The Division of

Engineering Education and Centers

(EEC)

Directorate for Engineering

National Science Foundation

Division Plan

2007–2011

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Support the development of diverse, creative, innovative and globally competitive engineers.

EEC Objectives for 2020

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2) **Promote the success of the undergraduate learning experience**
3) **Improve the pathway to graduate engineering programs for U.S. and permanent residents**
4) **Build a culture of discovery and innovation in engineering through multidisciplinary centers**

EXECUTIVE SUMMARY

The Engineering Education and Centers (EEC) Division has traditionally provided support to the engineering community in three main areas: Research Centers, Engineering Education and Human Resources Development—the second category aimed at developing the nation's engineering workforce.

EEC also has two characteristics that make it unique among divisions in the Engineering Directorate. First, EEC serves no particular disciplines or research communities, but rather supports all disciplines through funding of research teams that address the frontiers between disciplines. This research is also unique because it emphasizes development of engineered systems that exist at these multidisciplinary research frontiers. Second, while all divisions of the Directorate for Engineering (ENG) are implicitly involved in the development of engineering faculty and students, EEC has explicit responsibility for advancing engineering education at all levels. Providing diverse pathways for young people to study engineering and to advance through undergraduate and graduate study, and ensuring their preparation for effective practice, is a principal responsibility of EEC programs.

As will become clear in this document, the EEC Division Plan directly connects with two of the basic objectives of the *American Competitiveness Initiative.* These are:

- Invest in "a system of education through the secondary level that equips each new generation of Americans with the educational foundation for future study and inquiry in technical subjects and that inspires and sustains their interests;" and
- Invest in "institutions of higher education that provide American students access to world-class education and research opportunities in mathematics, science, engineering and technology."

Objectives

EEC's 2007 Division Plan focuses on six basic objectives. The first four objectives outline some challenging, but inspirational goals. Looking ahead a dozen years to 2020, these goals challenge both EEC and the engineering community to commit to the following:

(1) Enhance the K–12 pipeline

Goal: 10 percent of all students matriculating at four-year colleges will study engineering.

(2) Promote the success of the undergraduate engineering learning experience

Goal: Three of four students who begin the study of engineering will complete at least a B.S. in engineering.

(3) Improve the pathway into graduate programs for U.S. and permanent residents

Goal: 5,000 Engineering Ph.D.s granted annually to U.S. and permanent residents.

(4) Build a culture of discovery and innovation in our Engineering Research Centers

Goal: 1,000 students working in the Engineering Research Centers (ERCs) will graduate annually with ERC-related research and development experience.

These goals are challenging. Their attainment is quite clearly beyond the domain of a single division of NSF, or even the whole of NSF. But NSF can and must promote interest and support among American universities for these goals and help to catalyze the educational objectives of the nation.

An interesting parallel is that far less than 1 percent of the capital value of U.S. stocks are traded on the New York Stock Exchange each day, but these trades set the prices (and expectations) of the world's capital markets around the world. Similarly, NSF is viewed as a trend-setter and policy-maker in U.S. engineering research and education. What other federal agency besides NSF could realistically be seen as the leader in establishing national priorities in engineering research and education? A major role of EEC is to advocate for the future needs of the engineering workforce and its effective preparation. The engineering community needs a clear destination.

To help accomplish these goals, priorities for EEC funding are to respond to the following four questions, derived from our first four objectives:

(1) How can we increase students' interest in the study of engineering? Currently, less than 7 percent of entering university freshmen pursue engineering programs.
(2) How do students best learn engineering ideas, principles and practices and what are the impediments to adopting and supporting educational innovations in engineering schools? Furthermore, how do we increase the focus on developing creative and innovative engineers?
(3) What changes are needed in both undergraduate engineering curricula and the graduate pathways to attract more U.S. citizens and permanent residents into advanced engineering, especially Ph.D. programs?
(4) How do we involve and develop the ERC programs to provide opportunities to a larger set of institutionally diverse schools, particularly those not in the upper tier, to benefit from the systems-focused, cross-disciplinary nature of an ERC?

The first priority area—expanding the pipeline from K–12 into our engineering schools—has been and will continue to be of primary interest to EEC.

The second priority area addresses how change and innovation can best be implemented in engineering schools. Are engineering schools organized effectively to reward and promote the careers of the engineering faculty who are in regular contact with nearly 400,000 U.S. engineering students? This priority has been highlighted in the October 2006 *Journal of Engineering Education* with the article "Special Report: The Research

Agenda for the New Discipline of Engineering Education" (see "Engineering Learning Systems;" v.95, no. 4).

The third priority area addresses the national concern that every year, fewer and fewer U.S. citizens and permanent residents are pursuing and completing engineering Ph.D.s. In 2004, only 43 percent of our engineering Ph.D.s were awarded to U.S. citizens and permanent residents, compared to 50 percent 20 years ago. What kind of programs, innovations and pathways are needed to make advanced study a more desirable and rewarding career step?

The fourth priority area is focused on expanding the proven impact of the ERC concept into a broader range of engineering schools. ERCs provide students and faculty with the experience of being part of the overall process of discovery, development and building of products and systems—an integrating activity not usually visible in or part of a typical engineering program. Most engineering programs do not have the capability and resources to include an overall engineering system within their curricula.

Many of these EEC objectives are, of course, addressed quite successfully by EEC programs already underway. The Research Experiences for Undergraduates (REU) program is directly aimed at students with interest and potential for graduate schools, and has had considerable success. A recent study by SRI International showed that REU engineering students increased their likelihood of pursuing Ph.D.s from 25 percent before an REU experience to 48 percent after.

Our Research Experiences for Teachers (RET) Program reaches out to 500 high school teachers annually, a sizeable number but far short of the estimated one-quarter million math and science educators in middle and high schools nationwide.

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The remainder of this Division Plan is divided into several sections. The following three sections present EEC's future plans (both continuing efforts as well as new initiatives) in the three broad areas of education, human resources development, and ERCs. Finally, four appendices make this plan as self-contained as possible. These appendices include background on ERC programs, a brief summary of past EEC planning documents, and a selected set of assessments of past EEC programs.

ENGINEERING EDUCATION PLANS

Continuing Efforts:
- Engineering Education Research;
- Engineering Education Program;
- Nanotechnology Undergraduate Education (NUE);
- International Research and Education in Engineering (IREE); and
- Fall 2007 Education Grantee Meeting

New Initiatives:
- Council of Associate Deans for Undergraduate Programs
- The Business of Engineering Education
- Workshop on Renaissance in Engineering Ph.D. Education.

Continuing Efforts

Engineering Education Research

Throughout the 1980s and 1990s, there was a major push by NSF through the Engineering Coalitions Program to reform and modernize engineering education, and then institutionalize the changes.

This program met with moderate success and offered many lessons. Probably the program's most significant changes occurred in two areas:.first, there was widespread reform of the first-year experience in engineering programs to increase retention. An outgrowth of this effort was the Department Level Reform Solicitation, which was focused on Undergraduate Engineering Education Reform. This program was directed at departmental or larger units looking to transform their programs or develop new curricula in order to meet the nation's need for a vibrant engineering workforce. Funding was available as either a one-year planning grant for $100,000 or as an implementation grant for up to $1 million. The project's annual allocation was $4.5 million before the program was terminated in fiscal year 2005.

Second, engineering education research was established as an area of scholarly pursuit for engineering faculty (examples include the Vanderbilt, Northwestern, Harvard/MIT, Texas (VaNHT) ERC, National Academy of Engineering (NAE) Center for the Advancement of Scholarship in Engineering Education (CASEE), and ASEE's *Journal of Engineering Education*).

With the establishment of engineering education as a research area, Engineering Education at NSF has supported the formation of a national research agenda and a shift from an unsolicited proposal approach to a more focused one. Fundamental research is needed to define the fundamental knowledge and skills that engineers should possess, how they can best learn these skills, and how the engineering curriculum can be structured to make efficient and effective use of university and faculty resources. EEC has established the Engineering Education Program to effect this more focused approach.

Engineering Education Program

The two main objectives of the Engineering Education Program are: (1) to support research that contributes to a basic understanding of how students learn engineering and (2) to attract talented students, especially women and underrepresented minorities, to all levels of engineering education.

The program funded seven awards in its first year, fiscal year 2006, and 10 awards in fiscal year 2007.

It is expected that projects will be supported that contribute to significant breakthroughs in understanding so that our undergraduate and graduate engineering education can be transformed to meet the needs of the changing economy and society. Specifically, we are interested in research that addresses the following areas, briefly described as:

- **Area 1—Engineering Epistemologies:** Research on what constitutes engineering thinking and knowledge within social contexts now and into the future.
- **Area 2—Engineering Learning Mechanisms:** Research on engineering learners' developing knowledge and competencies in context.
- **Area 3—Engineering Learning Systems:** Research on instructional culture and institutional infrastructure, and on the knowledge of engineering educators.
- **Area 4—Engineering Diversity and Inclusiveness:** Research on how diverse human talents contribute solutions to social and global challenges and thus to the relevance of the engineering profession.
- **Area 5—Engineering Assessment:** Research on, and the development of, assessment methods, instruments and metrics to inform engineering education practice and to inform learning.

Additional areas that are being considered are Entrepreneurial Education, e-Learning, and Capstone Design:

Entrepreneurial Education

The American *Competitiveness Initiative* states that "sustained scientific advancement and innovation are key to maintaining our competitive edge." Additionally, the NAE report *Engineer of 2020* indicates that students will need to be educated as innovators, with more direct exposure to cross-disciplinary topics and the workings of an entrepreneurial economy.

As more colleges and universities seek to incorporate innovation and entrepreneurial activities into their curricula, researchers will need to study and address new issues. They will need to assess entrepreneurial programs to gauge how they assist and prepare students to work in entrepreneurial environments; how they facilitate learning of concepts related to entrepreneurship; what role entrepreneurial programs play in helping students learn how to incorporate innovation into product and service design and commercialization; and how they help students learn entrepreneurial skills. Researchers will also need to understand what constitutes entrepreneurial skills; how well students understand the innovation process; and what the concepts of entrepreneurship are.

Some of the leading entities in this area are the Kauffman Foundation, the National Collegiate Inventors and Innovators Alliance, and the Lemelson Foundation.

