

Appendix B: College of Engineering Decadal Study – Full Report of Faculty & Staff Discussions Fall 2005

As part of the 2005 strategic planning process, the College of Engineering scheduled five “Decadal Study” sessions between August 15 and October 28, 2005. Faculty and staff were invited to attend one or more of the roundtable discussions during this phase of the strategic planning process. Sixty-one members of the faculty, two research scientists and two members of the college administrative staff participated in the discussions on the opportunities and challenges that will be facing society over the next few decades and the role of engineering and science educators and researchers in addressing the emerging challenges and opportunities. A summary of the discussions that took place during these five College-wide decadal study meetings is provided below.

The National Academy of Engineering book entitled *The Engineer of 2020* was used as a basis for discussions at several meetings. This book identified deteriorating infrastructure, including IT and communications, water, transportation, energy, and environmental issues as major challenges society will face, along with changing population demographics.

FUTURE GLOBAL CHALLENGES AND OPPORTUNITIES IDENTIFIED BY THE COLLEGE OF ENGINEERING GROUPS:

- ✘ **Lasers and photonics** – this is a key area that has a strong overlap with **nanotechnology**. Examples of research include looking at properties of materials such as gas. Mechanical engineering, electrical & computer engineering, and biological sciences are the primary disciplines involved.
- ✘ **Clean energy** – needs, demand, cost-effectiveness. Energy and energy technologies are a higher focus in Europe and Asia, and the U.S. is missing opportunities in these areas.
- ✘ **Air pollution** – this is another area of global concern that involves a number of our departments and faculty members.
- ✘ **Climate** – changes/patterns, adaptability/predictability, related energy use issues including nuclear energy and pollution, legislation affecting, water and its effect on climate, and developed vs. underdeveloped countries.
- ✘ **Water** – the engineering of water in all its aspects, including sanitation, efficiency, clean and adequate water resources, and conservation is a societal concern today that will become critical in the future; water issues cut across many disciplines.
- ✘ **Information Technology** – modeling, virtual world, real-time views, e.g., via satellites. There has been an explosion in the last decade that no one could predict, and making projections on where IT is going is equally difficult. We can capitalize on the strong IT presence on the Front Range.
- ✘ **Physical modeling** – interdisciplinary data sharing, successes and failures.
- ✘ **Networking and computer systems** – security measures against identity theft, putting controls on systems so they are not misused.

- ✘ **Human health** – decision support groups, managing system complexity, education of students in project management and system complexity, and the education of the world community.
- ✘ **Access to data** – information vs. “hype”, robustness, privacy, and preventing IT terrorism.
- ✘ **Green engineering** – this is an area of strong interest to faculty from several departments, who see green engineering as an umbrella for interdisciplinary research. Our international tradition is a great context in which to cultivate that research.
- ✘ **Sustainability** – in areas of energy, health, agriculture, water, and addressing issues such as pollution in China where standards are being revised to portray a better public image.
- ✘ **Communication** – the recent hurricanes point to the need for better communication of science and technology since citizens were not adequately informed of the dangers three days in advance when it was known that Katrina was developing beyond a major storm.
- ✘ **Microelectromechanical systems** – the microelectronics, microfabrication and micromachining technologies known collectively as MEMS, is being applied to **biomedical applications** and has become a new field of research unto itself, known as BioMEMS. This is another possible growth area for the college, with NIH and NSF funding potential.
- ✘ **Applying climate forecasts to infrastructure and food systems** – adding preparation or resiliency to our systems.
- ✘ **Computation, communication and controls** – miniaturization, **sensor networks**, making more connections with Atmospheric Science faculty via networking through miniaturization (CASA ERC), smart dust.
- ✘ **Materials and molecular level engineering** – materials science including biomaterials, processing, including structures, human needs, nanoscience and nanotechnology, mesoscale technology; multidisciplinary.
- ✘ **Informatics program.**
- ✘ **Renewable energy** – e.g. Sampath’s work in photovoltaics, and CSU is also a leader in solar energy, biodiesel, fluid mechanics and wind engineering, so could capitalize on this strong heritage.
- ✘ **Feedback controls** is another important emerging area.
- ✘ **Biotechnology** within biomedical engineering and chemical/biological engineering is going to impact us for the next 10 years, mainly in the generation and application of new data.
- ✘ **New optic techniques for biological probing and imaging techniques** – there is funding in NIH and other agencies, and challenges of interest to faculty.
- ✘ **Robotics/automation and controls** - Some areas of innovation that could be expanded in the college to address societal needs include **control and robotics related to public works**: restoring cities after they have suffered a major disaster by bringing all the systems back online. Broadening the scope of automation and controls as applied to our infrastructure could be a potential supercluster involving all disciplines.
- ✘ **Artificial intelligence applied to mechanical systems** – this is a potential supercluster area that is interdisciplinary, involving Computer Science, Electrical & Computer Engineering and Mechanical Engineering
- ✘ **Wind engineering** – this was an area of strength at CSU for many years, and could be again as the nation develops plans to mitigate the effects of natural disasters on our infrastructure. A national wind engineering program has been established by Bush with funding anticipated before the end of the year. **Wind energy generation** is also a focus

