

## Engineering Research Centers: Linking Discovery to Innovation

*Driving the discovery, dissemination, and deployment of transformational knowledge and technologies and a new generation of graduates in service to industry and the Nation*

The Engineering Research Centers (ERC) program was created in 1984 to bring technology-based industry and universities together in an effort to strengthen the competitive position of American industry in the global marketplace. These partnerships established cross-disciplinary centers focused on advancing fundamental engineering knowledge and engineered systems technology while exposing students to the integrative aspects of engineered systems and industrial practice. As a result, over the past quarter century this partnership has produced a wide range of engineered systems and other technologies aimed at spawning whole new industries or radically transforming the product lines, processes, and practices of current industries. At the same time it has produced a new generation of engineering graduates who are highly innovative, diverse, globally engaged, and effective as technology leaders in industry.

NSF has continually refined the goals and purposes of the ERC program to meet the needs of industry in an increasingly global economy where the U.S. competitive advantage lies in its capacity to innovate. The goal of today's ERCs is to create a culture that actively stimulates technological innovation through partnerships with industry in research to accelerate technology transfer to member firms and in translational research to explore commercialization of high-risk technologies with small firms, and with organizations devoted to entrepreneurship. Given this evolving and outward-looking program management, current and future ERCs will continue to advance transformational engineered systems and produce graduates who will be creative innovators in the global economy.

To achieve this goal, ERCs have the following key features:

- A guiding **strategic vision** for a transformational engineered system and the development of an innovative, globally competitive engineering workforce
- A strategically planned, systems-motivated cross-disciplinary **research program** spanning from fundamental research to proof-of-concept systems testbeds
- **Education programs** strategically designed to produce creative, innovative engineers by engaging students in all phases of the research and innovation process, and to bring engineering concepts to the pre-college classroom to attract students to engineering degree programs and careers
- **Partnerships with industry, local government agencies, and local-level organizations** devoted to accelerating technology transfer, translational research, and innovation.

From their inception the ERCs have embodied NSF's strategic interests in the integration of research and education, the integration of science and engineering disciplines, partnerships between academe and industry, and strengthening the engineering workforce to meet the nation's needs in a global economy. In many ways the program has redefined the concept of an academic research center, serving as a model for the development of other Centers programs in the U.S. and around the world.

Each ERC is established as a 3-way partnership involving academe, industry, and NSF (in some cases with the participation of state, local, and/or other Federal government agencies). In FY 2016, total annual funding provided directly to each ERC by NSF ranged from \$2.68 million (for centers in their phase-down period prior to graduation from NSF support) to \$3.5 to \$4.8 million per year for ongoing centers.<sup>1</sup>

NSF funds each ERC for up to 10 years. Since 1985, a total of 64 ERCs and 3 Earthquake ERCs<sup>2</sup> have been formed across the United States, with 17 ERCs currently in operation. Surveys of industry employers have shown that ERC graduates are viewed by 80% of their supervisors as being more productive than their peers because, through their ERC experience, they know how to integrate knowledge across disciplines and manage teams to advance technology. A 2010 study of the impacts of ERC-generated technologies found that the economic value of products and processes deriving from the ERCs was already in the tens of billions of dollars, with some centers having had a transformational impact on their field of engineering and technology.

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<sup>1</sup> NSF funding ramps down in the last two years of a Center's life as an ERC..

<sup>2</sup> Three Earthquake Engineering Research Centers were funded in 1997 with funds outside of the ERC Program but were managed by the ERC Program from 1999 through their graduation from NSF support.

