

NOTRE DAME 2010
- A QUEST FOR LEADERSHIP –
Strategic Plan
of the
College of Engineering

October 10, 2002

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EXECUTIVE SUMMARY

In a recent assessment of the nation's academic enterprise, it was stated that Stanford University is the *first truly great American University*, not one rooted in European traditions but one that embodies a uniquely American ethos in its pursuit of excellence. Today Notre Dame stands at the threshold of becoming the *first truly great nonsecular University of the world*, one that *seeks to integrate faith with reason, knowledge, and the pursuit of social justice*. But, increasingly, the course of human lives and events is being shaped by technology, and if Notre Dame and its graduates are to maximize their contributions to making a better world, the University must have engineering programs that are strong by any measure and linked to other disciplines through teaching, research and service.

A goal of the College of Engineering is to *provide preeminent educational experiences that prepare students for leadership in their profession and society*. To achieve this goal, the College will continue to invest significantly in advancing the technical content of both its undergraduate and graduate curricula. But to make its program *distinctive*, it will also integrate values- and ethics- based considerations into existing courses, as well as develop new courses that engage both engineering and non-engineering students in the broader (social, political, and economic) dimensions of technology.

A second goal of the College is to conduct *world-class research that addresses critical needs of society*. Research priorities will be guided by the overarching themes of *information technology, bioengineering, environmental studies, and materials*. Related activities cross all departments of the College, and in each case, involve significant collaborations with the College of Science. *The ability of faculty to think and act collaboratively will be an important factor in achieving the College's objectives*.

The College's faculty view academic reputation seriously, and each department aspires to achieving at least a top-quartile ranking, while the College as a whole aspires to placement among the top thirty by the end of the decade. These goals are ambitious, and in some cases achievement is problematic, particularly without a significant commitment of new resources. But, what is not problematic is the resolve of the faculty to achieve the goals and the clarity of the related vision.

MISSION, VISION AND ASPIRATIONAL PEERS

Any strategic plan must be framed as an action plan for manifesting the underlying values and goals of an organization. In broad strokes, these principles may be embodied by mission and vision statements:

OUR MISSION

*To nurture the intellectual growth of our **students** and to serve **humanity** through the creation, application and dissemination of **knowledge** relevant to **technology**.*

We are in the *knowledge business* and our specialty is *technology*, but we must be ever mindful that, whether in the classroom or the laboratory, we are here to educate our *students*. In the best traditions of the engineering profession, we must also contribute to *advancement of the human condition*.

OUR VISION

- To provide *preeminent educational experiences* that are stimulating, responsive to needs of the 21st Century and prepare our students for leadership in their profession and society.
- To conduct *world-class research* that addresses *critical needs of society*.
- To gain *national recognition* as a first-tier college of engineering.
- To contribute to the *Catholic character* of the University.

The first three bullets comprise a lofty vision, one that some would say is audacious, if not unattainable. We are the only nonsecular College of Engineering in the world that has such aspirations. Nevertheless, the majority of our faculty aspire to achieve recognition for excellence in education and research, for themselves, their departments, the College and the University. Moreover, many of the faculty, including non-Catholics, wish to do so in harmony with the most fundamental of Catholic commitments to humanity.

But is the vision realistic? If one chooses to benchmark against private institutions such as MIT and Stanford, or large public institutions such as U.C. Berkeley and the Universities of Michigan and Illinois, it is *not*. The long-standing commitments of such institutions to engineering and their provision of the requisite resources for excellence in research render them unassailable, at least for the foreseeable future. It is also sobering to note the substantial investments in faculty and facilities that have been made, and continue to be made, by other institutions to enhance the reputation and impact of their engineering colleges. Nevertheless, we believe that if we choose our targets carefully and proceed with dedication and a spirit of cooperation, we can become recognized as a program of distinction by 2010.

Using data from the 1993 NRC report and more recent USNWR rankings, each of the College's five departments has identified and assessed its aspirational peers. Metrics by which programs are compared include faculty size, annual research funding and PhD graduates per faculty member, publications per faculty in key journals and related citations, and faculty recognitions such as major awards and appointment to the National Academy of Engineering.

From its assessment, each department believes it can improve its current ranking, with two departments, Chemical Engineering and Electrical Engineering, having aspirations for movement into the top twenty by 2013. To achieve these objectives,

- each department has identified critical research areas in which its efforts will be concentrated;
- each department projects a significant increase in graduate student enrollment, to a maximum of approximately 500 students (for the College) by 2007;

- each department has targeted an average annual graduation rate of 0.5 PhDs per faculty member;
- departmental objectives for average annual research funding per faculty member range from \$200k to \$350k (in 2002 dollars), with a target of \$300k for faculty associated with research centers.