Web-based Education e-Learning

E-learning continues to grow within higher education. Resources and research to help educators develop practices in this area are greatly needed. E-learning describes issues related to online learning, Web-based training and technology-delivered instruction. Critical to the advancement of e-learning is the ability to offer information supporting student learning through the use of information and communication technologies. Issues of interest might include: the use of network technologies to create, foster, deliver and facilitate learning, anytime and anywhere; and the delivery of individualized, comprehensive, dynamic learning content in real time, aiding the development of communities of knowledge and linking learners and practitioners with experts.

Capstone Design

All programs accredited by ABET, Inc. (previously the Accreditation Board for Engineering and Technology) require a capstone design experience, often a sequence of courses. Faculty members seek projects, often from external sources, that challenge students to apply their knowledge from a wide spectrum of their curriculum. The primary objective is to encourage innovation in product and process design, often in a team setting. For many engineering students, the experience is the first opportunity to work with a client on an open-ended problem. Many agree that the capstone experience is the single most important component of the engineering student’s education.

Nanotechnology Undergraduate Education (NUE)

The Nanotechnology Undergraduate Education (NUE) program, initiated in fiscal year 2003 as a component of the NSF Nanoscale Science and Engineering (NSE) program, provides grants that enable individuals, departments, programs or campuses to integrate nanoscale science and engineering into their curricula. It includes the Nanoscale Interdisciplinary Research Teams (NIRT), the Nanoscale Exploratory Research (NER), and the Nanoscale Science and Engineering Centers (NSEC) programs.

In its first two years, fiscal years 2003 and 2004, the NUE program was managed by the Division of Chemistry in the Directorate for Mathematical and Physical Sciences (MPS), with co-funding provided by ENG. MPS participation stopped in fiscal year 2005. The EEC assumed management of the program with co-funding from the Directorate of

Education and Human Resources (EHR) and the Directorate of Social, Behavioral and Economic Sciences (SBE).

The NUE program emphasizes new approaches to undergraduate engineering education through interdisciplinary collaborations. These collaborations could lead to, but are not limited to:

- New examples of undergraduate nanoscale engineering courses that are presented through the development of laboratory and demonstration experiments, manuals and other written materials, software, and Web-based resources;
- Development and dissemination of new teaching modules for nanoscale engineering of relevance to engineering education that can be used in existing undergraduate courses.

Award amounts in the first two years of the program were $100,000. In fiscal year 2003, 33 awards were funded for a total of $3.3 million and in fiscal year 2004, 34 awards were funded for a total of $3.3 million. Beginning in fiscal year 2005, the award amount was increased to $200,000 for a period of 24 months. The total number of awards funded in fiscal year 2005 was 14 for a total of $2.7 million and, in fiscal year 2006, 11 for a total of $2.1 million.

The NUE program, now in its fifth year, involves three NSF directorates for fiscal year 2007: ENG, SBE and EHR. The fiscal year 2007 program solicitation is focused on nanoscale engineering education with relevance to devices and systems. Another focus is on ethical, legal, economic and other social implications of nanotechnology. The total budget available for fiscal year 2007 is $1.9 million; it is estimated that 10 awards will be funded.

International Research and Education in Engineering (IREE) Program

The IREE program provides supplements to existing awards supported by ENG divisions to enable early-career researchers in the United States to gain international research experience and perspective. Additionally, by broadening existing research projects funded by ENG programs through partnership with self-supported foreign counterparts, IREE seeks to enhance U.S. innovation in both research and education. Early-career researchers include undergraduate and graduate students, postdoctoral fellows, and early-career faculty members.

Initiated in 2006, IREE funds medium-duration (three to six months) visits by U.S. early-career researchers to collaborating institutions and laboratories outside of the United States. The visits must be related to the objectives of ongoing work in current projects, augmented by evidence of engagement with the cultural activities in the countries visited.

Because of its connection with both the Engineering Education and the Human Resources programs of EEC, and because it focuses on developing the potential of early-career researchers, IREE is also linked to EEC's leadership role in integrating research with education. Thus, the principal mission of IREE enables the connection of the research programs of ENG divisions with the education of students.

The IREE partnerships together create an important bridge between EEC and other ENG divisions and between EEC and the Office of International Science and Engineering (OISE). In 2006, this bridge linked EEC to more than 100 awards in other ENG divisions. These awards represented a total estimated investment by the ENG divisions of at least $50 million.

Fall 2007 Education Grantees Meeting

In the spring of 2005, EEC, along with the Directorate for Computer and Information Science and Engineering (CISE) and EHR, hosted a grantees meeting focused on engineering and computer science education. A second meeting occurred in the fall of 2007. It is intended that EEC will annually sponsor the grantees conference focusing on research briefings, new ideas and the benchmarking of best practices.

New initiatives

Council of Associate Deans for Undergraduate Programs

There are nearly 400 accredited colleges of engineering in the United States, and most are organized alike. A dean serves as the CEO with several chief operating officers, who in academe have titles like Associate Dean of Graduate/Research Programs and Associate Dean for Undergraduate Programs. Larger schools may have additional officers focusing on administration, outreach, and the like.

Interestingly, the Associate Deans of Graduate/Research Programs have, for the last 25 years or so, organized into the Engineering Research Council under the umbrella of ASEE. The council hosts regular communications, annual meetings, and even an award for Outstanding Administration. It exists to promote graduate education and research in engineering and, while doing so, share best practices across all engineering colleges.

For reasons that are not altogether clear, a corresponding “Council of Associate Deans for Undergraduate Programs” in engineering has never evolved. Surely, many of the undergraduate issues that exist at different engineering schools are not unique. Engineering programs are all accredited by ABET, Inc., and professional societies, such as IEEE, ASME, and the Institute of Industrial Engineers, serve their student members uniformly across the nation. Unfortunately, no formal council of these leaders in undergraduate engineering education exists. Such a body could be a significant force in shaping, assessing, and implementing research in engineering education and in defining new needs.

Associate Deans of Undergraduate Programs have responsibility and oversight with many of the following functions:

- Assignment of instructors;
- Coordination of faculty who are teaching mathematics, chemistry and physics;
- Course evaluations by students;
- Assignment of space for rooms and laboratories;
- Orientation of new faculty for teaching effectiveness;
- Workshops for teaching assistants;
- Leadership of K–12 outreach efforts; and
- Compilation and analysis of retention statistics.

No doubt these faculty members have other responsibilities. Even more important than their duties is the fact that faculty members appointed to such leadership positions invariably have had outstanding careers of teaching and advising. As a result, they could form a powerful group for advancing the quality of and commitment to improving undergraduate engineering education.

The Business of Engineering Education

A longstanding issue about faculty career paths in academe, especially in engineering, is the balance between teaching and research. It is the common belief among engineering faculty that accomplishments and success in research are rewarded at a significantly higher level than similar success in the classroom. Certainly, success in research brings financial resources and high visibility to an engineering school and various national ratings and rankings seem to be dominated by research and scholarship of the faculty. Often a faculty member's teaching success is only of minor consequence in reaching tenure, and being satisfactory is often enough, much like a pass-fail grade.

One of the inherent difficulties in promoting the importance of quality in the classroom relates to its measurement and how this measurement relates to the business model of the college or university. Faculty classroom success or lack thereof is measured principally in one of the following ways: 1) student evaluations, 2) classroom peer assessment or 3) curricula materials.

Some schools use (require) all these processes, but the single most important is usually the student evaluations. This instrument provides an immediate and vivid view of the student's real-time assessment of the class and instructor. Some schools require that every course and every instructor in every term be evaluated by the students; but there is great variation among schools.

However, the use of student evaluations for measuring course quality is by no means universally accepted as valid. The two major criticisms of this metric are, among others, that:

- A student's evaluation is influenced by the student's expected grade, and
- Students often rate an instructor as "superior" based on the instructor's personality rather than on what they actually learned.

At the same time, a study of more than 60,000 course evaluations at one school (in 2004/2005, Northeastern University) strongly suggests that neither of these criticisms is valid. Course evaluations for all courses (freshman through seniors) at Northeastern University included 14 questions answered on a scale of 1–5, with 5 being the highest. Three of the questions were:

1. Overall teacher effectiveness
2. Amount learned
3. Expected grade (F-1,D-2 … A-5)

Linear regression was determined for answers given for (1) and (2) and then for answers given for (1) and (3), and the correlation coefficient for each comparison showed a clear trend. The correlation coefficient between (1) and (2) was positive (0.85), suggesting a strong relationship between a student's perception of teacher effectiveness and the amount the student feels she learned. The correlation coefficient between (1) and (3) was almost zero (-0.3), suggesting no relationship between a student's perception of teacher effectiveness and the grade he expects to receive.

Could these results be replicated across all U.S. engineering schools, which differ in size, location, mission (public vs. private), etc.? This question remains to be answered, but the Northeastern University data certainly suggest that teaching effectiveness and the desired outcome of knowledge transfer are highly and positively correlated. Importantly, this result underscores the intrinsic value of "quality teaching" to the college and the critical role of the engineering educator. But does it then automatically elevate the importance of teaching relative to research? Without any further insight, probably not!

What is missing are clear links between teaching effectiveness and retention/graduation and, ultimately, revenue. Clearly there must be some relationship as evidenced in the Seymour and Hewitt 1997 study, *Talking About Leaving: Why Undergraduates Leave the Sciences*. Shockingly, 98 percent of the students who left the sciences cited poor teaching by science, mathematics, engineering, and technology faculty as a reason to leave engineering. In a comprehensive study by Adelman (1998), *Women and Men of the Engineering Path: A Model for Analysis of Undergraduate Careers*, slightly more than 56 percent of all students who began pursuing a B.S. in engineering completed an engineering degree by age 30. Today, various estimates place the engineering graduation rate in the low 60 percent range. Obviously, retention and throughput in our engineering schools remain a critical problem.

When a faculty member receives a research grant the impact and, importantly, the revenue are immediately measurable, particularly its impact on the bottom line of the college budget. When a faculty member delivers a sterling course to 100 students, the impact on the bottom line is certainly not as immediate and, even more importantly, it is difficult to measure. What engineering colleges (or universities as a whole) lack is an understanding of how quality in their classrooms impacts their revenue streams.

EEC intends to support a program entitled "The Business of Engineering Education." This program will assess the impacts and benefits of engineering education from a business standpoint. The overall question is: To what degree does quality in the classroom impact the bottom line of the college and university?

Workshop on Renaissance in Engineering Ph.D. Education

The number of doctorates in engineering granted to U.S. citizens and permanent residents has fallen to little over 40 percent of the overall output (a total of 2,838 doctorates to U.S. and permanent residents compared to 3,766 foreign nationals in 2004). Furthermore, only about 3 percent of the doctorates in engineering are being granted to African American, Hispanic and Native American students. We are obviously in a crisis in the area of overall representation and diversity within this pipeline. What is happening and why?

