May 4, 2008

Biological & Agricultural Engineering Department
University of California, Davis

Strategic Plan for 2009 – 2014

Overview

The Department of Biological and Agricultural Engineering is internationally recognized by peer institutions, potential students, and industry professionals as a foremost center for biological and agricultural engineering in the United States. The department's foundations are fundamental and applied engineering research, problem solving, education, and outreach related to materials, processes, design and development for production and use of biological and agricultural materials. The department mission is **to discover, develop, apply, and disseminate knowledge for the sustainable production, management, and use of biological materials, and to educate students for this work.**

The department integrates engineering, biological, and agricultural disciplines to perform interdisciplinary research and education in fields that are undergoing rapid transformation at both the fundamental and applied levels. The unifying theme of the department's mission is the production and management of biological materials and processes, particularly under the resource and environmental constraints of the western U.S. The department's research mission addresses the full continuum from discovery to implementation and application. Our vision over the next decade is to be among the best academic programs (research and teaching) in the world in the general discipline of biological engineering, and to have the best research and outreach programs in the application of engineering to agriculture.

To be among the best academic programs (research and teaching) in the world in the general discipline of biological engineering, our goals over the next five to ten years are to:

- expand and solidify our research strength in biotechnical engineering, bio-based production and processing, bioenergy, and sustainable use of resources
- hire bright and curious faculty, capable of adapting and changing as research problems come in and go out of public focus and funding priority, while maintaining a long term outlook toward societal and disciplinary issues
- attract and support top-ranked graduate students
- modernize research facilities in Bainer Hall and the Western Center for Agricultural Equipment (WCAE)
- expand funding for basic research at the federal level and for applied research at the commodity group and industry level
- continue to develop and refine Biological Systems Engineering as a discipline-focused undergraduate major
- strengthen bridges and create new links between alumni and current students through internships and employment opportunities
- engage the faculty more fully in student advising and career guidance

To have the best research and outreach programs in the application of engineering to agriculture, our goals over the next 5-10 years are to:

- develop a Center for Agricultural Engineering to promote research and outreach

- reinvest FTE and resources in agricultural engineering by hiring research and extension specialists to work broadly in machinery, mechanization, and energy efficiency
- partner with other institutions in California and the western US
- develop an endowment fund in support of the Center and establish an endowed chair in Agricultural Engineering to direct the Center
- strengthen connections with industry providers (e.g., machinery, seed, fertilizer and agrochemical companies), large farming operations, and commodity boards to identify needs, support research, and promote outreach
- expand federal funding opportunities to support mechanization research,
- focus on resource (energy, water and soil) management and conservation

Research Areas

The Department of Biological and Agricultural Engineering currently has programmatic strengths in four general areas of research:

- *Agricultural Engineering* - precision agriculture, equipment and system development, instrumentation, ergonomics, waste management
- *Biological Engineering* - biotechnology, bioprocessing, bioenergy, biosensing
- *Food Engineering* - processing, packaging, human health
- *Natural Resources Engineering* - water, land, air, forest

Agricultural Engineering and Food Engineering have long been the department's premier research areas and the basis for its world renown, and will continue in the future. Biological Engineering research has gained considerable attention and visibility over the past 15 years, and the current crisis in energy supplies has put the department's research programs in bioenergy on display around the nation and world. Although energy currently dominates the political and social discussion, the department's long-standing expertise in Natural Resource Engineering will inevitable come to center stage as the population of California grows, its climate changes, and water becomes ever more scarce.

Graduate Program

The graduate program of the department is named Biological Systems Engineering to broadly reflect the application of life sciences and agriculture in engineering. The goals of the graduate program are (1) to enhance the capacity for teaching and research in biological and agricultural engineering and (2) to train the future generation of professionals to address challenges associated with the sustainable production, management, and use of biological materials. Our objectives for the next five years are to increase student enrollment in the Biological Systems Engineering graduate program, improve the quality of our students, and increase the diversity of our graduate student population. Achieving these objectives will require faculty who are actively engaged in student mentoring, working at the interface of the biological sciences and engineering, and collaborating with scientists and engineers outside the department, both on and off campus.