of renewable energy conferences, and economically feasible if we partner with NREL. Addressing **international hazards** and natural disasters via agencies such as AID is another aspect of this research. This is a potential supercluster, involving Mechanical, Civil, and Electrical & Computer Engineering, Atmospheric Science, and Sociology.

- ✘ **Self-healing machines** – this is a potential supercluster involving Biological Science, Mechanical, Electrical & Computer Engineering, etc.
- ✘ **Health** - pandemic issues such as Avian Flu, as well as biological warfare or terrorist activities could be aligned under a supercluster, involving all areas of engineering as well as the **Center for Disease Control** and atmospheric scientists who could model the pollutant plume.
- ✘ **Disaster prevention: hurricanes, floods, tornadoes, tsunamis and earthquakes** - this is a potential supercluster involving Civil, Mechanical, and Chemical & Biological Engineering, Atmospheric Science, and Natural Resources.
- ✘ **Nuclear engineering for Earth and in Space** - nuclear energy will be even more important not only on Earth but also as a means of space exploration to remote regions. As a supercluster, it would include Mechanical Engineering, Physics, Political Science, Sociology, and Radiation Biology at CSU, as well as the CU-Boulder space program. Colorado already has a great space-base, with NORAD, Ball, Lockheed Martin and other companies that could play a role. Also research into expanded use of satellites for communications, weather prediction and all the other new research that ties into space.
- ✘ **Remediation and cleanup** – explore opportunities in Colorado and on a global scale, involving CSU’s Chemical & Biological and Civil Engineering, Radiological Health Science, as well as CU-Boulder and School of Mines.
- ✘ **New areas for superclusters identified through collaboration with Front Range companies** – it was recommended that the college build collaborations with the top chemical, civil, mechanical, and electrical and computing companies located along the Front Range, determine what the companies need and how we can meet their needs through our research, and invite them to participate in superclusters. The companies like to hire our students so the way has been paved to develop this next step.

THE CHANGING FACE OF EDUCATION AND THE WORKPLACE:

Members of the COE decadal study groups suggest that an agile academic program must be developed within the college in order to meet the global challenges and educate for tomorrow's needs. They noted the following trends and/or areas of concern that we need to address over the next few decades.