The NAE report *The Engineer of 2020* emphasizes that increasing technological complexity, and an increasingly global business climate, demand that engineers possess a variety of skills. Three of those skills, aside from technical expertise, are communication skills, business and management acumen, and traits of good leadership. Added to this list should be the ability to be strong teachers so that many generations of engineers can meet the NAE requirements.

However, despite the clear need for a new kind of engineer, a Ph.D. in engineering still represents deep understanding of one technical area. Doctoral students gain experience in research methods and learn to communicate research results, although these skills vary greatly. Some Ph.D. candidates gain teaching experience, for example as teaching assistants, but many do not.

Clearly, all the ENG divisions have a principal responsibility for ensuring that university Ph.D. programs not only remain strong and vibrant and continue to attract the most talented students, but also that they are training students to become both researchers and educators.

Additionally, the stark lack of diversity in Ph.D. programs does not bode well for the future. Some serious questions need to be addressed by the constituencies involved in U.S. engineering Ph.D. programs, including:

- Are our Ph.D. programs too narrow and specialized?
- Are our Ph.D. programs too lengthy?
- Are our Ph.D. programs too insulated?

We will host a Workshop on Renaissance in Engineering Ph.D. Education in the summer/fall of 2007 with representatives from academe, industry, government, and NSF to address these critical pedagogical issues.

HUMAN RESOURCES

Continuing Efforts:

- Research Experiences for Undergraduates (REU)
- Research Experiences for Teachers (RET)
- NIBIB-NSF Bioengineering and Bioinformatics Summer Institutes (BBSI)

New Initiatives:

- Partnerships in Pathways to Engineering
- Catalyze the Plan for a Pre-AP in Engineering.

Continuing efforts

Research Experiences for Undergraduates (REU)

In 1958, NSF established the Undergraduate Research Participation (URP) program to encourage the development of undergraduates into independent research investigators. The program was highly successful and provided support for a substantial number of talented undergraduates. Participants in the program were juniors or seniors from the institution receiving a URP program grant. Although the URP program ended in 1979, the importance of undergraduate involvement in research was not dismissed.

In 1986, the Research Experiences for Undergraduates (REU) program was established across the NSF, with both site and supplement grants awarded in 1987. The primary differences between the earlier URP and the present REU programs are: (1) the URP program did not emphasize the importance of recruiting underrepresented students and (2) it accepted participants primarily from the institution receiving the URP grant. The REU program emphasizes the importance of involving underrepresented groups (women, minorities and persons with disabilities) and requires that a significant number of the student participants come from outside the host institution or organization.

The REU program is a major contributor to the NSF goal of developing a diverse, internationally competitive, and globally engaged science and engineering workforce. The REU program is considered one of the most effective avenues for attracting talented undergraduates to and retaining them in careers in science and engineering, including careers in teaching and education research.

The REU program goals are to: (1) expand student participation in all kinds of research—whether disciplinary, interdisciplinary or educational—encompassing efforts by individual investigators, groups, centers, national facilities and others; (2) help develop a diverse, internationally competitive, and globally engaged scientific and engineering workforce; (3) promote the integration of research and education; and (4) encourage faculty to seek talented students traditionally not included in research activities. The program aims to develop undergraduates into independent researchers, rather than dependent learners. Whereas the typical academic experience separates education and research, the REU program provides a research opportunity for undergraduates, a value-added component of their formal undergraduate education.

The REU program objectives are achieved by providing research experiences for undergraduates through two funding mechanisms: REU sites and REU supplements. REU sites are based on independent proposals, submitted at an annual deadline, to initiate and conduct projects that engage a number of undergraduates in research. The sites must have a well-defined common focus that enables a cohort experience for students. Currently there are more than 100 active ENG/REU sites, each with a group of 10 or more undergraduates who work with faculty and graduate mentors on carefully defined projects aligned with the research programs of the host institution.

REU supplement programs may be included in proposals for new or renewal ENG grants or as supplements to ongoing ENG-funded projects. REU supplements generally provide support for a small number of students (usually one or two), and are limited to a maximum of $6,000 per student for one year, with the exception of REU supplements for ERCs, which include usually five or more students.

In 2002, NSF's Division of Research, Evaluation and Communication (REC) commissioned a nationwide study, *Undergraduate Research Opportunities* (URO), to examine all NSF mechanisms supporting undergraduate research, including REU sites and supplements. It covered a wide range of NSF programs and directorates, but did not obtain detailed information about any one.

ENG aims to obtain in-depth information about the activities, outcomes and impacts of its REU sites and supplements programs from the perspectives of the former REU students, principal investigators (PIs) and other faculty mentors. In November 2006, ENG contracted SRI International to conduct a study of the REU programs in order to compare REU sites funded by EEC, REU supplements funded by the ERC program (ERC Supplements) and REU supplements funded by other ENG divisions. The study will also assess differences among respondent groups (undergraduates, PIs, other faculty mentors). Among undergraduates it will assess differences by gender, race and ethnicity, and total duration of the undergraduate research experiences.

The study will begin with a survey of faculty and undergraduate participants in ENG REU programs and be followed two years later with a survey of undergraduate participants.

It is anticipated that the study results will help NSF better understand the components and characteristics of effective REU sites and supplements and will help provide direction to the ENG program directors in management and oversight and in determining the future direction of the programs. Results from the initial surveys are expected in October 2007 and the final follow-up survey results are expected in September 2009.

Research Experiences for Teachers (RET)

Encouraging active participation of K–12 teachers in NSF projects is an excellent way to reach broadly into the U.S. teacher talent pool and to encourage more K–12 students to pursue engineering studies by increasing their understanding of engineering, as conveyed by their teachers. In order to pursue this goal, ENG initiated the Research Experiences for Teachers (RET) program in fiscal year 2001 as a pilot effort intended to bring knowledge of engineering and technological innovation to the precollege classroom.

In its first year, the program provided support for supplements to ongoing NSF/ENG projects and to groups of K–12 in-service and pre-service teachers at nine ERCs. This successful pilot effort within these ERCs was the catalyst for launching the annual ENG-wide RET site competition in fiscal year 2002.

In fiscal year 2003 the program was further expanded to include and encourage the participation of community college faculty in ongoing research and education activities funded by ENG. To date, as a result of the five annual ENG/RET site competitions, 32 RET site awards have been funded and approximately 500 K–12 teachers and community college faculty participate in these programs each year.

The RET program aims to build long-term collaborations among in-service and pre-service K–12 teachers, community college faculty and the engineering research community in institutions of higher learning. RET also aims to support the active participation of these teachers and future teachers in research and education projects funded by NSF/ENG, to facilitate professional development of K–12 teachers and community college faculty through strengthened partnerships between institutions of higher education and local school districts, and to encourage researchers to build mutually rewarding partnerships with teachers.

The RET program achieves its objectives by building partnerships between teachers and engineering researchers through two funding mechanisms: RET supplements and RET sites. RET supplements may be included in proposals for new or renewal ENG grants or as supplements to ongoing ENG-funded projects and are limited to a maximum of $10,000 per teacher for one year. RET sites are based on independent proposals to initiate and conduct research participation projects on campuses for a number of K–12 teachers and/or community college faculty. RET sites are limited to a total maximum of $500,000 for a duration of up to three years.

ENG strongly encourages all of its grantees, including grantees from the Small Business Innovation Research (SBIR) and the Small Business Technology Research (STTR) programs, to identify talented teachers for participation in the RET sites. ENG also strongly encourages the use of RET supplements and sites to enable K–12 teachers of science, mathematics and engineering, as well as community college faculty, to participate in ongoing REU programs.

In 2003, NSF contracted with SRI International to **evaluate the ENG RET program** (see http://www.sri.com/policy/csted/reports/university/index.html#ret2006.) The primary objective of this evaluation was to understand how the RET experiences of ENG RET participants affected their teaching techniques, attitudes about teaching and professional development activities. Also examined were outcomes and impacts beyond the teachers' classrooms, such as knowledge transfer activities or formal partnerships formed between the RET PI and the teacher's school system/district. The study did not assess the impacts of RET on students, other than through participants' reports.

The evaluation found that a majority of the 2001–2005 ENG RET participants were enthusiastic about their participation. Almost all reported that they had received a variety of personal and professional benefits from the program, including new enthusiasm for their teaching; new teaching strategies; a greater awareness of research methods, issues and career opportunities; and enhanced professional opportunities. Moreover, the majority said that their students also had benefited, most often through increased enthusiasm for science, technology, engineering and mathematics subjects and increased awareness of science, technology, engineering and mathematics careers.

The RET program solicitation has been revised, strengthened and improved based on feedback received from survey participants, recommendations received from the academic community, NSF ENG staff and others interested and involved in the RET program. Specifically, RET site programs funded in fiscal year 2007 and beyond will require a strengthened and substantive follow-up plan between the university participants and the teachers and their students throughout the academic year to ensure classroom implementation of curricula and other materials developed during the summer experience. This addition grew out of suggestions RET participants made during the SRI International survey of the RET program (see above).

The on-campus program for teachers will last at least six weeks during the summer and PIs will be strongly encouraged to select teams of teachers (at least two teachers per school) from underrepresented school districts to maximize the impact of the RET project. The total funding request level for an RET site program has been increased to a total of $500,000 over three years. It is anticipated that five RET site awards will be funded in fiscal year 2007, based on an estimated available budget of $3 million.

A supplemental funding opportunity for the support of RET sites within ENG's Center and Network programs will be offered under the annual RET program solicitation. The Centers/Networks include all ongoing ERCs, the Nanoscale Science and Engineering Centers (NSECs), the NNIN and the NCN.

NIBIB-NSF Bioengineering and Bioinformatics Summer Institutes (BBSI)

The creation of the National Institute of Biomedical Imaging and Bioengineering (NIBIB) within the National Institutes of Health (NIH) in 2001 signaled recognition of the importance of bioengineering and the emerging field of bioinformatics to the nation. Soon afterward, in fiscal year 2002, NSF and NIBIB established a jointly funded and administered program, NIBIB-NSF Bioengineering and Bioinformatics Summer Institutes (BBSI), aimed at beginning to create a supply of professionals trained in bioengineering and bioinformatics.

