ERC BEST PRACTICES MANUAL
CHAPTER 4: EDUCATION PROGRAMS

4.1 INTRODUCTION

From the beginning of the Engineering Research centers (ERC) program, ERCs have been focused on creating a culture that integrates research, education, and industrial practice to produce engineering graduates who are more effective in industrial practice, and to infuse new knowledge at the interface of disciplines into the engineering curricula. Third-generation (Gen-3) ERCs—that is, all ERCs established in FY 2008 and after—have an additional mandate, to increase the creativity of engineering graduates and expose them to innovation, entrepreneurship, and research practices in other countries and to produce graduates who will be creative U.S. innovators in a globally competitive economy." Each center is built on three pillars; research, education, and innovation through technology translation/transfer. All three of these components must be fully integrated in a successful center.

ERCs are motivated by an engineered systems vision and structured by a strategic plan that defines a research program to address barriers in the way of realizing the vision. The strategic research plan structures an integrated program of fundamental and applied research that feeds into proof-of-concept enabling and systems technology testbeds.

An ERC's education program is comprised of a university program and a precollege program. The university education mission of an ERC is to prepare students for effective practice in industry and to enhance their capacity for creative and innovative leadership throughout their careers. The precollege education mission rests on long-term partnerships with K-12 institutions to expose science, technology, engineering, and math (STEM) teachers to engineering and deliver engineering concepts and experiences to their classrooms to stimulate student interest in engineering careers. The interface of the research and educational culture of the ERC enriches the participating universities through the transfer of ERC-generated knowledge into engineering curricula.

A team of faculty, students of all levels, and staff who share the ERC's vision develop the ERC's culture. They come from different disciplines and perspectives of research, education, and technological innovation, and they include rich perspectives offered by diversity in gender, race, ethnicity, and other demographics.

According to the ERC Program culture and each center's specific education strategic plan, each center is expected to attract new students to engineering and to produce engineering graduates who will be highly effective in industrial practice and be the creative innovators of the global economy of the future. There are four main target audiences: graduate students, undergraduate students (including community college students and veterans), precollege students, and the general public.

Each ERC's engineering education program is expected to include:

- University undergraduate and graduate education programs strategically designed to produce graduates with the skill sets needed to be creative, adaptive, and innovative, well prepared for effective leadership in industry through knowledge about industrial practice, technology advancement, entrepreneurship, and innovation. "Strategically designed" means that there should be an education strategic plan for the center, and it is especially important for Gen-3 ERCs since there is an expectation that the center develops and implements purposefully the education plan that will produce the type of students that the center is aiming to graduate.
- Advances in curricular materials derived from the ERC's interdisciplinary and systems-focused research;
- Long-term precollege partnerships aimed at exposing K-12 STEM teachers to engineering and to delivering engineering concepts and experiences to their classrooms (either directly or via the teachers) in order to stimulate student interest in engineering careers and increase enrollment in college-level engineering degree programs.

- General Outreach to involve precollege students in the ERC activities.
- Strategies to recruit and retain a diverse body of students who are involved in the education activities carried out by the ERC.

NSF provides guidance with respect to outcomes expected from a successful center education program. These outcomes are clearly articulated in the applicable solicitation and are repeated below:

- The goals of the university education strategic plan will impart skill sets to undergraduate and graduate students so that they will be:
    - Effective in advancing technological innovation in industry
    - Adaptive and creative innovators
    - Effective in innovation in a globally connected, innovation-driven world.
- The strategic plan clearly specifies:
    - Desired characteristics and skill sets of graduate and undergraduate student researchers
    - Approaches to impart these skill sets to students via the education program
    - Measures to assess progress and impacts through longitudinal data
    - Mechanisms to incorporate assessment feedback to improve program content and delivery
    - Actionable plans to mentor students, post-doctoral researchers, and junior faculty.
- The education program will be integrated with the center's research with foreign collaborators so that students have the opportunity to carry out research relevant to the ERC's goals at foreign laboratories for a time sufficiently long to provide knowledge of foreign research practices, equipment, and other competencies.
- Effective plans are in place to integrate the ERC's cross-disciplinary and systems research into courseware and curricula and to disseminate outcomes and curriculum/outreach products to all ERC partners and for workforce training.
- The precollege education program will develop an effective long-term partnership with up to five precollege institutions (school districts or individual schools) nearby the lead and/or partner universities, to incorporate middle and high school teachers and students in ERC-related activities.
- If community college or technical college faculty and students are involved, the experience will add value to the educational capacity of the faculty and students as well as to the faculty and students of the ERC.
- Effective assessment tools are utilized to incorporate feedback from assessments/evaluations into the education programs to improve program content and deliver on program goals.