- ✘ Engineering is getting more focused; yet the challenges are getting broader, requiring a **more interdisciplinary solution** than in the past.
- ✘ Technology and knowledge will keep advancing at a rapid pace, and there is a need to **educate for life-long learning**.
- ✘ **Technologies are becoming more complicated**, and we need to teach above the very-good level to give students the background they need.
- ✘ At the same time, we will need to remain well grounded in the basic fundamentals of mathematics, physics, statistics and basic science and engineering, as the NAE book points out, and the basics of math and physics have not changed much.
- ✘ Engineering education has historically been responsive rather than proactive, according to the NAE book, and thus always late in adapting the curriculum to the needs of society. We need to **look into the future and provide students with the fundamentals and the basic understanding of how to learn** so they can adapt to the changes that are coming.
- ✘ In today's global economy, we are seeing **routine analytical functions, low-level technical jobs and design work being sent to China and India** where U.S. companies can hire employees at a much lower salary. We need to give our students the strongest undergraduate experience we can, so that they can take jobs above entry-level technician. That means we need to teach more over the four year period that students are with us, so that we are not graduating people who will just perform at the technical level in industry. The technical jobs are not going to exist in the U.S. for the majority of our graduates, but will be outsourced at a cheaper rate elsewhere, so we need to increase our standards.
- ✘ **China is investing in higher education** and according to projections discussed at the NSF meeting last year, China will graduate 1 million engineers in 2010 (see <http://www.nsf.gov/statistics/seind04/c2/c2s5.htm>) and thinking they are not trained as well as U.S. engineers is flawed thinking. China has a strong interest in areas such as semiconductors and is investing in large technology projects, with the same level of sophistication as the U.S., but utilizing employees who make lower salaries. There is no choice: **we need to graduate people who will perform at a top level**, people the companies will want to hire, and that ties into our research. We need to get students involved very early in their academic careers, as freshmen or sophomores, to give them the additional training and experiences they need to obtain these jobs, and that means providing **more research experiences for undergraduates in our laboratories**. Both Chinese and Indian academic institutions are successfully competing for international students and the U.S. has seen a **marked decline in international student applications**, particularly since 9/11 terrorism activities.
- ✘ Another reason for the decline in foreign students is the fact that the U.S. has educated a large number of foreigners who are now professors in their own countries, so we have to **learn to work in the foreign market** to attract students to the U.S. universities.

- ✘ With this global economy and movement of jobs overseas, we also need to **educate students to be creators and innovators, to manage and lead, and to sell the products**. This includes the ability to write proposals and papers and present their ideas via formal presentations.
- ✘ While industry is asking us to expand our curriculum to incorporate more **interdisciplinary** subjects as well as **communication, business and management skills**, we are being told by **the State** not to make our degree programs costlier or lengthier.
- ✘ Part of the **mission of the land-grant university** is to help people raise their status in life, so by giving students an introduction to engineering and **teaching them how to think**, we are preparing them to go on to successful careers in different areas.
- ✘ **Political science education** is lacking in the U.S. engineering curriculum today and there will be an increasing need to have more policy-makers, lawyers and politicians who possess an engineering and science background and can bring an understanding of engineering and science to the issues society will face. Engineers hold high-level political positions in countries such as China and across Europe, and thus have a stronger voice in public policy and social issues than in the U.S.
- ✘ **Legal and institutional issues at all levels – federal, state, and local – are sometimes as important as the engineering** when you're working in a certain company, and we need to do a better job of educating people about the legal aspects of engineering and science. Water resources, for example, especially relating to water rights, is an area where the legal issues currently must be learned on the job. Engineering law was a required course for some faculty when they were undergraduates.
- ✘ **Ecological issues** will be more important in the future.
- ✘ **Information technology issues** will continue to rise in importance.
- ✘ Will there be a need for a **commodity engineer**, with production moving to China and programming being outsourced? If we prepare students in a traditional manner, will there be a job for them when they graduate?
- ✘ There will be a need to **incorporate alumni into our educational program** as one means of passing current information and knowledge about U.S. and global industrial experiences onto our students.
- ✘ We need to ensure there is a **sustainability emphasis** in our curriculum.
- ✘ Faculty members' external roles with policy makers and legislators, and the disconnect that exists with government representatives who lack science and engineering backgrounds, will continue to affect **U.S. policy and decisions governing science and engineering**.
- ✘ **Continuous education** will be required of everyone since the former model of learning one field and working for one company over your lifetime began changing in the 80s and is changing more rapidly today.
- ✘ **Distance education** through new technologies that expand on our use of the Internet, including canned courses burned onto DVDs, will benefit those working in the new global marketplace.
- ✘ Today, companies such as Intel might hire PhD graduates who are educated in one area and then place them in different areas. These **companies are looking for people trained in solving problems**, so they can place them in areas where they have no preconceived notions about how to solve them.
- ✘ Some **companies expect employees to hit the ground running** regardless of their assignments in the company. However, in universities today we are seeing new graduate

students fail to perform as expected when presented with a problem that is not well-defined, and these **graduate students do not have a broad enough background to work abstractly**, even though the master's degree is geared to solving problems so should have provided this experience.