We offer four graduate degrees: Master of Science, Master of Engineering, Doctor of Philosophy and Doctor of Engineering. The majority of our students select the MS or PhD degrees rather than the design-oriented ME and DE degrees. Research emphases include the following:

- Aquacultural engineering
- Bioenergy

- Bioenvironmental engineering
- Bioinstrumentation and Control
- Biomass, fiber and forest engineering
- Biotechnical engineering
- Ecological systems engineering
- Ergonomics, health and safety engineering
- Food engineering
- Machine systems engineering/precision agriculture
- Postharvest engineering
- Soil and water engineering

There are 50 graduate programs in agricultural, biological systems and similarly-named engineering in North America (42 in the United States and eight in Canada). Our program has consistently ranked in the top five in the United States by U.S. News and World Report. Key strengths of our program include the diversity of research, breadth of courses, and professional opportunities for our students.

There is a need for more graduate engineers in the United States with broader academic training, particularly in the life sciences. Many opportunities exist now and will continue to expand as the basic research results in molecular biology and biotechnology are brought to an industrial scale and as we strive to maintain abundant, safe food and energy supplies with limited natural resources. We recently hired two new faculty under the Energy for the Future Initiative and have made an offer to a food process engineering candidate under the Foods for Health Initiative that will have a 40% appointment in Biological and Agricultural Engineering. These new faculty bring considerable expertise in applied biology, nanotechnology and biological engineering and offer opportunities to increase our interactions with the life sciences, develop and teach new courses in biological and food engineering, and work with the growing biotechnology and bioenergy industries of California.

Research and graduate advising constraints. The factors currently most relevant to graduate student enrollment in Biological Systems Engineering include the number and quality of applicants, the number of faculty mentors that work at the interface of biology and engineering, and available research and office facilities.

Our enrollment goal is 50 graduate students - about two students per graduate program member, with approximately 60% in the PhD program. We have limited office space for our students, which we plan to address by better oversight of existing offices. About 10 new students per year would make sizes of required courses manageable.

Financial support required for nonresident tuition remains a serious impediment to expanding or even maintaining our graduate program at the current level. Most of our students come from outside the state of California and require nonresident tuition. More than half of our students are from overseas. Faculty members are reluctant to offer long-term financial commitment unless they have multi-year grants, which are less common in our discipline than other science and engineering programs. This encourages faculty to hire non-students as research staff. This trend can be reversed only by seeking other avenues to support graduate students with nonresident tuition expenses.

Teaching constraints. There are a number of outstanding and well-recognized graduate courses offered on and off campus that are instructed by BSE faculty who will likely retire in the next five to ten years. These courses support students in Biological Systems Engineering and in several other departments and off campus. The Department of Biological and Agricultural Engineering encourages new faculty to develop courses in their area of research, however, there are existing courses the BSE program and others either rely on for specific student training or require their students to take that would need instruction by new faculty. Teaching needs for the department should also be considered in hiring new faculty.

Our faculty and students apply engineering to solve problems in biological systems. This is accomplished by strong collaborations with faculty in life science disciplines and in other engineering departments. Many faculty are members of cross-departmental graduate groups. In addition, essentially all work with faculty in other departments.

Our faculty members with appointments in other life science disciplines involve our graduate students as teaching assistants in their courses taught to non-engineering students. These opportunities provide cross discipline engagement for our students to enhance their educational experience. Similarly, a number of our faculty members mentor graduate students from disciplines other than engineering. Our graduate students benefit by collaborating with students from other disciplines as they study their respective topics in a collaborative environment. Our faculty members who have active research programs in collaboration with industry and state agencies engage graduate students to actively interact with outside personnel. These opportunities provide excellent platforms for our students to participate and contribute to solving contemporary problems in biological systems and agriculture.

