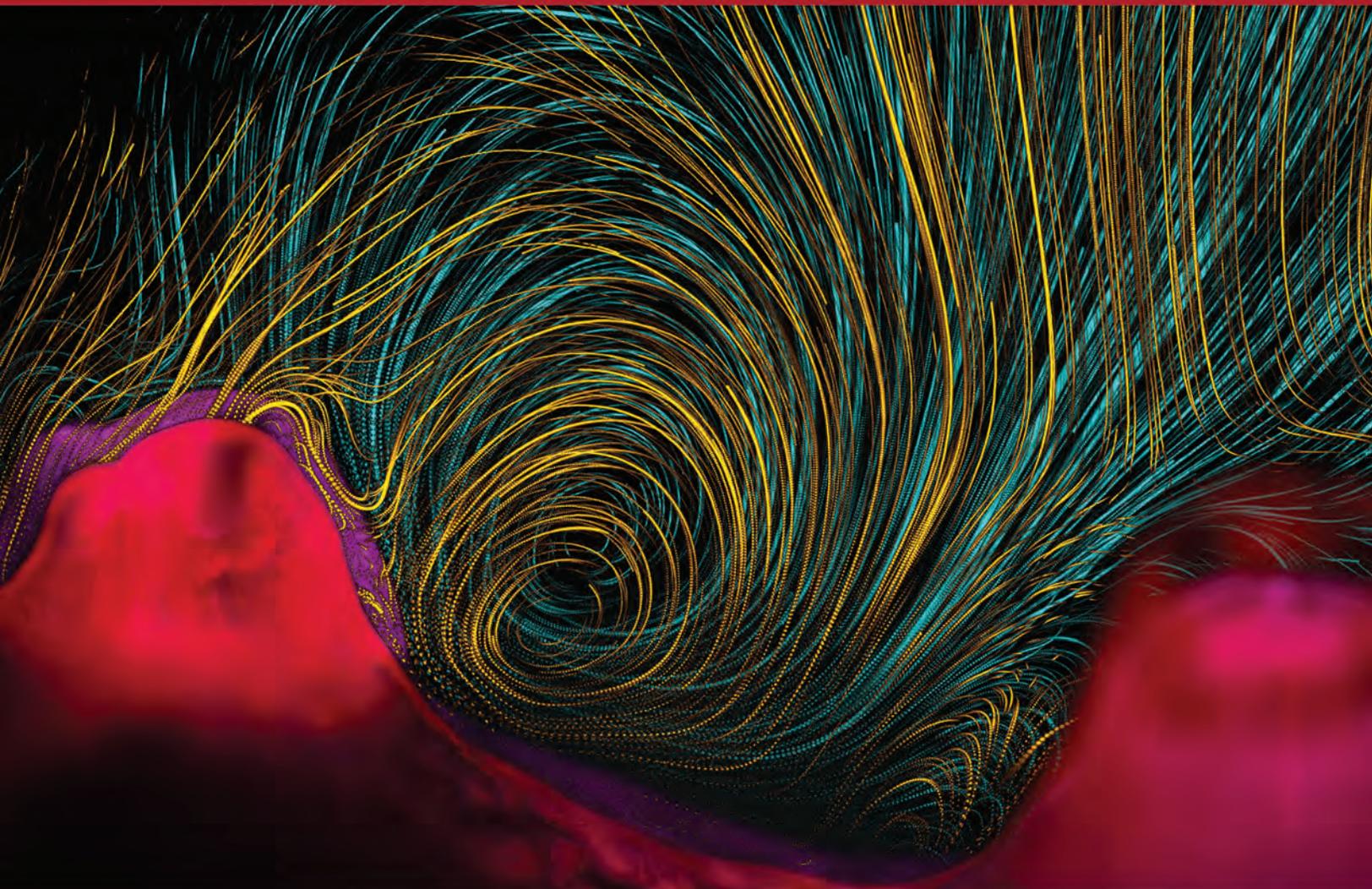


# MAKING FUTURE TECHNOLOGIES POSSIBLE



Engineering



National Science Foundation

# From Frontiers of Research to Foundations for Innovation

Investments in engineering research and education are critical building blocks for the nation's future prosperity. Engineering breakthroughs address national challenges, such as smart manufacturing, resilient infrastructure and sustainable energy systems. Engineering also brings about new opportunities in areas ranging from advanced photonics to prosthetic devices.

Research funded by the National Science Foundation's (NSF) Directorate for Engineering (ENG) has enriched the understanding of natural systems, enhanced electronics, fortified the nation's infrastructure and introduced the exciting possibilities of engineering to the next generation.

After a competitive, merit-based review, ENG makes awards that have the potential to break new ground, fuel important innovations and prepare the engineering workforce for tomorrow. Results from these awards stimulate economic growth and improve Americans' health and quality of life.

