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College of Engineering

2050 CHALLENGE

Resources and Strategic Outlook

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Foreword

Look ahead to the year 2050, to a world of nine billion people, and ask yourself what critical challenges must be met over the next four decades to ensure the expectation of a high-quality life. Renewable nonpolluting energy. Abundant clean water. Access to modern health care. Sustainable agriculture and manufacturing. Safe roads and bridges. Adequate preparation for, and protection from, natural and man-made disasters.

Meeting these challenges requires the technical expertise and social ingenuity to collaborate locally and globally, with a full appreciation of cultural values and priorities. The work will take determination and vision. Who has the capability and commitment to lead us to solutions, and to implement those solutions?

The College of Engineering at Iowa State University calls this the 2050 Challenge. It is a challenge to ourselves and to the world. We are meeting it by taking the lead in Iowa and throughout the global community. How? By applying practical engineering technologies and implementing pragmatic solutions to immediate problems. By educating high-quality students who become graduates with the technical expertise to be successful professionals. By embracing the fundamental ideals of the land-grant institution: that hard work produces results, a personal approach builds relationships, and a commitment to service fulfills the purpose of higher education.

We also understand the role of state-of-the-art research in addressing long-term problems, and we recognize the responsibility we have to address them. Our outstanding faculty and on-campus access to the highest level of research technology give us the capability to approach complex problems from a systems perspective.

Each day, the College of Engineering is improving the quality of life in Iowa, the nation, and the world. Our solutions are not just mechanisms and processes: they are pathways to human progress. The engineers we prepare are more than just technical experts: they are the foundation for leadership in academics, law, medicine, industry, and government. Through foresight, knowledge, and leadership, we are creating the opportunity for a safe, productive, meaningful life today, with the promise of such a life in 2050.

1. Introduction

For a culture attuned to immediacy, the year 2050 seems distant. Historically, we overcome the crisis that is upon us and then move on. Ingenuity and determination drive us through turmoil and into the calm. For America in 2009, wars, terrorism, and a troubled economy are the immediate crises. They demand urgent action.

Yet some see more than just the next obstacle to overcome. There is the more fundamental question of global sustainability. The very survival of the world and our quality of life.

We in the College of Engineering at Iowa State University believe in the immediacy of this impending global crisis. That is why helping to meet the 2050 Challenge is the strategic focus of our college.

We do this because our children's futures are in our hands. The decisions we make today about the directions and priorities of engineering research and education will help determine their quality of life decades in the future.

The next section of this report will provide background and motivation for our decision to identify this challenge as being real, as encompassing our current efforts, and as constituting our vision for engineering research and education.

History as Prologue

We have been to a place like this before. Consider the outlook of the United States fifty years ago. The circumstances and the challenges were different, but the similarity was the urgent need to respond at a watershed moment.

Most of the world's infrastructure had been severely damaged by World War II and subsequent conflicts in China and Korea. Many of today's strongest powers were crippled.

The United States had supplanted Great Britain as the preeminent economic influence in the world. We dominated manufacturing, from machine tools to automobiles to aircraft. We were laying down the cross-continental freeways that would underpin a new age of transportation. We believed that we were, rightfully, world leaders.

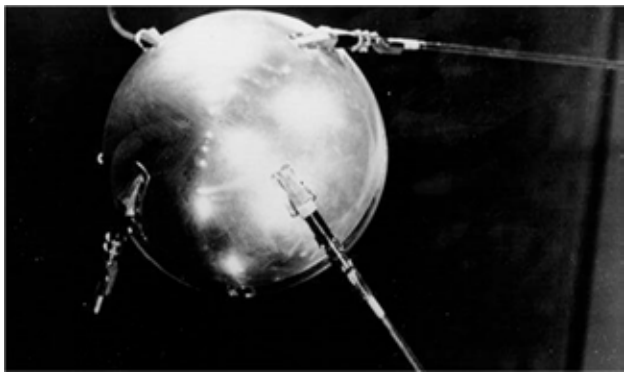
But there were some worrisome developments. Throughout the 1950s the cold war was gaining momentum. The Soviet Union carried out a continuing nuclear test program, an amazing technical feat for a country that was mostly destroyed by war. And then came another remarkable technical feat, one visible to all [1].

> History changed on October 4, 1957, when the Soviet Union successfully launched Sputnik I. The world's first artificial satellite was about the size of a beach ball (58 cm. or 22.8 inches in diameter), weighed only 83.6 kg. or 183.9 pounds, and took about 98 minutes to orbit the Earth on its elliptical path. That launch ushered in new political, military, technological, and scientific developments. While the Sputnik launch was a single event, it marked the start of the space age and the U.S.-U.S.S.R space race.

It is widely understood that Sputnik led to the National Defense Education Act in 1958 [2].

> The NDEA was instituted primarily to stimulate the advancement of and education in science, mathematics, and modern foreign languages; but it has also provided aid in other areas, including technical education, area studies, geography, English as a second language, counseling and guidance, school libraries and librarianship, and educational media centers.

The Act still provides institutions of higher education with 90% of capital funds for low-interest loans to students. NDEA also gives federal support for improvement and change in elementary and secondary education. The Act contains statutory prohibitions of federal direction, supervision, or control over the curriculum, program of instruction, administration, or personnel of any educational institution.



Sputnik I—October 4, 1957

First Man on the Moon—Apollo 11 • July 20, 1969

Then in 1960 came a young and charismatic new president. In his inauguration speech on January 21, 1961 [3], he said:

> Now the trumpet summons us again—not as a call to bear arms, though arms we need; not as a call to battle, though embattled we are—but a call to bear the burden of a long twilight struggle, year in and year out, "rejoicing in hope, patient in tribulation"—a struggle against the common enemies of man: tyranny, poverty, disease, and war itself.

President Kennedy coupled NDEA with a daunting technical challenge. In a 1962 speech given at Rice University [4] he said:

> We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.

Kennedy knew that American ascendancy, and possibly even survival, was at stake and understood the power of a focused challenge. The nation soon reaped the benefits of facing up to that challenge—the benefits of building intellectual capacity and technical strength. Going to the moon was followed by U.S.-led digital and information revolutions. This was America at peak power.

Now it is clear that, several decades into this boom time of intellectual achievement, we have reached another watershed moment. America, still preeminent but now inextricably linked to a global network of economies and cultures, faces a new set of challenges, and more than just political ideologies are at stake. Our leadership is crucial to quality of life, if not survival, on a global scale. Just as we see that some of our shortcomings can adversely affect those around us, we understand that our contributions can help to build a sustainable world. This leads to the situation we have today, the initial conditions for our future.

Initial Conditions

The United States remains a dominant economic power, but it dominates a troubled world. It seems economic stimulus is the remedy for our current economic malaise—we are hoping to stabilize the economy using massive spending on top of a national debt that has increased from about $5.5 trillion in 2000 to about $10.5 trillion now [5].

Most of the world's people remain very poor, without access to clean water, reliable food supplies, or good medical care. Some poor nations are striving to attain weapons of mass destruction. The current world population is about 6.5 billion and is estimated to rise to 9.5 billion by 2050. This is unsustainable.

But by looking back to the lessons of the late 1950s and early 1960s, we can sort out powerful positives. We are an innovative people with excellent institutions of higher education. We are capable of the breakthroughs that can change the world. And we have just inaugurated a charismatic young president.

In his inauguration speech on January 20, 2009, President Obama [6] said:

> Starting today, we must pick ourselves up, dust ourselves off, and begin again the work of remaking America.
>
> For everywhere we look, there is work to be done. The state of the economy calls for action, bold and swift, and we will act—not only to create new jobs, but to lay a new foundation for growth. We will build the roads and bridges, the electric grids and digital lines that feed our commerce and bind us together. We will restore science to its rightful place, and wield technology's wonders to raise health care's quality and lower its cost. We will harness the sun and the winds and the soil to fuel our cars and run our factories. And we will transform our schools and colleges and universities to meet the demands of a new age. All this we can do. All this we will do.

This then is our charge: to build and restore, create and transform. To meet the demands of a new age. This is the 2050 Challenge.

We see the 2050 Challenge not just as a vision for which we strive, but also as a way to describe the work that is already underway in our college. This report provides a focused overview of our undergraduate curriculum; our ongoing and emerging research thrusts; and the implications of the 2050 Challenge for human resources as seen in our faculty, staff, and student body. Appendices present supporting details on each of the topics. Appendix 1 contains facts and figures of general interest about Iowa State University and the College of Engineering.

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2. Undergraduate Education and the 2050 Challenge

Introduction

The futures of the engineering profession and of engineering education have been examined and discussed intensively for the past few years through reports and forums led by the National Academies and other institutes and organizations.

The National Academy of Engineering's 2004 report on the vision of *The Engineer of 2020* [1] laid the groundwork for more broadly defining the profession. For example, it states:

> By 2020 we aspire to engineers who will assume leadership positions from which they can serve as positive influences in the making of public policy and in the administration of government and industry.
>
> We aspire to an engineering profession that will rapidly embrace the potentialities offered by creativity, invention, and cross-disciplinary fertilization to create and accommodate new fields of endeavor, including those that require openness to interdisciplinary efforts with nonengineering disciplines such as science, social science, and business.
>
> We should reconstitute engineering curricula and related educational programs to prepare today's engineers for the careers of the future, with due recognition of the rapid pace of change in the world.

Shortly afterward, the *Rising Above the Gathering Storm* report [2] was prepared by the National Academies Committee on Prospering in the Global Economy of the 21st Century. The report is an action agenda for federal policy makers to enhance the science and technology competitiveness of the United States.

Following on these reports, including participation by college administration and faculty in national meetings, Iowa State's College of Engineering articulated its vision as the 2050 Challenge (see Foreword).

Thus, the college was well positioned when the National Academy of Engineering recently published its Grand Challenges for Engineering [3] in which the role of engineering in society is clearly and boldly stated. Fourteen challenge areas are presented by the NAE, encompassing energy, water, infrastructure, health care, security, learning, and discovery. The introduction on the Web site concludes, "Today, we begin engineering a path to the future."

Through the 2050 Challenge, this journey has already begun. It is a journey informed and guided by several other reports published in the past year.

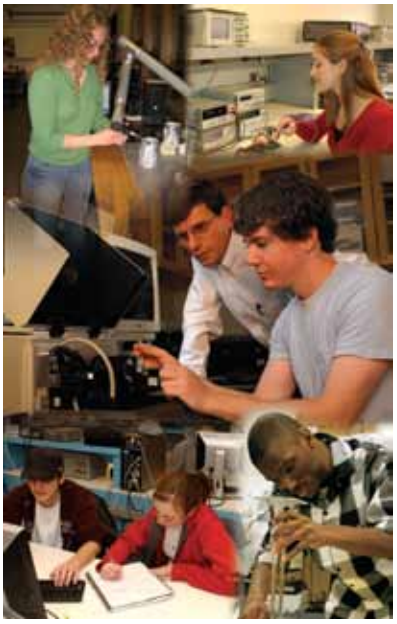
One of these is *Engineering for a Changing World* [4]. In the Preface, Jim Duderstadt writes about the possibility of the engineering discipline "taking its place among the 'liberal arts' characterizing a 21st-century technology-driven society"—with the engineering profession "addressing both the urgent needs and grand challenges facing our society" (pp. iii–iv).

Complementing this report is *Educating Engineers: Designing for the Future of the Field* [5] by Sheri Sheppard, Kelly Macatangay, Anne Colby, and William Sullivan. *Educating Engineers* is the result of a three-year study of engineering education in the United States by the Carnegie Foundation for the Advancement of Teaching as part of its Preparation for the Professions Program. The study began with an

extensive review of the literature followed by visits and field research at six universities. The goal of the research was to understand educational practices and their role in preparing future engineers, and thus to motivate questions, solutions, and change.

Finally, *Changing the Conversation: Messages for Improving Public Understanding of Engineering* [6] written by the National Academy of Engineering's Committee on Public Understanding of Engineering Messages, is the result of an 18-month study by the committee, funded by the National Science Foundation, to identify and test a small number of messages to improve the public understanding of engineering. The messages should convey the critical role that engineers play in the world. Whereas *Educating Engineers* concludes that students need to understand how to develop as professionals, this report concludes that the public needs to understand the profession, and in particular, its role in technological innovations that are transforming society.

The educational programs, services, and activities in our college are motivated by these visionary goals and challenges for the profession.



Initial Conditions

Not every institution can offer the infrastructure and intellectual capital required to prepare these future engineers. Proven performance, a deep talent pool, and sheer size distinguish Iowa State. Appendix 1 provides supporting details.

The College of Engineering offers rigorous and engaging curricula across twelve undergraduate engineering degree programs in aerospace, agriculture, biological systems, chemical, civil, computer, construction, electrical, industrial, materials, mechanical, and software engineering. Nearly 5,000 undergraduates were enrolled in fall 2008. All undergraduate BS programs in engineering at Iowa State (except software engineering, new in 2007, and biological systems engineering, new in 2009) are ABET accredited. Iowa State's programs are fourth on the *U.S.News & World Report* ranking of best undergraduate engineering programs among public universities in the region. Overall, *U.S.News & World Report* ranks Iowa State's undergraduate engineering programs 38th. Among the top 25 undergraduate programs, agriculture engineering ranks fourth in the country and materials engineering ranks 15th.

The student experience in engineering at Iowa State receives high scores on the National Survey of Student Engagement. Iowa State's learning communities are consistently ranked by *U.S.News & World Report* as among the top 25 programs in the nation. In addition, Iowa State is one of only 10 public universities recognized for outstanding internships/co-ops according to *U.S.News & World Report*. Iowa State is ranked 20th among public universities in the nation by Washington Monthly magazine for its commitment to community service, research and advanced degrees, and success in graduating students from lower-income families. A strong culture of outcomes assessment and continuous improvement supports student achievement and accreditation processes. Curricular learning outcomes, workplace competencies, and learning community objectives are measured and used to improve the student experience. These are critical attributes because there is more to our challenge than merely providing excellent career preparation: enrollment in engineering programs does not match an impending exodus of retirees. The Iowa State experience must be one that is cultivated among all types of students far before they reach college age and continued once they arrive on campus—and beyond.

Programs Focusing on the 2050 Challenge

This section highlights several programs and innovations that have particular relevance to the 2050 Challenge. Details about these and other programs that support the college's 2050 mission are available in Appendix 2.

Experiential Education

Most Iowa State engineering graduates have direct work experience as interns or co-op students prior to their commencement. The experts at Engineering Career Services guide students through diverse opportunities to learn about and engage in engineering practice while developing professionally.

Engineering Career Fairs at Iowa State University are the largest in the United States. More than 300 companies participate in the annual fall career fair, and 250 participate in the spring. In addition, nearly 5,000 job interviews are conducted annually on campus. Iowa State students not only find jobs, but also have the opportunity to learn about the breadth of engineering practice and to access a diverse collection of employment opportunities. Over 90 percent of first semester freshmen attend these events, learning firsthand from employer representatives and practicing engineers the breadth and choice of engineering practice. Employers value the student career fair participation, providing them with an opportunity to begin early identification and relationship building with potential candidates. For many Iowa State students, their first networking and relationship-building experience at a career fair significantly contributes to establishing a personal identity with the engineering profession, to selecting a degree program, and to enhancing their retention in the College of Engineering. The average annual starting salary for graduates is over $56,000, and there is a 98 percent placement rate (job/military/graduate school) six months after graduation. Graduates not only pursue career opportunities within engineering, but also go on to careers in medicine, law, business, academia, the public sector, and the military.

