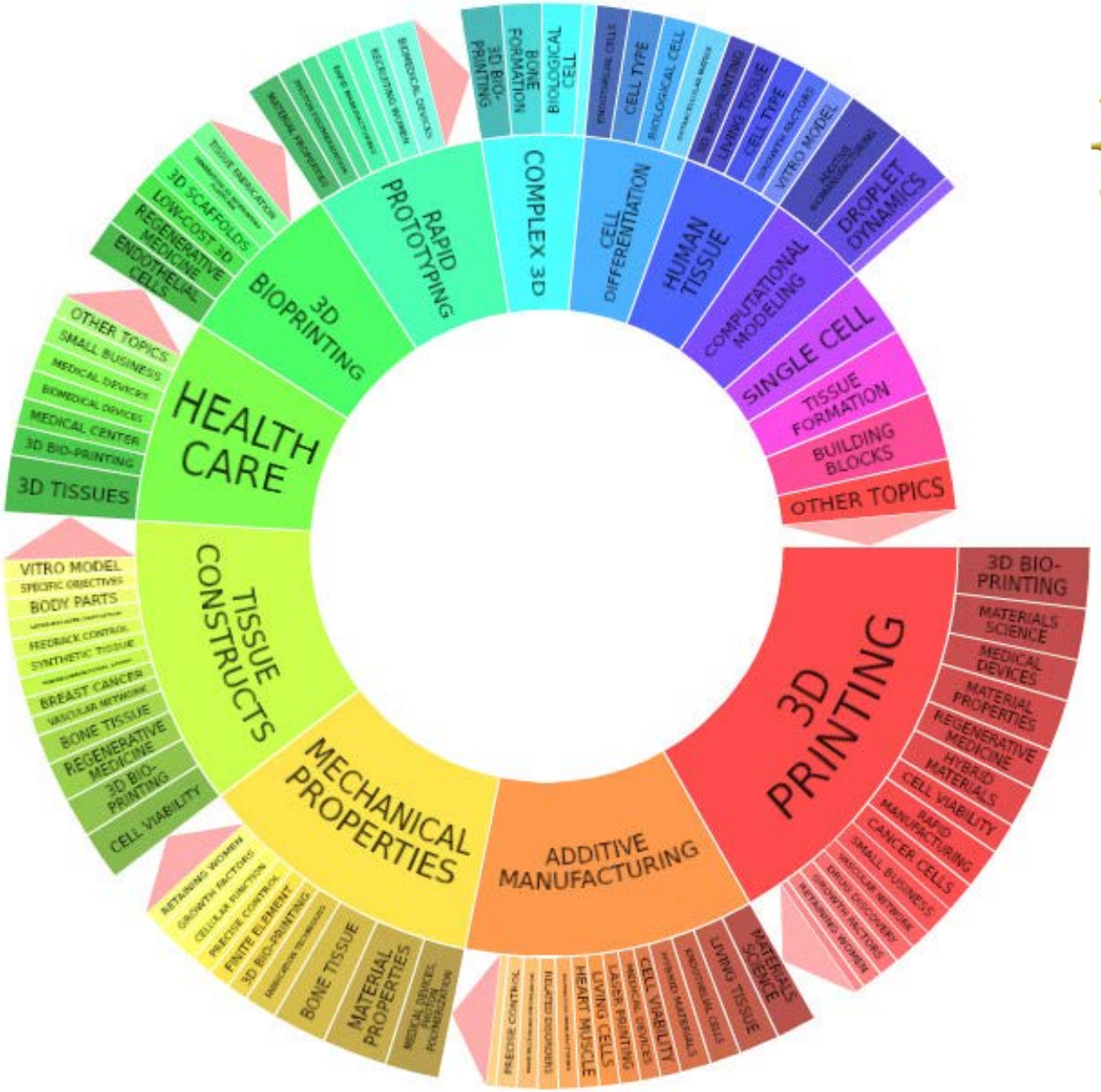


AM/3DP Funding by Topic Area



- NSF support of AM/3DP for biomedical use emerged in early 1990s
- 2014 & 2015: ~$13M in new AM/3DP research for Health/Medical