Our goal is to increase graduate student enrollment to 50 students. This level of enrollment is needed to maintain the quality of our existing research programs, support the growth of the research programs of our new faculty and maintain quality teaching interaction in graduate level courses. Expanding our graduate program will require hiring new faculty that will be actively involved with graduate student advising. Obtaining additional funding for students is equally important. We plan to obtain additional funding by pursuing training grants from federal agencies and by including graduate student support in grants from industry, state and federal agencies. Increasing the diversity of our graduate student population is also an important goal. Active participation in recruitment efforts coordinated by the Graduate Outreach and Recruitment Office within the Office of Graduate Studies and the Graduate and Research Office within the College of Engineering that specifically aim to increase the enrollment of underrepresented graduate students with outstanding academic abilities in science and engineering will help achieve this goal.

Undergraduate Program

Our department provides instruction in the College of Engineering and the College of Agricultural and Environmental Sciences. The major we offer in the College of Engineering is also called Biological Systems Engineering, and was introduced in 1992. The curriculum has evolved over the years and eight specializations are now available to students: agricultural engineering, aquacultural engineering, bioenergy, biomechanics/pre-medicine/pre-veterinary medicine, biotechnical engineering, ecological systems engineering, food engineering, and forest engineering. Although we have no majors in the College of Agricultural and Environmental Sciences, we offer two minors: Geographic Information Systems and Precision Agriculture. We

also offer a range of courses in agricultural systems technology at the WCAE and are actively exploring how we can link these better with the Student Farm activities and the Agricultural Sustainability major that is being developed.

In 1992 our department made extensive revisions to its former Agricultural Engineering major and essentially created our current major, Biological Systems Engineering. Largely as a result of this revision, the number of students in the major has risen from approximately 40 in fall 1992 to nearly 167 in fall 2007, having peaked at 181 in 2005. Interest in the major in terms of freshman applications peaked in 2001 at 380. The new Biomedical Engineering program began the following year, drawing many students who probably would have otherwise applied to our program. Since then, numbers of applicants to our major have averaged about 200 per year. These are adequate to maintain our program at its current level. This matches well with our current capacity because, due to the declining size of our faculty and the limitations of our laboratory infrastructure, our department could not enroll many more students at present.

The quality of freshmen students entering the Biological Systems Engineering program is very good on average. The mean high school GPA and SAT scores for freshmen enrolled in Biological Systems Engineering have fluctuated somewhat over the last eight years. The GPA and SAT scores for 2006 admits were 3.89 and 1865, respectively. The corresponding values for 2007 admits were 3.94 and 1857. The number of transfer students coming into our program has averaged 3 students per year over the last seven years. Although not many of our graduates take the Fundamentals of Engineering exam, those who take it have a very high passing rate (94 % over 2000-2005).

After several years of evolution to the Biological Systems Engineering curriculum, we are now in the process of a thorough review. The review is being based in part on an assessment of how our current program is preparing students, and in part on where we see our profession going over the next decade. In the revised curriculum, we plan to strengthen the biological training of our students, increase the number of core engineering courses and improve their coordination, and group our specialties into fewer, broader areas. We want to maintain class sizes and program structure such that our courses can have significant laboratory experiences.

The challenges we face in our undergraduate program are: maintaining high quality and adequate numbers of applicants, creating a clear identity for our major, ensuring that the laboratory experiences provided to our students use up-to-date equipment and techniques, and continue the evolution of the major in response to anticipated changes in the profession and to societal needs.

We see continued growth in the need for engineers with a strong training in biology. We believe that Biological Systems Engineers can make significant contributions in the search for solutions to some of the most serious problems we face as a society – energy availability, climate change, water quality and quantity limitations, food supply, and food safety. Our challenge is to develop a curriculum that will prepare students to contribute to the solution of those problems.