Learning Communities

One myth that Iowa State works to dispel is that engineering is an isolated endeavor. Our students learn early that mutual support and teamwork are crucial. Every engineering program in the college has its own learning community (LC). All of these have course linkages for freshman students during the first semester, with several continuing into the second semester and into sophomore or junior years. Four additional LCs cut across all of the engineering programs; they focus on multicultural students, those who have not declared a program of study, women, and transfer students. Most engineering learning communities have experienced a 5–15 percent retention increase among their first-time, first-year students, compared with non-LC students. Overall student satisfaction and engagement is higher for learning community students. Several general LC objectives are common to program development and ongoing assessment:

- To build community for entering first-year students within each curricula
- To increase the retention of first-year students in each curricula
- To increase recruitment of students in each program, especially underrepresented students (women and minorities)
- To enhance learning and team skills using collaborative, learning-based educational methodology in the learning community courses
- To improve problem-solving skills by solving engineering problems related to each curricula

As of fall 2008, over 1,000, or nearly 85 percent, of first-year, full-time students in engineering participated in learning communities.

Distance Education

Engineering Distance Education uses the latest learning and teaching technologies to support educational programs for on-campus and off-campus students. These facilities enable access to engineering courses literally anywhere and anytime. Appendix 5 provides additional details.

Precollege Programs for Youth

To meet the 2050 Challenge, the college recognizes the need to grow and diversify engineering talent. This starts with precollege programs to develop interest in STEM. K–12 education programs for youth provide engineering opportunities for students in kindergarten through eighth grade that are fun, hands-on, and educational. The outreach program is designed to address the demand for engineering and technologically literate students to enter the pipeline of higher education. Activities include FIRST LEGO League (http://www.eng.iastate.edu/techknow/fll/geninfo/geninfo.htm), Junior FIRST LEGO League, Engineering Summer Kids Camps, ISEK Web-based Club (http://www.isek.iastate.edu/camp/), visits to/from schools, displays at conferences and large state-wide events, and Experience Engineering Days for grades 3–8. The College of Engineering annually hosts the statewide FIRST LEGO League Iowa Championship, in which over seventy teams of 9- to 14-year-olds fill Howe Hall to compete with LEGO robots on tabletop missions that simulate real-world problems.

IT-Adventures is a new and innovative program unique to Iowa State that engages Iowa high school students in exploration and experimentation with information technology through instructional material delivery, competitive events, and service learning projects. It is a partnership forged between Iowa State University's Information Assurance Center, the Iowa Department of Economic Development, the Technology Association of Iowa, and Iowa businesses. The program is dedicated to increasing interest and awareness of information technology among high school students across the state. The capstone event for the students participating in the club is participation in the IT-Olympics at Hilton Coliseum, where they have an opportunity to showcase the knowledge they have gained over the past year (http://www.it-adventures.org/).

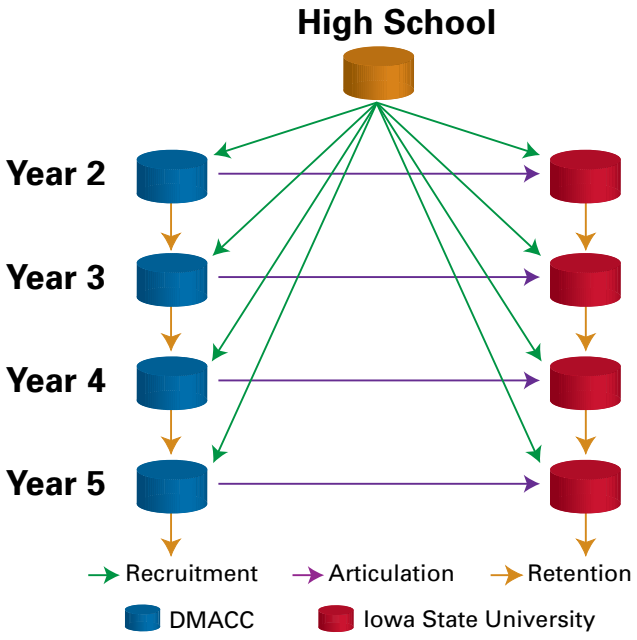
Iowa State University and the University of Iowa partner to promote Project Lead The Way in the state of Iowa. Project Lead The Way is a national precollege educational program that gives middle and high school students a rigorous introduction to engineering. Iowa now has over 120 schools registered to participate in Project Lead The Way, and the state ranks 3rd nationally in new registrations in the past year.

Recruitment and Retention

Workforce development is important to the 2050 Challenge. As one of the largest undergraduate schools in the United States, Iowa State's College of Engineering is committed to the high number and the quality of its engineering graduates. Iowa State ranks in the top ten to fifteen schools annually in engineering enrollment and graduation numbers. This is accomplished through effective and innovative recruitment and retention programs.

In 2007, with a $2 million grant from the NSF STEP Program, Iowa State and Des Moines Area Community College began a five-year project to attract more students to engineering. At Iowa State, the goal is 120 more students earning bachelor's degrees in engineering every year. At DMACC, the goal is more students studying pre-engineering, science, and technology. The cornerstone of the STEM Student Enrollment and Engagement through Connections (SEEC) project is the success of learning communities for recruitment and retention. A learning village approach focuses on retention at DMACC and Iowa State, including tailoring Iowa State's Admissions Partnership Program for engineering transfer students. With ISU Extension and other partners, we are working to improve the public awareness and understanding of engineering, especially among students and their parents (http://www.eng.iastate.edu/seec/).

The college also administers a merit-based scholarship program that complements the university's scholarship program. Last year, the college distributed over $2.2 million in engineering scholarships to undergraduate students. In 2009, with a $600,000 grant from the NSF S-STEM Program, the college will begin awarding need-based scholarships as part of the E2020 Scholars Program. This four-year program will provide scholarships for cohorts of undergraduate students (incoming freshmen and transfers) within our established learning community infrastructure, giving specific attention to the aspirations and attributes of the NAE's vision for the engineer of 2020 (http://www.engineering.iastate.edu/e2020).



In 2007, the college began offering a minor in engineering studies for nonengineering majors. It's one of only a few similar programs in the country, although the emphasis on technology literacy is expanding nationwide (see Duderstadt's report [4]). The first students graduated with the minor in 2008. The NSF CCLI Program has awarded a new grant starting in 2009 to pilot a teaching model for this program patterned after the Preparing Future Faculty Program (http://www.eng.iastate.edu/mes/).

Student Development

A broad education has been charted for the future of engineering education by the NAE and others [1, 4, 5]. In response to the *Engineer of 2020* [1] and the 2050 Challenge, the college launched a new leadership program in 2006 supported by a $1 million grant from the 3M Foundation. The Engineering Leadership Program (ELP) is the student-centered portion of the college's Engineering Policy and Leadership Institute (http://www.engineering.iastate.edu/epli). ELP creates a values-based learning community of engineering students committed to civic leadership (http://www.eng.iastate.edu/leadership/). The program was designed to provide opportunities for engineering undergraduate students to learn about and practice skills that are usually not covered in the classroom. The goal is to help students to become more effective engineers and better citizens of the world so they are prepared to address the challenges outlined by the National Academy of Engineering. The first cohort of 17 student scholars was selected for fall 2006. In all, four cohorts of incoming students will be funded as 3M Scholars. With additional corporate and private donor scholarship funding, over 70 students currently participate. The Engineering Leadership Program received over 130 applications for the 2008 incoming freshman cohort, from which sixteen were selected. Among the group are six women and ten men, three students from underrepresented minority groups, two students with disabilities, seven Iowans, and nine out-of-state students.

A new and novel interdisciplinary undergraduate program is the minor in bioengineering for engineering majors (http://www.eng.iastate.edu/bioengineering/). The first courses were offered in 2008–09. In addition to providing a core background in bioengineering, the minor provides specializations in bioinformatics and systems biology, biomaterials, biomechanics, biomicro systems, biobased products, and bioprocessing. It complements a student's major discipline by providing additional insight into the interactions between various engineering disciplines and biological systems, emphasizing new ways of solving biological problems. The program provides students with unique educational experiences to apply engineering skills. We have framed engineering study within the context of interdisciplinary areas in new outreach materials for prospective students; e.g., http://www.eng.iastate.edu/discovery/.

Global Awareness

Students have an array of engineering study and work abroad options to select from based on their individualized goals. The college offers over thirty international programs in over twenty countries; these are in addition to international programs offered by the university. Twenty percent of all our engineering graduates have studied or worked abroad.

A notable curriculum option for Iowa State students is the Languages for Cultures and Professions Program. It is a second major offered by the College of Liberal Arts and Sciences (LAS) in which students gain proficiency in a foreign language and experience living and working in another culture. Students in engineering may also receive additional credit for any international study or work experience as it relates to professional development by enrolling in ENGR 320, International Experience Report, in which students prepare a report and presentation on their international experience. An on-campus opportunity—the Technology, Globalization, and Culture course—jointly offered by the College of Engineering and the Department of World Languages and Cultures in LAS, examines the present and future impact of globalization with a focus on preparing students for leadership roles in diverse professional, social, and cultural contexts. The course includes lectures by practicing professionals, and students participate in critical analyses, discussion and debate, and projects.



International service learning is an emerging opportunity for students. Engineers for a Sustainable World coordinates projects in Uganda and India. Engineers Without Borders was approved as a new student organization in 2008. Both of these organizations involve faculty and students working on projects within communities to improve the quality of life.

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3. Our Research Mission and the 2050 Challenge

Introduction

We believe that our research mission is to advance our global impact by addressing the society-changing challenges that will define worldwide quality of life in the coming decades. The nation and the world face critical challenges that require innovative solutions. It is difficult to imagine a vibrant world economy in 2050, let alone a vibrant national economy, still as heavily dependent on petroleum as we are now. It is difficult to imagine a stable and prosperous global economy in the year 2050 if there are billions of people without access to clean water. It is difficult to imagine maintaining a high quality of life in 2050, let alone improving the quality of life for the billions in the third world, using natural resources at the same per capita rate as we do now.

The responsibility to meet these challenges is a collective one involving governments, private industry, and research institutions—including universities. At this university, we believe that fundamental solutions are predicated on the wise use of technology. Of government, industry, and research institutions, only universities have this fundamental mission: to develop the technologies upon which those solutions will be based.

At Iowa State, this mission is characterized by a long-standing culture of interdisciplinary work.

The College of Engineering is involved in research activities that cut across molecular biology, quantum physics, energy, marketing, psychology, atmospheric and plant sciences, and medicine. In addition to being affiliated with academic departments, our researchers are associated with more than 60 research centers and institutes. A number of our faculty are affiliated with the Ames Laboratory of the U.S. Department of Energy. The college has outstanding facilities in the areas of bioengineering, materials science, virtual reality, and high-performance computing. Our research expenditures exceed $68 million annually, and we educate more than 1,000 graduate students in the college. Over the past three years, we have averaged 80 PhD degrees and 200 MS degrees. Our faculty have a strong culture of interdisciplinary research, evidenced by the strong connections we have with interdepartmental graduate programs in areas as diverse as bioinformatics, systems engineering, and transportation. Appendix 3 has a more complete listing of our achievements in research, graduate education, and economic development.

In 2001, President Geoffroy launched the creation of six highly interdisciplinary Presidential Initiatives in areas of national need. Faculty from the College of Engineering were involved in all of them and had leadership roles in four—the Information Infrastructure Institute, the Institute for Combinatorial Discovery, the Bioeconomy Initiative, and the Human Computer Interaction Initiative. The

college has continued the strong focus on interdisciplinary research by collaborating with other colleges and institutes on campus and seeding teams of faculty members developing proposals for large, interdisciplinary research centers. The intent of funding these teams is to develop the concepts as well as internal and external academic and industrial partnerships, and generate preliminary data and background materials, to write nationally competitive proposals for large research centers. Indeed, these investments have paid off already, with researchers from the college winning the $18.5 million NSF Engineering Research Center for Biorenewable Chemicals.

Leveraging all of these resources to meet the 2050 Challenge will be a daunting undertaking, but the stakes are equally as daunting. Our mission is to be an important collaborator and source of innovation working toward addressing these critical challenges. To best serve the educational needs of our present and future students, and to maximize our ability to engage in research that addresses important national and international needs, we must configure ourselves in a seamless, interdisciplinary environment that builds upon our strengths yet enables us to extend our reach beyond our present intellectual boundaries.

The most critical investments we will make toward achieving these goals are in our faculty. The tenure-track and tenured faculty we welcome to the College of Engineering will have and build expertise in areas of scholarship that will address these society-changing challenges. While acknowledging our role in addressing these global challenges, we must also meet the shorter term educational needs of our departments. These sometimes opposing goals can be met by having an environment where interdepartmental and intercollegiate research are common, as is teaching across department lines, should the need arise.

The Clusters

Our ability to make an impact in a technology or science area is in part predicated on a critical mass of collaborative faculty. To help enable this collaboration, much of the hiring of new faculty in the college has been in clusters. A cluster is a group of faculty with common scholarship interests in a technology or science area who, through their collaborative efforts with our current faculty, advance the state of the art. Their efforts will contribute toward meeting society's new challenges while also bringing innovation to instruction by teaching across departmental boundaries.

The cluster areas were chosen by a faculty committee that focused on grand challenges where interdisciplinary efforts in engineering are needed to solve problems and not just on developing specific techniques or specialties within engineering. Figure 1 presents the five cluster areas chosen by this faculty committee in 2006.

These five areas share three common traits.

The first is that all of them require innovative thinking and game-changing approaches to problems related to the 2050 Challenge. The areas themselves overlap generously with the key aspects of the 2050 Challenge—energy, environment, food, water, infrastructure, and climate change.

The second is that all of the areas are interdisciplinary or "transdisciplinary" (i.e., transcending disciplines). We believe that the daunting problems that lie ahead will need transdisciplinary approaches and will need to bring together experts from highly diverse areas. We anticipate that the cluster faculty will provide leadership to move our college in that direction and help break down some of the silos that have historically formed, largely along departmental lines.

The third is that they all require a "systems engineering" approach that is consistent with the goal of focusing on interdisciplinary efforts in engineering that are needed to solve problems and not just on developing specific techniques or specialties within engineering. The 2050 Challenge is a large systems problem, and local solutions without the entire systems context will likely not work. The cluster faculty will need to percolate these common traits into the thinking of our students, both through their research and educational activities.

Figure 1

Our idea is that cluster hiring is strategically aligned with the 2050 Challenge. Clusters will initially be populated by our present faculty and expanded over the years as we recruit more cluster hires. A cluster hire is also expected to serve more than one academic department (within or outside the college). The desired attributes of these faculty are:

- Strong interest in interdepartmental and intercollegiate research in areas that will sustain and increase in their importance into the future
- Excellent research and teaching skills
- Ability and desire to be visible nationally and internationally
- Excellent interpersonal and communication skills as well as passion for student success
- Compelling desire to make the world a better place
- Willingness (and qualifications) to teach across department boundaries

We believe that the interdisciplinary cluster hires will prepare our students for the challenges ahead by forging innovative partnerships and doing groundbreaking research that will shape our future. Our commitment to this concept is demonstrated by how this hiring initiative is funded. In fall 2006, the college implemented a differential tuition program for upper-division students (juniors and seniors). Part of this revenue has been used to fund the salaries of the cluster hires. This underscores the emphasis we place on providing the kind of education and research training that students need to approach the 2050 Challenge.