Research Topics within Additive Manufacturing for Health Awards



AM/3DP for Biomedical Devices

Photo Credit: NBC Learn

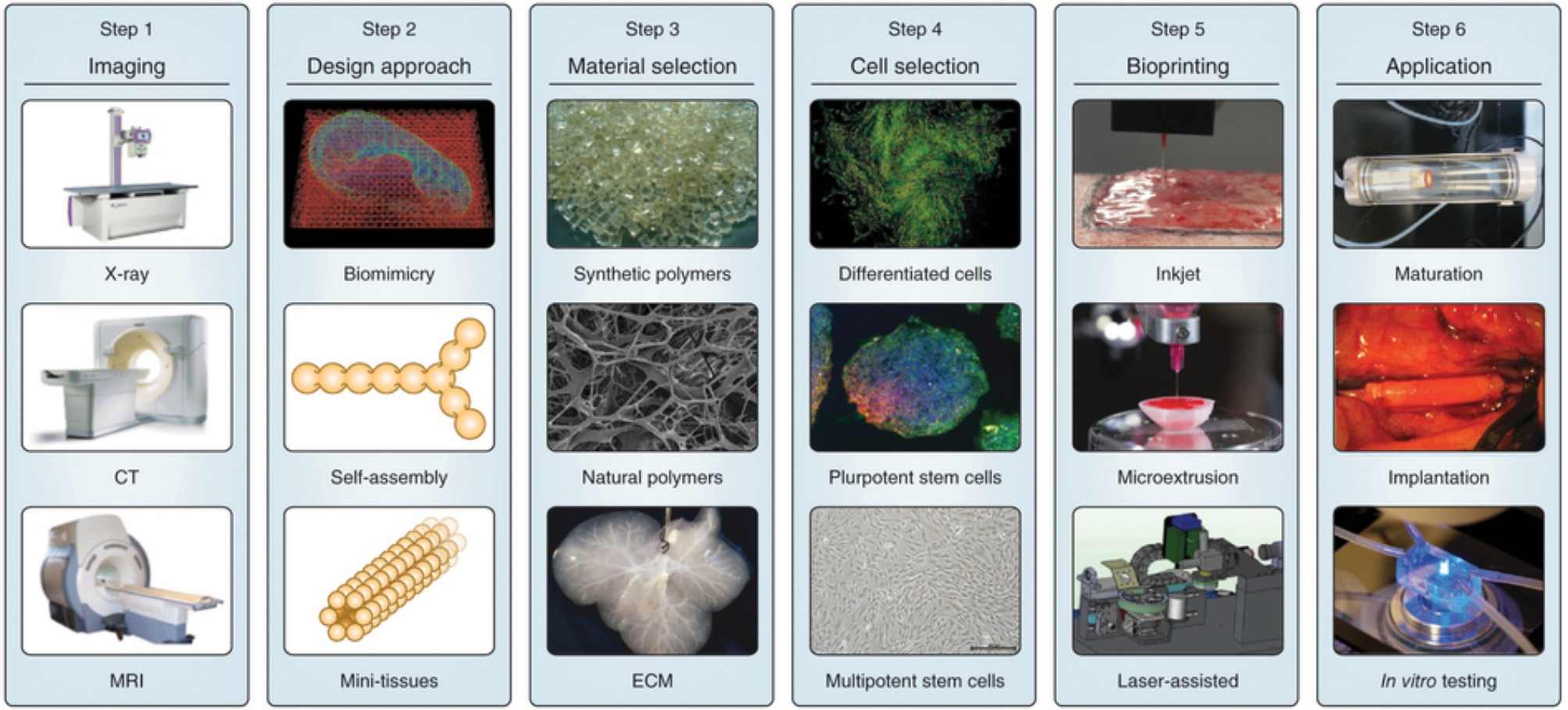
- *Additive Manufacturing of Wear Resistant Metal-Composites for Biomedical Devices (ENG/CMMI)
- Collaboration on Novel Materials and Methods for 3D Printing of Microscale Medical Devices (ENG/CMMI)
- Customized Manufacture of Protective Headgear for Mitigation of Fall Related Injuries (ENG/IIP)

AM/3DP for Bioprinting

- 3D Printing of Heart Muscle Using Soft Hydrogels (ENG/CMMI)
- Design of Self-assembling Bio-inks for Cell-based 3D Printing (MPS/DMR)
- *Bioprinting Personalized Islets (ENG/CBET)

Image: Adam Feinberg at Carnegie Mellon University; Photo Credit: NBC Learn

A Typical Process for Bioprinting 3D Tissues



ENG, CISE | ENG, CISE | ENG, MPS | ENG | ENG | Post-NSF (IIP)