The major technological areas upon which current ERCs focus are:

- Advanced Manufacturing
- Biotechnology and Health Care
- Energy, Sustainability, and Infrastructure
- Microelectronics, Sensing, and IT

### ADVANCED MANUFACTURING

**ERC for Biorenewable Chemicals** (Class of 2008)  
Iowa State University (lead institution) in partnership with the University of California, Irvine, the University of New Mexico, Rice University, the University of Virginia, and the University of Wisconsin-Madison

**ERC in Compact and Efficient Fluid Power** (Class of 2006)  
University of Minnesota, Minneapolis, MN (lead institution) in partnership with Georgia Institute of Technology, Purdue University, the University of Illinois at Urbana-Champaign, and Vanderbilt University

**Center for Structured Organic Particulate Systems** (Class of 2006)  
Rutgers University, New Brunswick, NJ (lead institution) in partnership with Purdue University, New Jersey Institute of Technology, and the University of Puerto Rico at Mayagüez

**Nanosystems ERC for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies** (Class of 2012)  
The University of Texas at Austin (lead institution) in partnership with the University of New Mexico and the University of California, Berkeley

### BIOTECHNOLOGY AND HEALTH CARE

**ERC for Revolutionizing Metallic Biomaterials** (Class of 2008)  
North Carolina A&T State University (lead institution) in partnership with the University of Cincinnati and the University of Pittsburgh

**Nanosystems ERC for Advanced Self-Powered Systems of Integrated Sensors and Technologies** (Class of 2012)  
North Carolina State University (lead institution) in partnership with Pennsylvania State University, Florida International University, University of North Carolina at Chapel Hill, and University of Virginia

**NSF Engineering Research Center for Sensorimotor Neural Engineering** (Class of 2011)  
University of Washington in partnership with the Massachusetts Institute of Technology and San Diego State University

### ENERGY, SUSTAINABILITY, AND INFRASTRUCTURE

**ERC for Quantum Energy and Sustainable Solar Technologies** (Class of 2011)  
Arizona State University (lead institution) in partnership with the California Institute of Technology, the University of Delaware, the Massachusetts Institute of Technology, and the University of New Mexico (co-funded with DOE)

**ERC for Bio-mediated and Bio-inspired Geotechnics** (Class of 2015)  
Arizona State University (lead institution) in partnership with the Georgia Institute of Technology, New Mexico State University, and the University of California, Davis

**ERC for Future Renewable Electric Energy Delivery and Management Systems** (Class of 2008)  
North Carolina State University (lead institution) in partnership with Arizona State University, Florida A&M University, Florida State University, Missouri University of Science and Technology

**Lighting Enabled Systems & Applications ERC** (Class of 2008)  
Rensselaer Polytechnic Institute (lead institution) in partnership with Boston University and the University of New Mexico

**Nanosystems ERC for Nanotechnology Enabled Water Treatment Systems** (Class of 2015)  
Rice University (lead institution) in partnership with Arizona State University, the University of Texas at El Paso and Yale University

**ERC for Re-Inventing America's Urban Water Infrastructure** (Class of 2011)  
Stanford University (lead institution) in partnership with the University of California, Berkeley, Colorado School of Mines, and New Mexico State University

**ERC for Ultra-wide Area Resilient Electric Energy Transmission Networks** (Class of 2011)  
University of Tennessee-Knoxville (lead institution) in partnership with Northeastern University, Rensselaer Polytechnic Institute, and Tuskegee University (co-funded with DOE)

### MICROELECTRONICS, SENSING, AND IT

**ERC for Integrated Access Networks** (Class of 2008)  
**University of Arizona** (lead institution) in partnership with the California Institute of Technology, Columbia University, Norfolk State University, Stanford University, Tuskegee University, the Universities of California at Berkeley, San Diego, and Los Angeles, and the University of Southern California

**Nanosystems ERC for Translational Applications of Nanoscale Multiferroic Systems** (Class of 2012)  
University of California, Los Angeles (lead institution) in partnership with Cornell University, the University of California, Berkeley, and California State University, Northridge

**ERC for Power Optimization for Electro-Thermal Systems** (Class of 2015)  
University of Illinois at Urbana-Champaign in partnership with Howard University, Stanford University, and the University of Arkansas

*At the end of their ten-year life-cycle as NSF-supported Engineering Research Centers, most ERCs graduate from NSF support and become self-sustaining. Currently there are 38 graduated ERCs and 3 graduated Earthquake ERCs:*