- ✘ Some **undergraduate students cannot think inferentially** since they are used to the traditional lecture format, so we should rethink our whole paradigm on teaching and lecturing. It is hard to teach people to problem-solve and work abstractly. Many **students don't know how to extrapolate knowledge and are operating by pattern recognition**; they cannot take fundamental knowledge and apply it to brand new information.
- ✘ **Economics will continue to drive the modeling**, e.g. the response system that was in place during the recent tsunami.
- ✘ **Education that can be gained outside the classroom** through projects and working with faculty as role models will be even more important.
- ✘ **Maintaining the depth in our curriculum while addressing emerging issues** related to specialization is a concern that we must address.
- ✘ **Cultural training and more foreign languages** will be needed due to the globalization facing science and engineering firms; it will no longer be possible to conduct business if you just know one language.
- ✘ **Interdisciplinary projects** will become even more important.
- ✘ It has been proposed by the NAE and others that engineers need to be more broadly grounded in **history, literature and philosophy**.
- ✘ **Web-based technologies** may need to be expanded in more of the standard classes so that faculty members' time can go into a truly interactive bi-directional setting.
- ✘ We need to determine whether we can accommodate all of these courses and skill sets mentioned above into an already full curriculum that can already take 4.5-5 years to complete, and this does not seem feasible. We can choose to remain strong in the **basic fundamentals of a four-year degree program** and students can go on to **graduate or professional school** for more training. One alternative is the **European educational model**: a 5 or 6 year program where students receive the core curriculum in four years and then go into a specific discipline for advanced training and education; if ABET decides to support the 5- or 6-year terminal degree nationwide, it will be possible to implement it at CSU.
- ✘ The **economic challenges in the U.S., along with increasing costs of education and material goods are impacting the way we teach**. Educators are also challenged today because students increasingly are involved in extracurricular jobs and other activities that take time away from their studies, with some students working 20 hours a week while taking a full course load.
- ✘ **Interdisciplinary research at the graduate/Ph.D. level** is an increasing focus of federal funding agencies, including NSF and USDA. Some universities are blending research into new graduate programs such as ecological engineering or new initiatives such as the University of Nebraska's \$1.4M water initiative that enabled them to hire 7 faculty members under joint appointments. Is this something that CSU's COE should consider?
- ✘ Many institutions are also including **education of the public** as one of their initiatives, and this is not a trend we have followed to a great extent.

- ✘ **High school students** are required to select their discipline when they enter CSU; in the past we had two years of **core courses** before asking them to make that decision. Is this something of value that we should reconsider?
- ✘ It will be increasingly more important to establish an **effective recruiting and retention program for women in** order to raise the number of female engineering students throughout the college. This number is much lower in some departments. One reason for this is that many women who seek higher education want to better society, so the medical and law professions are more appealing to them than **engineering, which is not perceived as benefiting society. This perception needs to be changed** through public relations and marketing efforts. **Green engineering** is a degree program that would be attractive to women, and there are others. Getting more women into engineering would give the U.S. an advantage and cause a shift in innovation, communication and other areas. **Another issue is the U.S. culture, wherein girls are under pressure not to be the smartest in class.**
- ✘ The number of female faculty in the College of Engineering is extremely low and a negative message is being sent to our students. We need to look hard at this problem and **hire more women faculty members** to increase the percentage and provide more role models for female students. We need a competitive edge to attract the few numbers of women faculty on the market, and the University may need to help with **additional resources for salaries and start-up packages.**
- ✘ We also have to **do things differently in order to retain women and minority faculty and students.**
- ✘ Our **faculty must be flexible** enough to meet whatever challenges and opportunities develop between now and 2020.

RECOMMENDATIONS FOR EDUCATION IN THE NEXT DECADE:

The primary recommendations on ways to positively impact society through changes in our curriculum or expansion of our activities are listed below.