AM/3DP for Education

- Exploring Appropriate 3D Printing Paradigms in Special Education (CISE/IIS)
- REU Site: Advances in Additive Manufacturing and Bio/Nano Applications (ENG/EEC)
- Low-cost 3D Bio-printer Toolkit for STEM Education (ENG/IIP)

Photo Credit: Samantha McDonald, University of Maryland, Baltimore County

Continuing Priority Areas

- Cybermanufacturing
- Cellular Biomanufacturing
- Scalable Nanomanufacturing

AM/3DP for Cybermanufacturing

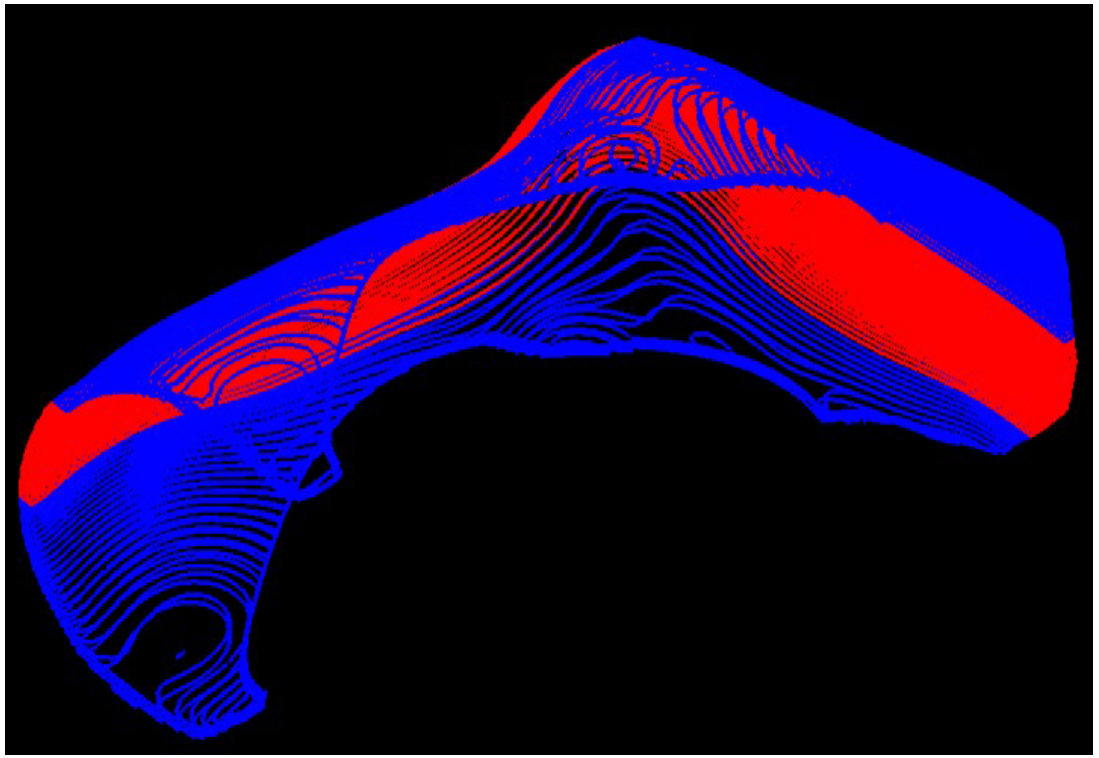


Photo Credit: Albert Shih, University of Michigan

- *Cyber-Physical Service System for 3D-Printing of Adaptive Custom Orthoses (ENG/IIP,CMMI)
- Smart Manufacturing Platform for Tissue Engineering (ENG/CMMI)
- *Cloud-based, Rapid Microscale 3D Bioprinting (ENG/CMMI)

AM/3DP for Biomanufacturing

- Multi-scale High-aspect Ratio Structures (HARS) for Constructing Dynamic 2D and 3D Cellular Bioreactors (ENG/CBET)
- Bioengineering of 3-Dimensional Brain Surrogate Tissue Models (ENG/CBET)