Information on employment of our students was derived from records maintained in the department and a survey of recent graduates, conducted in 2006. We have data on employment and/or advanced education for approximately 40% of the 150 graduates from Fall 2000 through Winter 2005. Of the 63 students for which information was available, 44% were employed in industry or business and 10% by public agencies or universities; an additional 40% attended graduate or professional school. Most (83%) were employed as engineers or were in engineering

graduate school, and another 14% were in disciplines such business administration, landscaping, medicine or pharmacology where education in engineering and/or biology would be important or useful. Of the 38 students employed, 47% were in the relatively new fields (for our program) of biomedical engineering, biotechnology, ergonomics, medicine and pharmacology, 24% were in agricultural and/or other resource management, and approximately 10% were in each of the following areas: food engineering, other engineering, and other/unknown.

The employment trends are clearly mirrored by the expressed interests of our undergraduates, as elicited by surveys of students in EBS75, our second-year core course. A majority of the students is interested in two of our newest specializations – Biomechanics/Ergonomics/Pre-Medical/Preveterinary Medicine (formerly Pre-Medical/Biomedical Engineering) and Biotechnical Engineering. Less than 10% of the students expressed primary interest in either Agricultural Engineering, or, in recent years, all other specializations combined. We will be introducing a new specialization, Bioenergy, during fall 2008. Our faculty have been very active in this field, and we expect a great deal of interest on the part of students in this new and topical area.

We see a continued demand for our graduates as industrial applications of biology become more widespread. Specific areas such as Biotechnical Engineering and Bioenergy will likely see employment growth over the next years, as will Agricultural Engineering with the changing labor situation. Demand in more traditional areas such as Forest Engineering and Food Engineering will hold steady. One of the challenges facing our graduates is the lack of recognition on the part of potential employers for what the major is or what it trains students to do.

Our program has a long and distinguished tradition and is recognized as one of the top programs in the nation and the world. One of our challenges as a department is to live up to this tradition and reputation and to continuously improve our quality. An important part of that challenge is being leaders in the development of curricula that reflect the evolution of our profession, as it moves from the application-based Agricultural Engineering to the discipline-based Biological Systems Engineering.

The instructional FTE of the department is split between the CoE (2.96 in 2006-07) and CA&ES (3.42 in 2006-07). The corresponding 2000-01 values for the two colleges were 2.77 and 1.97, respectively. Teaching Assistant FTE is provided by both CA&ES (1.33 in 2000-01 and 2.38 in 2006-07) and CoE (1.83 in 2000-01 and 1.50 in 2006-07). Given the Instructional FTE split between the two colleges and the fact that we offer a major in the College of Engineering only, the teaching work-load as measured by the ratio between the full time equivalent students (FTEs) and Instructional FTE is very different for the two colleges: 9.39 for CA&ES and 22.47 for CoE. Combining these, our overall course work-load for 2006-07 was 15.45.

Outreach

The goal of the department's extension program is to work with groups who share our areas of research interest, such as the farming community, equipment manufacturers, government agencies, and environmental groups to solve industry and societal problems.

The department has a long tradition of working with our clientele through its Cooperative Extension (CE) engineers to solve real-world problems. CE engineers have always worked in

areas needing cooperators from a range of discipline backgrounds. Solving real-world problems requires a synthesis of expertise from engineering, biological sciences, and human sciences. The department will continue this successful approach of using CE engineers to identify problems in agriculture, food processing, and the environment, and then engage a team of UC faculty, industry, environment and governmental representatives to solve the identified problems.

We have or have had strong programs in energy use and conservation, postharvest handling of durable and perishable commodities, chemical application systems, farm safety, and mechanization of agricultural processes. Retirements have decimated the CE faculty in the department. The one remaining specialist focuses on energy and postharvest handling and he is scheduled to retire at the end of 2009.