## Expanding Engineering Frontiers

ENG provides about 32 percent of the federal funding for fundamental research in engineering at academic institutions. The directorate distributes about 1,600 research awards across the fields of engineering each year.

These awards expand engineering capabilities and support the U.S. research enterprise, funding the work of approximately 14,000 senior researchers, innovators and other professionals. ENG awards also prepare future leaders, entrepreneurs and visionaries in engineering, supporting about 13,000 undergraduate and graduate students and postdoctorates.

## Building Businesses From Engineering Foundations

ENG is home to many of NSF's activities that foster innovation and technology transfer. NSF's renowned Small Business Innovation Research (SBIR) and Small Business Technology Transfer programs enable companies to undertake research and development with high technical risk and high commercial reward. The Innovation Corps™ program enables faculty and students to pursue commercialization of technologies based on previous NSF-funded research. Small businesses in 47 states received research funding from NSF in fiscal year 2013 alone.



Colorado-based Modular Robotics, an ENG-SBIR awardee, created unique construction kits that introduce children to robotics. In 2013, the company received the distinguished Tibbetts Award from the U.S. Small Business Administration.

## The Value of NSF-funded Small Business

Each year, many small businesses that have received ENG support are acquired by other companies. The acquisition prices have reached the hundreds of millions of dollars, demonstrating the value of NSF investments.

### 2012

IBM acquired Vivisimo for its big data navigation and discovery software.

Saint-Gobain acquired SAGE Electrochromics Inc. for more than \$80 million.

DropBox acquired Anchovi Labs for its image annotation service.

### 2013

Twitter Inc. acquired Bluefin Labs for nearly \$100 million.

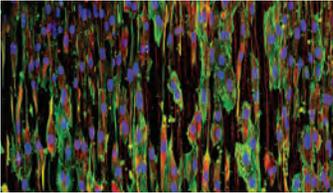
Waters acquired Blue Reference for \$14 million.

Outerwall Inc. acquired EcoATM Inc. for \$350 million.

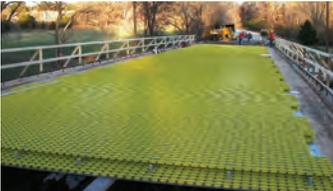
Monsanto Co. acquired Grassroots Biotechnology for their gene expression platform and other technologies.

## Overcoming Challenges, Unlocking Opportunities

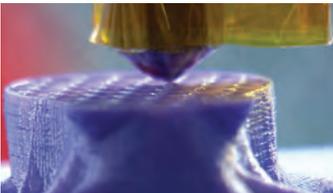
Engineering affects every aspect of daily life, from smartphones to drinking water. Researchers, entrepreneurs and educators supported by the ENG Directorate explore and innovate to better people's lives.



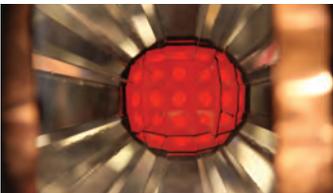
Fundamental engineering research for improving **health** leads to the creation of new drug delivery systems, advanced monitoring and diagnostic systems and assistive technologies.



Funding for **infrastructure** research increases the safety, resilience and intelligence of the nation's buildings and transportation systems, water and power supplies, and communications and cyber networks.



Investments in **advanced manufacturing** materials, processes and systems promise faster, more agile production that is more efficient, precise and sustainable for the benefit of U.S. industry and quality of life.



Investigations into **energy and environment** give people options for low-cost, sustainable practices and technologies that protect natural resources while meeting essential human needs and supporting economic progress.



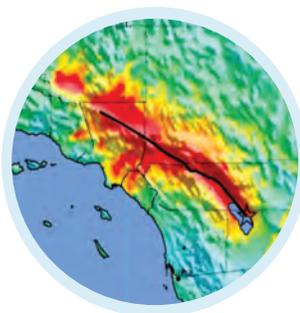
Broadening pathways to engineering degrees, providing hands-on research opportunities and improving engineering education help create a diverse, flexible, innovative **future engineering workforce** that can meet the changing needs of the American economy.

Engineering education, research and industrial development in the U.S. is of ever-increasing importance to spur innovation, address societal needs, strengthen the economy and maintain a global lead in high-tech manufacturing. The following examples underscore the leadership resulting from NSF-funded engineers who work to develop innovative technologies that touch everyday lives and improve the overall standard of living.