The development of an ERC education program requires strategic planning, a team of experts, and participation from all stakeholder groups. These teams can benefit from the collective experience of Education Program Directors at existing centers. This chapter has been assembled by these experts in ERCs across the country and is intended as guidance to those considering developing an ERC or ERC-like education program, as well as for new ERC education personnel who join an ongoing center.

It is important that new centers not interpret the contents of this chapter as a list of requirements for ERCs. Instead, it is a resource describing the collective wisdom of multiple ERC University Education and Precollege Education Directors. It can be used to identify programs and techniques

that have worked in the past, being aware that each situation is different. *Specific review criteria for each component of an ERC by age of the ERC are available at the ERC documents website*.[1]

Nonetheless, in addition to the prescribed goals above, the ERC must include a Research Experiences for Undergraduates (REU) Program, Research Experiences for Teachers (RET) Program, and Young Scholars (YS) Program (for Gen-3 ERCs only). However, NSF encourages centers to apply the same creativity and innovation that drive their research programs in determining how they develop and implement these education programs at their particular ERC. Additionally, latitude is given with respect to specific details and programming for other education and general public outreach programs that involve precollege students in ERC activities.

This chapter is divided into six sections: Program Planning, Precollege Education, Undergraduate Education, Graduate Education, Assessment and Evaluation, and Program Sustainability. Each has two parts. The first is a summary of the topic and includes suggestions and recommendations. The second part, a corresponding appendix, is a collection of center-specific program descriptions that offer an example of how that particular center has implemented a given program. These examples describe how a given program works in a specific center; together they illustrate the breadth of programs offered by centers as well as how centers have implemented required programs and developed new ones. Each example includes contact information, and readers who would like to import a given program are encouraged to contact ERC program personnel directly to learn additional details.

Current and prospective ERC Education Program Directors are urged to start with the planning section and follow the steps regarding identifying desired outcomes, identifying local programs that can be leveraged, identifying local opportunities for new programs, including assessment and evaluation in the process, and being mindful of opportunities for sustainability.

Each ERC Education program must support the mission of the center and each component must be consistent with the mission. Additionally, ERCs have historically been leaders in promoting diversity in all of their programs and all centers are expected to continue this tradition of including those who have been underrepresented in the Nation's science and engineering enterprise.

The following Exhibits provide data gathered by the NSF ERC Program from the ERCs in the portfolio. They give prospective and current ERC Education Directors information on the type of outcomes and investments made in Education by ERCs. The data was obtained from the NSF ERCWEB program database.