In addition, each department is conscious of the importance of excellence in scholarship and of publishing work of high impact in the best journals of its fields.

Of the two departments that aspire to top-twenty rankings, Chemical Engineering has the best prospects for success. Faculty size is not a limitation, with the number of faculty ranging from 12 to 22 for departments ranked from 10 to 20 in the 1993 NRC survey. However, the prominence of senior faculty is a significant determinant of national recognition, and the department believes its best path of entry to the top twenty would be to have two or three more distinguished scholars on its faculty.

Aspirations of a top twenty ranking are more problematic for Electrical Engineering. In this case, faculty size is a factor. Excluding Cal Tech, the faculty count in all of the top-twenty departments exceeds 40, is well above 50 in most cases, and exceeds 100 in some cases. Moreover, Electrical Engineering at Notre Dame is disadvantaged by not having a computer engineering component. Twenty-two of the top 26 departments have such a component, with 14 of them termed Electrical and Computer Engineering.

Nevertheless, a top twenty ranking is within the realm of possibility. All of the department's 22 faculty members are conducting sponsored research in critical areas of technology and are involved in fruitful collaborations that cross departmental, college and university boundaries. Many of the senior faculty are well recognized in their fields, and the junior faculty are on sharply ascendant career trajectories. By adding faculty of comparable quality and developing more effective collaborations with the Computer Science and Engineering Department, a significant increase in reputation/ranking can be achieved.

For the College as a whole, there are no NRC rankings, but comparisons may be based on USNWR data. We have chosen to benchmark against eight private institutions. With their 2002 rankings in parentheses, they are CMU (10), Dartmouth (46), Duke (34), Johns Hopkins (24), Northwestern (20), Princeton (18), Rice (32) and Vanderbilt (46). We believe that a top 30 ranking by 2010 is achievable. To do so, the College must continue to aggressively advance research programs of high quality and impact.

SOME SIGNIFICANT THEMES AND ORGANIZATIONAL ISSUES

Before enumerating specific strategies, it is useful to identify overarching themes for engineering education and research, themes that are likely to be critical well beyond the end of this decade.

One such theme is embodied by what is broadly known as *information technology* (IT). In its concern for the processing, distribution and storage of information, IT includes readily identifiable activities such as computing, communications, imaging, and neurology, as well as all

manner of systems (autos, appliances, structures, the environment, the human body, etc.) that will increasingly be endowed with *intelligence* to monitor and control their function and/or well being. IT involves the development of micro and, soon-to-be, nano devices that are its basic building blocks and provide enormous capabilities in ever smaller devices. It is at the heart of an emerging *global nervous system*, for which micro/nano devices will converge with communication networks to monitor and maintain anything of importance to the human condition.

For the College of Engineering to achieve its goals, it must have strong programs in the two departments (EE and CSE) concerned with the *development* of IT. But there must also be focused and visible activities dealing with the *application* of IT in *all* departments. For the past two years the College has been examining how its Electrical Engineering and Computer Science and Engineering Departments may be structured to achieve maximum impact and reputation. In 2001, a distinguished group of external reviewers recommended that the two departments be merged to enhance collaboration and to exploit the effects that increased size would likely have on reputation. While their arguments are compelling, a decision has been made to retain dual departments in the near term, while encouraging greater collaboration, including joint appointments between departments. In large measure, the decision was driven by the comparative youth of the CSE Department (established in 1990) and the need for more time to achieve its goals. However, the issue of merging the two departments will be reconsidered periodically.

Another critical area of technology relates to the *intersection of engineering with medicine and biology*. The challenges and opportunities are boundless, and almost monthly, colleges of engineering are announcing formation of new Bioengineering Departments. Such a recommendation is not likely to be made at Notre Dame, at least in this decade. *However, in this century, no college of engineering can achieve its desired impact or reputation without strong programs in bioengineering.* The same may be said for traditional engineering departments, such as chemical and electrical engineering.

For the foreseeable future, the plan is to encourage and nurture the development of bioengineering activities in each of the College's departments. A foundation on which to build is in place. Significant research programs have been established in biomaterials (chemical and mechanical engineering) and medical imaging (electrical engineering and computer science), and programs in bioinstrumentation (electrical engineering) and bioinformatics (computer science) are emerging. Related undergraduate and graduate courses are being developed, and a course in molecular/cellular biochemistry will soon be required for all first-year students. However, students choosing a bioengineering option will be recipients of an engineering education first, with a supplementary education in the life sciences.

Although our efforts are, in some ways, constrained by the absence of a medical school at Notre Dame, there remain many opportunities for collaboration with the College of Science, industry and medical schools at other universities.