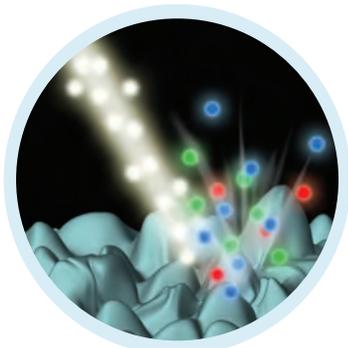
### LEDs for Low-cost Lighting

Light-emitting diode (LED) lighting is emerging as a powerful way to save energy. North Carolina-based Cree Inc., which employs 2,000 people in its home state alone, is one of the largest LED lighting businesses in the U.S. Cree's products rely on advances in silicon carbide semiconductor technology and manufacturing methods that were discovered through ENG-funded research at the University of Arkansas; a Virginia-based small business, LT Technologies, LLC; and the Delaware small business AstroPower, which Cree later acquired. Today, Cree LEDs are 85 percent more efficient and last twice as long as conventional fluorescent lighting.



### Earthquake-resistant Water Pipelines

NSF-funded researchers have discovered how to make underground water lines that bend and move rather than snap and rupture in an earthquake. The team found that medium and high-density polyethylene pipelines remain intact even when the Earth liquefies and shifts. Based on positive laboratory tests and successful real-world performance in Christchurch, New Zealand, the city of Los Angeles is now installing these pipelines in the Elizabeth Tunnel, which provides half the city's water supply.



### Routine Cancer Screening With Light?

Cancer accounts for about one of every four U.S. deaths. ENG-supported researchers in Illinois have developed optical techniques that can detect nanoscale changes in cells that indicate cancer, even in its earliest stages. The new screening methods, discovered through NSF-funded biophotonics research, are less expensive, less invasive and more accurate than conventional methods. Clinical studies for the detection of colorectal, lung, ovarian and pancreatic cancers have shown promising results that could soon translate into routine use during medical checkups.



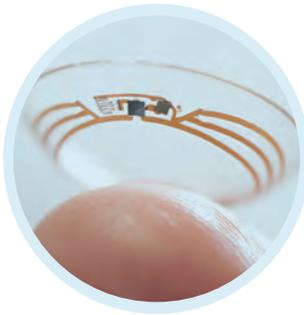
### Let There Be Sight

In 2013, the U.S. Food and Drug Administration granted market approval of an artificial retina, the first bionic eye approved for U.S. patents. The prosthetic system—developed with early, crucial support from NSF—will allow people with blindness (including the 100,000 people in the U.S. with the inherited, degenerative eye disease retinitis pigmentosa) to locate objects, detect movement, improve orientation and mobility, and discern shapes such as large letters. The artificial retina is manufactured and distributed by Second Sight Medical Products Inc. in California.



### Diamonds, a Manufacturer's Best Friend? Coatings for Tiny Tools

NCD Technologies, based in Wisconsin, has received several SBIR grants to develop durable, low-friction diamond coatings for tiny tools, including drill bits that are less than a hair's width across. The diamond coating allows the tools to run faster for longer periods of time with fewer replacement tools, reducing manufacturing time from eight days to six in some cases. NCD won *R&D Magazine's* 100 list for technological excellence—the "Oscar for Innovation"—in 2013.



### A New Eye on Diabetes

ENG-funded researchers created a prototype smart contact lens that can detect and monitor health conditions. With advances in biosensors, energy harvesting and control systems, the smart lens can provide continuous, non-invasive monitoring of glucose levels found in tears, allowing people with diabetes to forego multiple daily finger pricks for blood analysis. Google[x] is now testing the technology with an eye toward clinical trials and eventual commercialization. This innovation would potentially save the 25.8 million Americans who have diabetes from painful skin-prick tests.

### Nano-engineered Glass Cleans Contaminated Water

While investigating sensors for explosives detection, an ENG-funded research team discovered a glass that could swell up to 14 times its original weight and trap environmental toxins, pharmaceuticals and industrial chemicals. The nanostructured material, called Osorb<sup>®</sup>, is now being used to remediate stormwater runoff, contaminated groundwater and produced water from oil and gas wells. In fact, it was tested for water remediation in the Gulf of Mexico following the Deepwater Horizon oil spill. The Osorb research team founded ABSMaterials Inc., a company that has grown to nearly 40 full-time employees at two Ohio locations with support from ENG small business funding.



### Rapid Response to West Virginia Chemical Spill

On Jan. 9, 2014, about 10,000 gallons of crude 4-methylcyclohexane methanol (MCHM), a chemical primarily used to clean coal, leaked from a storage tank near Charleston, W.Va., and bled into a river upstream of a water-treatment plant. As a result, about 15 percent of West Virginia residents were advised not to use the water. In less than two weeks, NSF awarded grants to engineering research teams at West Virginia University, the University of South Alabama and Virginia Tech to study MCHM's fundamental chemical and physical properties and the plumbing and water treatment systems surrounding the area.



### Mini Manufacturing

Nanoscale advances are transforming manufacturing and the marketplace, with revenue from nano-enabled products growing from almost \$340 billion in 2010 to more than \$730 billion in 2012. A 30-micron Mona Lisa, created by Georgia Tech researchers, is made possible by a process at the nanoscale called thermochemical nanolithography (TCNL). The technique produces chemical concentration gradients and variations on the sub-micrometer scale, as evidenced by the "Mini Lisa."