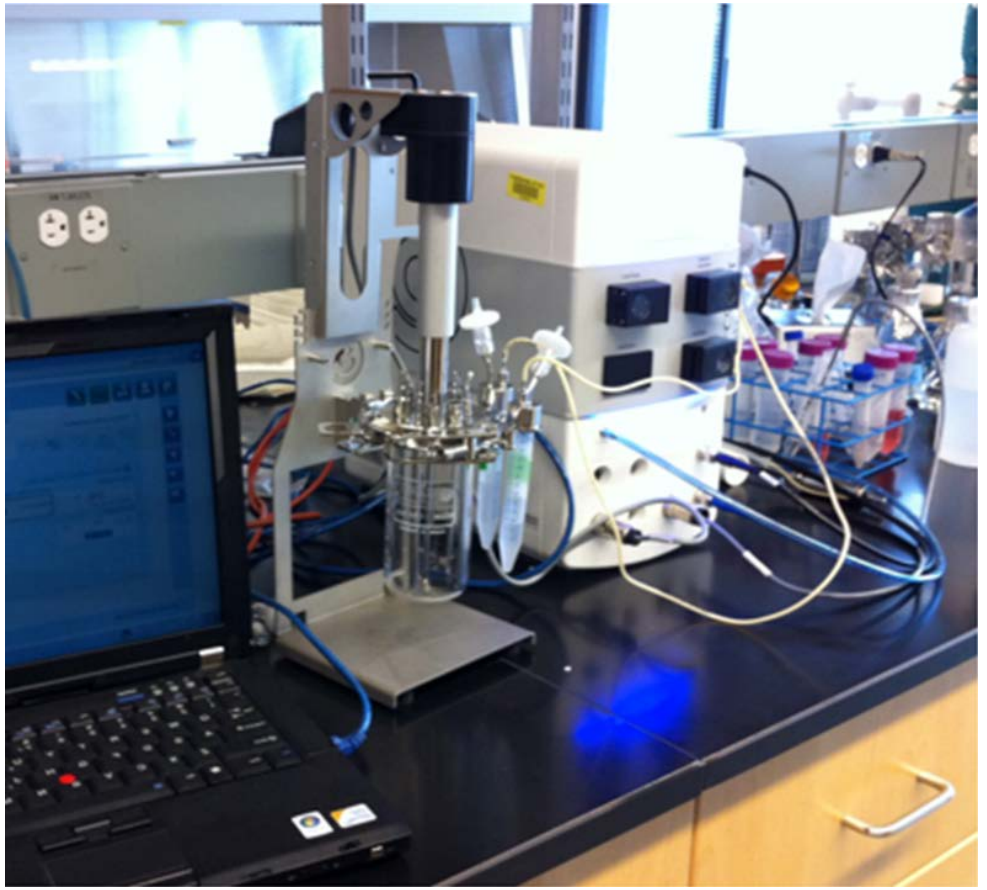


Photo Credit: Emmanuel Tzanakakis, Chemical and Biological Engineering, Tufts University

AM/3DP for Nanomanufacturing

- *Continuous and Scalable Nanomanufacturing for 3-Dimensional Functional Biomedical Devices (ENG/CMMI)
- Algorithmic Design Principles for Programmed DNA Nanocages (CISE/CCF)