[1] https://www.erc-reports.org/public/library

Exhibit A. Current ERCs in FY2014 and Technology Clusters of the ERCs

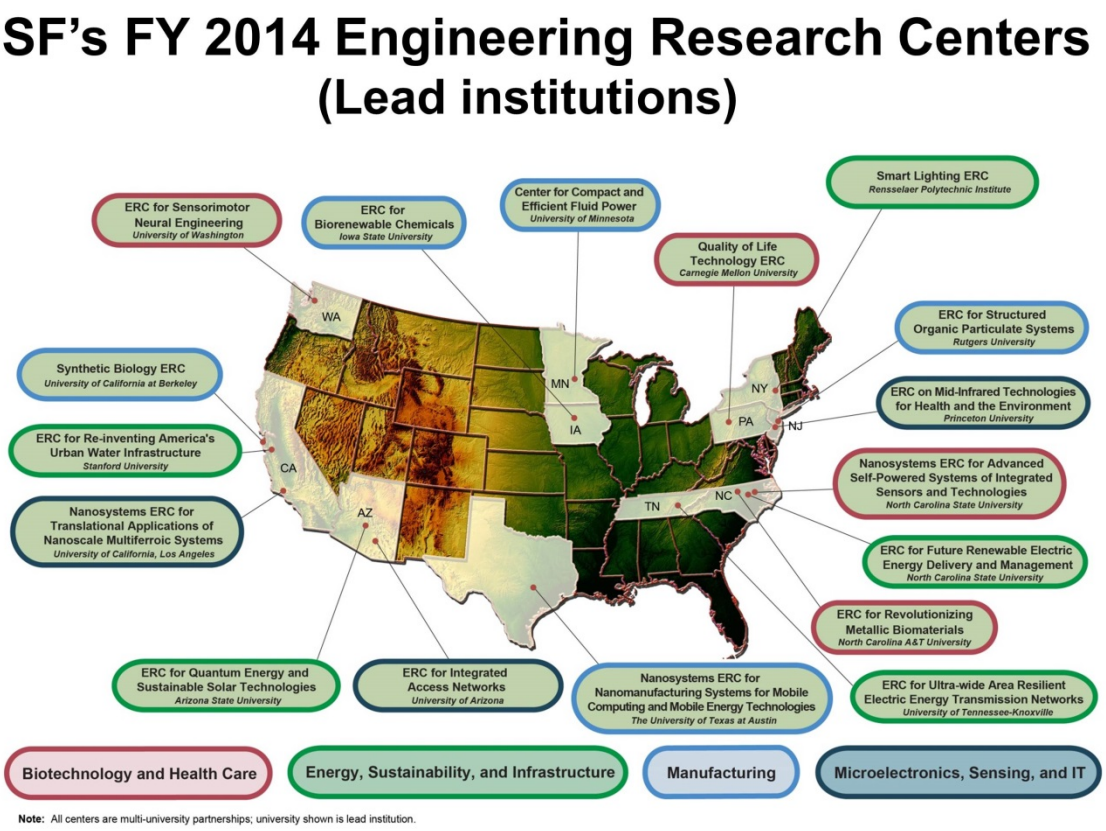


Exhibit B. ERC Influence on University Curriculum, Historical[2]

ERC Influence on Curriculum, FY 1985–2013

	FY 2013 (20 ERCs)		FY 2008–2012 Annualized		FY 1985–2013 (58 ERCs)
Degrees	***Total***	***Per Center***	***Total***	***Per Center***	***Total***
New Full-Degree Programs Based on ERC Research	2	< 1	3	< 1	42
New Degree Minors Based on ERC Research	2	< 1	3	< 1	30
New Certificate Programs Based on ERC Research	4	< 1	2	< 1	28
Courses	***Total***	***Per Center***	***Total***	***Per Center***	***Total***
New Courses Based on ERC Research	63	3	46	3	864
Ongoing Courses With ERC Content	303	15	161	10	1,453
Course Modules Based on ERC Research	30	2	21	1	497
Textbooks	***Total***	***Per Center***	***Total***	***Per Center***	***Total***
New Textbooks Based on ERC Research	10	1	3	< 1	152
New Textbook Chapters Based on ERC Research	13	1	7	< 1	52

Does not include centers from the Earthquake Technology Sector

[2] 20 ERCs in ERC FY2013 are: Center for Integrated Access Networks at University of Arizona (CIAN), ERC for Quantum Energy and Sustainable Solar Technologies (QESST), NSF Nanosystems ERC for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) at North Carolina State University, ERC for Re-inventing the Nation's Urban Water Infrastructure at Stanford University (ReNUWIt), Quality of Life Technology ERC at Carnegie Melon University, Smart Lighting ERC at Rensselaer Polytechnic Institute, ERC for Extreme Ultraviolet Science and Technology (EUV) at Colorado State University, ERC for Structured Organic Particulate Systems (C-SOPS) at Rutgers University, ERC for Biorenewable Chemicals at Iowa State University (CBiRC), Synthetic Biology ERC at the University of California, Berkeley (SynBERC), ERC for Compact and Efficient Fluid Power at the University of Minnesota – Twin Cities, Nanosystems ERC for Translational Applications of Nanoscale Multiferroic Systems (TANMS) at UCLA, Nanosystems ERC for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT) at University of Texas-Austin, ERC for Ultra-wide-area Resilient Electric Energy Transmissions Network (CURENT) at the University of Tennessee, ERC for Revolutionizing Metallic Biomaterials at North Carolina A&T State University (RMB), ERC for Collaborative Adaptive Sensing of the Atmosphere at the University of Massachusetts (CASA), Future Renewable Electric Energy and Management Systems ERC at North Carolina State University (FREEDM), ERC for Biomimetic MicroElectronic Systems at the University of Southern California (BMES), ERC on Mid-Infrared Technologies for Health and the Environment at Princeton University (MIRTHE), and the ERC for Sensorimotor Neural Engineering at University of Washington (CSNE)

"Annualized ERCs" includes the 20 ERCs above and the following additional 12 ERCs: University of Michigan - Wireless Integrated Microsystems' Vanderbilt/Northwestern/Texas/Harvard/MIT Center for Bioengineering Educational Technologies; Northeastern University Subsurface Sensing and Imaging Systems; University of Hawaii – Marine Bioproducts Engineering Center; Clemson University – Center for Advanced Engineering Fibers and Films; Georgia Tech/Emory Center for the Engineering of Living Tissues; University of Kansas – Center for Environmentally Beneficial Catalysis; Virginia Tech – Center for Power Electronics Systems; University of Illinois– Compound Semiconductor Microelectronics; Johns Hopkins University – Computer-Integrated Surgical Systems and Technology; University at Buffalo Multidisciplinary Center for Earthquake Engineering Research; and University of California at Berkeley – Pacific Earthquake ERC.