One thrust area in which we are not constrained is that of *environmental science and engineering* (ESE). Stresses placed on the environment by social, economic and technical factors will not

diminish, and effective stewardship will depend critically on new knowledge and leadership from engineers and scientists well educated in related issues. The College and the University are well positioned to have a significant national and international impact. Within the College, leadership will come from the Civil Engineering and Geological Sciences Department and from Chemical Engineering. If it can fully exploit synergisms between its environmental engineering and environmental geosciences components, the CEGEOS department will create a unique capability with significant impact and visibility at the national level. A focal point for environmental studies in Chemical Engineering deals with pollution prevention through the development of environmentally benign chemical processes.

Since the advancement of many technologies will continue to depend on the development of materials with unique electrical, mechanical, chemical and/or biological properties, the fourth major thrust relates to *materials synthesis and processing*. Although the College does not have a Materials Science and Engineering Department, extensive research is conducted in four of its five departments.

Each of the foregoing thrusts involves significant opportunities for collaboration across the College's five departments and with the College of Science.

UNDERGRADUATE EDUCATION

If we are to be a world-class College of Engineering and true to our Notre Dame heritage, we must be a leader in undergraduate education.

It is a rarely publicized fact that there are still many institutions committed to advancing their reputation through research at the expense, or with benign neglect, of their undergraduate programs. Notre Dame is *not* among them. We will continue to concurrently (and symbiotically) advance undergraduate education and graduate education and research.

The message is so important that it merits repetition. *To be world-class, an institution must be world-class in both education and research.* No better affirmation of this premise can be given than to note that two of the most prestigious engineering research institutions in the world, MIT and Stanford, are deeply committed to undergraduate curriculum innovation and enrichment.

Our primary **goals** are:

- to become recognized as an **innovative leader** in undergraduate engineering education and **among the best programs in the nation;** and
- to provide a **distinctive undergraduate education** that is **unique to Notre Dame**, one that engages students in the broader dimensions of the profession, including the role of technology in society, ethical issues and service.

In the last four years the College has made significant strides towards its objectives of becoming an innovative leader in engineering education. Its prototype Learning Center and its new first-

year courses, EG 111/112, provide a superb *introduction to engineering*, and its business elective courses (EG 498A, B) provide an excellent introduction to issues that will confront graduates who choose careers in industry. In recognition of its likely significance to technology in the 21st Century, *all* of the College's first-year students will take a course in molecular and cellular biochemistry, effective in AY 2003-04. To our knowledge, we are only the second College of Engineering, after MIT, to institute this requirement. Others will surely follow. The College has also strengthened its outreach programs for middle and high schools students, as well as its commitment to diversity through investments in *Minority and Women's Engineering Programs* (MEP and WEP).

Numerous changes have been and continue to be made in our each of our departments. In *Chemical Engineering*, for example, the life sciences are being integrated throughout the curriculum, and in name, as well as practice, the department plans to transition to one of *Chemical and Biomolecular Engineering*. In *Aerospace and Mechanical Engineering*, there is greater emphasis on intelligent systems and automation, while the *Geosciences* curriculum has been restructured to emphasize environmental matters. In *Electrical Engineering and Computer Science and Engineering*, an innovative *Bits-to-Chips* curriculum has been developed to introduce students of both departments to the complete spectrum of activities associated with the design and fabrication of integrated circuits.

It is noteworthy that, apart from infrastructure needs of the Learning Center, the foregoing initiatives have been implemented without additional resources. The College is fulfilling teaching responsibilities for EG 111/112 with existing faculty; new positions, such as the Directors of the Engineering/Business Curriculum and the WEP, are being funded through a reallocation of resources in the Dean's office; and funds to support curriculum development are being obtained from external grants. It is noteworthy that, in the last four years, the faculty have received \$2,700,000 from the National Science Foundation and private foundations to fund major curriculum development initiatives. These activities reveal a strong commitment of the faculty to excellence in undergraduate education, and the impact and visibility of the College's efforts will be enhanced by the increased space and capabilities of the Learning Center planned for the new engineering building.

Another goal is to produce graduates who, in the words of one department's plan, *will improve the impact of engineering on society*. Our students must be more than good problem solvers in the technical sense. They should also be cognizant of the broader dimensions of the profession, including the impact of technology on culture and society, as well as its relation to issues such as ethics and social justice. If we are able to achieve this goal, we believe that we would be providing a truly *distinctive* engineering education, one that can be differentiated from those offered by the best of engineering programs at secular universities and is consonant with Notre Dame's mission as a Catholic university.