These interdisciplinary hires will help build a top-quality and nationally competitive College of Engineering, which is vital to Iowa as it seeks to develop the human resources necessary to compete in a technology- and knowledge-based economy.

The Cluster Hires

The College of Engineering is in its third year of implementing the cluster hiring plan. In the last two years, the college has hired nine faculty members spanning four of the five cluster areas and all eight academic departments within the college and two departments outside the college. The cluster faculty have already begun to play a major role in our curricular and research activities. Several of them have proposed new courses that provide exciting opportunities for our graduate and undergraduate students. Many of them have quickly identified collaborations that have resulted in new ideas, grants, and publications.

Table 1 lists the names of the faculty members, their doctoral degree institutions, their academic home(s), and their cluster area. A brief description of each cluster hire's research area follows.

Name	PhD Institution and Year	Academic Home(s)	Cluster Area	Year Hired	Starting Position
Tim Bigelow	U. of Illinois, 2004	ECpE and ME	Biosciences	2008	Assistant Professor
Sumit Chaudhary	UC Riverside, 2006	ECpE and MSE	Energy Sciences	2007	Assistant Professor
Wei Hong	Harvard, 2006	AerE and MSE	Biosciences	2008	Assistant Professor
Valery Levitas	Kiev, 1995	ME, AerE, and MSE	Energy Sciences	2008	Schafer 2050 Challenge Professor
Erin MacDonald	U. of Michigan, 2007	ME and Art and Design	Sustainability	2008 (starting August 2009)	Assistant Professor and Mike and Denise Mack 2050 Scholar
Ian Schneider	NC State, 2005	CBE and GDCB	Biosciences	2009	Assistant Professor
Michelle Soupir	U. of Illinois, 2007	ABE and CCEE	Sustainability	2008	Assistant Professor
Richard Stone	SUNY Buffalo, 2008	IMSE and ME	Information Sciences	2008	Assistant Professor
Lizhi Wang	Pittsburgh, 2007	IMSE and ECpE	Information Sciences	2007	Assistant Professor

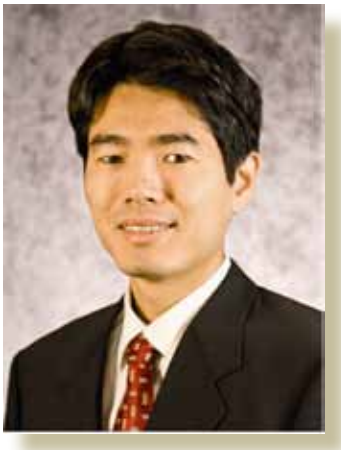
Table 1

Tim Bigelow

Dr. Bigelow strives to combine his engineering disciplines with life sciences by collaborating with faculty in veterinary medicine, biology, and animal science. He is investigating the increasing challenges of treating an aging population and developing the tools to address new diseases and other health threats. He is currently focusing on the diagnostic and therapeutic effectiveness of medical ultrasounds. This line of research is just one example of his goal to improve quality of life through technological advances.

Sumit Chaudhary

Dr. Chaudhary researches energy infrastructure to address growing energy demands. He sees an organic future in solar cell construction, and his vision focuses on organic solar cell polymers. The goal is to make solar energy affordable enough to be a widely accessible option. His research projects involve working with hybrid polymer-silicon and polymer-titania solar cells to enhance the efficiency and stability of plastic solar cells through novel device designs, incorporation of nanostructures, and improved processing conditions.



Wei Hong

Dr. Hong is advancing the understanding of how various smart materials respond to stimuli and how those responses can be optimized by engineering the size, shape, and structure of the material. His research examines the use of electroactive materials such as artificial muscles or actuators that could be used in place of a motor to make a robot move or to fly a miniaturized unmanned vehicle. He is also studying gels and how they could be designed to release a drug at the site of a targeted cell in the human body. As a theoretician, Dr. Hong collaborates with experimentalists from across the college and throughout the university to design medical devices and systems that enhance the quality of life.

Valery Levitas

Advancing the fundamental understanding of material behavior, Dr. Levitas studies the stress- and strain-induced phase transitions and chemical reactions of materials. His findings will contribute to future technologies that create new energetic, superhard, and pharmaceutical materials. Each of these materials can be applied in varied capacities, ranging from a new form of energy supply to medication that more effectively treats a disease. His research melds multiple perspectives, spanning the disciplines of advanced mechanics, physics, material science, chemistry, and applied mathematics. His comprehensive outlook is enhanced through worldwide collaborations with leading researchers.

Erin MacDonald

Dr. MacDonald is interested in product design methodologies that incorporate values, concerns, and perceptions. Her work is highly interdisciplinary and incorporates decision-making principles, particularly in sustainable design. She studies the role of construction of preferences in product design, product heuristics, and judgment; she studies pseudo-sacred preferences for green product attributes; and she links marketing/engineering product optimization models.

Ian Schneider

Dr. Schneider's research is aimed at understanding how fundamental molecular and cellular processes drive tissue dynamics during the progression of human diseases, such as cancer. This includes understanding how cells communicate with each other and how that communication results in cellular responses such as migration. His lab will take advantage of several quantitative high-resolution light microscopy techniques in order to visualize dynamic processes in and around living cells. The data from these techniques can then be used to build spatiotemporal mathematical models with the eventual goal of predicting how therapeutic interventions will alter tissue organization during disease.

Michelle Soupir

Dr. Soupir is working to develop sustainable water systems by examining the occurrence, fate, and transport of pathogens, pathogen indicators, and contaminants of emerging environmental concern. She is also conducting research in nonpoint source pollution control, watershed management, and water quality monitoring. She reaches out to undergraduates by teaching an advanced Technology Systems Management course that focuses on agricultural impacts on water quality.

Richard Stone

Dr. Stone seeks ways to enhance human performance while taking health and safety into consideration. He is investigating the human ability to effectively control multiple robots and examines cognitive, physiological, environmental, and technological factors involved in enabling humans to complete successful missions with robots such as search-and-rescue robots and robots used for mining. He is a faculty affiliate of the human-computer interaction graduate program in the Virtual Reality Applications Center.

Lizhi Wang

Motivated by the vast potential of popularized green technology, Dr. Wang is searching for ways to make that technology sustainable. As part of the search, he is using network models to design incentives that will optimize the growing interdependence of energy and transportation infrastructures. His focus on operations research extends into mathematical programming, statistics, economics, and game theory. His work can be applied to economical, environmental, and social assessment of plug-in hybrid electric vehicles, deregulated electricity markets, and engineering sustainability.

4. Diverse Human Resources and the 2050 Challenge

Introduction

Diverse human capital is critical to meeting the 2050 Challenge for three reasons.

First, it is a matter of supply meeting demand. As more baby boomers leave the U.S. work force in the next decade, critical shortages will occur. The demand can be met only by increasing participation by groups historically underrepresented in engineering—in particular, women and people of color. For example, the August 2008 U.S. Census Bureau News released projections that "minorities, now roughly one-third of the U.S. population, are expected to become the majority in 2042, with the nation projected to be 54 percent minority in 2050. By 2023, minorities will comprise more than half of all children" [1].

Second, the quality of education is enhanced by a diversity of viewpoints and experiences leading to a richer educational environment.

Third, as more of our citizens are able to rise out of poverty and contribute positively to society, we will be healthier socially and stronger economically. Moreover, as our country progresses toward racial and gender equality, the strengths of all our citizens will be needed to meet the 2050 Challenge.

The importance of diversity to our national future has been eloquently stated by Joseph Bordogna, a former Deputy Director of NSF, as follows [2]:

> If our 21st Century science and engineering workforce is not representative of our citizenry, we as a nation will miss the most promising opportunity for continued U.S. success. The loss will cut two ways—it will rob worthy individuals of the chance to enrich their lives and to contribute to the engine of our economy and culture, and it will undermine the ability of our nation to prosper within an increasingly competitive world.

Subsequent sections here provide diversity-based data about our college and plans for improving our diversity. Appendix 4 lists ongoing programs to help attain that improvement.

Initial Conditions

Increasing the enrollment of women and people of color is not a new challenge in engineering, but it is now more critical than ever to make progress in this area. (See Appendix 4, pages iv–viii, for figures that supplement the following discussion.) U.S. undergraduate enrollment trends from 1995 to 2005 indicate that female enrollment reached a maximum around 2000 but has been steadily dropping since [3]. For Latin Americans (LA) there is a slow upward trend, but for African Americans (AAm) there is a slow downward trend. For LA, this could be a reflection of population trends, while the downward trend for AAm is likely more reflective of a decreasing pool of young AAm; e.g., the rising incarceration rates of black youths. All of these groups are much less than the proportion of population they represent. Similar data from Iowa State illustrates a downward trend for female enrollment about 2 percent less than national averages. For LA and AAm, our enrollment percentages are considerably less than the national values and do not reflect the divergence of LA and AAm as in national data, though in 2007 there is some indication that LA may be overtaking AAm. The fact that our enrollments for LA and AAm lag behind national trends is in part explained by the Iowa undergraduate pool, which is significantly less diverse than the national average.

Enrollment data for females, LA, and AAm indicates that first-year retention appears to be improving for all groups [4]. However, it should be noted that first-year retention has been dropping considerably for AAm since 2005. ACT test scores and high school class rank play a role in this effect. The drop in AAm retention correlates well with drops in class rank and test scores. Also, a significant

drop in LA first-year retention occurred in 2007. Since this does not correspond with drops in test scores and class rank, a possible explanation is not readily apparent. This drop is currently being investigated.

It seems clear that the most critical factor for increasing the number of women in engineering is to recruit more women into the incoming class. (That is, retention is not necessarily the issue.) Some research even suggests that the recruitment effort should start as early as K–6 education.

U.S. [5] and Iowa State graduate enrollment data follow the data for female undergraduates but report significantly lower values for LA and AAm on a national level. Iowa State numbers are similar. We believe that an improvement in graduate student diversity will follow an improvement in our faculty diversity, an area we are actively addressing. We have placed high importance on diversity standards in our faculty searches. In order for an offer to be made to a faculty candidate, there must be evidence of diversity in the candidate pool, and, if lacking that, due-diligence is exercised in searching out diverse candidates. For example, this new policy has more than doubled the rate of interviewing female faculty candidates. During the past year, 21 percent of regular faculty candidates interviewed were women.

It is clear that bold and creative initiatives are necessary. To accelerate our efforts, the college recently established the Engineering Diversity Affairs (EDA) Office and appointed Professor Derrick Rollins as assistant dean for diversity, a new position. This office provides collegewide assistance in programming, fund-raising, and networking to enable our success in increasing diversity at all levels. In particular, this office oversees the recruitment and mentoring of multicultural and female undergraduate engineering students and provides critical input and accountability to our success in diversifying our graduate programs and faculty ranks.

Striving for Improvement

The data suggest that the number of female students will grow if we recruit and mentor them at an early age. However, the growth of students of color will also require aggressive recruiting, particularly outside of Iowa. Our ability to recruit and successfully educate students from economically disadvantaged backgrounds, whose K–12 education is often less than ideal, will contribute to meeting the 2050 Challenge. Due to the small pool of students of color in Iowa high schools, we have a two-fold strategy to increase their enrollment. The first is to expand our recruiting efforts to cities outside of Iowa with large multicultural populations such as Kansas City, Peoria, St. Louis, Omaha, and Dallas. To develop affordable financial aid packages we have been working with the Office of Financial Aid and actively developing scholarship sources from foundation giving and projects such as the new E2020 scholarship program and SEEC program (both discussed in Section 2). The second way we are seeking to increase enrollment via transfer students is through 2/3 partnership with historically minority-serving institutions. For example, we are currently developing articulation agreements with the University of Arkansas at Pine Bluff and Southern University in Baton Rouge, Louisiana.

There is an African proverb that says, "It takes a village to raise a child." This is how we approach outreach. More specifically, we are engaged in a comprehensive, coordinated, and synergistic effort of stakeholders in the college's units and departments and in university student services, as well as through faculty and staff in targeted high schools, alumni and friends of the university, and our industrial partners. Here are a few examples:

- Alumni accompany us on our recruiting trips when we visit their areas and visit family of prospective students in their areas.
- One of our industrial partners has played the leading role in making contacts and setting up our recruiting visit to their city. The person that led in this effort is a member of our Diversity Affairs Industrial Advisory Board. Similar advisory board members are starting and heading efforts in their communities.
- Several of our industrial partners conduct professional development workshops for our summer bridge program, called the "Summer Program for Enhancing Engineering Development" or SPEED.
- In addition to the generous financial support by our industrial partners, they provide numerous networking activities throughout the academic year, such as our annual awards banquet.

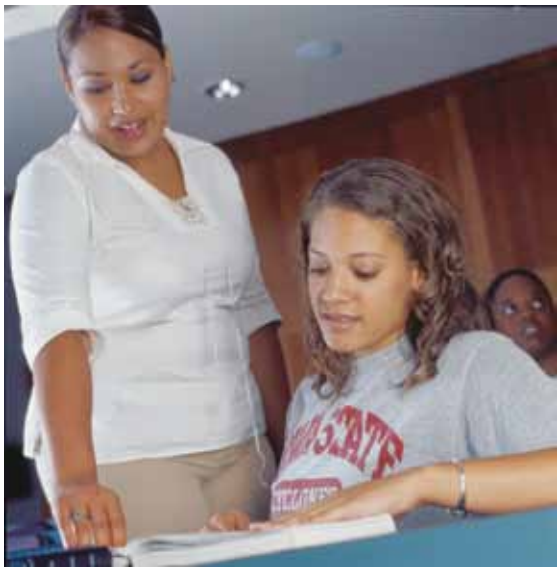
Perhaps the most important services we offer our students are those academic programs that address transition from high school. The SPEED Program targets disadvantaged students. The goal is to strengthen their problem solving abilities in math, physics, and freshman engineering. It is an intensive experience. The program's unique motivator is the use of a weekly salary that is reduced when students underperform. We have found this motivator to be quite effective. The program was successfully piloted last summer with 10 students. It is our goal to expand this to 30 students this coming summer with major funding coming from the Student Affairs Office and industrial partners.

We were successful in obtaining substantial funding for a federal earmark project in partnership with Florida A&M University (FAMU) and the South Dakota School of Mines & Technology (SDSMT). FAMU is a Historically Black College and University, and SDSMT has a substantial Native American population. These partnerships will provide us with direct access to undergraduate students of color for internships and graduate school.

College of Engineering research centers are changing the culture by developing research partnerships with historically serving-minority institutions and new initiatives. For example, the Bioeconomy Institute hosted a visitation at Iowa State this past fall with faculty from the University of Puerto Rico-Mayaguez, Prairie View A&M, and Tuskegee that is leading to collaborative projects and exchanges. Our newly formed NSF Engineering Research Center for Biorenewable Chemicals, in partnership with the Iowa State Science Bound Program, established both a research internship/mentoring program for high-ability minority high school students and one with the Diversity Affairs Office for transitioning high school students that is used to help recruit the most promising students of color.