Exhibit C. Curricular Impact of ERCs, FY 2007-2013

Curricular Impact of ERCs, FY 2007–2013

	FY 2013 (20 ERCs)		FY 2008–2012 Annualized		FY 2007–2013** (32 ERCs)
New and Ongoing Courses, Workshops, Short Courses, Webinars, and Textbooks Based on ERC Research	*Total*	*Per Center*	*Total*	*Per Center*	*Total*
With Engineered-System Focus	335	17	208	13	1,470
With Multidisciplinary Content	280	14	208	13	1,396
Offered at Undergraduate Level	196	10	125	8	889
Offered at Graduate Level	313	16	176	11	1,264
Used at More Than One ERC Institution	40	2	43	3	267
Team Taught by Faculty in More Than One Department	78	4	52	3	373

Does not include centers from the Earthquake Technology Sector
*** Data collection of curricular impacts started in 2007.*

Exhibit D. ERC Student Degrees, FY 1985-2013

	FY 2013 (20 ERCs)		FY 2008–2012 Annualized		FY 1985–2013 (58 ERCs)
Degree Type	*Total*	*Per Center*	*Total*	*Per Center*	*Total*
Bachelor's	88	4	82	5	3,895
Master's	104	5	87	5	3,750
Doctoral	134	7	135	8	4,151
Total	*326*	*16*	*305*	*18*	*11,796*

Does not include centers from the Earthquake Technology Sector

Exhibit E. ERC Graduate Employment (20 centers) FY2013

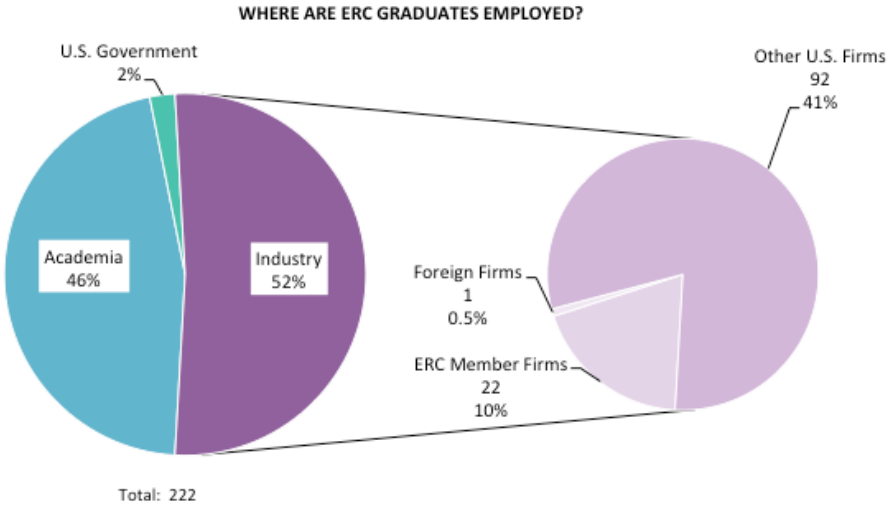
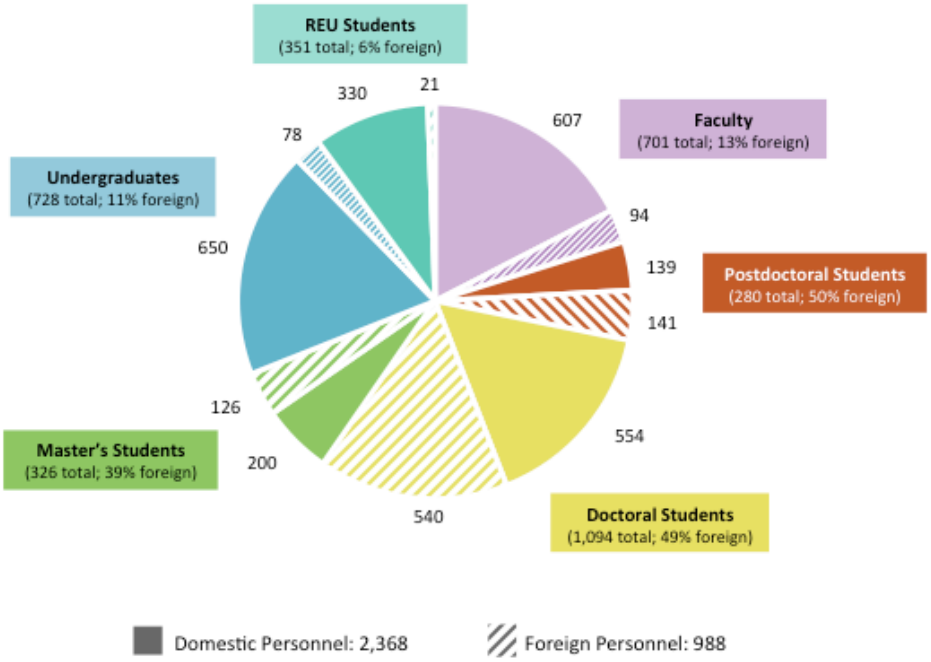