NSF and NIBIB/NIH identified bioengineering and bioinformatics as essential interdisciplinary disciplines for physical and life sciences and these two areas are considered in their broadest sense. Examples include: tissue engineering, biomaterials, drug delivery systems, implant sciences, biosensors, platform technology development, computational modeling, algorithm development, medical imaging, and image analysis. New areas that would benefit from the significant value added of applying the technologies and methods of bioengineering and bioinformatics include the dynamics of complex physical and/or chemical systems, biomimetic systems, systems that demonstrate emergent behavior, genomics, systems biology, biodiversity and ecology.

To date, as a result of two BBSI competitions, 22 BBSI awards to 13 universities have been funded through the support of NIBIB/NIH and five NSF directorates—ENG, MPS, CISE, Biological Sciences (BIO), and EHR. NIBIB and NSF support the program equally ($1.5 million total per year—$750,000 from NIBIB and $750,000 from NSF); but the BBSI program is managed within EEC.

The purpose of the BBSI program is to provide undergraduate and early-stage graduate students majoring in the biological sciences, computer sciences, engineering, mathematics, and physical sciences with well-planned, interdisciplinary bioengineering or bioinformatics research and education experiences in active Summer Institutes, thereby increasing the number of individuals pursuing careers in bioengineering and bioinformatics at the graduate level and beyond. NSF and NIBIB/NIH are collaborating on an important effort to meet anticipated bioengineering and bioinformatics human resource needs, specifically by targeting the career pipeline at a critical juncture.

Each BBSI award includes about 15 undergraduate and graduate students and receives joint NIBIB-NSF support of up to $200,000 (total cost) per year for up to four years. There have been two program solicitations since the program was established in fiscal year 2002. The first solicitation resulted in nine summer institutes being awarded nine four-year programs that began in 2003. All nine of those programs received renewed funding in fiscal year 2006 for additional three-year programs.

New initiatives

Partnerships in Pathways to Engineering

Today, less than 7 percent of all students entering four-year colleges are choosing to study engineering, compared to 10 percent of students two decades ago. Engineering enrollment has maintained a reasonably constant level in absolute numbers over this time period, relying simply on the steady increase in the number of high school graduates. But the number of high school graduates will begin to decline in 2010 and, if trends in student interest in engineering remain constant, an absolute decrease will occur. What is needed is a change in how middle and high school students come to know (or not) about engineering.

Interest in the K–12 pipeline into engineering fields is not a new concern. Business and government have invested substantial resources in the study and improvement of this pipeline for some time. The NAE's *Rising Above the Gathering Storm* and the president's *American Competitiveness Initiative* both address this pipeline as a critical national resource. It is also an EEC priority. One example is the RET program, discussed above, which supports about 500 teachers annually. These teachers impact the thinking of many students. But with an estimated 250,000 math and science teachers nationwide, the RET program is difficult to scale adequately.

However, some programs operated by non-profit organizations do scale well. Most programs are either curricular or extra-curricular. As the names suggest, curricular programs are directed at the school curriculum itself, while extra-curricular programs focus on after-school activities. Three programs deserve mention.

Project Lead the Way began in 1997 with 12 high schools in New York state. These high schools adopted and implemented curricular material relating to topics in engineering such as digital electronics, computer-integrated manufacturing and engineering design. Today, Project Lead the Way is in place in 1,300 schools in 45 states. In some cases, the program has helped students gain college scholarships and enroll in engineering programs. These students may not have been able to attend college otherwise ("Engineering Program Builds Road to College," *Washington Post*, June 3, 2007).

Another successful curricular project is Retirees Enhancing Science Education through Experiments and Demonstration (RESEED). This project, which began in 1991 and is centered in New England, recruits and trains retired engineers to assist science teachers in middle schools. Seventy-five percent of all teachers of physical science for the seventh and eighth grades do not have degrees in the physical sciences!

Entrepreneur Dean Kamen started the FIRST Robotics Program in 1992 with eight high schools in New Hampshire. Teams of high school students, with industry mentors, build human-sized robots with the capability to move, transport and deposit items like balls and cartons into goals, setting the stage for competitions. Today, nearly 1,500 high schools maintain teams and nearly 20,000 seniors per year graduate with real experience in the engineering sequence of design, build and test as a member of a real team.

The question is: Are programs like these contributing to the engineering pipeline? Some impact is obvious. But do a larger percent of FIRST and Project Lead the Way students matriculate into engineering programs? Are they retained at a higher rate than other students with little connection to engineering? Do they become the real leaders and innovators?

Another systematic opportunity that will be investigated is the relationship between the leaders of engineering schools (deans) and those of K–12 school districts (superintendents and principals). Past and present NSF programs have focused on connecting the operating personnel of the two institutions, namely professors and high school and middle school teachers. Programs like RET and Graduate Teaching Fellows in K–12 Education (GK–12) represent such partnerships.

However, unlike formal partnerships between engineering schools and industry (Industry Advisory Boards), no similar partnerships exist between superintendents and principals and engineering deans. It is important to understand what barriers are inhibiting such partnerships. Do the leaders of a given school district know where their students are headed after graduation and do they have reasons to care?

EEC proposes a program that will seek answers about the impact of these programs on the engineering pipeline. It is anticipated that several schools might be supported to partner with these organizations to help collect and analyze demographics as well as the longitudinal impact on students' career choices and their retention in and graduation from engineering programs.

Catalyze the Plan for a Pre-AP in Engineering

Historically, the College Board has offered a broad range of courses and national standardized tests designed for high school students to demonstrate the necessary proficiency to gain placement in advanced college courses. However, students seeking to gain advanced placement in engineering introductory college-level courses are not provided the same opportunity offered to those in the sciences, mathematics and other disciplines. That is to say, there is no AP Engineering test to fuel creation of an AP engineering course.

Over the past 24 months, ENG has provided funds to research the feasibility and the practicality of a Pre-Advanced Placement (AP) model for engineering. A Pre-AP in engineering would be offered to ninth and tenth graders and potentially pave the way for a AP engineering course. This research effort has involved the interviewing of teachers, engineering faculty, educators and experts from industry, trade associations and funding organizations. The research encompassed eight focus groups around the United States involving more than 100 people, more than 20 expert interviews, and a pilot study involving 155 students at nine sites on the East and West coasts.

In order to gain feedback on the results of the research, presentations have been made to organizations like the College Board, the American Society of Mechanical Engineers and the American Society of Civil Engineers. The College Board responded by issuing a statement in early February of 2007 saying it "applauds … the National Science Foundation for funding and conducting the research." In particular, the College Board accepted the study's finding that a pre-AP engineering course would prepare students to enter into an engineering course of study.

In a statement entitled "Engineering Programs in U.S. Secondary Schools," the College Board wrote that they "would be eager to explore what work could be done to build the sort of high school engineering programs that would prepare students for college-level engineering courses." Therefore, the College Board staff was prepared to work with the research team to explore the possibility of a first-time-ever pre-AP course of study—for any disciplinary subject! The pre-AP most likely will reach a much more demographically diverse audience of students, including not only those interested in exploring engineering, but also those who are curious to learn about the design process through the practice of mathematics and science concepts.

The engineering community can provide leadership to develop a course of study or process for a pre-AP that could eventually be replicated and thereby impact STEM education across the United States.

ENGINEERING RESEARCH CENTERS

ERCs: History and impact

Continuing Efforts:
    Award five new Gen-3 ERCs in fiscal year 2008

New Initiatives:
    ERCs for EPSCoR States

ERCs: History and Impact

Industry, academe, and the White House joined in 1984 to ask the National Science Foundation to create the ERC program to join academe and industry in partnership to strengthen the competitive position of industry in a global economy. The partnership establishes cross-disciplinary centers focused on advancing fundamental knowledge and systems technology and providing a design and manufacturing experience for students. The aim is to produce graduates who are leaders in realizing innovation in industry.

A committee from the National Academy of Engineering (NAE) developed the goals and structure of the ERC program. NSF accepted the challenge, Congress provided a start-up budget of $10 million, and the program issued its first solicitation in 1985. Since then, the sustained goal has been to support centers that provide a unique culture where faculty and students integrate research and education across disciplines and focus on a continuum of research from fundamentals to systems technology.

An ERC opens a unique dimension on campus that complements the disciplinary, basic science academic culture. The objective is to produce engineering graduates who are highly innovative and productive in industry. The ERC program gives them realistic engineering experience from design and “build,” through to proof-of-concept testbeds. This culture also serves to attract pre-college students to engineering, impacts the curriculum for undergraduate and graduate engineering students, and motivates engineering undergraduate students to complete their degrees and pursue graduate studies.

For example, the MIT Biotechnology Process Engineering (BPEC) ERC educated a cadre of graduates who were capable of speedily developing the processing technology needed to advance new pharmaceuticals. BPEC graduates were in place to produce the manufacturing technology for protease inhibitors, the anti-HIV Aids drug now saving lives around the world.

Examples of other ERC contributions are described in the Appendix, page 34.

Continuing efforts

Award Five New Gen-3 ERCs in Fiscal Year 2008

The ERC program started its third decade in fiscal year 2006 and, at the request of the fiscal year 2004 Committee of Visitors (COV), the program revised its goals to initiate the third generation (Gen-3) of ERCs. The Gen-3 ERCs will catalyze engineering schools to produce creative and innovative graduates who can successfully compete in a global economy. The goal of the ERC program is to build a culture that integrates discovery and innovation in a global economy by joining academe, industry and practitioners in partnership to:

- Advance fundamental knowledge and transformational engineered systems;
- Provide a model for engineering education to produce graduates who are leaders in innovation in a globally competitive economy; and
- Speed the translation of knowledge to technology and innovation through partnerships.

To achieve those goals, the ERC key features have been restructured as follows through ERC Solicitation NSF 07-521, which will establish five new Gen-3 ERCs in fiscal year 2008.

These new ERCs will:

- Have a stronger focus than current ERCs on combining fundamental research with research and education focused on innovation. The innovation focus will support small firms engaged in transformative research within the ERC's research program to speed innovation and expose students to the innovation process. Partnerships will include industry and practitioners, state and local government, or academic programs designed to stimulate entrepreneurship.

- Prepare students for success in the global economy, and may include a foreign university as a core partner. Support for the foreign university is to be provided by foreign sources.

- Operate strategically designed education programs to develop graduates who are experienced in the creative process and cross-cultural collaboration.