### **Manufacturing**

**ERC for Environmentally Benign Semiconductor Manufacturing** — University of Arizona, Tucson, AZ (lead institution) in partnership with Arizona State University, the University of California at Berkeley, Cornell University, MIT, and Stanford University (established in 1996, graduated in 2006) [this ERC was jointly funded by the Semiconductor Research Corporation]

**Synthetic Biology ERC** — University of California at Berkeley CA (lead institution) in partnership with Harvard University, the Massachusetts Institute of Technology, Prairie View A&M University, and the University of California at San Francisco (established in 2006, graduated in 2016)

**ERC for Engineering Design** (now the Institute for Complex Engineered Systems) — Carnegie Mellon University (established in 1986, graduated in 1997)

**Center for Advanced Engineering of Fibers and Films** — Clemson University, Clemson, SC (lead institution) in partnership with MIT (established in 1998, graduated in 2008)

**ERC for Particle Science and Technology** — University of Florida, Gainesville, FL (established in 1995, graduated in 2005)

**Systems Research Center** (now the Institute for Systems Research) — University of Maryland/Harvard University (established in 1985, graduated in 1994)

**Center for Reconfigurable Machining Systems** — University of Michigan, Ann Arbor, MI (established in 1996, graduated in 2007)

**Center for Interfacial Engineering** (now the Industrial Partnership for Research in Interfacial and Materials Engineering, or iPrime) — University of Minnesota (established in 1988, graduated in 1999)

**ERC for Net Shape Manufacturing** — Ohio State University (established in 1986, graduated in 1997)

**Center for Intelligent Manufactured Systems** — Purdue University (established in 1985, graduated in 1994)

### **Biotechnology and Health Care**

**ERC for Emerging Cardiovascular Technologies** — Duke University & other North Carolina Institutions (established in 1987, graduated in 1998)

**ERC for the Engineering of Living Tissues** (now the Regenerative Engineering and Medicine Research Center) — Georgia Institute of Technology, Atlanta, GA (lead institution) in partnership with Emory University (established in 1998, graduated in 2008)

**Center for Computer-Integrated Surgical Systems and Technology** — Johns Hopkins University, Baltimore, MD (lead institution) in partnership with the Brigham and Women's Hospital, Carnegie Mellon University, the Johns Hopkins University Hospital, MIT, and Shady Side Hospital (established in 1998, graduated in 2008)

**Bioprocess Engineering Research Center** — Massachusetts Institute of Technology, Cambridge, MA (established in 1985, graduated in 1994)

**Biotechnology Process Engineering Center** — Massachusetts Institute of Technology, Cambridge, MA (The BERC recompeted as BPEC and was reestablished in 1994, graduating in 2005)

**Center for Biofilm Engineering** — Montana State University, Bozeman, MO (established in 1990, graduated in 2001)

**ERC for Biomimetic MicroElectronic Systems** — University of Southern California - Keck School of Medicine and Viterbi School of Engineering, Los Angeles, CA (lead institution) in partnership with California Institute of Technology and the University of California, Santa Cruz (established in 2003, graduated in 2013)

**VaNTH ERC for Bioengineering Educational Technologies** — Vanderbilt University, Nashville, TN (lead institution) in partnership with Northwestern University, the Harvard University-MIT Division of Health Sciences and Technology, and the University of Texas at Austin (established in 1999, graduated in 2007)

**Engineered Biomaterials Engineering Research Center** — University of Washington, Seattle, WA (established in 1996, graduated in 2007)

### **Energy, Environment, and Infrastructure**

**Advanced Combustion Engineering Research Center** — Brigham Young University/University of Utah (established in 1986, graduated in 1997)

**Multidisciplinary Center for Earthquake Engineering Research** — University at Buffalo (lead institution) in partnership with Cornell University, University of Delaware, University of Nevada at Reno, and University of Southern California, as well as other collaborating institutions and private entities throughout the U.S. (established in 1997, graduated in 2007)

**Center for Advanced Technology for Large Structural Systems** — Lehigh University (established in 1986, graduated in 1997)