During the academic year, in addition to services such as learning communities and tutoring that are common to all Iowa State students, we recently implemented skill enhancement workshops to supplement freshman math, science, and engineering courses. These interactive workshops address weaknesses in problem solving and test performance as well as helping students with time management and building strategies to succeed.

Although diversity efforts in the college are broad and substantial, there is still a lack of coordination between departments and programs. As a result, the college is looking at ways to be more effective in reaching our



goals. For example, the mechanical engineering (ME) department, in an effort to significantly increase undergraduate and graduate females, has hired two staff members dedicated to the recruitment and retention of female students. To this end, ME has planned and hosted a number of visitation and social activities to increase the connection of its female students to members of their department. Another example worth noting is the pool of candidates that chemical and biological engineering interviewed this academic year—6 of the 11 were either a woman or person of color.

Through the college's Diversity Committee we will continue to provide workshops to educate on best practices and work with all members of our college. For example, this spring the committee will organize the first COE Diversity Fair to promote communication, networking, and collaboration among units and departments.

Final Remarks

Our world is changing rapidly, and we understand that for U.S. engineering to provide the technology to meet future world demands, it will require critical cultural changes in the present that make engineering the destination of choice regardless of gender, ethnicity, or income level. Our college is committed to broadening participation in engineering fields as we work diligently to become a destination of choice for underrepresented students, faculty, and staff. We are confident that significant growth will continue to occur over many years as we work with our stakeholders and find creative ways to increase recruitment, retention, and graduation rates of our students and as we diversify our faculty and staff. This section has presented some of our progress and current ideas in accomplishing our diversity objectives as we look to the year 2050.

References

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[2] Bordogna, J. (former deputy director, National Science Foundation). 2003. Quote. Engineering Societies Diversity Summit II. 17 September.

[3] Engineering Workforce Commission. 2006. *Engineering & Technology Enrollments: Fall 2005*. Washington, D.C.

[4] Engineering Workforce Commission. 2006. *Engineering & Technology Enrollments: Fall 2005*. Washington, D.C.

[5] National Science Foundation, Division of Science Resources Statistics. *Survey of Graduate Students and Postdoctorates in Science and Engineering, 1998–2005*.

5. Looking Forward

In his latest book [1], Tom Friedman says:

> In a world that is getting hot, flat, and crowded, the task of creating the tools, systems, energy sources, and ethics that will allow the planet to grow in cleaner, more sustainable ways is going to be the biggest challenge of our lifetime.

We agree.

This report has provided a blueprint for how our engineering college is trying to focus on this challenge. We hope we can look forward to staying with this for the long run so that our students of today and tomorrow will, in 2050, be enjoying a livable and sustainable lifestyle and be proud that they have had a part in making it possible.

References

[1] Friedman, T. 2008. *Hot, Flat, and Crowded.* Farrar, Straus & Giroux.

2050 CHALLENGE

APPENDIX 1—Facts and Figures

Iowa State University Profile

Iowa State's nearly 2,000-acre, park-like campus includes more than 200 buildings; many are included on the National Register of Historic Places. The campus is located in Ames, Iowa, 30 minutes north of Des Moines, Iowa's state capital and largest population center.

The nonengineering-degree-granting colleges include agriculture and life sciences, business, design, human sciences, liberal arts and sciences, and veterinary medicine. There are about 45 research centers and institutes housed outside of the College of Engineering that are led by and/or have key participants that are engineering faculty. The list includes The Ames Laboratory of the U.S. Department of Energy, the Bioeconomy Institute, the Center for Transportation Research and Education, the CyberInnovation Institute, and the Institute for Physical Research and Technology, to name a few.

College of Engineering Profile

The College of Engineering currently occupies 16 buildings, including about 430,000 net assignable square feet. The facilities are available to approximately 5,000 undergraduate and 1,000 graduate students. These facilities include specialized labs for robotics, bioengineering, nanotechnology, materials science, high-speed electronics, renewable energy, and parallel computing. (A statement and a brief history about each building can be found at http://www.engineering.iastate.edu/visitors.html.)

The college's organizational structure includes eight academic departments, six nonacademic supporting departments, and eight research centers.

The academic departments include aerospace engineering; agricultural and biosystems engineering (jointly administered by the Colleges of Engineering and Agriculture and Life Sciences); chemical and biological engineering; civil, construction, and environmental engineering; electrical and computer engineering; industrial and manufacturing systems engineering; materials science and engineering; and mechanical engineering.

The nonacademic supporting departments include Engineering Administration; Engineering Academic and Student Affairs; Engineering Communications and Marketing; Engineering Computing Support Services; and Engineering Distance Education.

The research centers include Analog and Mixed-Signal VLSI Design Center, Asteroid Deflection Research Center, National Science Foundation Engineering Research Center for Biorenewable Chemicals, Computational Fluid Dynamics Center, Electric Power Research Center, Industrial Assessment Center, International Materials Instrumentation for Materials Informatics and Combinatorial Materials Science, and Power System Engineering Research Center.

Student Expenses

Academic costs for two semesters, 2008–2009, are estimated, based upon an average course load, as follows:

	Resident			Nonresident		
	Undergrad	Undergrad	Graduate	Undergrad	Undergrad	Graduate
	Frosh and Soph	Jrs and Srs	Students	Frosh and Soph	Jrs and Srs	Students
Tuition and Fees	6,571	8,129	7,993	17,561	19,103	18,877
Room and Board	6,956	6,956	8,321	6,956	6,956	8,321
Books and Supplies	984	984	983	984	984	979

Operating Revenues

Operating revenues for the current fiscal year, 2008-2009, are estimated as follows:

Undergraduate Tuition	20,373,000
Graduate Tuition	5,571,000
Indirect Costs	2,932,000
State Appropriations	36,512,000
Total Operating Budget	**65,388,000**

Private Support

Iowa State has two years left on its $800 million, 7½-year comprehensive campaign. The college's goal within that campaign is $275 million. As of 12/31/08, we have raised $233 million toward that goal.

The college's fund-raising efforts over the last several years have been primarily focused on completing several large capital projects (the cost split is typically 50-50 public and private support) as well as building endowments for faculty positions, scholarships, and undesignated support of the college and departments.

In FY08, 3,680 donors made gifts and commitments totaling over $21 million to support the College of Engineering. In the first six months of FY09, the college has raised $11 million in gifts on a $23 million goal. The college has a four-person development team..

The college has a mature program of volunteer activities, publications, dean involvement, and nationwide events that support the development effort. We possess good data on the 36,000 living alumni of the college. The development team is currently working to improve its efforts on eight- to nine-figure gifts as well as improving the involvement of the department chairs in the fund-raising effort.

Human Capital

Fall 2008 Faculty and Staff FTE	
Faculty	191.33
Professional and Scientific	113.75
Merit	46.84
Post Doc	23.84
Non-Student Hourly	2.27
Contract	0.63
Total—College of Engineering FTE	**378.66**

Faculty Profile

There is a total of 227 tenured and tenure-track faculty, including three members of the National Academy of Engineering, 15 distinguished professors and university professors, and 22 endowed chairs and professorships. There are 67 full- and part-time nontenure eligible faculty, including 36 lecturers and senior lecturers and 31 adjuncts, affiliates, and visiting professors. Our faculty includes 30 recipients of NSF Presidential/New Young Investigator and CAREER Awards, two TR100 Awards, and 16 R&D 100 Awards.

Departments	Tenure-Track Faculty	Lecturers, Senior Lect.	Adjuncts, Affiliates, Visiting
Aerospace	28	4	10
Agricultural and Biosystems	31	4	1
Chemical and Biological	18	2	2
Civil, Construction, and Environmental	32	11	7
Electrical and Computer	53	2	4
Industrial and Manufacturing Systems	14	2	0
Materials Science	23	3	5
Mechanical	28	8	2
Total Faculty	**227**	**36**	**31**

Student Profile

A total of 5,634 students enrolled at Iowa State's College of Engineering in fall 2008, including 4,676 undergraduate students and 958 graduate students. Over half, 62% of our students, are Iowa residents.

Degree Programs

The college has 10 ABET-accredited undergraduate degree programs: aerospace, agricultural, chemical, civil, computer, construction, electrical, industrial, materials, and mechanical engineering.

We also have two non-ABET-accredited undergraduate programs—biological systems and software engineering. Biological systems is a new degree program that will be offered starting the fall semester of 2009. Software engineering is another new program that began fall semester of 2008. Plans are underway to have both these programs ABET accredited.

Undergraduate Degree	2007–2008	Fall 2008
Programs	Graduates	Enrollment
Aerospace	78	544
Agricultural	23	181
Chemical	76	402
Civil	92	534
Computer	72	387
Construction	73	372
Electrical	88	358
Industrial	65	206
Materials	32	168
Mechanical	191	1014
Software	0	40
Undeclared	0	470
Total Undergraduate Students	**790**	**4,676**

We have 10 master's and doctoral programs: aerospace, agricultural, chemical, civil, computer, electrical, engineering mechanics, industrial, materials science, and mechanical engineering.

There are also nine university-wide interdisciplinary master's and doctoral programs that rely on engineering faculty: bioinformatics and computational biology, biorenewable resources and technology, environmental science, human-computer interaction, information assurance, sustainable agriculture, systems, toxicology, and transportation.

Master's Degree Programs	2007–2008 Graduates	Fall 2008 Enrollment
Aerospace	14	26
Agricultural and Biosystems	10	21
Biorenewable Resources and Technology	0	1
Chemical and Biological	6	5
Civil, Construction, and Environmental	25	67
Electrical and Computer	37	91
Environmental Science	1	6
Human-Computer Interaction	7	9
Industrial and Manufacturing Systems	0	18
Information Assurance	9	23
Materials Science	5	18
Mechanical	25	83
Sustainable Agriculture	1	0
Systems	19	99
Transportation	1	0
Total Master's	**160**	**467**

Doctoral Degree Programs	2007–2008 Graduates	Fall 2008 Enrollment
Aerospace	4	30
Agricultural and Biosystems	4	26
Bioinformatics and Computational Biology	1	7
Biorenewable Resources and Technology	0	5
Chemical and Biological	7	49
Civil, Construction, and Environmental	12	34
Electrical and Computer	15	178
Environmental Science	1	4
Human-Computer Interaction	1	9
Industrial and Manufacturing Systems	4	20
Materials Science	12	56
Mechanical	14	73
Sustainable Agriculture	1	0
Total Doctoral	**76**	**491**

Total Graduate Students	**236**	**958**

Research

In the most recent fiscal year, faculty College of Engineering research expenditures were nearly $68 million across a broad range of topics including biomaterials for drug delivery and tissue engineering, advanced transportation systems, clean energy sources, disaster immune electric power grids, hacker-proof computer networks, and safe and secure food items.

Approximately one-fourth of these awards are administered within the College of Engineering. Of the remaining, the majority of the awards are administered within Iowa State research centers and institutes.

Centers and Institutes

College of Engineering faculty have established a strong track record of collaborative research, and this has resulted in their participation in more than 65 centers and institutes across campus. The centers and institutes in which the college faculty have leadership or significant roles are shown in the table below.

NAME OF CENTER OR INSTITUTE	DIRECTOR
Asteroid Deflection Research	Bong Wie (Aer E)
Bioeconomy Institute	Robert Brown (ME)
Biosafety Institute for Genetically Modified Agricultural Products	Manjit Misra (ABE)
Bridge Engineering Center	Terry Wipf (CCEE)
Catron Center for Solar Energy Research	Vikram Dalal (ECpE)
Center for Industrial Research and Service	Ron Cox (Aer E)
Center for Nondestructive Evaluation	Bruce Thompson (Aer E and MSE)
Center for Sustainable Environmental Technologies	Robert Brown (ME)
Computational Fluid Dynamics Center	Z. J. Wang (Aer E)
Cyberinnovation Institute	Jim Oliver (ME)
Electric Power Research Center	Tom Baird (ECpE)
Engineering Policy and Leadership Institute	Ed Jaselskis (CCEE)
Institute for Combinatorial Discovery	Krishna Rajan (MSE)
Institute for Physical Research and Technology	George Kraus (CHEM)
Institute for Transportation Research	Shashi Nambisan (CCEE)
Iowa Space Grant Consortium	William Byrd (Aer E)
Microelectronics Research Center	Vikram Dalal (ECpE)
NSF ERC for Biorenewable Chemicals	Brent Shanks (CBE)
NSF IMI on Combinatorial Sciences and Materials Informatics	Krishna Rajan (MSE)
NSF IUCRC for Aviation Systems Reliability	Bruce Thompson (Aer E and MSE)
NSF IUCRC for Power Systems Engineering	Jim McCalley (ECpE)
Virtual Reality Applications Center	Jim Oliver (ME)

Patents and Start-ups

Iowa State filed its first patent application in 1923 and received its first patent in 1926. It established an office in 1938 (one of the first universities to establish such an office) to manage the protection and commercialization of research results through collaborative efforts with industry under license agreements granting industry rights to utilize the protected results. According to a recent NSF-funded study (www.innovationassoc.com/docs/TTCP.ExSumm.pdf), Iowa State is a model of economic development activity. Nationally, Iowa State is ranked 2nd in licensing technologies, 6th in the number of active licenses, and 22nd in start-up companies launched. The faculty in the College of Engineering have had a strong history of entrepreneurship and innovation. Of the 381 active patents at Iowa State, 167 are held by engineering faculty. Our faculty have also been heavily involved in starting companies that have been very successful and that have contributed to economic development efforts in the state of Iowa. Some examples of companies started by CoE faculty include Engineering Animation, Inc.; EnSoft Corp; Microchannel Technologies; Palisade Systems, Inc.; and many others.

Appendix 2—Education and the 2050 Challenge

Priorities and programs in the following areas of engineering education in the college are synergistic with the 2050 Challenge: maximizing student success, growing and diversifying engineering talent, and broadening student development. These three priorities are illustrated in the diagram below and labeled as Success, Quantity, and Quality, respectively.

Several programs representing college strengths in these areas are described in this appendix.

Maximizing Student Success

Rigorous and Engaging Curricula

In addition to nationally ranked undergraduate programs, the college offers students numerous options through the concurrent BS/MS program. Students may concurrently pursue a graduate MS degree and their undergraduate BS degree in the following programs: agricultural, chemical, civil, computer, construction, electrical, materials, and mechanical engineering. In addition, the College of Engineering and the College of Business offer an integrated, concurrent program leading to a bachelor of science degree and master of business administration (MBA) degree. The Engineering/MBA Program is available to undergraduate students majoring in civil, computer, electrical, industrial, or mechanical engineering. The program reduces by one year the normal time period for completing both degrees separately.

Each of the academic programs provides numerous opportunities for students to gain hands-on experience in state-of-the-art instructional laboratories.

Experiential Education

In the experiential education workplace, many engineering students first experience taking ownership of their own learning. These students experience the opportunity to demonstrate ABET Criterion 3 (i): "a recognition of the need for, and the ability to engage in, lifelong learning." From Engineering 101 to graduation, engineering students have access to competency/ability-based assessment and professional development tools. These formative assessment instruments are fully integrated as a large collection of learning tools and professional development resources, many focused on communication, teamwork, ethical responsibility and leadership. Personal

ownership of assessment and professional development encourages Iowa State engineering students to develop and demonstrate "a recognition of the need for, and the ability to engage in, life-long learning."