The planned Center for Agricultural Engineering (CAE) will serve as the integration point, where CE engineers will facilitate clientele's access to the broad range of expertise available on campus to solve their problems. Within the CAE, we have identified two broad areas of industry need that will form the core of future requests for CE FTE:

(1) The high cost and limited availability of labor, particularly for harvesting fresh market fruits and vegetables, is a crucial concern for the viability of the industry. A CE mechanical systems engineer will develop a partnership of farming, equipment companies, processors and food marketing companies who will work with us to develop safe, labor-efficient harvest methods. The center will contribute research expertise in areas such as: developing horticultural systems adaptable to mechanical harvest, methods of product quality measurement, and product quality effects of the new processes. We expect project specific funding, collaboration, and resources will come primarily from small groups of farming companies, processors and equipment manufacturers. Funding may also be available from USDA specialty crops funds in the new farm bill. One large multinational farm equipment manufacturer is evaluating the possibility working in this area.

(2) Resource inputs for agriculture, including water, energy, pest-control chemicals, and fertilizers, are increasing in cost and their use is a source of greenhouse gases. The industry is under increasing pressure to more efficiently use these expensive and limited resources. A CE natural resources engineer will assemble a team of UC, governmental agency, industry, environmental, and public representatives to address issues in resource use. Potential problems include improving water-use efficiency, modifying irrigation and processing operations to minimize electricity use during summertime peak periods, reducing greenhouse gas emissions from agricultural operations, more efficiently using agricultural chemicals, and reducing water pollution. We expect the majority funding for this work will come from government agencies, commodity boards, and private foundations.

Faculty Resources and Future Requests

Faculty are the critical resource necessary for the department's current work and future growth. Acquisition of future positions is the foremost strategic concern and represents the greatest investment of institutional resources. To achieve institutional support for necessary positions and the success of individuals within those positions, the department will ensure that each planned position fills a need that will find financial support from public and private sources. Therefore, the priority needs of both academic science, the community, and other stakeholders to be served will be identified and articulated in position requests, while weighing the long term

issues and core strengths required by the department. Concomitant with the recruitment, development and retention of outstanding faculty is the recruitment and the intellectual and financial support of outstanding graduate and undergraduate students and postdoctoral associates.

The rising cost of energy will focus ever more emphasis on development of alternative sources such as bioenergy. Changing immigrations laws and labor markets will rekindle interest in machinery systems for agricultural production and processing. Transitions in bioscience and industry that will play a stronger role in the department's future are the revolution in biological sciences at the cellular and molecular scales, and the transformation wrought by new methods and products on the production, processing and uses of biological products. Emerging biological and biotechnical industries are of growing importance to California and the US, while agriculture and food processing remain large and productive sectors with notable growth in some markets, especially valued-added products and renewable bio-based materials, energy, and products. Continued competitiveness of these industries will depend on innovative production, processing and marketing strategies. The department recognizes that growth in the important new areas of biotechnology must be predicated on continued strength in engineering research and education at the organism and biological system levels. Moreover, California faces many constraints related to its natural resources, especially water, air quality and population growth in rural areas; the department has a major obligation to help solve resource-related problems.

Considering the demographics of the department and estimating retirements in the next five to ten years, we are certain to lose individuals who contribute substantially to our excellence in three of the four areas with current programmatic strength. Expected retirements in these vulnerable areas (including recent actual retirements) are:

- Agricultural Engineering (JAM, JFT, SKU, REP, MJD, DKG, RHP)
- Food Engineering (RPS, JMK)
- Natural Resources Engineering (DJH, WWW, MAM, BRH)

It is clear that Agricultural Engineering will sustain the greatest loss at a time of increasing industry demand. In Food Engineering we will loose two of our highest visibility faculty, including a member of the National Academy of Engineers. And during a period of great uncertainty in the state's water resources management, most of our current faculty will have retired.