- Form long-term sustained partnerships with precollege educational institutions to attract more students to engineering. Partnerships will connect teachers and students in precollege institutions with students in ERCs to bring engineering concepts into the classroom and engage talented high school students in the ERC's research programs as Young Scholars. Thus the new ERCs will help to increase the enrollment and diversity of domestic students in engineering and science degree programs.

These goals were designed to align directly with the *American Competitiveness Initiative* goals to increase the number and quality of U.S. engineering and science graduates and also with the imperatives set down in the NAE's *Rising Above the Gathering Storm*.

APPENDICES

APPENDIX A
BACKGROUND OF ENGINEERING RESEARCH CENTERS

ERCs: Impacts of specific centers

Between 1985 and fiscal year 2006, NSF established 46 ERCs. The second generation of ERCs, which were funded since 1994, has produced graduates who are viewed by 80 percent of their supervisors as more productive than their peers because of their ERC experience. Ninety percent of ERC member firms join the program to gain access to new ideas and know-how from the ERCs, 70 percent indicate that the ERCs have impacted their R&D agendas, and 60 percent indicate that they developed new products or processes as a result of their ERC membership. Similar results were reported in a study of the first generation of ERCs. The history of funding ERCs is shown in Figure 1.

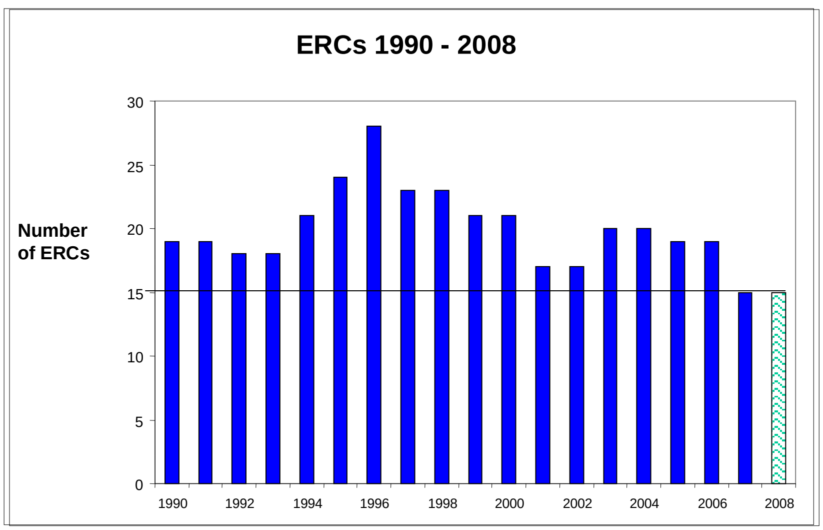

Figure #1

The ERC Program is responsible for the oversight and support of ERCs and Earthquake ERCs (EERCs). Since 1985 these centers have been key in advancing new fields. For example, 10 ERCs have laid the engineering foundation in research and education for bioengineering.

As an example of ERC impacts in the microelectronics field, the Packing Research Center at Georgia Tech brought the systems perspective in electronic packaging to the microelectronics industry, whose products depend on small-scale packaging. In addition, this center had a broad-based economic impact on Georgia. A study commissioned by the

Georgia Research Alliance, an investment partner in the ERC with NSF and industry, found that between 1994 and 2004, the $32.5 million invested by Georgia in the ERC had a quantifiable direct impact on Georgia's economy of nearly $192 million over the 10 years.

The Digital Persona Corp. is an example of the impacts an ERC can achieve through spin-off firms created by innovative students. Two undergraduates from the Caltech Neuromorphic Engineered Systems ERC, Vance Bjorn and Serge Belongie, established Digital Persona in 1996 to commercialize their invention of "U are U" fingerprint identification technology. They won the coveted Best of Comdex award for computer peripherals in 1997, and impacted the market recently by the incorporation of their technology in Microsoft products and in major banks in Mexico and China.

Table (A-1) lists high levels of productivity in the program's quantitative performance indicators, based on a survey of the universities.

Table (A-1) Indicators of ERC Productivity

Outputs	**1985–2005 (41ERCs & EERCs)**	**Per Center**
Curricular Impact		
New Degree Programs	155	4
Courses Impacted	2,156	53
Texts	193	5
Degrees Granted to ERC Students		
B.S.	3759	92
M.S.	3500	85
Ph.D.	3425	84
Total	10684	261
Intellectual Property		
Patents Filed	1045	25
Patents Awarded	528	13
Licenses Issued	1890	46
Spin-off Firms	113	3

The ERC Program also has a long-standing commitment to increasing the diversity of the engineering workforce through the inclusion of women and underrepresented minorities in the ERC cohorts of faculty and students. Viewing the success of the program, and its potential further impact on schools of engineering and science who provide their faculty and students to ERCs, in fiscal year 2004, at the request of Joseph Bordogna, NSF Deputy Director at that time, the ERC program formalized its diversity goals by requiring each ERC to develop a diversity plan in partnership with its deans and department chairs. The ERCs were asked to report annually to NSF on the results, which were benchmarked against national engineering-wide averages. This policy included requirements that at least one of the core or outreach partners be a minority-serving institution, and that the ERCs partner with NSF-supported Louis Stokes Alliances for Minority Participation (LSAMP) and the Alliances for Graduate Education and the Professoriate (AGEP).

The percentage of underrepresented groups (women, underrepresented racial minorities, and Hispanics/Latinos) among the faculty and graduate and undergraduate students in ERCs exceeded engineering-wide averages by wide margins before the implementation of that policy. These charts also show that since the implementation of the policy, ERC diversity exceeds the national averages by wider margins, especially for undergraduates.

Nanoscale Science and Engineering Programs

The EEC Nanoscale Science and Engineering Research Programs represent EEC's contribution to the research efforts of the 25-agency, $1.3 billion/year National Nanotechnology Initiative (NNI), of which NSF's contribution is approximately $344 million. Within this amount, ENG's contribution is $128 million and EEC's is $28 million (all fiscal year 2006 funds). EEC's $28 million contribution includes approximately $10 million of support for nanoscale science and engineering research provided through EEC's other programs, primarily the ERC Program.

<u>Nanoscale Science and Engineering Centers (NSEC)</u>

The NSECs conduct research and develop educational and outreach materials focusing on phenomena at the nanometer scale. Overall coordination for the NSEC Program is provided by the Division for Materials Research (DMR) in the Directorate for Mathematical and Physical Sciences (MPS). EEC has oversight responsibility for six of the 19 NSECs supported by NSF, with participation by other divisions, as indicated:

- The Center for Affordable Nanoengineering of Polymeric Biomedical Devices at Ohio State University (six divisions).
- The Center for Biological and Environmental Nanotechnology at Rice University (two divisions).
- The Center for Integrated Nanomechanical Systems at the University of California at Berkeley (five divisions).
- The Center for Integrated Nanopatterning and Detection Technologies at Northwestern University (two divisions).
- The Center for Nanoscale Systems in Information Technologies at Cornell University (two divisions).
- The New England Nanomanufacturing Center for Enabling Tools at Northeastern University (seven divisions).

These NSECs received aggregate support of approximately $10 million from EEC in fiscal year 2006, with almost $7 million in additional funding provided by other divisions within NSF. In turn, EEC provided approximately $1.5 million in support to the following NSECs overseen by other NSF divisions, as indicated:

- The Center for Directed Assembly of Nanostructures at Rensselaer Polytechnic Institute (Division of Materials Research and two other divisions).
- The Center for Hierarchical Nanomanufacturing at the University of Massachusetts, Amherst (Division of Civil, Mechanical, and Manufacturing Innovation and five other divisions).
- The Center for Nano Connection to Society at Harvard University (Division of Social and Economic Sciences and two divisions).
- The Center for Nanotechnology in Society at the University of California, Santa Barbara (Division of Social and Economic Sciences and nine other divisions).

Network for Computational Nanotechnology (NCN)

The NCN (approximately $3.86 million total funding in fiscal year 2006, with $550,000 from outside EEC) provides a central focus to connect theory, experiment, and computation so that a broad range of researchers have access to the most up-to-date tools available in nanotechnology. NCN researchers, including researchers at NSECs, produce new algorithms, approaches, and software tools with capabilities not yet available commercially. As part of the NSF's infrastructure for the NNI, the NCN spearheads and maintains the nanohub, a Web-based initiative that is a resource for research and education in the areas of nanoelectronics, nanoelectromechanical systems, and their applications to nano-biosystems. The nanohub provides online simulation services as well as courses, tutorials, seminars, debates, and facilities for collaboration.

Nanoscale Interdisciplinary Research Teams (NIRT)

The NIRT ($4.68 million in fiscal year 2006) program funds interdisciplinary teams of from three to five researchers at a total level of $1.0 to $1.4 million over four years to conduct collaborative research and education in the areas of active nanostructures and nanosystems, and on the long-term societal change associated with these innovations. Active nanostructures change or evolve their structure, property, or function during their operation. The goal of this program is to support fundamental research and catalyze synergistic science and engineering research and education in several emerging areas of nanoscale science and engineering.

The NIRT competition was NSF-wide for awards made in fiscal year 2004 and restricted to ENG in fiscal year 2005 and fiscal year 2006. In both cases, the competition was managed outside of EEC, with representation by every directorate in NSF in fiscal year 2004 and every division in ENG and several divisions outside ENG in fiscal years 2005 and 2006. Funding by at least two divisions was required for each proposal. In fiscal year 2004, EEC provided partial funding to 10 NIRT awards, with oversight responsibility for two awards of specific interest to EEC, including one concerning the response of microorganisms to nanoparticles. In fiscal year 2005, EEC also provided partial funding to 10 NIRT awards, retaining oversight of two, one on toxicity of carbon nanoparticles and the other to develop a quantum dot nanoprobe to enable noninvasive bioimaging. The second was built on advances made in the ERC for Particle Science and Technology at the University of Florida.

In fiscal year 2006, EEC contributed to 17 NIRT awards, retaining oversight of none. None of the candidate proposals directly leveraged expertise within EEC or its centers, but EEC funding enabled several worthy proposals by underrepresented minority investigators and two proposals to study the societal impact of nanotechnology to be made. It is expected that many of the results of these projects will be useful to investigators at our current Centers and that some may result in future proposals to our Centers programs.