Engineering Career Services delivers to faculty large volumes of student self-assessment and supervisor-assessment data from the experiential education workplace, providing Iowa State engineering programs with rich information to support curriculum improvement and accreditation.

Innovative Learning Environment

An innovative learning environment stimulates excellence and enables students to succeed. This environment is supported in many ways: by members of the university community and their academic and scholarly pursuits, through state-of-the-art research, and by providing access to quality educational facilities that are continually improved through renovation and expansion. The learning environment is enriched by Iowa State's land-grant mission, which emphasizes education, research, and public engagement. Research opportunities for undergraduates provide interactions with faculty who are recognized experts in their fields. Academic advisers provide individual counseling on resources, scheduling, and orientation.

New construction is underway for the future home of the Department of Agricultural and Biosystems Engineering and Iowa State's Biorenewables Research Laboratory. The total cost of the complex is estimated at $66.5 million.

Two additions to the Department of Electrical and Computer Engineering are estimated at $38 million. The first addition, completed in 2008, includes new space for classrooms, teaching labs, and research.

The $70 million Engineering Teaching and Research Complex, a two-building complex (Howe Hall and Hoover Hall), was completed in fall 2003. The facility houses the Virtual Reality Applications Center, the Department of Aerospace Engineering, and the Department of Materials Science and Engineering.

With more than $4 million in recent upgrades, the C6—the country's first six-sided virtual reality room—now projects more than twice the resolution produced by any other virtual reality room in the world. Researchers are using the C6 to visualize data from as many as 22,000 genes, train soldiers for urban combat, show students how plant photosynthesis works, display data from an atom probe microscope, and help engineers visualize new products.

Growing and Diversifying Engineering Talent

Precollege Programs to Develop Interest in STEM

Another program unique to Iowa State supports technology education for teachers. The Toying With Technology program has included courses for education students and workshops for K–12 students and teachers. These workshops have been given to groups visiting campus and also presented at K–12 schools around the state. A two-credit graduate course is offered in the summer. The program is designed to explain the principles behind many of the technological innovations in wide use today through hands-on laboratory experiences based upon simple systems constructed out of LEGOs.
Part of the college's efforts to broaden participation in engineering, a recent project funded by the NSF, Female Recruits Explore Engineering, aims to understand how young women come to know and learn about engineering. The project involves Iowa State University, the University of Colorado, and Ohio State University; high schools and business partners in Iowa, Colorado, and Ohio; and 120 girls. High school girls (10th-graders), college professors, and school staff work together to explore engineering fields and think about engineering as a career. The girls take an active part in the project, helping to select the engineering areas to investigate, the activities to pursue further, and the career-related topics to discuss. Students use a password-protected online learning environment to discuss, share, and reflect on their growing knowledge and perceptions of engineering.

Recruitment and Advising Programs

Workforce development in the state, nation, and world is important to the 2050 Challenge. As one of the largest undergraduate schools in the United States, Iowa State's College of Engineering is committed to the high number and quality of its engineering graduates. Iowa State ranks in the top ten to fifteen schools annually in engineering enrollment and graduation numbers. This is accomplished through effective and innovative recruitment and retention programs.

The college develops and delivers programming in collaboration with academic departments to create awareness of and recruit undergraduate students to the College of Engineering. This is accomplished through developing, implementing, and evaluating outreach and recruitment programs; establishing and maintaining collaborative working relationships with other college and university programs including student organizations and volunteers; and providing contemporary print and multimedia information to prospective students, families, and interested others. The Enrollment Services and Precollegiate Programs office partners with Engineering Diversity Affairs on recruitment of women and minority students and with the Engineering Scholarship Program and Engineering Leadership Program in attracting high-ability students. Examples of programming include

Engineering & Beyond workshop (four-day summer camp for rising seniors), Scholars' Day (honoring admitted students who have received scholarships and their parents), and SHPE Shadow Day (coordinated with the student organization SHPE/Society of Hispanic Professional Engineers).

Iowa State University started the Admissions Partnership Program (http://www.admissions.iastate.edu/partnership) in 2006 to make it more convenient for community college students to transfer to Iowa State. Through the Admissions Partnership Program, community college students who plan to pursue a bachelor's degree at Iowa State receive the following special benefits to promote academic success at both schools before they enroll in Iowa State coursework:

- Mentoring and guidance from the community college partner and Iowa State
- Opportunities to live in Iowa State housing
- Access to career resources at Iowa State
- Iowa State student pricing for athletic and cultural events
- Opportunities to participate in early orientation and registration at Iowa State
- Guaranteed acceptance into a bachelor's program at Iowa State, provided all college and program requirements are met at the time of transfer.

Engineering Student Services provides a variety of support services for prospective and enrolled engineering undergraduate students and families. Professional advising staff provides academic advising for prospective, transfer, and current engineering students. Undeclared students are served by college staff, and each department provides services and advising for its own majors. The purpose of the advising system in the College of Engineering is to work constructively with students in developing their individual academic programs and to maintain close contact with students during their college careers.

Access to Education

As a land-grant institution, Iowa State prides itself on access to education, and this too is central to growing and diversifying engineering talent. Undergraduate engineering programs at Iowa State attract students from Iowa, from surrounding states, from across the nation, and from countries around the world. An engineering education from Iowa State remains the most affordable among all of the top engineering colleges in the Midwest. Only a handful of top engineering schools across the country have lower resident or nonresident tuition.

The college administers a merit-based scholarship program that complements the university's scholarship program handled by the Office of Student Financial Aid. The college program works closely with each of the academic departments. Awards are renewed annually based on student performance for up to four years. These engineering scholarships are in addition to university-level scholarships. Last year, the college distributed over $2.2 million in engineering scholarships to undergraduate students.

In 2009, with a $600,000 grant from the NSF S-STEM Program, the college will begin awarding need-based scholarships as part of the E2020 Scholars Program. This four-year program will provide scholarships for cohorts of undergraduate students (incoming freshmen and transfers) within our established learning community infrastructure, giving specific attention to the aspirations and attributes of the NAE's vision for the engineer of 2020. We have outlined a set of student development and learning opportunities consistent with this vision to be integrated into our curricular and co-curricular activities: leadership development, global awareness and understanding, systems thinking, and innovation. This scholarship program for engineering students promotes student engagement and development centered on these E2020 outcomes. These content areas will be developed and made available to all students in the college. (See http://www.engineering.iastate.edu/e2020.)

Technology Literacy

The college provides technology-based educational opportunities for precollege students, nonengineering students, and professionals. Programs such as FIRST LEGO League and Toying With Technology were introduced in Section 2. In 2007, the college began offering a minor in engineering studies for nonengineering majors. It's one of only a few similar programs in the country, although the emphasis on technology literacy is expanding nationwide (note Duderstadt's report). The purpose of the program is to provide technological literacy to nonengineering students. The program is designed so that students are not excluded due to insufficient prior preparation in mathematics or science. The required courses in the minor and many of the elective courses are specifically designed to offer a range of prerequisites, so that students from all majors will find coursework that supports an accessible and intellectually stimulating program of study. The first students graduated with the minor in 2008. The NSF CCLI Program has awarded a new grant starting in 2009 to pilot a teaching model for this program patterned after the Preparing Future Faculty Program. (See http://www.eng.iastate.edu/mes/.)

Broadening Student Development

A broad education has been charted for the future of engineering education by the NAE and others [1, 2, 3]. Important advancements at Iowa State include student leadership development, enabling graduates to shape public policy at all levels and become leaders in the public debate on the use of technology for the betterment of society; international experiences for students, enabling graduates to become leaders in a global profession; and advanced and interdisciplinary study opportunities for all majors. The national vision combined with the college's 2050 Challenge have led us to emphasize a set of student development and learning outcomes for collegewide integration into our curricular and co-curricular activities:

- Leadership development, including teamwork, communication, and service
- Systems thinking, including interdisciplinary engineering design
- Innovation, including creativity and entrepreneurship
- Global awareness and understanding, including cultural adaptability

These outcomes are the focus of the new E2020 Scholars Program. However, each is embedded in established programs in the college.

Leadership

The Engineering Leadership Program (described in Section 2) uses Iowa State's eDoc electronic portfolio system to help the college and students track progress toward fulfilling program outcomes. The electronic portfolio allows students to collect and present evidence demonstrating academic and professional competencies. At the center of this outcomes-based approach for the ELP is a leadership learning model. The model was developed to recognize several parallels between the characteristics of social leaders and abilities identified in the outcomes statements defined by ABET. Several of the ABET outcome statements (specifically, d, f, g, h, and i) are incorporated into the ELP leadership model along with three additional outcomes: (1) an ability to create a vision, articulate it, and inspire others to share and implement it; (2) an ability to effectively influence and innovate to deliver results; and (3) recognition of the need for actively encouraging diversity and an ability to create an inclusive environment. Each outcome is associated with a set of core competencies that are important for students to understand what the outcomes mean in terms of behavior.

Interdisciplinary and Systems Thinking

Activities to develop interdisciplinary and systems thinking include undergraduate research, multidisciplinary capstone design projects, and student design competitions, such as Team PrISUm (ISU Solar Car, http://prisum.org/) and the Solar Decathlon team (http://www.public.iastate.edu/~nscentral/news/2009/jan/decathlon.shtml). The college has taken steps to improve these opportunities. PERUSE, for example, is a new program, Providing Experiences in Research for Undergraduate Students in Engineering. The Web site connects undergraduate students with faculty research (http://www.engineering.iastate.edu/peruse.html). The college is piloting a new multidisciplinary design course with initial funding from Lockheed Martin (http://multidesign.engineering.iastate.edu/). The first courses were offered in 2008–09.

A new and novel interdisciplinary undergraduate program is the minor in bioengineering for engineering majors (http://www.eng.iastate.edu/bioengineering/). The first courses were offered in 2008–09. In addition to providing a core background in bioengineering, the minor provides specializations in biobased products, bioinformatics and systems biology, biomaterials, biomechanics, biomicro systems, and bioprocessing. It complements a student's major discipline by providing additional insight into the interactions between various engineering disciplines and biological systems, emphasizing new ways of solving biological problems. The program provides students with unique educational experiences to apply engineering skills. We have framed engineering study within the context of interdisciplinary areas in new materials for prospective students, e.g., http://www.eng.iastate.edu/discovery/. The bioengineering minor is an example of curriculum development associated with the biosciences area.

Innovation

Innovation, creativity, and entrepreneurship deserve attention, both within the aforementioned areas and as a special area. Creativity, for example, is the subject of an outcomes assessment project by faculty in the Department of Agricultural and Biosystems Engineering. The college participates in the Entrepreneurial Studies Minor Program offered by the College of Business (http://www.eng.iastate.edu/entrepreneur/). It is an interdisciplinary program that provides opportunities to students to learn about entrepreneurship, the process of creating value through recognizing and developing opportunities. It serves to complement the student's major area of study by offering a means of putting theory and science into practice. In addition to feasibility analysis and business planning, the program deals with the topics of innovation, opportunity recognition, technology transfer, industry analysis, and competitive strategy.

Global Awareness

The final key area for student development is global awareness. The 2050 Challenge is a global challenge. Engineering is a global enterprise. The college in concert with every academic department offers increasing opportunities for international experiences to prepare students to become leaders. These opportunities are based on partnerships with high-quality international universities aligned with the values of Iowa State University and the College of Engineering. Through Engineering International Programs and Services (EIPS), the college maintains a broad range of services and support for undergraduate and graduate students, faculty, and staff. The college offers over thirty engineering international programs in over twenty countries, in addition to programs offered by the university. Twenty percent of all engineering graduates have studied or worked abroad.

Students have an array of engineering study and work abroad options to select from based on their individualized goals. These include semester- and yearlong exchange programs and group programs, short summer programs in several countries, and various independent learning abroad experiences. Work abroad experiences are often facilitated by industrial partners who strategically engage with both Iowa State and an international university. These experiences are managed in collaboration with Engineering Career Services as internships and cooperative work with companies such as John Deere, Sauer-Danfoss, and HON. Students also participate in various undergraduate and graduate research experiences in international university laboratories. Students receive one-on-one advising from trained staff in coordination with their academic advisers. Staff advises students regarding their options and provides predeparture orientation for both undergraduate and graduate students. The Society of International Engineers, a student organization managed by EIPS, promotes the value of international learning to Iowa State students, hosting incoming exchange students and providing "re-entry" support to returning Iowa State students. Every fall, hundreds of engineering students attend the "Tour the World" Engineering Study and Work Abroad Fair. Students talk with program coordinators and student leaders, and academic advisers are available to answer questions.

The Languages for Cultures and Professions Program, offered by the College of Liberal Arts and Sciences (LAS), allows students to gain proficiency in a foreign language and experience living and working in another culture. Students in engineering may also receive additional credit for any international study or work experience as it relates to professional development by enrolling in ENGR 320, International Experience Report, in which students prepare a report and presentation on their experience after returning. Another notable opportunity for students is right on campus, the Technology, Globalization, and Culture course, jointly offered by the College of Engineering and the Department of World Languages and Cultures in LAS (ME/WLC 484/585) (http://www3.me.iastate.edu/me484/). This course is a cross-disciplinary examination of the present and future impact of globalization with a focus on preparing students for leadership roles in diverse professional, social, and cultural contexts. The course includes lectures by practicing professionals, and students participate in critical analyses, discussion and debate, and projects.

Engineers for a Sustainable World has been active on campus for a number of years (http://www.stuorg.iastate.edu/esw/). Projects in Uganda and India are ongoing or under development. Engineers Without Borders was approved as a new student organization in 2008. Both of these organizations involve faculty and students working on projects within communities to improve the quality of life.

Articulation agreements with international universities have involved a number of departments in the college. These agreements are typically of two types: undergraduate 2+2 programs (or variations) or graduate dual degree programs. Several international universities have established agreements with departments in which the first two years of academic study are undertaken at the international university and the final two years are completed at Iowa State, resulting in an Iowa State BS degree. Also, there are agreements with several international universities for graduate students to spend time at both institutions, resulting in MS or PhD degrees from both Iowa State and its partner.

Appendix 3—Research: The Cluster Areas

Biosciences and Engineering: Building the Interface between Engineering and the Life Sciences

The scale and complexity of today's biomedical research problems increasingly demand that scientists move beyond the confines of their own discipline and explore new organizational models for team science. In its recent roadmap report, NIH noted that it wants to stimulate new ways of combining skills and disciplines in the physical and biological sciences. Through leveraging programs in fields such as molecular biology, bioinformatics, biochemistry, and veterinary medicine here at Iowa State University, there are exciting opportunities for developing novel interdisciplinary programs in biosciences and engineering. The viability of leveraging these resources has been demonstrated by the recent establishment of a series of initiatives involving the College of Engineering faculty, including:

- The creation of the Iowa Center for Advanced Neurotoxicology;
- The multidisciplinary university research initiative award from the Office of Naval Research on vaccine and drug delivery materials development;
- University of Nebraska Medical Center and Iowa State University collaboration on nanotechnology applications in pancreatic cancer and infectious diseases.

These are just a few examples of ongoing work that demonstrate that we are well poised to develop strong interdisciplinary programs of future opportunities in the interface between biosciences and engineering.