To a large degree, we have relied on external agents to imbue our students with the foregoing attributes. The required courses in theology and philosophy and a campus culture that embraces ethical considerations and social concerns certainly contribute to achieving our objectives, but without adoption of a more proactive approach by the College, there will remain in the minds of

our students, a disconnect between engineering and its impact on society. The College will attempt to rectify the matter by

- developing courses that integrate **technology with social, economic, and political issues**,
- melding consideration of **values and ethics** with existing courses, and
- strengthening the content of **projects that involve service to local and global communities**.

The continuous and seemingly relentless advancement of technology profoundly influences the lives of people throughout the world, in less developed as well as industrialized nations, and for impoverished as well as wealthy populations. The effects are ubiquitous. Technology affects political, economic and social conditions on local, national and global levels. It also exerts a strong influence on sustainability of the earth's resources and ecosystems, and on the accumulation and distribution of wealth throughout the world.

Despite the multifaceted linkages of technology to the well-being of society, the degree to which these linkages are understood by Notre Dame students, much less by decision makers in the highest levels of business and government, is low. If the College is serious about providing a *distinctive* undergraduate education, it must include exposure to and serious discussion of the *broader dimensions of technology* in its curriculum. The College will therefore endeavor to develop a suite of related courses in important topical areas such as *energy and water resources*, *environmental effects* including *global climate change*, *telecommunications*, and *biomedical technologies*. The science/engineering content of the courses would be held to a level that encourages co-enrollment by non-engineering students. The courses would thereby contribute to enhancing *technical literacy* of non-engineering/science students.

We should not need recent developments to remind us of the enormous damage that is done when individuals in a position to influence the lives of others decouple ethical and moral considerations from their decisions and actions. Issues of ethics and morality are too important to be left to a few courses on the subject. The College will therefore seek ways to systemically and comprehensively integrate ethical considerations throughout its curriculum. We believe this can be accomplished seamlessly and in ways that enhance student interest in technical matters.

The College currently offers service opportunities for its students, principally through its *Engineering Projects in Community Service (EPICS)* program. However, faculty and student participation is low, the projects are detached from the core curriculum, and the engineering content is, at times, marginal. To strengthen the program, we will therefore endeavor to meld, where appropriate, service opportunities with existing courses, including EG 111/112, and to focus on projects that enhance the technical component of a student's education, while addressing an important community need.

If we are able to make substantive progress on the foregoing objectives, we will be able to *walk the talk* and say that a Notre Dame engineering education is, indeed, *distinctive*.

While the College will become proactive in pursuing the foregoing objectives, it will do so in a manner that is open to partnerships with other stakeholders, namely all other colleges and the Center for Social Concerns.

Additional goals are to:

- be more successful against the nation's best engineering schools in **recruiting** students of exceptional ability and character;
- increase the number of **women, under-represented minorities, and students from disadvantaged backgrounds** in our undergraduate and graduate populations;
- provide more incentives and opportunities for **undergraduate research participation**;
- expand **international programs** to include study and work in non-English speaking nations;
- introduce **instructional technologies** that enhance instructor effectiveness and student learning;
- enhance the computing or, more generally, *IT literacy* of our students;
- view **assessment** as an integral part of curriculum development and improvement; and
- improve our **undergraduate advising** processes through richer modes of student/faculty interaction, as well as through web-based and student self-assessment initiatives.

To achieve the first two goals, the College will amplify its recruiting efforts at leading science/technology high schools, as well at high schools largely populated by disadvantaged students. In both cases emphasis will be placed on the University's natural constituency of Catholic schools. The College will also expand its summer programs for high schools students to include specific engineering concentrations, as well as a general introduction to engineering.

With respect to *assessment*, we must make the process an integral and systemic component of our curriculum review activities, one that is implemented by instructors for each course, as well as by departments and the College for entire programs. At a minimum, the process must include a clear articulation of learning objectives, metrics for determining the extent to which the objectives are achieved, and use of the metrics to suggest measures for improvement.

GRADUATE EDUCATION AND RESEARCH

By all measures, the College's graduate education and research activities are in a significant growth mode. Since 1998-99, the graduate student population has increased by approximately 40% to its current level of 388 students. The trend has been driven by ever larger increases in external support for research. Total awards increased from approximately \$8,000,000 in 1998-99 to \$18,000,000 in 2000-01, with a slight reduction to \$15,000,000 in 2001-02. However, early indications are that 2002-03 will be a banner year, with the total expected to exceed \$20,000,000. These trends must be sustained if we are to achieve our objective of becoming a top-30 College of Engineering.