### Additive Manufacturing With 3-D Printers

In 2012, 3-D printing contributed to more than \$2.2 billion in global industry and is forecast to double by 2015. Innovative 3-D printing and other additive manufacturing methods quickly make 3-D objects by building up material, layer upon layer. With the guidance of a digital design U.S. companies are adopting this additive manufacturing innovation to make aerospace, automotive and medical technologies. The methods enable rapid prototyping and customized parts and devices. Many of the foundational techniques for additive manufacturing were discovered and patented in the 1980s. Three of these methods, selective laser sintering, sheet lamination and 3-D printing, were developed with support from NSF.

# Emerging Opportunities for Engineering

The ENG Directorate constantly engages with the research community for new and emerging areas of opportunity—where creative researchers are approaching breakthroughs, where dreams inspire young engineers to make a difference, and where small business discoveries can change entire industries. Above all, ENG seeks emerging opportunities that can address national needs and improve quality of life for Americans. The following opportunities underscore the leadership resulting from ENG-supported research and education efforts.

**Adapting to climate change**

**Advancing bioelectronics**

**Creating seamless assistive technologies**

**Designing robots compatible with human needs**

**Developing intelligent infrastructure**

**Devising tools to understand the brain and body**

**Enabling mass-customized manufacturing**

**Engineering biomedical treatments**

**Exploring sustainable energy sources**

**Gaining fluency in intercellular communication**

**Improving methods for life-cycle analyses**

**Learning from biological systems**

**Mitigating impacts of natural hazards**

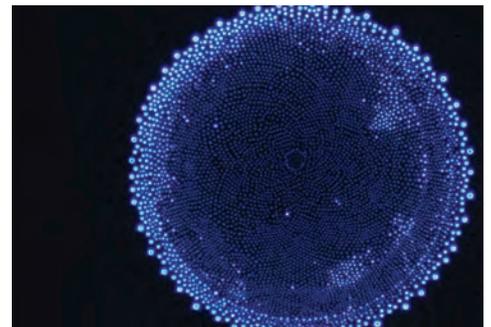
**Modeling enterprise systems**

**Pursuing frontier approaches to cybersecurity**

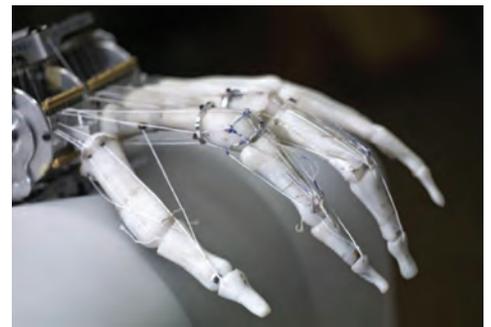
**Understanding nanotechnology's effects  
on biological systems**



Earthquake simulations on the world's largest outdoor shake table at the University of California, San Diego, test retrofits to help buildings withstand earthquakes.



The Nanotechnology Research Center at Georgia Tech applies nanofabrication methods to bioengineering and biomedicine and provides open user facilities for characterization, fabrication, design and simulation.



The “anatomically correct testbed hand” has three fully actuated fingers with the same biomechanical structure as the human hand.

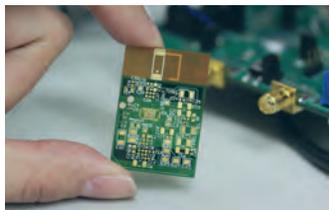
# Collaborating to Advance Engineering

From creating new knowledge to launching new technologies, ENG strategically strengthens the nation's innovation ecosystem. ENG programs spur translation of fundamental research, encourage collaboration with industry and educate students to be innovators. Whether engaging small groups or multi-university centers, the programs listed below firmly link scientific discoveries with industry to accelerate technological development.

## Partnerships With Academia



**Engineering Research Centers.** University teams turn new knowledge into new systems technologies in partnership with business and regional stakeholders.



**Grant Opportunities for Academic Liaison With Industry.** Members of industry and academia transfer knowledge through research collaborations and fellowships.



**Industry/University Cooperative Research Centers.** Faculty and students investigate fundamental questions shared by multiple industry sectors.



**Innovation Corps.** Faculty and students begin commercializing their discoveries with the help of industry mentors.



**Nanoscale Science and Engineering Centers.** University teams address complex nanoscale science and engineering opportunities in collaboration with industry.



**Partnerships for Innovation.** Broad-based, regional collaborations help translate academic knowledge into innovations.

## Small Business Incubation



**Small Business Innovation Research.** Small businesses engage in translational research to create prototypes and scale up production.



**Small Business Technology Transfer.** Small businesses and academic partners collaborate in pursuit of technological innovation.



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