Energy Science and Technology: Engineering for Energy Systems

Energy production, sustainable energy, and energy storage and distribution are critical engineering technologies, and the College of Engineering is well poised to make major contributions in this cluster area. With a seamless interaction with Ames Laboratory supported by U.S. DOE, we are in a unique position to have national leadership among academic institutions in the field of energy science and technology. When coupled with other centers supported by the state and other funding sources, such as the Iowa Energy Center, Bioeconomy Institute, NSF-funded Engineering Research Center for Biorenewable Chemicals, and Catron Center for Solar Energy Research, it is clear that an infrastructure that exists at Iowa State can serve as a foundation for building this cluster hire initiative. The broad range of faculty already participating in numerous interdisciplinary programs with a strong track record of funding and scholarship further supports energy science and technology as a cluster topic.

Engineering for Extreme Events: Science after Natural and Man-Made Disasters

A recent editorial in *Nature* [1] noted that "disaster reduction has an immense social dimension—people can be protected only as part of a broader fight against poverty." Indeed, our recent response and recovery experience after disasters—ranging from the 9/11 terrorist attack to earthquakes, tornados, hurricanes, and floods to tsunamis to collapse of critical bridges and power systems to near or complete nuclear reactor meltdowns in Pennsylvania and Russia—has provided a recurring lesson in the critical value of a suitably conceived and appropriately implemented engineering response for remediation and rapid recovery of our critical infrastructure systems after extreme events. Furthermore, preparing for such events to mitigate their impact is important. Ongoing academic research initiatives in the country that address these issues are not focused on the fundamental engineering issues across a broad range of extreme events, and hence there is an opportunity to build leadership in this important area. By developing a cross-disciplinary initiative between engineering departments and taking advantage of existing centers and infrastructure such as the Center for Transportation Research and Education, Center for Nondestructive Evaluation, Information Assurance Center, and Wind Simulation and Testing Laboratory, as well as large-scale structural and field testing capabilities will provide the infrastructure for developing this cluster initiative.

Information and Decision Sciences: Data Deluge, Knowledge Discovery, and Cyberinfrastructure

Information technology platforms that have emerged in the last decade have made possible processing, manipulating, storing, and transfer of large data sets rapidly and inexpensively. At the same time, wireless technology and sensor and actuator technology have led to a significant increase in functionality and flexibility in terms of mobility and ubiquitous connectivity. The combination of these abilities has spawned new enterprises and endeavors that did not seem possible just a decade ago. Examples include multidisciplinary and separate research groups producing large incongruous data sets to enable scientific discovery; informatics techniques for the design of new materials (material informatics); a large set of relatively independent agents that need to execute a global objective (cooperative behavior); and monitoring of critical infrastructure like transportation, power, and health care infrastructures. These opportunities have led to new challenges that include methods to manage large data sets to produce meaningful inferences, paradigms for dynamic data-driven applications with the need for a proper interface between the information infrastructure, and applications and methodologies for distributed decision making with information constraints. A coordinated effort in developing an engineering cyberinfrastructure program for research and education of the type that NSF is promoting is a good example of the kind of activity in this cluster hire area. There are many interdisciplinary programs and facilities at Iowa State University that provide exciting opportunities for the growth of this cluster hire initiative, including the recent acquisition of two supercomputers, Iowa State's participation in the Great Lakes Consortium for Petascale Computing, the Cyberinnovation Institute, and interdepartmental programs in bioinformatics and computational biology.

Engineering for Sustainability: Engineering the Environmental and Social Impact of Technology

As human populations continue to grow, it is increasingly challenging to provide humans with the basic necessities of life—for example, food, clean water, and clean air—while providing technological societies with the energy and carbon supplies necessary to achieve their material standards of living. This is a global issue, with strong local implications for Iowa; there will be increasing opportunities to build a strong, sustainable bioeconomy based upon our land base and upon recent advances in the sciences and engineering related to biorenewable resources and decision sciences. Issues of production and conversion efficiency are closely related to disciplines including agricultural, chemical, biological, and mechanical engineering. Issues related to food security and safety are being addressed by engineering faculty with expertise in decision sciences and food engineering. A cluster hire initiative in sustainability could be built upon these strengths. When coupled to the university's academic strengths in agricultural engineering, statistics, and agricultural economics, as well as the other areas outlined in this report, this cluster initiative will provide a rich opportunity for interdisciplinary research and education. The Bioeconomy Institute and the Center for Sustainable Environmental Technologies are already addressing some of these issues.

References

[1] Editorial. 2005. Preparing for disaster. *Nature* 438:889.

Appendix 4—Diversity

This appendix gives some of the recent notable diversity-related programs and activities in the LEAD Program, the COE Diversity Committee, and faculty and staff in collaboration with departments and central units in the college and university.

Retention

- Continued support from Lockheed Martin allows the LEAD Program to have the Lockheed Martin Homework Help Center available for student use. Upper-class LEAD students who excelled in entry-level calculus, chemistry, and physics courses are paid to give homework help and basic tutoring to under-class students. The center, staffed 25 hours per week, has increased traffic to the LEAD Study Center by 50 percent and significantly increased informal peer mentoring.
- The LEAD Learning Community.
- Tutoring for female engineering students in collaboration with the Program for Women in Science and Engineering.
- The Department of Mechanical Engineering has initiated the Women in Mechanical Engineering support program for current and prospective female students. The goal of the Women in Mechanical Engineering Program is to substantially increase the percentage of undergraduate women in the program (it is currently ~7 percent), as well as retain the current women and enhance their overall satisfaction and experience in the department.

Networking

- 2008 Welcome Reception—The first event of the fall 2008 semester was a reception and dinner to welcome new students to campus, welcome back returning students, and encourage networking among students, faculty, and staff. Faculty members from various departments were in attendance.
- 2008 Welcome Back Chili Supper—The purpose of this event was for students to meet Assistant Dean Rollins, who discussed the COE vision for students of color and innovative ways in which the LEAD Program can help students reach their full potential. During this event, the LEAD Program announced the establishment of a Student Advisory Board.
- Brown Bag Lunch—This lunch took place with industrial representatives at the LEAD External Advisory Board Meeting.
- LEAD Awards and Networking Banquet—This event showcased students' academic accomplishments throughout their experience at Iowa State and honored graduating seniors. This year, Engineering Diversity Affairs (EDA) transitioned the event into an awards and networking banquet. Not only were students commended on their academic accomplishments, but they also networked with peers, faculty, and staff, as well as corporate leaders and recruiters from industry. Parents of both graduating seniors and students receiving awards were invited to the event as well. By providing students with the opportunity to attend this event, the college showcased the talents of multicultural students and provided industry with the opportunity to interact with students. There were five corporate sponsors in attendance that contributed $4,000 to make this event successful.

Notable Faculty Efforts

- The Toying with TechnologyTM Program coordinated by faculty in the Department of Materials Science Engineering is one of the largest outreach efforts in the College of Engineering, impacting thousands of K–12 students per year and hundreds of teachers. The program also has a three-credit undergraduate engineering course for education majors (pre-service teachers) and a two-credit graduate engineering summer class for practicing (in-service) teachers.
- Faculty in the Department of Industrial and Manufacturing Systems Engineering are actively involved in various university committees and national organizations that promote ethnic and gender diversity in engineering and academia.

Professional Development Opportunities

- Build Your Resume Workshop—In partnership with the Office of Multicultural Student Affairs and Engineering Career Services, the College of Engineering hosted a professional development workshop on resume building to prepare multicultural students for the Engineering Career Fair. This session provided students with useful tips on how to prepare their resumes and how to utilize the online services of the Career Management Service to create an account and upload a resume.
- Diversity Networking Reception—The purpose of this event was to provide an opportunity for students to interact with recruiters from various companies prior to the Engineering Career Fair. There was an attendance of approximately 60 students.
- Stress Management Workshop—The purpose of this event was to help students deal with the high levels of stress during midterms. Students engaged in conversation with Ray Rodriguez and Katie, his student presenter.
- National GEM Consortium Presentation—The LEAD Program organized a session along with a presenter from the National GEM Consortium to encourage multicultural students to pursue graduate school. Students walked away with information in regard to what to look for when choosing a university they would like to attend for graduate school along with support in their future endeavors.
- Financial Planning Workshop—The purpose of this event was to expose students to the various ways of managing their finances. During the event Dr. Doug Borkowski, writer of the Financial Tip of the Week, spoke to students about credit report scores (student loans, paying bills on time, building credit), buying a home (percentage of gross income that should be your monthly payment 28/40), credit card debt, student loans, etc.
- The College of Engineering also provided funding for members of the Society of Women Engineers, National Society of Black Engineers, American Indian Science and Engineering Society, Society of Hispanic Professional Engineers (SHPE), Society of Mexican American Engineers and Scientists (MAES), and National Organization for the Professional Advancement of Black Chemists and Chemical Engineers to attend national meetings, as well as participate in regional leadership opportunities. These opportunities involved interacting with leaders and recruiters from corporations and graduate schools. By sending students to these meetings, the college both showcases the talents of students of color and women and provides students with a means to develop professionally and as leaders while improving the visibility of the College of Engineering.

Contributions from Donors

To date, for this school, nine corporations have donated more than $40,000 for undergraduate diversity activities and programs.

Multicultural Events

- The College of Engineering actively participated in and co-sponsored the Iowa State Conference on Race and Ethnicity. Some members of our college are active members of the planning committee, and various faculty, students, and staff presented at the conference. Attendance to this conference is mandatory for students who are George Washington Carver (GWC) or Multicultural Vision Program (MVP) Scholars, as well as for students who are members of the LEAD Learning Community.
- Throughout the academic year, EDA via LEAD offers opportunities to minority students to develop their leadership potential and career development. Some of these funded opportunities are 15 participants for Noche de Cultura/Night of Culture, one table for Diwali Night, one table for the Legacy Ball, and one table for the NAACP Freedom Fund Banquet.
- With the purpose of celebrating the accomplishments of our students of color, EDA and LEAD provide sponsorship for the graduation celebration of People of Nia. This event is organized by the Black Student Alliance and the Black Graduate Student Association but recently joined forces with the Latino Graduate Student Association to make this a larger-scale celebration.

Notable University and Regent Awards and Honors For College of Engineering Multicultural Students

- Rachel Iheanacho, CBE—The Wallace E. Barron All-University Award
- Brandon M. Kennedy, ME—The W. Robert Parks and Ellen Sorge Parks Senior Scholarship
- Whitney Bynum 2008, ME—"Women Impacting ISU" Calendar
- Korin Reid, CBE—Alliant Energy Erroll B. Davis Jr. Award, presented by the Board of Regents

College/Unit Diversity Training and Resources

- Classroom Climate Workshops—In collaboration with the Center for Excellence in Learning and Teaching (CELT), the College of Engineering presented the workshop series "Enhancing the Climate in Engineering" to share best practices for improving the climate for students in engineering. The methods are intended to increase participation, leadership, and sense of community for all students and thereby help retain multicultural students and women in engineering.
- Fall 2007 Dr. James Johnson Presentation—With the intent of increasing the commitment of engineering faculty to understand and implement practices leading to increasingly positive undergraduate classroom climate, Dr. James Johnson, dean of Engineering, Architecture, and Computer Science at Howard University, visited the College of Engineering in October 2007. He is the 2005 recipient of the National Society of Black Engineers Lifetime Achievement Award in Academia and is recognized as a national leader in the development of strategies to increase underrepresented groups in science, technology, engineering, and math disciplines. While here, Dr. Johnson met with the College of Engineering Diversity Committee and a group of engineering department chairs and directors of graduate education. Additionally, he gave a public talk entitled "Diversity in the Worlds of Math, Science, and Engineering."
- Spring 2008—On February 12, 2008, approximately 40 people gathered in the Oak Room of the Memorial Union for a lunch workshop titled "Planning Inclusively for Classroom Diversity." The workshop was partially a response to the call of President Geoffroy in the fall of 2007 for student recruitment and retention to be a major priority for Iowa State. The presenter was Dr. Susan Yager, associate director of CELT.
- NAMEPA Conference—Derrick Rollins and Laura Centeno-Díaz, the LEAD Program coordinator, attended the 2008 National Association of Multicultural Engineering Program Advocates (NAMEPA) Conference in Atlanta, Georgia. This conference provided networking opportunities with other professionals in similar positions and information about ways to recruit and retain students with compliance to current laws and practices.

Curriculum, Pedagogy, Research, Scholarship, and Outreach Efforts

For the past academic year, outreach efforts included the following:

- The College of Engineering partnered with Enrollment Services and Precollegiate Programs to host 24 prospective students of color at "Evening with Engineering" in February 2008, an event that provided students and their parents with information about academic and social support available through the LEAD Program.
- In collaboration with SHPE/MAES, the annual SHPE/MAES High School Shadow Day was held to encourage Latino students from the state of Iowa to explore the field of engineering and connect with successful and influential engineering students. Over 25 SHPE/MAES members and volunteers participated in the 2008 High School Shadow Day.
- In collaboration with the Office of Multicultural Student Affairs, the College co-sponsored the Academic Program for Excellence during the 2007 summer.
- The College of Engineering participates in the Multicultural Vision Program (MVP), which has an emphasis on recruitment. Currently there are 46 MVP scholarship recipients in the college, and three are graduating the spring of 2008. Furthermore, recruitment of high-achieving minority students has led to 30 new students from the college receiving George Washington Carver Scholarships for the 2007–08 year. Currently there are 126 GWC scholarship recipients in the College of Engineering, and 16 will be graduating in the spring of 2008.

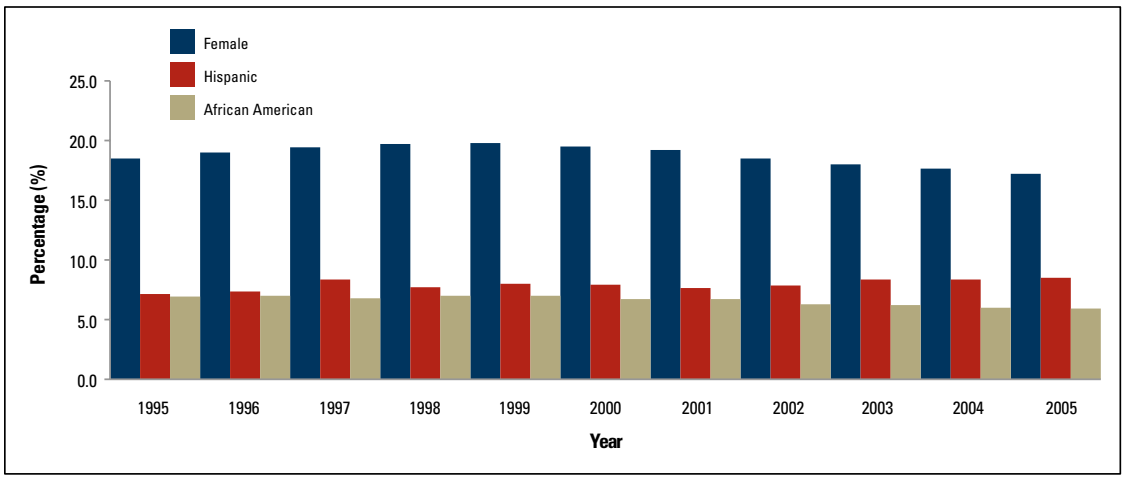


Figure 1. U.S. enrollment data from 1995 to 2005 for engineering undergraduates for all years.