Considering these projections and the departmental goals, our priority of faculty position requests in the next five to ten years is the following:

1. **Agricultural Engineers** - cluster hire of research faculty (AES/IR) and extension faculty (CE/IR) in mechanization and precision agriculture – to launch the Center for Agricultural Engineering
2. **Water Resources Engineer** – water use efficiency, irrigated agriculture
3. **Food Engineer** – food processing and safety – majority appointment in BAE and housed in Bainer

Resources and Infrastructure

As indicated in the preceding section, the most critical need for the 5 to 10 year outlook is the addition of faculty FTE in the areas of Agricultural Engineering, Water Resources Engineering, and Food Engineering. The department realizes that the outlook for significant increases in FTE

with the CoE and CA&ES is uncertain. The department's demographic profile is similar to that of the CA&ES, where significant numbers of faculty with skills and experience for addressing applied, bioresource production problems will be retiring within the next decade. Moreover, simply replacing faculty when they retire can result in loss of program momentum, especially where success in funding and project outcomes is related to close interaction with and the professional trust of industry and key leaders in California agriculture – both production and processing. Mentoring of young faculty can leverage the existing momentum and reputation of current research and outreach programs to position the young faculty for success. Clearly, there is urgency in addressing the renewal of our faculty.

Laboratory resources for both Agricultural Engineering and Food Engineering are increasingly limited. Much of the laboratory space within Bainer Hall has been reconfigured to support the thrust into Biological Engineering. This space is more of the traditional bench and hood type laboratory. Agricultural and Food Engineering, along with the scale-up and pilot plant phases of Biological Engineering require research space that is large and flexible, yet still provides secure, high quality bench space. Additionally, research land is required for machinery and process development prior to transfer to grower-scale or industrial-scale research. New faculty hires in Agricultural Engineering will require not only bench space but also large, prototyping areas that are easily accessible to their campus offices, as they strive to balance the teaching and research demands during their early career years.

The department has recently resumed management of the machine shop facility that provides service not only to BAE but also to CA&ES and CoE. Significant opportunity exists for improvement in and focus of the capabilities of the shop to support the expanding portfolio of departmental research. However, resources will be required during the transitional period as the Bainer Shop and the satellite research areas are integrated into an efficient support system for the faculty teaching and research.

The department is fortunate to have the Western Center for Agricultural Equipment (WCAE), a strong, tangible confirmation of the industry's appreciation. This teaching, research and outreach facility is located on 40 acres in the western area of campus, about one mile west of Bainer Hall. The 18,000 ft^2 building includes a 1,500 ft^2 lecture room, 2,000 ft^2 general teaching lab, 4,000 ft^2 project lab, and a 3,000 ft^2 fabrication shop. The lecture room is hardwired with fiber-optic cable for interactive instruction and video conferencing. The general teaching lab is used for power and machinery instruction, primarily related to combustion engines, electric power, and fluid power. The WCAE was created as a department-industry partnership and built substantially through private donations. The department foresees the WCAE as being an integral, but not exclusive, part of the Center for Agricultural Engineering (CAE). The WCAE is a physical resource while the CAE will be a functioning center with thematic projects and outreach related to the projects. It will serve as a strong link between the UCD researchers and colleagues at other academic institutions across the west and the nation

The department can also benefit from associations with the newly established UC Davis Energy Institute and other institutes across campus such as the Agricultural Sustainability Institute, the Institute of Transportation Studies, the John Muir Institute of the Environment, and many others. Departmental programs in bioenergy and other renewable energy can directly support plans for pilot energy research facilities and longer range objectives for an energy research and teaching facility, similar to affiliations with the Mondavi Wine and Food Institute. The continuing development of high quality facilities will be of increasing importance in attracting and retaining

highly qualified undergraduate and graduate students as well as new faculty. The department has immediate needs to enhance and expand laboratory and other research space in support of new faculty hires and growth in student enrollments. Major industry support has recently funded important new research instrumentation and equipment. Identifying ways to leverage industry and agency support will remain an important objective for ensuring that resources and facilities continue to support the high levels of distinction in research, teaching, and outreach which characterize the department.