If the foregoing success can be attributed to a single factor, it would be *the ability of the faculty to think and act collaboratively*. Four years ago, a decision was made to identify *critical areas of technology* and to establish strong, multi-investigator collaborations in these areas. Initially, attention was directed to areas in which the College could build on existing expertise, as in

nanoelectronics and *materials*. More recently, attention has also been focused on fields such as bioengineering, which are nascent to the College but in which strong capabilities must be developed. In all cases, attempts are made to capitalize on synergisms afforded by collaboration across departments, colleges (particularly the College of Science), institutions (including national laboratories), and industry.

The College's strategic plan leans heavily towards continuation of the foregoing strategy and builds on the research thrusts identified by each of its departments. These thrusts are summarized as follows:

Aerospace and Mechanical Engineering (AME)

Intelligent Systems (Flow Control, Mechatronics, Robotics)
Biomaterials/Biomechanics
Scientific/High Performance Computing

Chemical Engineering (ChEg)

Environmentally Benign Chemical Processing and Sustainable Development
Material Synthesis
Cellular and Biomolecular Transport Processes

Civil Engineering and Geological Sciences (CEGEOS)

Natural Hazard Assessment and Mitigation
Environmental Geochemistry and Mineralogy
Environmental Hydrology
Environmental Treatment and Remediation

Computer Science and Engineering (CSE)

Core Competencies:

Computer Architectures and Design
Network and Software Systems
Algorithms

Priority Cross-Disciplinary Areas:

Intelligent Systems/AI/Cognitive Sciences
Scientific/High Performance Computing
Bioinformatics/Computational Biology

Electrical Engineering

Micro/Nano Electronics
Wireless Communications and Signal Processing
Distributed and Networked Sensors and Controllers
Bioinstrumentation

Each of the thrust areas in CSE and EE is a subset of *Information Technology* (IT), and these departments are expected to provide leadership for the College and University in advancing the development and utilization of IT. Two of the designated thrusts for AME (*Intelligent Systems, Scientific/High Performance Computing*) relate to IT, and although such thrusts are not explicitly stated for ChEg and CEGEOS, applications of IT are prominent in their strategic plans, particularly in the areas of *High Performance Computing* (ChEg and CEGEOS) and *Intelligent Systems* (CEGEOS).

Although not as ubiquitous as IT, but with important linkages to IT, *Environmental Science and Engineering* (ESE) is a second area of emphasis for the College. It may be said that the mission of the CEGEOS department is aligned entirely with ESE. The *Mitigation of Natural Hazardous Events* deals with the impact of extreme events (earthquakes, hurricanes, tornados) on built structures. *Environmental Treatment and Remediation* deals with the remediation of anthropogenic wastes, including nontraditional environmental threats such as heavy metals and toxins; while *Environmental Hydrology* and *Environmental Geochemistry and Mineralogy* deal with the fate of pollutants in the natural environment. A thrust of the ChEg Department (*Environmentally Benign Chemical Processing*) deals with the development of pollution prevention technologies, in contrast to remediating or tracking the fate of pollutants once they are produced. Each of the foregoing thrusts provides excellent opportunities for collaboration across the University and particularly with the College of Science.

The evolution of new technologies has depended and will continue to depend significantly on the development of *materials* with advanced electronic, magnetic, chemical, biological and structural properties. Evidence of the importance of this field is manifested by the fact that most Colleges of Engineering have a Materials Science and Engineering Department. Although Notre Dame eliminated its Materials Engineering Department more than a decade ago, research in the field remains an important component of the College's mission. Activities are centered in ChEg, but they are strongly linked to three of the College's other departments, as well as to three departments in the College of Science.

Apart from traditional environmental engineering programs in CEGEOS, until recently, the College has had little activity in bioengineering. However, the situation is changing, and continued program development is a priority in the College's strategic plan. In Chemical Engineering, molecular biology will become one of the fundamental disciplines on which education and research are based, with emphasis on cellular and biomolecular transport, biomaterials, and bio/microfluidics. In Mechanical Engineering strong programs are emerging in biomechanics, biomaterials, orthopedic implants, and tissue engineering. Although in nascent stages of development, programs in bioinstrumentation and computational biology/bioinformatics are emerging in EE and CSE, respectively, while linkages of CEGEOS to

the life sciences are being enhanced through new programs in *Environmental Geosciences*. In all cases collaboration with the College of Science, medical schools and/or the medical industry is a necessity.

In summary, research priorities for the College relate to *Information Technology*, the *Environment*, *Materials* and *Bioengineering*. Within the broad spectrum of information technology, fields such as *Nanoelectronics*, *Wireless Communications* and *Information Systems* will receive special attention, as will *Bioinformatics*, which is at the intersection of the life and computer sciences. These priorities will influence faculty recruiting through the allocation of open (existing and new) slots, as well as the allocation of other resources and the formation of research centers.