APPENDIX B
PAST EEC PLANNING DOCUMENTS: SUMMARY

EEC: A Brief Funding History

The EEC division was formed in 1992 by the merger of the former Office of Engineering Infrastructure Development and the former Division of Engineering Centers. Until 2001, EEC programs were dominated by the ERCs and Engineering Education Coalitions programs, which were allocated the majority of the division's budget, the remainder being applied to the REU Site, Industry and University Cooperative Research Centers (I/UCRC), Combined Research-Curriculum Development Programs, the Action Agenda for Systematic Engineering Education Reform, and ENG commitments to NSF-wide programs, including the Integrative Graduate Education and Research Traineeship (IGERT), Graduate Research Fellowship (GRF), Graduate Teaching Fellows in K–12 Education, and Interagency Education Research Initiative (IERI) programs. Discretionary funds not allocated to any specific program were typically in the range of $1 to $2 million per year and covered panel expenses, IPA salaries, studies, and the funding of a few unsolicited proposals. Planning for individual programs was primarily managed by the program directors overseeing the programs.

Coinciding with the institution of a divisional annual reporting process within ENG in fiscal year 2000, substantial funds became available from the phase-down of the Engineering Education Coalitions program. The availability of these funds allowed the incorporation of elements in the fiscal years 2000 and 2001 annual reports.

Highlights of the Fiscal Years 2000 and 2001 Annual Reports

The plan for EEC proposed to maintain a critical mass of coordinated funding for the transformation of engineering education as the Engineering Education Coalitions phased out, rather than to supplement a number of existing programs or start small, disconnected programs.

An element of the plan was to connect EEC and EHR programs to provide young engineers smooth pathways from middle school through high school, college and graduate school to engineering careers by:

- Creating an Engineering Education Program to receive unsolicited proposals. EEC had never had a mechanism for receiving unsolicited proposals, which typically generate many new ideas by promoting discussion between investigators and program directors.
- Increasing enrollments through engineering-focused curricula in K–12 (Bridges for Engineering Education).
- Reformulating, streamlining and updating engineering programs to increase their relevance to engineering practice and improve retention (Department-Level Reform, Engineering Centers for Learning and Teaching).

Additional funds were made available through the termination of the Action Agenda for Systemic Engineering Education Reform Program, which was intended to directly leverage innovations coming out of the Coalitions but was judged to have produced disappointing results. Funds also were freed with termination of the Combined Research–Curriculum Development Program, a 10-year old program to fund faculty research on the condition that they produce related coursework. It was felt that sufficient faculty interest in engineering education had developed to prefer programs aimed directly at curriculum improvement, without the research component.

The plan for ERCs concentrated on refocusing the program on transforming engineered systems, requiring outreach to K–12 students and teachers, simplifying the ERC solicitation, eliminating any unnecessary or redundant burdens on the ERCs, and increasing funding levels for individual ERCs. The I/UCRC Program concentrated on increasing the fundamental research content of the center programs.

The human resources portion of the plan was to increase REU stipends from $5,000 to $6,000 per year and conduct an REU Grantees Workshop.

Highlights of the Fiscal Year 2005 Division Plan

No annual reporting process existed for fiscal years 2002 through 2004. Program reporting was limited to the submission of project summaries (nuggets) to the Office of the Director. In fiscal year 2005, ENG instituted a divisional planning process.

The goal for fiscal year 2005 was to advance the United States into emerging technology areas by examining assumptions underlying the ERC programs. Specific tactics included:

- Investigating a new organization of the ERC program to allow a full range of innovation.
- Investigating moving educational initiatives from the ERCs to the engineering education component of EEC.
- Developing a blue-ribbon panel to review and assess the proposed changes.
- Developing a World Technology Evaluation Center study on how ERCs are run and operated worldwide.
- Developing a vision ERCs that will be as effective in the next 20 years as in the last 20 years.
- Developing a transition plan for the suggested changes.

The goal of the fiscal year 2005 plan for the engineering education component of EEC was to transform engineering education to produce an engineering workforce that is diverse and creative, understands the impacts of its solutions on both technical and social systems, and possesses the ability to adapt to the rapidly evolving technical environment.

The first strategy for achieving this goal was to develop an understanding of how students learn engineering to better inform engineering curriculums. Specific tactics included:

- Bringing the best scholars on engineering education together in workshops to define a research agenda based on how students learn.
- Developing a solicitation to support the research agenda.
- Working with other agencies and ABET, Inc. to implement a new curriculum based on findings of the workshops and funded research.

The second strategy was to attract and retain talented students and faculty, particularly women and underrepresented minorities, to all levels of engineering education. Tactics to implement this strategy included:

- Expanding the RET and REU programs.
- Establishing an AP course in engineering.
- Examining the engineering education culture and pedagogy as a means for increasing diversity.
- Partnering with other agencies in areas of their interest.
- Developing opportunities for networking and mentoring of graduate students.
- UseERC experience for developing a graduate curriculum that focuses on the knowledge and skills all engineering Ph.D.s should possess.
- Investigating a requirement that all ENG grants demonstrate effective mentoring and advisement of graduate students for careers in engineering or academe.
- Developing support networks for women and minority faculty, leveraging CAREER awards.
- Examining new entry paths for women and minorities into the engineering professoriate, either from other disciplines or from industry.

The goal of the fiscal year 2005 plan for organizational excellence was to become the top division at NSF in the development, processing and guiding of engineering programs. The first strategy for achieving this goal was to make full use of all available tools. Tactics to implement this strategy included:

- Examining and developing a plan for electronic processing of all proposals.
- Examining and developing a plan for work distribution that defines primary and secondary responsibilities for all programs.

The second strategy was to develop EEC staff to their full potential. Tactics to implement this strategy included:

- Investigating how staff functions would change to use new systems and develop new responsibilities accordingly.
- Ensuring that staff members take full advantage of professional development opportunities.

APPENDIX C
EEC PROGRAM ASSESSMENTS

Program Evaluations and Studies Conducted by EEC: 1990 to March 2007			
Title	Initiator(s); Year Completed	Purpose	Use of Results
EEC Studies			
1. Engineering Research Centers Studies			
Industry Perceptions of ERC Graduates: An Examination of Employers of ERC Graduates. Evaluating outcomes in science education: A survey of employers of NSF center graduates PI: Craig Scott, University of Washington	ERC Program 1990	The purpose was to examine employers of ERC graduates of four ERCs. Employers reported that ERC graduates are generally better at demonstrating key skills than are non-ERC graduates from otherwise comparable institutions. Also, ERC graduates tend to demonstrate greater understandings of concepts that are important to industry than do non-ERC graduates from otherwise comparable institutions.	Results and recommendations were presented at the 1991 ERC meeting in Boulder, Colo.
Job Performance of Graduate Engineers who Participated in the NSF ERC Program Results in Chapter 5 of http://www.nsf.gov/pubs/1998/nsf9840/nsf9840.htm Conducted by Abt Associates PI: Stephen Fitzsimmons	ERC Program 1996	Study of former graduate students at the first 14 ERCs to evaluate the impact of the ERC research and education experience on the effectiveness of masters and doctoral graduates working in industry, academia, and other sectors relative to contemporaries.	Results presented at ERC Annual Meeting; initiated Student Leadership Councils at all ERCs to provide center identity and cohesion to students involved in ERCs; initiated Student Retreat day at the ERC Annual Meetings; provided each center with center-level results and study briefing materials to help ERCs enhance the impact on students of ERC involvement.
The Impact on Industry of Interaction with Engineering Research Centers http://www.sri.com/policy/stp/erc/ Conducted by SRI International PI: Cathie Ailes	ERC Program 1997	Identify the types of results and value to industry of interaction between ERCs and their industrial sponsors; determine which types of interaction are most useful to industry, estimate the frequency of occurrence of the most useful types in different settings, and examine the process by which firms make use of results of ERC research.	Results presented at ERC Annual meeting; Initiated training visits to Industrial Liaison Officers (ILOs) at new ERCs by experienced ERC ILOs to jumpstart development of strong industrial partnerships; Provided each center with center-specific results and study briefing materials to enhance impact of industry partnerships.
Documenting Center Graduation Paths Two annual reports Conducted by SRI International PI: Cathie Ailes	ERC Program 1999, 2000	Evaluate the extent to which centers that graduate retain the characteristics that made them ERCs, e.g., engineering systems approach to research, interdisciplinarity, industrial collaboration, testbeds, team-based research, and involvement of graduate and undergraduate students in ERC activities.	Results presented at ERC Annual Meeting and provided to centers to use with their industrial partners; caused introduction of required graduation plan in 6th year renewal proposals; focused attention on importance of university support in retention of ERC education an outreach activities after graduation.

The Impact on Institutions of Hosting and ERC Report Conducted by SRI International PI: Cathie Ailes	ERC Program 2001	Examine the extent to which the ERC awards were agents of change in the awardee engineering schools, particularly through the emphasis on being interdisciplinary, on undergraduate research, and on long-term collaborations with industry.	The results pointed to the engineering education impacts as being often the most profound. This was important in light of results of the ERC Graduation studies that pointed to ERC education programs being the most vulnerable when centers moved to self-sufficiency. The centers have been made aware of the need to prepare for the education programs, not just the research, to be self-sufficient.
An Analysis of Industry Support for the NSF's Engineering Research Centers Results in Doctoral Dissertation of Jonathon Tucker PI: Christopher Hill, George Mason University	ERC Program 2003	As follow-on to grant research funded by the Science and Technology Studies program in SBE, the project team examined the veracity of prevailing views among ERC personnel that industry funding was scarce and only available for short-term proprietary research.	The study identified important differences among ERCs and the technology sector and characteristics of firms that were most likely to be interested in supporting the centers. The most important distinction among ERCs was whether they were paradigmatic —working in mature technical areas of interest to large, established firms—and pre-paradigmatic—centers working in new areas not relating to existing firms' product lines or established firms with a tradition of R&D support. Subsequent studies of the ERC Program have used this distinction in designing studies and analyzing results. This study's findings were also instrumental in explaining in a policy paper to the DRB the need for expecting differing levels of industrial support to ERCs based on the characteristics of each center and the firms that would be attracted to it.
The Economic Impact on Georgia of Georgia Tech's Packaging Research Center Report Available Conducted by SRI International PI: David Roessner	Georgia Research Alliance 2004	Evaluate the Direct and indirect economic impact of the investment in the NSF Packaging Research Center, an ERC at Georgia Tech, on the state of Georgia.	Found a 6 to 1 direct economic impact on Georgia as a result of a $32.5 million investment in the PRC by the Georgia Research Alliance. Direct impact from jobs created spin-off and spin-in companies, jobs created, technical assistance to GA companies, cost savings to GA firms by hiring PRC grads, benefits to member firms
The Impact on Industry of Interaction with ERCs, Repeat Study Report in Word Conducted by SRI International PI: David Roessner	ERC Program 2005	Examine how member firms in mature second-generation ERCs benefit from ERC collaboration and underlying dynamics that affect if/how firms are positioned to take advantage of ERC research, students, emerging technology, engineered systems, etc.	A comparison of results from this study and the original study of first-generation ERCs is in progress. The results will be provided at the 2004 ERC annual meeting and the base study results were provided at the 2003 meeting at the invitation of the ERC Industrial Liaisons, who use them to assist in positioning their centers to attract more firms and to inform their Industrial Advisory Boards about program-level impacts on industry.
Report on Knowledge Transfer Activities in Connection with Nanoscale Science and Engineering Report Conducted by SRI International PI: David Roessner	NSF-wide Nanoscale Science and Engineering (NSEC, NIRT,NCN 2006)	Provides a comprehensive evaluation of quantitative outputs related to the research, collaborations, economic impacts, interdisciplinary nature, education and training, and the societal, ethical, environmental, health, and safety implications of the NSF NS&E Programs	**Completed in December 2006**
ERC Strategic Planning Best Practices Report in draft PI: Steve Currall, Rice University	ERC Program underway	Grant to business school faculty members to determine how the ERC Program's three-plane strategic planning construct is used in ERCs and to determine lessons learned to strengthen ERCs and the ERC Program	**in progress**