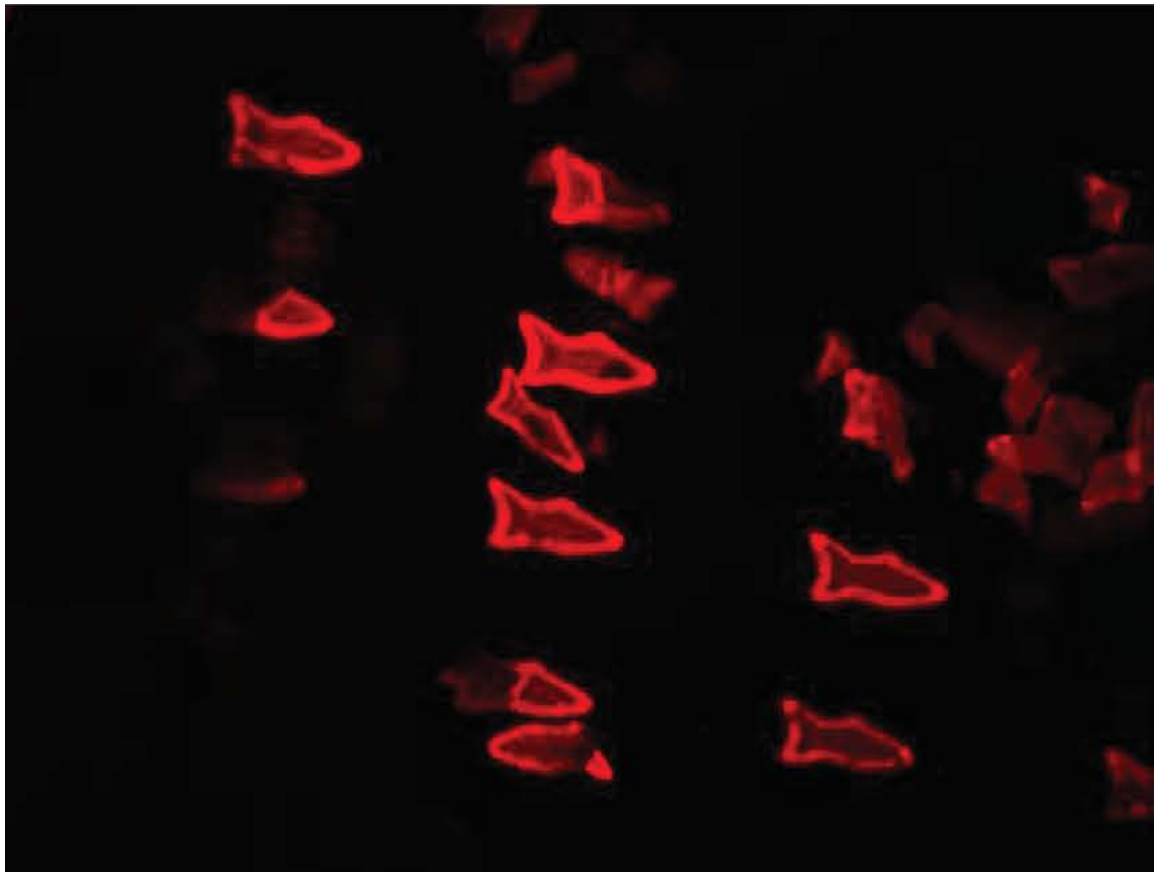


Photo Credit: Wei Zhu and Jinzxing Li, University of California, San Diego

Funding Opportunities

- Directorate for Mathematical and Physical Sciences (MPS)
  - Materials Research (DMR)

- Directorate for Computer & Information Science & Engineering (CISE)
  - Computer and Network Systems (CNS)
  - Cyber-Human Systems (CHS)
  - Cyber-Physical Systems (CPS)

Funding Opportunities - ENG

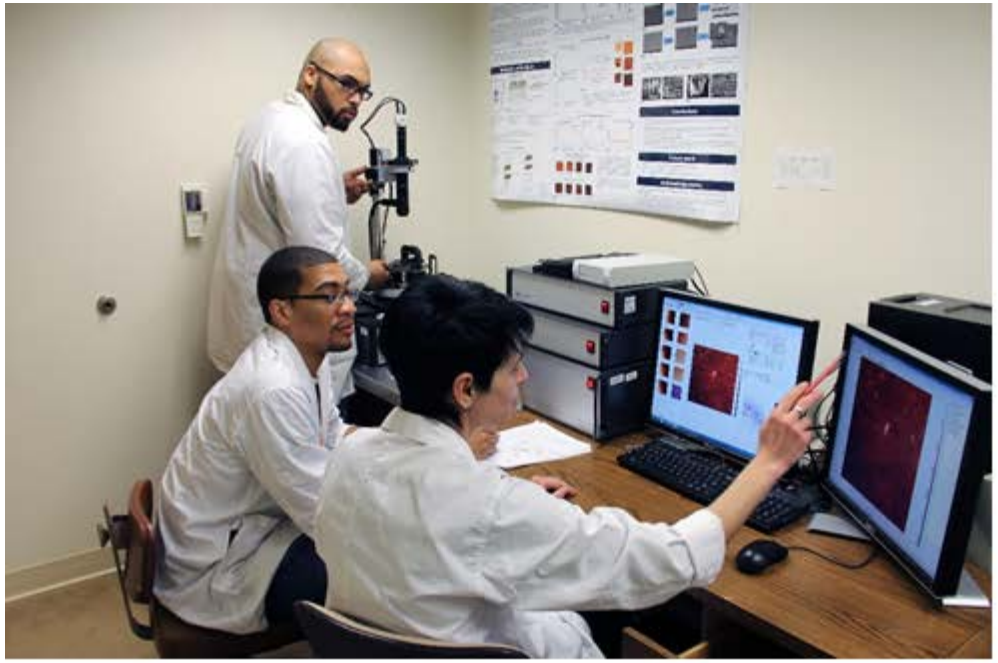
- Division of Chemical, Bioengineering, Environmental, and Transport Systems
  - Biomedical Engineering (BME)
  - Biotechnology and Biochemical Engineering (BBE)
  - Biomanufacturing