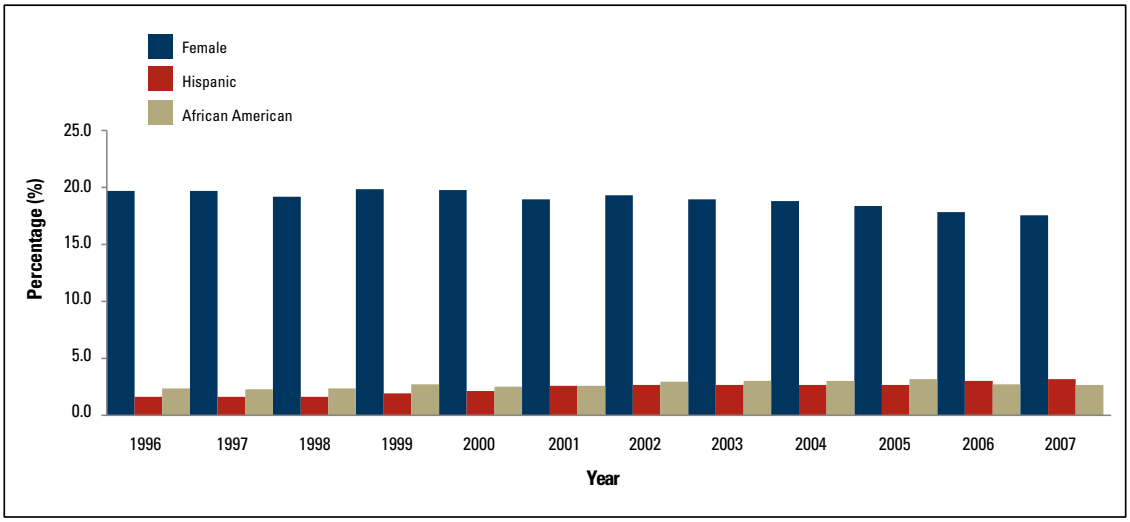
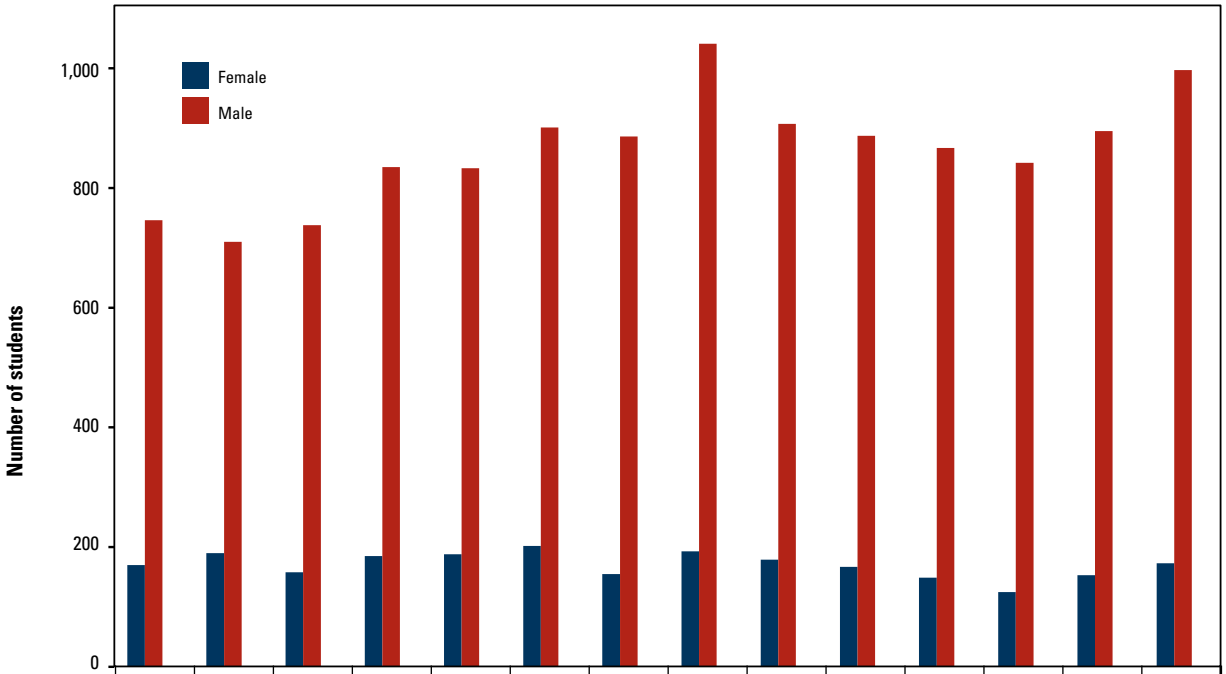
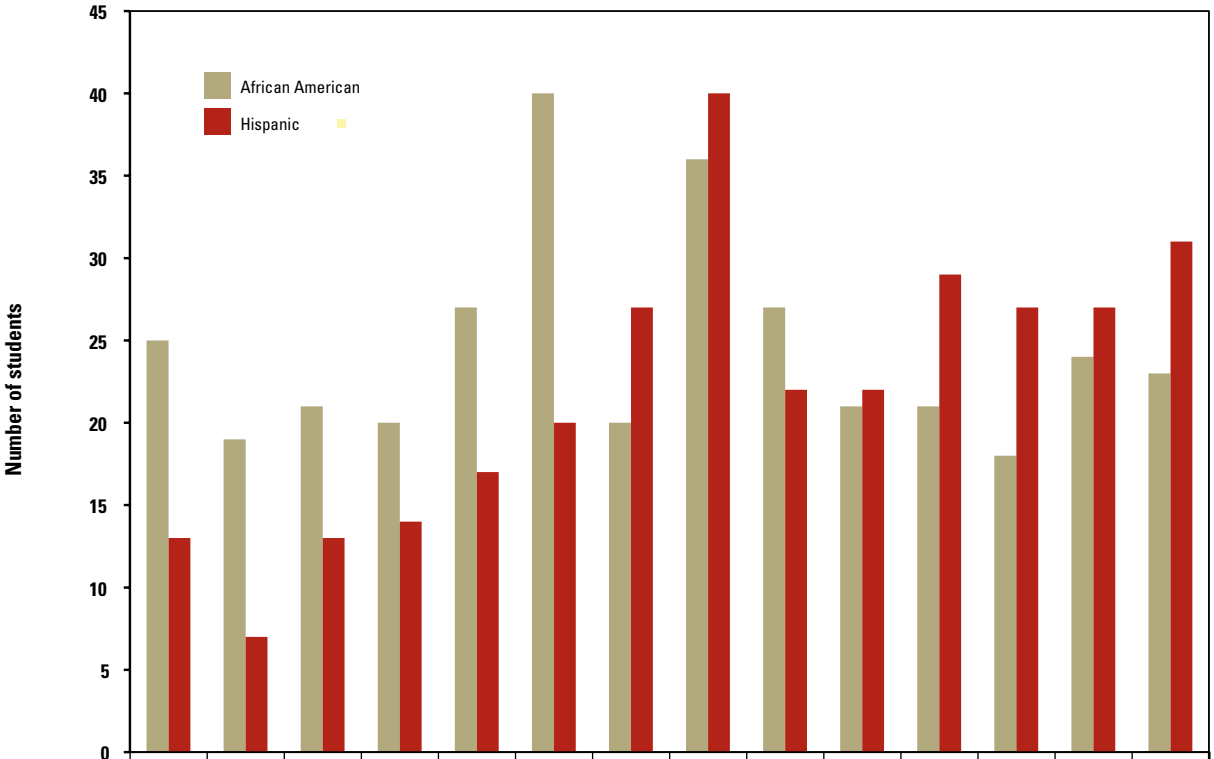


Figure 2. Iowa State University enrollment data from 1996 to 2007 for engineering undergraduates for all years.



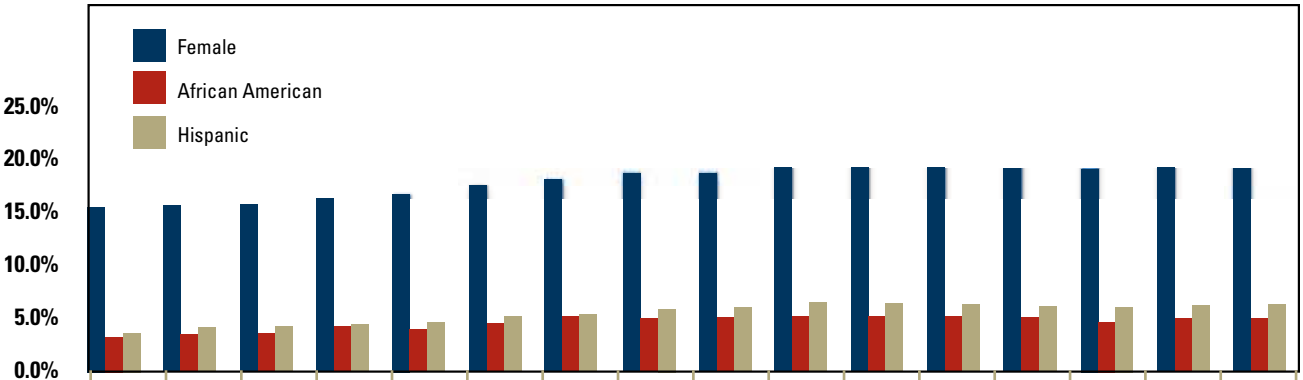
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Female	170	190	158	185	188	202	155	193	179	167	149	125	153	173
Male	746	710	738	835	833	901	886	1,041	907	887	867	842	895	997
% Female	18.6%	21.1%	17.6%	18.1%	18.4%	18.3%	14.9%	15.6%	16.5%	15.8%	14.7%	12.9%	14.6%	14.8%

Figure 3. Number of students enrolled in engineering freshmen class from 1994 to 2007 at Iowa State.



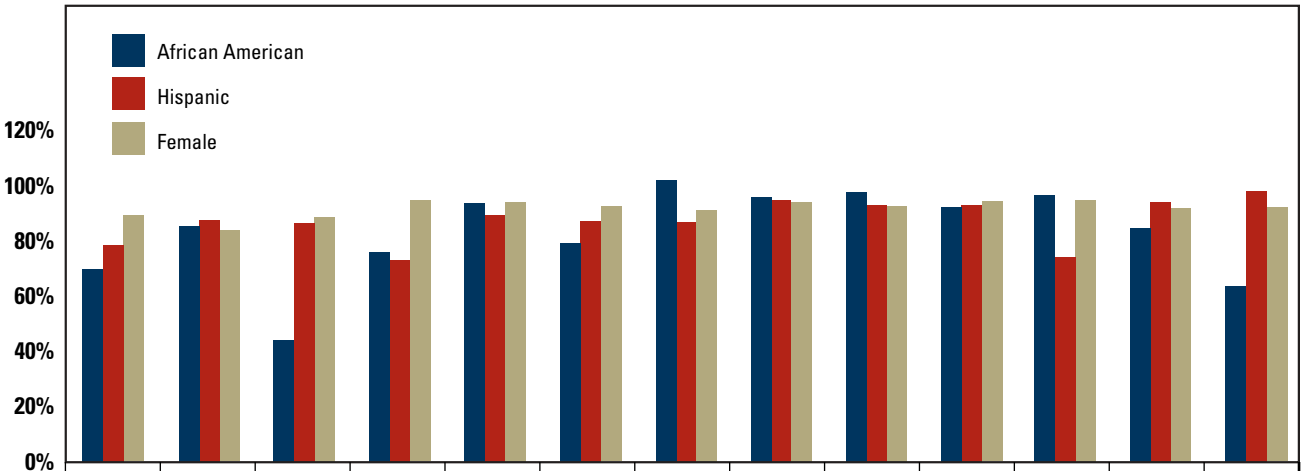
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
African American	25	19	21	20	27	40	20	36	27	21	21	18	24	23
Hispanic	13	7	13	14	17	20	27	40	22	22	29	27	27	31

Figure 4. Number of students enrolled in engineering freshmen class from 1994 to 2007 at Iowa State University by race.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Female	15.4%	15.7%	15.7%	16.1%	16.6%	17.5%	18.0%	18.7%	18.6%	19.8%	20.6%	20.2%	20.5%	20.1%	20.1%	19.6%
African American	3.3%	3.6%	3.7%	4.1%	4.3%	4.5%	4.8%	4.9%	5.0%	5.1%	5.0%	4.9%	4.9%	4.6%	4.9%	4.9%
Hispanic	3.7%	4.2%	4.3%	4.4%	4.7%	5.3%	5.4%	6.2%	6.2%	6.5%	6.5%	6.4%	6.3%	6.2%	6.3%	6.4%

Figure 5. U.S. data on bachelor's degrees awarded from 1990 to 2005.



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
African American	68.0%	84.2%	42.9%	75.0%	92.6%	77.5%	100.0%	94.4%	96.3%	90.5%	95.2%	83.3%	62.5%
Hispanic	76.9%	85.7%	84.6%	71.4%	88.2%	85.0%	85.2%	92.5%	90.9%	90.9%	72.4%	92.6%	96.3%
Female	87.6%	82.6%	87.3%	93.0%	92.6%	91.1%	90.3%	92.7%	91.6%	92.8%	93.3%	90.4%	90.2%

Figure 6. Iowa State University one-year retention rates from 1994 to 2006.

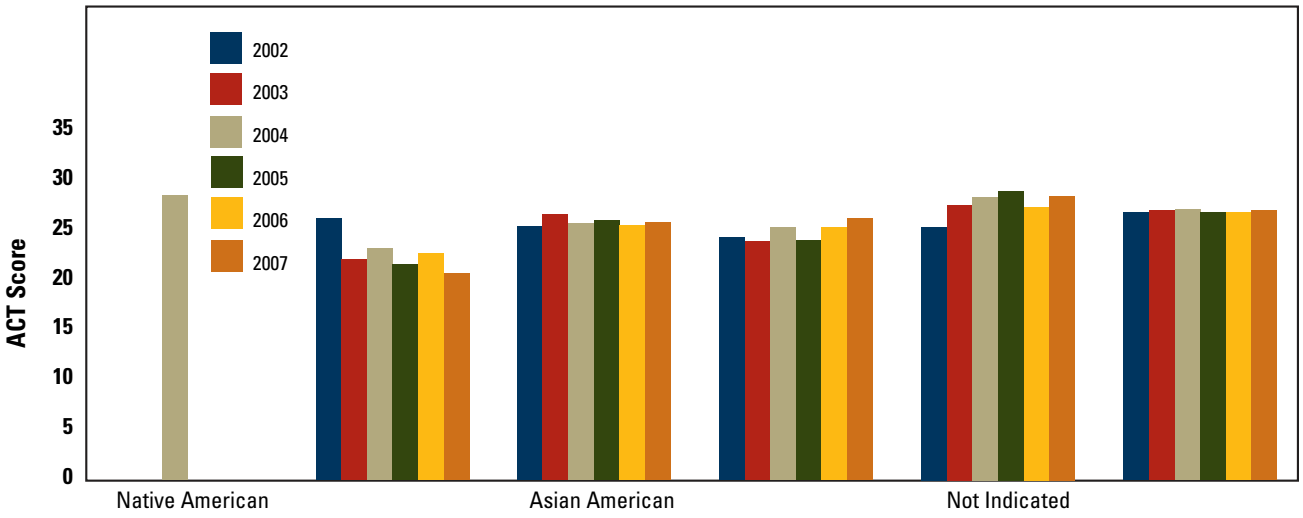


Figure 7. College of Engineering ACT composite scores by ethnicity/race from 2002 to 2007.