ERC Economic Impact Conducted by SRI International PI: David Roessner	ERC Program underway	Study of the state economic impacts of Georgia Tech's Packaging Center, commissioned by the state of Georgia, is being expanded by the ERC Program to examine the regional and national economic impact of three graduating and graduated ERCs.	**in progress**
International Study of Research Centers Programs Similar to the ERC Program Conducted by STPI/IDA PI: Bhavya Lal	ERC Program underway	To study the operating characteristics of centers established around the world in configurations similar to ERCs to determine best practices for the ERC Program	**in progress**
2. Education Programs Studies			
Progress of the Engineering Education Coalitions Program http://www.nsf.gov/pubsys/ods/getpub.cfm?nsf00116 Conducted by SRI International PI: Cathie Ailes	Engineering Education Program 2000	Examine the results of the program within the participating universities and more broadly after first five years of operation and identify areas in which improvements could be made.	Study took place after decision to make no more awards was made. Study results used to focus final years of the Coalition awards on identifying the best curricular products, evaluating them, implementing them beyond the originating institution, and dissemination of them beyond the originating Coalition.
CRCD Evaluation pilot test Hardcopy Report Conducted by Abt Associates PI: Stephen Fitzsimmons	EEC Education Program 2000	Examine how successful awards in the first three award years, FY 1992-94, had been in developing and implementing courses and curriculum that improve and make more relevant the content of engineering courses and serve as a means to engage and retain students in engineering degree programs.	Curricular materials developed by early awardees were provided for evaluation to an expert panel convened by the contractor. Not all awardees had materials to provide, so the project shifted to be a pilot test of the methodology, since there had been no previous study conducted in this fashion with EEC-funded engineering education curricular materials.
3. Human Resources Programs Studies			
Graduate Engineering Education (GEE) Traineeship Program Hardcopy report Conducted by Abt Associates PI: Ellen Schiffer	EEC Human Resources Program 2000	The goal was to learn what institutional collaborations brought about increased production of doctorates to women and underrepresented minorities.	This study was conducted after GEE was discontinued due to the creation of the NSF-wide IGERT program. However, the final report was very useful to program officers in EHR's HRD division who were beginning to fund similar collaborations to increase the production of doctorates to underrepresented groups and wanted understand what worked and what didn't work as well with collaborations funded by GEE in terms of achieving the goal of increasing doctorates to underrepresented groups.
Evaluation of the Research Experiences for Teachers (RET) Program: 2001-2003 Awards http://www.sri.com/policy/csted/reports/university/documents/reteval2005.pdf Conducted by SRI International PI: Susan Russell	EEC Human Resources Program 2005	Study the first three years of the RET Site and Supplement mechanisms to determine what the teachers did and circumstances that correlate with clear impact of the RET experience on the content and methods of teaching.	Results about duration of average RET experience, nature of activities, and extent of follow-on relationship during academic year led to changes in the RET program announcement and subsequent funded awards.
Evaluation of ENG's Research Experiences for Teachers (RET) Program, 2001-2005 http://www.sri.com/policy/csted/reports/university/documents/RET2%20FINAL%20REPORT%20June%2030%2006.pdf Conducted by SRI International PI: Susan Russell	EEC Human Resources Program 2006	Study covers awards in FY 2004-2005 to build trend data and to examine the results of changes to the RET program solicitation made as a result of the study of 2001-2003 awards. In addition, the study analyzes data from all four initial award years: 2001-2005.	Review criteria for proposals and subsequent program announcement updated.

Evaluation of the Research Experiences for Teachers (RET) Program: Second Follow-on Study Conducted by SRI International PI: Susan Russell	EEC Human Resources Program underway	The program director wanted to see whether changes to the annual program announcement and review criteria were bringing about the desired changes in what teachers did during and after RET and whether teachers and their RET PIs were building durable relationships between the teachers' schools and PIs' school or department for the benefit of the students.	**in progress**
Evaluation of the NSF-NIBIB Bioengineering and Bioinformatics Summer Institutes (BBSI) Program Conducted by SRI International PI: Jongwon Park	EEC Human Resources Program; NIH/NIBIB underway	Examine the activities of undergraduate and graduate students involved in the first group of three-year BBSI awards that provide intensive summer research and classroom education in the emerging areas of bioengineering and bioinformatics, the effect of the students' experiences on career decisions, and whether some aspects of the program's design were more successful than others.	**in progress**
Evaluation of the Research Experiences for Undergraduates (REU) Program in the Directorate Conducted by SRI International PI: Mary Hancock	EEC Human Resources Program; O/AD	Program directors wished to learn details about the undergraduate research experiences they were supporting across engineering and in a variety of academic research settings, e.g., similarities and differences across settings, institution size, students' home institution size and nature, recruitment patterns and student selection criteria.	**in progress**

APPENDIX D
CONNECTIONS AND RELEVANCE OF EEC PLANS

2004 EEC Committee of Visitors (COV) Report

In March 2004, a Committee of Visitors evaluated the processes, outcomes and direction of EEC programs. In order to best respond to COV findings, EEC summarized and grouped the 27 COV findings into eight broad findings/recommendations that captured the essence of the resulting COV report. Of those eight findings, four relate directly to EEC Division Plan initiatives.

2004 COV Finding	2007 EEC Division Plan Initiative
Finding 3: The COV found that the EEC portfolio of awards is consistent with program guidelines and reviewer recommendations. While praising the ERC program for its innovative awards, integration of research and education, and identification and support of new investigators, the COV recommends that smaller, interdisciplinary teams be funded in preference to increasing the size of individual ERC awards.	This division plan proposes to hold small center EPSCoR competitions. These centers would be smaller in scale, timeline and funding than the traditional ERCs but still maintain the ERC feature of interdisciplinary research, focused on engineered systems.
Finding 5: The COV observed that the majority of EEC awards are to research-intensive institutions and that more capacity needs to be built at other institutions.	The small center EPSCoR competitions should allow traditionally non-research intensive institutions to build their research capability.
Finding 6: The COV recommends that EEC undertake a comprehensive study to answer the following questions: What will ERCs look like in 5 to 10 years? What are the overarching goals of the EEC Education and Human Resources Development Programs?	ERCs have issued a new Generation III solicitation and EEC plans EPSCoR competitions for ERCs. This plan sets goals to increase the number of students matriculating in engineering programs and to increase the percentage of students completing engineering degrees and going on to graduate study.
Finding 7: The COV requests that increased attention be paid to planning and assessment of the education and human resource assessment programs, including cross-project evaluation.	SRI International study of the Engineering RET Program in 2004 and 2006: http://www.sri.com/policy/csted/reports/university/index.html#ret2006. The NIBIB-NSF Bioengineering and Bioinformatics Summer Institutes (BBSI) Program evaluation is due in the summer of 2007.

ENG 2005 Division Plan and 2007 EEC Plan

The 2005 Directorate for Engineering Division Plan focused on five overall goals:

1) Effectively invest in frontier engineering research that has potential for high impact in meeting national and societal needs;
2) Effectively invest in fundamental engineering innovation that has potential for high impact in meeting national and societal needs;
3) Effectively invest in frontier engineering education and workforce advancement that has potential for high impact;
4) Effectively invest in and seek partnerships to educate the public about the values of engineering research and education; and
5) Effectively organize the directorate to provide agile, multidisciplinary leadership in engineering research and education.

The 2007 EEC objectives connect very well with the goals of Fundamental Engineering Innovation (2) and Frontier Engineering Education (3).

2005 ENG Plan	**2007 EEC Plan**
(b) Fundamental Engineering Innovation	(4) Build a culture of Discovery and Innovation in Engineering through Multidisciplinary Centers. • Develop a special EPSCoR ERC competition
(c) Effectively Invest in Frontier Engineering Education. • Increase K–2 support by 25% • Ally with partners to revamp engineering education • Increase participation by women, minorities and the disabled	(1) Enhance the K–12 pipeline. (2) Promote the success of the undergraduate learning experience.

NSF 2006 –2011 Strategic Plan

The fundamental theme of the latest NSF Strategic Plan is “Investing in America’s future.” It recognizes that scientific and engineering discoveries are taking place at an *accelerated pace* and that such discoveries are occurring in a *dynamic, complex and competitive international environment*. To meet these challenges, the strategic plan is designed to provide leadership in sustaining the nation’s competitive edge through innovation, exploration and ingenuity. As the plan covers the entire NSF, only those goals that are relevant to EEC division are identified.