RESEARCH CENTERS

As part of an on-going effort to identify and maximize its impact on critical areas of technology, the College is increasingly turning to the establishment of focused research centers. The decision to establish a center is based on the following criteria. Centers should

- be focal points for multi-investigator, cross-disciplinary and world-class research of benefit to society;
- provide a collaborative environment that enhances the scholarship of each participant;
- increase the visibility/reputation of the university, college and participating departments;
- provide exceptional educational experiences for undergraduate, graduate and post-doctoral students;
- participate in mutually beneficial partnerships with the corporate sector, national laboratories and/or other universities;
- provide a forum for assessing new directions in technology, including their potential effect on the human condition; and
- be nationally competitive in securing external support for research programs beyond the scope of a single-investigator.

The College has three such centers, the first of which in *Nano Science and Technology* (NDnano) was established in 2000. It is concentrated in the Electrical Engineering Department, but includes participation by faculty from other departments in the Colleges of Engineering and Science. Based in Chemical Engineering, the closely allied *Center for Molecularly Engineered Materials* (CMEM) was established in 2001 and also includes faculty from several departments in the Colleges of Engineering and Science. Through the manipulation of matter at the atomic and molecular scale, both Centers seek to develop advanced technologies in fields as diverse as information processing and storage, medical diagnostics and treatment, the detection of chemical and biological agents, energy conversion, and environmental remediation. From engineered biological tissues to micro fuel cells and ever more powerful computers, their activities have the potential to significantly improve the human condition. Because the research requires extreme control over environmental conditions, such as airborne particles, temperature, humidity and vibration, both Centers will be moved to the new engineering building when it is completed. Established in 2001, the *Center for Flow Physics and Control* (FlowPAC) is based in the Aerospace and Mechanical Engineering Department and the Hessert Research Laboratory. Its

mission is to improve the performance of manned and unmanned aircraft through the intelligent and active control of internal and external flows, as well as through the use of advanced materials.

Despite their relative youth and the need to fine-tune operating procedures, the foregoing centers have already had a significant influence on the College's research culture. They have demonstrated the essential role of focused, collaborative efforts in addressing important complex and cross-disciplinary problems, as well as in securing the levels of external funding needed to have a significant impact on such problems. Centers will therefore play an increasingly more important role in the College's research activities.

The College will continue to explore the merits of establishing centers in critical areas of technology for which it has core competencies. Potential candidates include *Biotechnology* or key components thereof, such as *Bioinformatics*, *Biomechanics* or *Biomaterials*, and subsets of *Information Technology*, such as *Wireless Communications*, *Networked Embedded Systems* and/or *High Performance (Scientific) Computing*. Decisions to establish new centers, as well as to continue existing centers, will be based on satisfaction of the previously enumerated criteria. Such decisions may be influenced by success in responding to major national initiatives for collaborative and cross-disciplinary research, as was recently the case when Notre Dame won the competition for an *Environmental Molecular Science Institute*.

The College will also continue its participation in existing Centers based in the Graduate School or the College of Science, such as the *Centers for Environmental Science and Technology*, *Applied Mathematics* and *Biocomplexity*, and when their mission is aligned with its priorities, the College will support the formation of new centers in other academic units.

COMPUTING

The computing environment available to our faculty and students will strongly influence the extent to which we can achieve many of the foregoing aspirations. Computing has become ubiquitous to engineering, both as a powerful tool for education and research and, in and of itself, as an object of research.

Attributes of an effective computing environment include state-of-the-art software and hardware to achieve desired learning objectives for undergraduate students, as well as software and hardware for *high-performance computing*, *communication* and *visualization*. The term *high-performance* implies performance levels substantially exceeding those of modern desk-top computers, as well as state-of-the-art networking and visualization for enhanced communication and collaboration among research groups on and off campus. Excellence in *high-performance computing* also implies vibrant research activities on enabling technologies such as micro/nano devices, computer architecture and software, advanced algorithms for computationally demanding applications in engineering and science, and high-speed, high band-width data networks.

A critical issue in achieving the foregoing objectives concerns the role to be played by Notre Dame's *Office of Information Technology* (OIT). If *decentralization* of computing

responsibilities becomes a cornerstone of reorganization within OIT, it is imperative that the process be conducted in close cooperation with the College of Engineering. Decentralization without such cooperation would have a significantly deleterious effect on the College.

While the College is prepared to accept additional responsibilities for its computing environment, there are two major support activities that should remain in OIT, namely the *underlying infrastructure for electronic communication* and a *central file system*, such as the existing (IBM) AFS. The communication infrastructure should provide high-speed connections (for traffic on and off campus) with high levels of security. Deployment of Open AFS as a replacement for the IBM-AFS is strongly recommended.