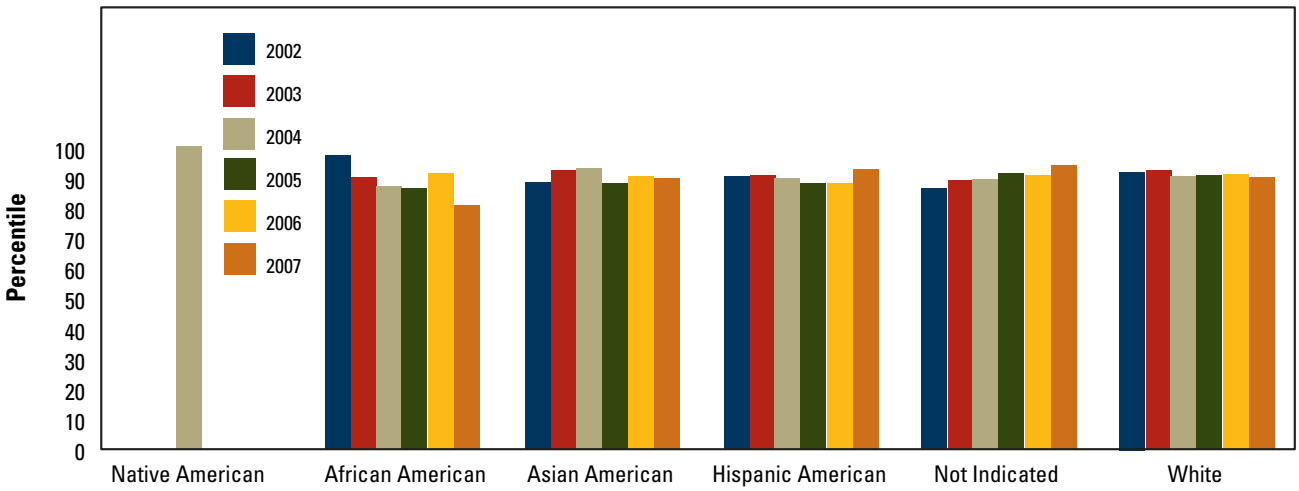
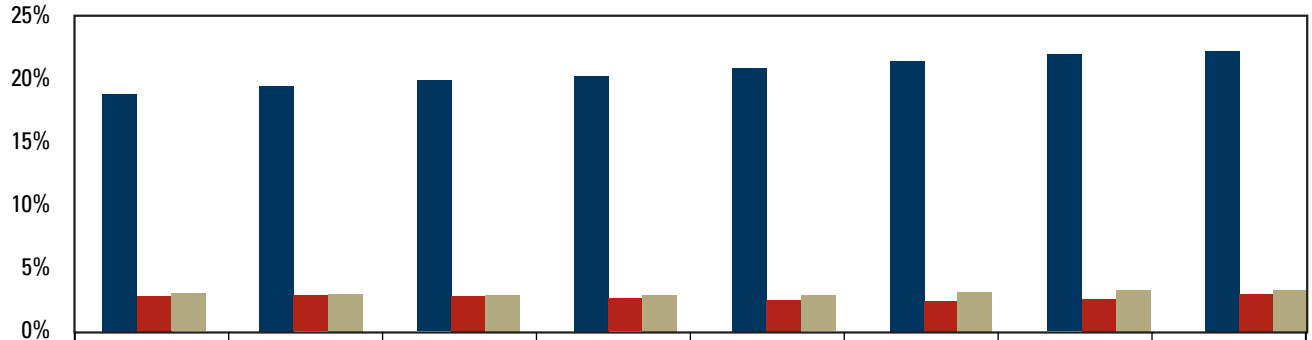
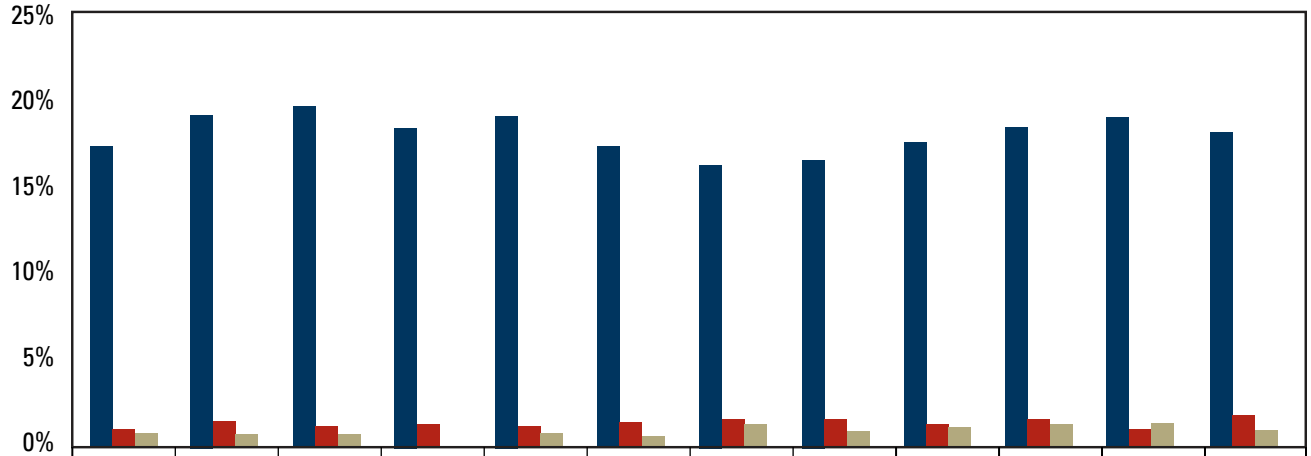


Figure 8. College of Engineering high school class rank for incoming freshmen by ethnicity/race from 2002 to 2007.



	1998	1999	2000	2001	2002	2003	2004	2005
Female	19.0%	19.6%	19.9%	20.3%	20.9%	21.7%	22.1%	22.3%
African American	2.8%	2.9%	2.9%	2.7%	2.6%	2.5%	2.8%	2.9%
Hispanic	2.9%	2.9%	2.9%	2.9%	2.9%	3.1%	3.4%	3.4%

Figure 9. U.S. graduate enrollment in engineering from 1998 to 2005.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Female	17.3%	19.1%	19.6%	18.3%	19.0%	17.3%	16.3%	16.4%	17.5%	18.4%	19.0%	18.0%
African American	1.1%	1.5%	1.2%	1.3%	1.2%	1.5%	1.5%	1.5%	1.3%	1.6%	1.0%	1.8%
Hispanic	0.8%	0.7%	0.7%	0.1%	0.8%	0.6%	1.2%	1.0%	1.1%	1.3%	1.4%	1.1%

Figure 10. Iowa State University graduate enrollment in engineering from 1996 to2007.

Appendix 5—Engineering Distance Education

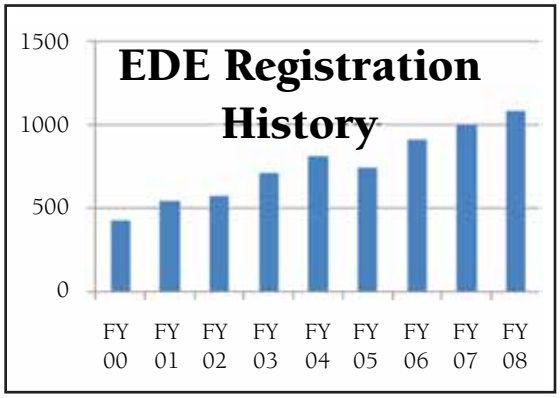
Introduction

In one important way, the mission of Engineering Distance Education (EDE) is no different from that of the rest of the college: we strive to provide engineers the knowledge and skills to meet the 2050 Challenge. But the way in which we accomplish that mission is what distinguishes EDE. World-class digital learning support is offered for our off-campus and on-campus students across the globe. We also provide engineers courses, certificates, and degrees that support their professional growth. Finally, noncredit virtual seminars are available that support working engineers and their employers.

EDE and the College of Engineering have been providing distance education since the program's inception in 1968. In 1969, Iowa State University received the National Extension Program Award for pioneering video-based continuing education to working engineers. EDE has continued its pioneering ways through numerous changes to its electronic delivery model and educational focus throughout the last 41 years.

Initial Conditions

Off-campus students comprise approximately 20 percent of the engineering graduate program enrollment. The growth of registrations has been rising for several years. EDE annually offers over 100 courses across nine complete graduate degree programs and six graduate certificate programs to over 1,000 working technical professionals located across the globe. The percentage of women taking EDE courses has been increasing since 2003.



Two of the master's programs have coursework-only degrees. Certificate programs require students to complete 12–15 credits hours.

Full details about programs and facilities follow.

Educating the Engineer of the Future

The college is expanding the number of graduate degrees that are based on only coursework. Departments that have not offered professional engineering degrees are starting or considering offering coursework-only degrees. Place-bound professionals need the convenience of 24/7 service and coursework-only degrees.

EDE is developing a noncredit course catalogue. A program has been implemented that gives incentives to professors and lecturers to produce three-hour modules. The opportunity for the growth in this area is very promising. The college has several areas of strength that will contribute to a stable and growing program.

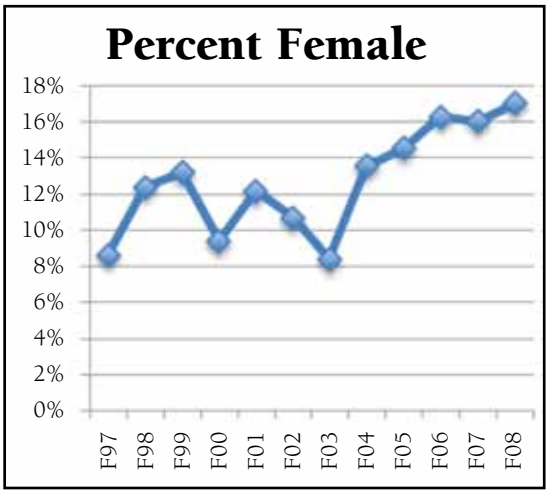
EDE will be piloting a new portable recording system for instructor use. EDE has been developing systems for several years to be used by EDE staff to record classes in rooms that have no distance education equipment. The new system will be configured in a manner that allows the instructor to record and then post the lecture online for on-campus students.

The economic downturn has not been a serious problem for the off-campus enrollments. Totally escaping the downturn is not possible; however, the addition of all coursework degrees and noncredit modules strengthens the program for the short and long term.

Facilities

Engineering Distance Education at Iowa State University offers a complete solution for the delivery of video-based educational content on the Web. EDE has four dedicated rooms in Howe Hall that are used to produce and capture live courses. Classes are offered online in real time or archived lectures and are accessible 24/7. EDE has equipped six remote rooms in four buildings for additional capacity. The remote rooms are controlled centrally from EDE's control room. To grow the credit program requires that additional classrooms and remote facilities with the flexibility and quality control necessary for a robust program.

The same instructional communications technologies and meeting rooms developed for our online programs are made available to support faculty engaged in multi-institution virtual collaborations. The technologies are standards based, well supported, cost efficient, and scalable to insure productive live virtual meetings.



Degree and Certificate Programs

Biorenewable Resources and Technology

Master's Degree and Graduate Certificate

Iowa State established the first graduate program in biorenewable resources and technology (BRT) in the United States and now offers both master's degree and graduate certificate programs in this critical area that are 100 percent online. The BRT Program offers students with a wide variety of science and engineering backgrounds the opportunity to study the use of plant- and crop-based resources for the production of biobased products, including fuels, chemicals, materials, and energy.

Civil Engineering: Emphasis in Construction Engineering and Management

Master's Degree

If we're going to maintain our standard of living, then we must rebuild America's critical infrastructure. Iowa State's construction engineering and management master's degree provides a unique blend of technical and managerial education that will help students solve problems and successfully compete in the ever-changing construction environment. This program focuses on the three critical areas of construction engineering and management: management techniques, construction operations, and construction methods.

Computer Engineering

Master's Degree and Graduate Certificate

Advanced computation lies at the heart of virtually every scientific and engineering discipline today. Whether it's computing and networking systems, secure and reliable computing, software systems, or another field, Iowa State offers a master's degree or graduate certificate in this vital area. If we're to meet the challenges of the 21st century, then computation will be the catalyst for progress across the engineering spectrum.

Electrical Engineering

Master's Degree and Graduate Certificate

From the smallest integrated circuit to the largest transcontinental grid, electrical systems permeate every aspect of the global economy. As we move to hybrid and all-electric transportation, electronic circuitry and electrical transmission technologies will only become more critical. Research at Iowa State in advanced electronics and materials, energy systems, communication, controls, and signals has given our faculty the knowledge and insight to create a strong program.

Environmental Engineering

Graduate Certificate

Iowa State faculty research is geared toward understanding the fundamental physical, chemical, and biological principles of engineered and natural systems, with an emphasis on elevating professionals' skills without committing to a full master's program.

Human-Computer Interaction

Master's Degree and Graduate Certificate

While computation may be a science, its extension into every facet of our lives today approaches the creative vision of the artist. The relationship between humans and computers has become one of the most dynamic and significant fields of technical investigation. HCI graduate programs reflect a broad recognition in academia and industry of the need to train researchers to meet the challenges faced by this rapidly evolving area of technological progress. HCI graduate students at Iowa State interact with faculty from every college in the university as well as researchers at the Virtual Reality Applications Center.

Industrial Engineering

Master's Degree

If the United States is to regain and retain the industrial preeminence that made us the economic engine of the world in the 20th century, we'll have to do it on a 21st-century playing field. That means producing goods of the highest quality in the most efficient manner possible. Our master of engineering in industrial engineering offers advanced training in topics vital to the well-being of U.S. industry, including engineering management, operations research, manufacturing processes, human factors, and enterprise computing.

Information Assurance

Master's Degree and Graduate Certificate

America's prosperity and even its survival depend upon protecting our information systems and networks. One of the National Security Agency's original Centers of Academic Excellence, Iowa State's Information Assurance Center offers a multidisciplinary program supported by six departments from three Iowa State colleges, including computer science; electrical and computer engineering; industrial and manufacturing systems engineering; logistics, operations, and management information systems; mathematics; and political science.

Mechanical Engineering

Master's Degree

Today more than ever, the knowledge and skills of talented people with advanced degrees in mechanical engineering are vitally needed to serve our society. From the design of clean energy technologies, complex fluid systems, simulation and visualization software, and more, the diversity of the field has made the work of mechanical engineers critical to problem solving in virtually every field of technology. Our graduate program is designed to meet these challenges and give to students the tools needed for success in the 2lst century.

Power Systems

Graduate Certificate

Iowa State has a long-standing international reputation for education and research in electric power engineering and is considered one of the top five such programs in the nation. Our power systems graduate courses provide in-depth education in advanced topics to specialists in government, academia, and the private sector.

Systems Engineering

Master's Degree and Graduate Certificate

Modern manufacturing and distribution systems call for unparalleled levels of coordination in order to compete in today's marketplace. Regardless of a student's undergraduate discipline, the program in systems engineering helps students develop the analytical abilities needed to design, evaluate, and build complex systems involving many components and demanding specifications. The program extends one's ability to work across disciplinary boundaries, as well as developing management capabilities critical in today's working environment.

Discovery with purpose

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