- Division of Industrial Innovation and Partnerships (IIP)
  - Partnerships for Innovation: Accelerating Innovation Research (PFI:AIR)
  - Small Business Innovation Research Program (SBIR)

Funding Opportunities - ENG

- Division of Civil, Mechanical and Manufacturing Innovation (CMMI)
  - Manufacturing Machines and Equipment (MME)
  - Materials Engineering and Processing (MEP)
  - Nanomanufacturing (NM)
  - Cybermanufacturing (CM)
  - Mechanics of Materials and Structures (MOMS)
  - Design of Engineering Material Systems (DEMS)
  - Engineering Systems and Design (ESD)
  - Dynamics, Controls, and System Diagnostics (DCSD)

  and others…



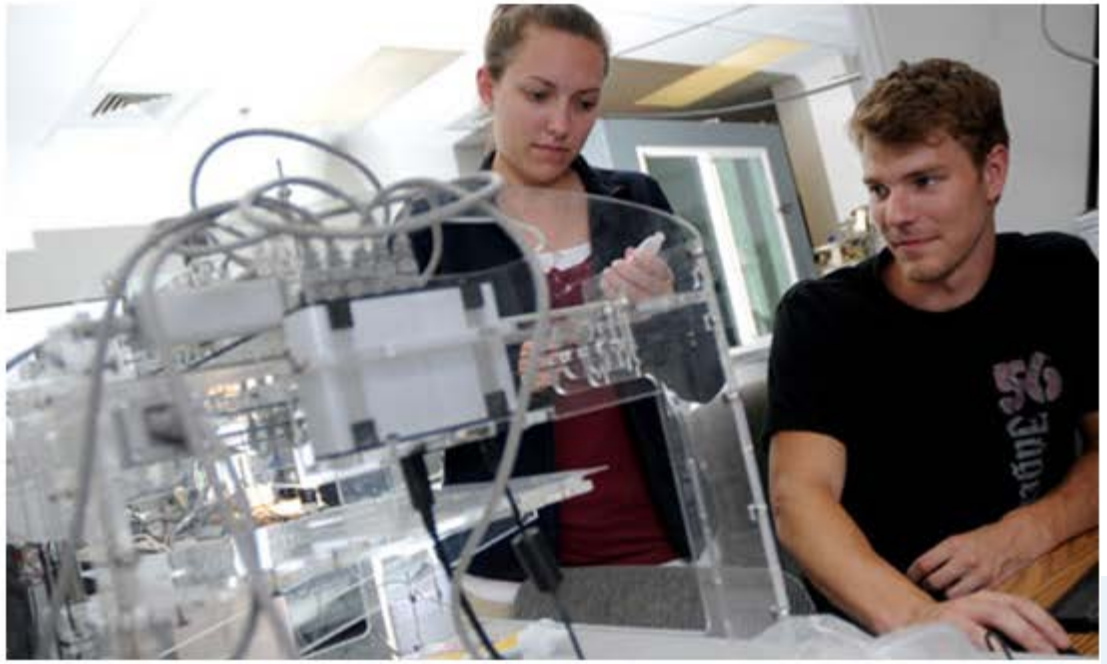


Image Credits:

- Title Slide (Images Left to Right):
- *BMMB:* Farshid Guilak of Duke and his team have developed a 3-D Fabric scaffold into which a strong, pliable hydrogel is integrated and infiltrated with stem cells, forming a framework for growing cartilage.
- *MEP:* Tak Sing Wong of Penn State and his team have developed nano/micro-textured, highly slippery surfaces able to outperform naturally inspired coatings like lotus leaves, particularly when the water is a vapor or tiny droplets. Credit: *Xianming Dai, Chujun Zeng and Tak-Sing Wong/Penn State*
- *NSEC:* Chemists at the University of Massachusetts Amherst have devised a multi-channel, signature-based approach to screening drugs using gold nanoparticles with red, green and blue outputs provided by fluorescent proteins. Credit: *Vincent Rotello, Department of Chemistry, University of Massachusetts-Amherst*
- *MOMS:* Nanshu Lu of U Texas at Austin and her team have developed prototype wearable device of an electronic skin patch as thin as a temporary tattoo that can store and transmit data about a person's movements, receive diagnostic information and release drugs into skin. Credit: *Donghee Son and Jongha Lee*
- *DCSD:* Maurizio Porfiri of NYU and his team have conducted the first study to show that in a side-by-side comparison, a robotic predator can spook zebrafish just as well as the real thing. These results may help advance understanding of fear and anxiety in animal populations, including humans. Image shows robotic and live predators. Credit: *NYU Polytechnic School of Engineering; picture by Simone Macrì*
- *GEM:* Patricia Culligan of Columbia and her team are developing best strategies for the design and spatial distribution of urban green roofs Credit: *Stuart Gaffin and Shaily Kedia, Center for Climate Systems Research, Columbia University*
- Graphs from Weber et al,. (2013) The Role of the National Science Foundation in the Origin and Evolution of Additive Manufacturing in the United States. Science and Technology Policy Institute. https://www.ida.org/~/media/Corporate/Files/Publications/STPIPubs/ida-p-5091.ashx

Image Credits (cont.):

- *Biomedical Devices:* Still from from “Science of Innovation: 3-D Bioprinting” produced by NBC Learn in partnership with NSF and USPTO http://www.nsf.gov/news/special_reports/science_innovation/01_3D_bioprinting.jsp
- *Bioprinting:* Adam Feinberg at Carnegie Mellon University has come up with a technique that expands the use of 3-D printing technology and could one day allow researchers to print heart tissue. (Still from “Science of Innovation: 3-D Bioprinting” produced by NBC Learn in partnership with NSF and USPTO http://www.nsf.gov/news/special_reports/science_innovation/01_3D_bioprinting.jsp)
- *A Typical Process for Bioprinting 3D tissues*: Figure taken from Sean Murphy & Anthony Atala (2014) 3D bioprinting of tissues and organs. *Nature Biotechnology 32*, 773-785.
- *Education*: Custom stylus holder produced by GripFab for individuals with limited hand dexterity. GripFab is a specialized piece of modeling software, created by Hurst's students, that takes accessibility into account in the creation of 3-D-printable assistive hand grips. Credit: Samantha McDonald, University of Maryland, Baltimore County
- *Cybermanufacturing*: Albert Shih of the University of Michigan and his team are developing the capability for Internet-based design and rapid manufacturing of customized foot orthoses and ankle-foot orthoses with motion sensors. This image shows the path planning for 3-D printing an ankle-foot orthosis. Credit: Albert Shih, University of Michigan
- *Biomanufacturing*: Emmanuel Tzanakakis of Tufts University is investigating the cultivation of stem cells and their conversion to pancreatic islet cells in bioreactors, which may be used in the commercial production of biopharmaceuticals. Biomanufacturing techniques could one day provide cellular material for pancreatic islet replacement therapies to help people with diabetes. Credit: *Emmanuel Tzanakakis, Chemical and Biological Engineering, Tufts University*

Image Credits (cont.):

- *Nanomanufacturing*: 3-D printed microrobot “microfish”. Nanoengineers at UCSD say these proof of concept synthetic microfish will inspire a new generation of “smart” microrobots that have diverse capabilities such as detoxification, sensing and directed drug delivery. Credit: Wei Zhu and Jinzxing Li, University of California, San Diego

Closing Slide(clockwise from top-left):

- Graduate students and scientists in the lab at the Engineering Research Center for Revolutionizing Metallic Biomaterials (ERC-RMB) investigate surface engineered Mg alloy technologies. Credit: *NSF ERC for Revolutionizing Metallic Biomaterials, North Carolina State University*
- Mike Buffalin, a student working at the National Center for Rapid Technologies (RapidTech), an Advanced Technological Education (ATE) center located at the University of California, Irvine, de-powders parts in a Z-Corp machine as part of a 3-D modeling process. RapidTech helps researchers and entrepreneurs swiftly design and build product prototypes. Credit: *RapidTech*
- Maggie Bollinger and Brad Harris, students at Missouri S&T Additive Manufacturing Research Experience for Undergraduates, test a 3-D printer. Credit: *Missouri S&T Photo Collection*
- A student in Champaign, Ill., creates an object with a classroom 3-D printer; Credit: *Joe Muskin, University of Illinois*