Exhibit F. Personnel Conducting ERC Research FY2013[3]



[3] The sum of the number of personnel for each category may exceed the total number of personnel because personnel may belong to multiple categories. Percentage of foreign personnel is calculated out of domestic and foreign personnel, excluding personnel who did not report citizenship.

Exhibit G. Education Program Expenditures from Unrestricted and Restricted Cash

All ERC Centers																				
				Unrestricted Cash									Restricted Cash							
Year	Average Education Total Per Center	Number of Centers	Education Total	Precollege Activities	University Education	Student Leadership Council	Young Scholars	REU	RET	Assessment	Community College Activities	Other	Precollege Activities	University Education	Student Leadership Council	Young Scholars	REU	RET	Assessment	Community College Activities	Other
2002	$391,429	19	$7,437,145	$0	$0	$0	$0	$0	$0	$0	$0	$6,110,864	$0	$0	$0	$0	$0	$0	$0	$0	$1,326,281
2003	$378,613	19	$7,193,646	$0	$0	$0	$0	$0	$0	$0	$0	$6,000,086	$0	$0	$0	$0	$0	$0	$0	$0	$1,193,560
2004	$403,921	23	$9,290,194	$0	$0	$0	$0	$0	$0	$0	$0	$7,156,937	$0	$0	$0	$0	$0	$0	$0	$0	$2,133,257
2005	$491,912	22	$10,822,064	$0	$0	$0	$0	$0	$0	$0	$0	$8,583,696	$0	$0	$0	$0	$0	$0	$0	$0	$2,238,368
2006	$472,110	19	$8,970,098	$0	$0	$0	$0	$0	$0	$0	$0	$7,487,375	$0	$0	$0	$0	$0	$0	$0	$0	$1,482,723
2007	$351,121	23	$8,075,792	$0	$0	$0	$0	$51,415	$0	$0	$0	$6,446,290	$0	$0	$0	$0	$5,085	$0	$0	$0	$1,573,002
2008	$342,188	20	$6,843,753	$0	$0	$0	$0	$361,495	$659,088	$0	$0	$4,693,267	$0	$0	$0	$0	$85,927	$180,374	$0	$0	$863,602
2009	$364,212	21	$7,648,450	$0	$0	$0	$0	$1,011,438	$1,030,134	$0	$0	$4,995,065	$0	$0	$0	$0	$53,145	$28,104	$0	$0	$530,564
2010	$500,653	15	$7,509,797	$0	$0	$0	$0	$1,067,033	$1,124,125	$0	$0	$4,550,277	$0	$0	$0	$0	$145,720	$117,146	$0	$0	$505,496
2011	$509,405	13	$6,622,268	$0	$0	$0	$0	$1,363,379	$763,888	$0	$0	$4,103,925	$0	$0	$0	$0	$106,731	$43,566	$0	$0	$240,779
2012	$534,243	17	$9,082,130	$1,370,005	$1,298,604	$256,727	$350,456	$1,583,759	$831,255	$474,437	$106,227	$775,924	$268,192	$4,734	$0	$0	$512,032	$1,102,250	$0	$0	$147,528
2013	$488,288	20	$9,765,755	$1,215,938	$1,248,793	$257,421	$435,112	$1,814,481	$964,016	$537,577	$133,885	$885,788	$447,311	$313,981	$11,515	$27,000	$497,581	$951,592	$0	$0	$23,764
Average All Years	**$435,675**	**19**	**$8,271,758**	**$215,495**	**$212,283**	**$42,846**	**$65,464**	**$604,417**	**$447,709**	**$84,335**	**$20,009**	**$5,149,125**	**$59,625**	**$26,560**	**$960**	**$2,250**	**$117,185**	**$201,919**	**$0**	**$0**	**$1,021,577**

* REU data was first collected in 2007, RET data was first collected in 2008, and Precollege Activies, University Education, Student Leadership Council, Young Scholars, Assessment and Community College Activities were first collected in 2012.