Given additional resources for hardware/software maintenance and upgrade, the College is prepared to assume responsibility for its computer clusters. To insure the most effective use of its resources, *test cells* would be established to evaluate new software and hardware options and to thereby provide a rational basis for tailoring cluster configurations to changing educational and research needs. Capabilities of the clusters would be enhanced to include state-of-the-art visualization facilities.

The College will also give high priority to establishing related research centers. One center (*High Performance/Scientific Computing*) would involve the development and application of advanced computer architectures, algorithms and software to address large-scale computational problems of importance to society (e.g. protein folding and global climate change). A second center (*Networked Embedded Systems*) would involve the development of networks with significant sensing and computing capabilities and their application to important problems such as the reliability of large structures and the health of environmental systems.

RESOURCE REQUIREMENTS

Four years ago, a case could have been made that the College of Engineering was adequately resourced in terms of available space, faculty size, support of graduate students by the University, and support for its physical infrastructure. That case could not be made today.

In the last four years the College has taken on new and significant responsibilities in undergraduate education and has substantially expanded its programs for graduate education and research. It has been proactive in its efforts to reverse the previous trend of declining undergraduate enrollments, with the number of 2nd through 4th year students having increased by approximately 12%. It has also significantly increased its contribution to the education of first-year engineering intents. Growth in research has been more pronounced, with a 45% increase in the number of graduate students and more than a 150% increase in the average annual funding per faculty member. As things now stand, faculty time is stretched to its limits; there is little left in the form of discretionary space; and funds for maintaining physical infrastructure, which includes laboratory equipment, are barely adequate. The College will not be able to sustain its current trajectory or to realize aspirations identified in this document without significant resource enhancements.

Space

Although the new engineering building will add approximately 50,000 NASF of space for education and research, its projected date of completion (December 2006) precludes it from having an impact on more immediate needs. The growth in research activities, the recruitment of faculty to fill slots vacated by the retirement of faculty with little or no research activity, and the recruitment of faculty to fill open Chairs all require space that is currently unavailable.

Projections are that approximately 20,000 NASF will be needed before the new building is ready. The space could be provided by reallocation of classrooms in Cushing Hall, the addition of a third floor to Cushing Hall and/or an addition to Hessert Center. In the longer term, consideration should be given to concurrently meeting space needs of the Colleges of Engineering and Science by co-locating relevant faculty, staff and laboratories in buildings established to address critical and enduring issues of mutual interest, such as the environment and biosciences/engineering.

Education

Other than the need for more faculty to make a substantive contribution to curriculum development at the intersection of technology, society and ethics, the College's needs for new resources in support of its educational initiatives are modest. When the new building comes on-line, *two support staff* (one technical, the other administrative) will be needed for the *Learning Center*, as will annual *nonsalary support* of approximately \$75,000 for *supplies and equipment maintenance/enhancement*. In addition, the College would like allocation of a new *faculty chair for excellence in education*, a *staff position* for coordinating *Engineering Projects in Community Service*, and recurring funds to encourage and support *undergraduate research participation*.

Faculty (T & R)

It will not be possible to meet our current commitments to excellence in both education and research or to achieve our aspirations for emergence as a first-tier College of Engineering without increasing faculty size. *Twenty-five additional slots* are therefore requested, with *five* in the category of exceptionally well endowed (*super*) *chairs*. The majority, if not all of the appointments would be made in the strategically targeted areas of *Information Technology, Bioengineering, Environmental Engineering and Science, and Materials*. The appointments would require appropriate capitalizations and, in the case of super chairs, an openness to using additional slots for development of an area.

Faculty (Research)

By enhancing research productivity and by mentoring undergraduate and graduate students, Research Faculty significantly leverage the efforts of Teaching and Research faculty. Research faculty play prominent roles at several of the College's aspirational peers and, with an increased presence at Notre Dame, could have significant impact on our research programs. The College is therefore requesting support for *fifteen half-time research professors*, with the remaining contribution to their salary provided by research grants and contracts.

Support Staff

Support staff, principally technical, are critical to the operation of instructional and research laboratories. They are particularly important to insuring state-of-the-art capabilities in laboratories at the leading edge of technology development and utilization. While, to a degree, staff support may be maintained from research grants, a base level of support is needed to sustain capabilities in the face of cyclical variations in research funding. The current trajectory of research activities, including those of current and projected research centers, indicates a need for University support of *18 new positions*, 16 technical and 2 administrative. Eight of these positions will be needed to support research activities in the new building, including four positions for the Materials Characterization Facility. This request does not include staff required for the new Learning Center (2) and for provision of the as-yet-unknown services that may be relinquished by OIT.