<u>Overall Relevance to EEC Vision and Mission</u>

The EEC mission of “Supporting the development of creative, innovative, and globally competitive engineers” closely aligns with the overall NSF strategic plan and its two cross-cutting objectives **“***To Inspire and Transform”* and “*To Grow and Develop.”*

NSF has specifically identified four areas for increased emphasis and additional funding. These are compared with EEC objectives:

<u>**NSF Strategic Plan**</u>	<u>**EEC Objectives**</u>
Discovery Promote transformational, multidisciplinary research, investigate human and social dimensions of new knowledge, further U.S. economic competitiveness	Build a Culture of Discovery and Innovation in Engineering through multidisciplinary centers.
Learning Improve K-12 teaching, advance the fundamental knowledge base on learning, develop methods to effectively bridge critical junctures in STEM education pathways, prepare a diverse, globally engaged STEM workforce, integrate research with education, and build capacity.	Enhance the K–12 pipeline; Promote the Success of the undergraduate learning experience
Research Infrastructure Fill the gaps in *enabling research infrastructure*, and strengthen the *nation’s collaborative advantage* by developing unique networks and innovative partnerships.	Formalize partnerships with organizations both within and external to NSF

Stewardship Strengthen the traditional partnerships and develop new collaborations with other agencies, organizations and corporations, identifying common goals that can unite and focus partnerships, expand efforts to broaden participation from underrepresented groups and diverse institutions.	Formalize partnerships with organizations both within and external to NSF; Develop EEC team capabilities

NSF Fiscal Year 2008 Budget

The following chart shows how the objectives of the 2007 EEC Division Plan are connected to the ENG and NSF budget themes in the recently announced NSF budget for fiscal year 2008. Among the six objectives of the EEC Plan (see Executive Summary), Objectives (1), (2), (4) and (5) are especially relevant.

<u>**NSF FY 08 Budget Emphases**</u>	<u>**2007 EEC Plan**</u>
NSF: "…the agency will use the funds to build on recent advances and to support promising initiatives to strengthen the nation's capacity for discovery and innovation."	(4) Build a culture of discovery and Innovation in our Engineering Research Centers: • Transition ERC to Gen-3 (5) Formalize Partnerships with both external as well as internal NSF organizations: • Transition IREE from EEC pilot to regular program.
NSF: "NSF works at the frontier of knowledge where high risk, high-reward research can lay the foundation for revolutionary technologies and tackle difficult problems that challenge society…"	(4) Build a culture of discovery and innovation in our Engineering Research Centers: • Focus Gen-3 ERCs and NCN on revolutionary technologies (5) Formalize partnerships with both external as well as internal NSF organizations: • Emphasize research and education related to revolutionary technologies in IREE partnerships with ENG divisions.
NSF: "…the new budget emphasizes new research on.…international collaborations."	(4) Build a culture of discovery and innovation in our Engineering Research Centers:

	• Support international partnerships in Gen-3 ERC; add foreign core partners into Gen-2 ERCs. (5) Formalize partnerships with both external as well as internal NSF organizations: • Support international partnerships through IREE
NSF: "International partnerships allow U.S. students, scientists and engineers to stay knowledgeable about new concepts and technologies emerging around the world, and provide the experience needed to operate effectively in from different nations and cultural backgrounds."	(5) Formalize Partnerships with both external as well as internal NSF organizations: • Support international partnerships jointly with OISE and ENG divisions through IREE.
ENG: "Discovery Research for Innovation."	(4) Build a culture of discovery and innovation in our Engineering Research Centers: • Enhance NCN • Fund Gen-3 ERCs (5) Formalize partnerships with both external as well as internal NSF organizations: • Emphasize discovery research in IREE partnerships with ENG divisions.
ENG: "National Nanotechnology Initiative."	(4) Build a culture of discovery and innovation in our Engineering Research Centers • Enhance NCN (5) Formalize Partnerships with both external as well as internal NSF organizations: • Enhance IREE funding in nanotechnology-related research through partnerships with ENG divisions.
ENG: "ENG is uniquely able to integrate research, education, and innovation…"	(5) Formalize partnerships with both external as well as internal NSF organizations: • Increase EEC emphasis on integration of research, education and innovation through Gen-3 ERC, IREE and NSEC programs.
ENG: "Preparing the Workforce of the 21st Century"	(1) Enhance the K–12 pipeline: • Strengthen RET

	(2) Promote the success of the undergraduate learning experiences: • Strengthen EEP, REU, NUE, BBSI • Strengthen IREE partnerships with ENG divisions.

***American Competitiveness Initiative* (ACI)**

Education is the gateway to opportunity and the foundation of a knowledge-based, innovation-driven economy. For the United States. to maintain its global economic leadership, we must ensure a continuous supply of highly trained mathematicians, scientists, engineers, technicians, and scientific support staff as well as a scientifically, technically, and numerically literate population. Recognizing the critical importance of science and technology to America's long-term competitiveness and building on previous efforts, in February 2006 President Bush introduced the *American Competitiveness Initiative (ACI)*, an aggressive, long-term approach to keeping America strong and secure by ensuring that the United States continues to lead the world in science and technology.

ACI	**2007 EEC Plan**
Overall Theme of ACI An overall theme of ACI is that the environment for innovation within the United States must be strengthened so that the American economy remains the most flexible, advanced and productive in the world. ACI describes education as key to this: "Education is the gateway to opportunity and the foundation of a knowledge-based, innovation-driven economy." ACI's proposed initiatives will help the nation's science, technology, engineering and mathematics workforce prepare for the 21st century, improve the quality of math and science education in U.S. schools, and prepare our citizens to compete more effectively in the global marketplace.	(1) Enhance the K–12 pipeline • Research Experiences for Teachers (RET) sites program (2) Promote the Success of the Undergraduate Engineering Learning Experience • Research Experiences for Undergraduates (REU) Sites Program • Nanotechnology Undergraduate Education (NUE) Program • NIBIB-NSF Bioengineering and Bioinformatics Summer Institutes (BBSI) Program • Engineering Education Program (EEP) (4) Build a Culture of Discovery and Innovation in our Engineering Centers: • Generation Three (Gen-3) Engineering Research Centers (ERC) Program (5) Formalize Partnerships with both External as well as Internal NSF Organizations: • International Research and Education in Engineering (IREE) supplements
Goals of the American Competitiveness Initiative (ACI)	(1) Enhance the K-12 Pipeline (2) Promote the Success of the Undergraduate

- **300** grants for schools to implement research-based math curricula and interventions; - **10,000** more scientists, students, post-doctoral fellows, and technicians provided opportunities to contribute to the innovation enterprise; - **100,000** highly qualified math and science teachers by 2015; - **700,000** advanced placement tests passed by low-income students; and - **800,000** workers getting the skills they need for the jobs of the 21st century.	Engineering Learning Experience (3) Improve the Pathway into Graduate Programs for US and Permanent Residents (4) Build a Culture of Discovery and Innovation in our Engineering Centers (5) Formalize partnerships with both external as well as internal NSF organizations: • Develop partnership with FIRST Robotics to enhance NSF's role in the K-12 pipeline into engineering schools • Foster a working relationship between engineering schools and school principals/superintendents to include ordinary "Supply-Chain" relationships in the K-12 pipeline • Help organize an Engineering Undergraduate Associate Deans Council to catalyze and implement engineering education research and innovation

Rising Above the Gathering Storm

In 2006, the National Academies was charged by Senator Lamar Alexander and Senator Jeff Bingaman of the Committee on Energy and Natural Resources to respond to the following questions:

> *What are the top 10 actions, in priority order, that federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century? What strategy, with several concrete steps, could be used to implement each of those actions?*

Ten weeks later, in October 2006, the National Academies Committee on Prospering in the Global Economy of the 21st Century released its findings to this charge under the title *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* This document defines the policy implementations that are necessary if America is to play any role in the face of rapidly changing market forces which are moving jobs to countries with less costly, often better educated, and more highly motivated work forces. Other factors that impact this jobs exodus are the fact that there has been a steady erosion of the U.S. scientific and technological building blocks that spanned our economic leadership and the presence of more friendly tax policies for businesses in other countries. The committee's biggest concern is that these factors will contribute to an abrupt loss of U.S. scientific leadership which, at a time when many other nations are gathering strength, can have dire economic consequences for the U.S.

To mitigate the negative consequences of these trends, the committee found that there are two major challenges that must be met:

- Creating high-quality jobs for Americans.
- Responding to the nation's need for clean, affordable, and reliable energy.

To meet these challenges, the committee defined four key recommendations which are summarized in the first column of the table below. The next six columns link the Recommendations with the EEC Objectives defined in the introduction.

***Rising Above* Recommendations**	**EEC Objectives**
Increase America's talent pool by vastly improving K-12 mathematics and science education	(1) Enhance the K-12 pipeline
Sustain and strengthen the nation's commitment to long-term basic research	(2) Promote the Success of the Undergraduate Learning Experiences (3) Improve the Pathway into Graduate Programs for US Students and Permanent Residents
Develop, recruit, and retain top students, scientists, and engineers from both the U.S. and abroad	(2) Promote the Success of the Undergraduate Learning Experiences (3) Improve the Pathway into Graduate Programs for US Students and Permanent Residents (4) Build a Culture of Discovery and Innovation in our Engineering Centers
Ensure that the United States is the premier place in the world for innovation	(4) Build a Culture of Discovery and Innovation in our Engineering Centers

It is noted that the first three recommendations set forth by the Committee on Prospering in the Global Economy of the 21st Century have been integral parts of the Engineering Research Center's Program structure for years. In addition, the 2007 release of the ERC's Gen-3 solicitation has added a new element aimed at enhancing the rate of innovation of the ERC technologies. Consequently, the fourth recommendation from the Rising Storm is now an integral part of the EEC objectives as well.

Educating the Engineer of 2020

This monograph was published through the efforts of the National Academy of Engineering in 2005. The monograph includes 10 recommendations. Five of these 10, shown below as (a) – (e), are directly related with EEC Division Objectives (1) – (5) as follows:

<u>**2020 Engineer Recommendation**</u>	<u>**EEC Objective**</u>
(a) “Colleges and Universities should endorse research in engineering education as a valued and rewarded activity for engineering faculty and should develop new standards for faculty qualifications.”	(2) Promote the Success of the Undergraduate Learning Experiences
(b) “Institutions should encourage domestic students to obtain MS and/or PhD degrees.”	(3) Improve the Pathway into Graduate Programs for U.S. Students and Permanent Residents
(c) “The engineering education establishment should participate in efforts…… to improve math, science and engineering education at the K-12 level.”	(1) Enhance the K-12 pipeline.
(d) “The National Science Foundation should collect data on program approach and student for engineering departments outcomes /schools so that prospective freshman can better understand the “marketplace” of available engineering baccalaureate programs.”	(5) Formalize Partnerships with both external as well as internal NSF organizations.
(e) “Institutions should take advantage of the flexibility inherent in EC 2000 accreditation criteria of ABET in developing curricula, and students should be introduced to the “essence” of engineering early in their undergraduate careers.”	(4) Build a Culture of Discovery and Innovation in our Engineering Centers