**Pacific Earthquake Engineering Research Center** — University of California at Berkeley, CA (lead institution) in partnership with California Institute of Technology, Stanford University, University of California at Davis, University of California at Irvine, University of California at Los Angeles, University of California at San Diego, the University of Southern California, the University of Washington, and nine affiliate institutions (established in 1997, graduated in 2007)

**Mid-America Earthquake Center** — University of Illinois at Urbana-Champaign, IL (lead institution) in partnership with Georgia Institute of Technology, the University of Memphis, MIT, St. Louis University, Texas A&M University, and Washington University (established in 1997, graduated in 2008)

**Offshore Technology Research Center** — Texas A&M University/University of Texas (established in 1988, graduated in 1999)

### **Micro/Optoelectronics, Sensing, and IT**

**Center for Neuromorphic Systems Engineering** — California Institute of Technology, Pasadena, CA (established in 1995, graduated in 2005)

**Data Storage Systems Center** — Carnegie Mellon University, Pittsburgh, PA (established in 1990, graduated in 2001)

**Optoelectronic Computing Systems Center** — University of Colorado/Colorado State University (established in 1987, graduated in 1998)

**ERC for Extreme Ultraviolet Science & Technology** Colorado State University, Fort Collins, CO (lead institution) in partnership with the University of Colorado at Boulder and the University of California at Berkeley (established in 2003, graduated in 2013)

**Center for Telecommunications Research** — Columbia University (established in 1985, graduated in 1996)

**Packaging Research Center** (now the 3D Systems Packaging Research Center) — Georgia Institute of Technology, Atlanta, GA (established in 1995, graduated in 2005)

**Center for Compound Semiconductor Microelectronics** — University of Illinois at Urbana-Champaign (established in 1986, graduated in 1997)

**ERC for Collaborative Adaptive Sensing of the Atmosphere** — University of Massachusetts, Amherst, MA (lead institution) in partnership with Colorado State University, University of Oklahoma, and University of Puerto Rico at Mayagüez (established in 2003, graduated in 2013)

**Center for Computational Field Simulation** — Mississippi State University, Mississippi State, MS (established in 1990, graduated in 2001)

**Center for Advanced Electronic Materials Processing** — North Carolina State University & other North Carolina Institutions (established in 1988, graduated in 1999)

**Center for Wireless Integrated MicroSystems** — University of Michigan (lead institution) in partnership with Michigan State University and Michigan Technological University (established in 2000, graduated in 2010)

**Center for Subsurface Sensing and Imaging Systems** — Northeastern University (lead institution) in partnership with Boston University, Rensselaer Polytechnic Institute, University of Puerto Rico at Mayagüez, Brigham and Women's Hospital, Lawrence Livermore National Laboratory, Massachusetts General Hospital, and Woods Hole Oceanographic Institution (established in 2000, graduated in 2010)

**ERC on Mid-Infrared Technologies for Health and the Environment** — Princeton University, Princeton, NJ (lead institution) in partnership with the City University of New York, the Johns Hopkins University, Texas A&M University, the University of Maryland–Baltimore County, and Rice University (established in 2006,

graduated in 2016)

**Integrated Media Systems Center** — University of Southern California, Los Angeles, CA (established in 1996, graduated in 2007)

**Center for Power Electronics Systems** — Virginia Polytechnic Institute & State University, Blacksburg, VA (lead institution) in partnership with North Carolina A&T State University, University of Puerto Rico at Mayagüez, Rensselaer Polytechnic Institute, and University of Wisconsin at Madison (established in 1998, graduated in 2008)

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Engineering Research Centers Program  
Engineering Education and Centers Division  
Directorate for Engineering  
National Science Foundation  
4201 Wilson Blvd., Rm. 585  
Arlington, VA 22230  
Phone: (703) 292-8381  
Fax: (703) 292-9051  
TDD: (703) 292-5090  
Division: <http://www.nsf.gov/div/index.jsp?div=EEC>  
ERC Association: <http://www.erc-assoc.org>