Graduate Assistants

Despite significant growth in its educational and research activities, the College has seen no change in its allocation of University GAs in at least the last four years. There is, of course, much that the College should do and is doing to support its graduate students. However, there are growing needs for University support of students as they begin their graduate studies and, in some cases, during the latter stages of their programs. New students need University support while they identify a research topic and take the courses need to establish appropriate levels of competency for conducting the research. Advanced students are occasionally confronted with a loss of external funding for their research, the frequency of which increases with growth of the research enterprise. The College is therefore requesting *fifty additional GAs*, front-loaded such that ten are provided in each of the first four years of this plan.

Infrastructure

At least since 1998, there has been no increase in the nonsalary component of the University budget. Yet, there has been significant growth in laboratory activities, both instructional and research. Moreover, increasingly, demands for cost sharing on grants and contracts, at both the department and college levels, are diverting funds that would otherwise be used for supplies, equipment maintenance, and equipment purchases. This condition can not continue.

It is conservatively estimated that, to maintain a strong base of *support for laboratory activities* in the College's departments and centers, *recurring funds in the amount of \$960,000* will be needed, \$460,000 of which will be used in the new building. Additional infrastructure needs relate to computing, enumeration of which will be made after release of the OIT strategic plan.

Miscellaneous

To strengthen the College's intellectual environment, there is need for additional support of *post-doctoral fellows*, *visiting scholars* and *seminar series* in strategic areas. Recurring income in the amount of \$175,000 is desired for this purpose.

Priorities

While all of the foregoing resource requirements bear on the College's ability to achieve its aspirations, limitations may well be imposed by current economic conditions and future economic uncertainties. Accordingly, the College's needs are prioritized as follows.

The *top priority* corresponds to the need for *space*. We are currently operating at capacity, and it will not be possible to fill several *existing faculty openings* (including two vacant chairs) without additional space. It will also be difficult to accommodate growth in the graduate student population that will accompany almost certain increases in research funding. Class rooms in Cushing Hall can be converted to offices to alleviate some of the need for additional office space, but the immediate need for laboratory space can only be met by new construction, for which additions to Cushing Hall (third floor) or the Hessert Center are the most plausible options. Planning should commence immediately, with new space made available as early as July, 2003.

If, as planned, the new building is completed by December, 2006, approximately 12,000 NASF would be released by transfer of some activities from Cushing/Fitzpatrick to the new building. It is anticipated that most of this space would be used for research and would be available by January, 2008. Beyond 2008, it is anticipated that additional needs would be met by new buildings that serve cross-college needs, such as those related to environmental and life science issues.

The *second priority* is for additional *T&R faculty positions*, without which we cannot keep pace with our aspirational peers or deliver on our commitment to develop courses that integrate technology with social, economic and political issues. Funding for the first two of these positions should be provided for the 2004-05 academic year.

Our need for *support staff* and *research faculty* are at the *third* and *fourth* levels of *priority*, respectively. At least 8 new staff positions will be required to support educational and research activities in the new building. In terms of the productivity of T & R faculty, it is well known that research faculty provide a significant amplification effect, augmenting growth in research while providing T & R faculty the time needed to strike appropriate balances between their teaching and research duties.

The *fifth* and *sixth priorities*, respectively, are assigned to new allocations of *discretionary (nonsalary) funds* and to the provision of additional *Graduate Assistants*. This assignment does not imply an absence of need. Growth in our research activities has put significant pressure on the nonsalary component of the College's budget, while allocation of additional GAs would maintain stability in the face of a large increase in the graduate student population. Nevertheless, if necessary, the College can sustain improvement and growth of its programs during a reasonable period over which these enhancements are deferred.

The *last priority* is assigned to the *miscellaneous* request for support of post-doctoral fellows, visiting scholars and seminar series. While such support would enhance our intellectual climate, it is not essential to achieving our objectives.

SUMMARY

The prominence of technology in modern life is a new element in the history of civilization. It is one of the primary forces shaping the evolution of our society.

Steven B. Sample
President
University of Southern California

The College of Engineering is at a crossroads. Progress with which all can be proud has been made over many years, and a culture of excellence is in place, with strong commitments to a *triad of fundamental responsibilities in education, research and service*. However, if we accept the status quo, we will surely slip relative to our peers. If we improve, but do so incrementally, there will still be slippage. Discernible advancement will require strong commitments from the College's faculty and the University.

The University is also at a crossroads. What is to be its role in a world increasingly driven by the course of technology? What role will engineering and science play in its vision for the future? Should all Notre Dame graduates be equipped to understand and deal with the broader implications of technology in their lives? *Engineering and science are critical to becoming the world's first great nonsecular university.*