- ✘ Establish an **interdepartmental PhD degree in biomedical engineering.** We need to produce more PhDs to help raise our ranking and such a degree would attract new students, especially out-of-state students, without drawing students away from existing PhD programs. Also, we could work with the Graduate School to give PhD credit to the home department of the student's adviser, effectively increasing PhD production in the departments. Biomedical engineering is becoming more important for both diagnostic work and treatment of patients, and everything is getting smaller, so having facilities on campus for fabrication would also help grow this program.
- ✘ Create a new degree program that would tie public policy, science technology and human values together. **Social engineering** deals with engineering specifically geared toward changes in society and population growth, involving infrastructure and environmental engineers in the process, and this tie will be even more important over the next several decades. A new program in this area would be attractive to many students including Native Americans and women. Having policy makers who graduated from Colorado State would definitely benefit our school.
- ✘ **Co-Create** is one example of the type of **service-learning experience** benefiting our students, where they have cross-cultural interaction on a project. Another example of a

program of this type that brings disciplines together is the **National Academy of Engineering Honors EPICS (Engineering Projects in Community Service)** program which gives students the opportunity to learn valuable skills while working to solve real-world problems in the community, working with not-for-profit organizations, elementary schools and other community efforts.

- ✘ **Better connections between disciplines**, between the College and University and **K-12 educators**, between the college and others in the **university community**, and between the college and **industry** are all critical elements of our strategic plan. We need to become better at promoting **interdisciplinary and cross-cultural cooperation** in the universities because these will be increasingly more important as we address more complex global challenges.
- ✘ An **expanded cooperative education program** would benefit our students and address some of the needs they have for a more broad-based and global educational experience. We could expand the co-op program in a more organized project fashion and take it overseas.
- ✘ **Interdisciplinary research programs** that could be developed or expanded include water resources, energy, IT, climate change and environmental quality, and these should be agile programs that can adapt to changing needs.
- ✘ We are uniquely positioned to **apply specialized climate forecasting to infrastructure and food systems**, to add preparation and resiliency to these systems. With large numbers of people living in coastal regions, this connectivity between disciplines will grow in importance.
- ✘ A **Minor in Pre-Law**, utilizing the new B.S. in education/engineering degree would also benefit us since issues such as patent law apply to all disciplines. The minor could be pre-law B.S. in education/engineering to encourage students to remain through the fifth year and work in the public policy and legal arenas so as to benefit the science and engineering professions on the national and international levels.
- ✘ CSU has **nationally recognized programs that could be combined with other programs** to the benefit of all. One example is remote sensing, where we are bringing atmospheric scientists together with electrical & computer engineers to raise the impact of the remote sensing research. Another example is computation, communications and controls where ATS and ECE are connecting through NSF's CASA ERC.
- ✘ In the **materials science area**, faculty from diverse departments could be pulled together to work on new ideas. CSU has strength in this area and it provides a foundation for new research collaborations that cross disciplines.
- ✘ **Mentors from industry** could be invited to participate in a variety of educational activities at CSU to share their expertise and experiences. And when asked to participate at some level, they usually thank us for giving them this opportunity, so could be tapped more as a resource.
- ✘ Promoting more industry collaborations by expanding the number of **undergraduate internships and graduate fellowships** would benefit our students and our research programs.
- ✘ To address the issue of training students to problem-solve and work abstractly, CSU's Department of Mechanical Engineering assigns **senior design projects**. This approach might be mimicked by other departments in the college since it has proven to be successful, focusing on the interdisciplinary projects that will help undergraduates prepare for the workplace by focusing on their specialties while solving real-world problems and communicating with students from other disciplines in the process. It was

noted that the senior design projects are difficult to manage and require a large portion of faculty time, especially in the face of the current faculty-student ratio, so we need to reprioritize what faculty are doing. **A half-credit course in teaching, using external speakers**, was taught many years ago in the college and could be considered again in order to train more students in how to teach, expand communication skills, and provide instructional support for senior design projects.

- ✘ We need to continue providing students with the **core analytical skills** while preparing them for the challenges they will face over the next decade. Examples included teaching numerical methods along with an understanding of the underlying principles behind them.
- ✘ **Communication, leadership, and management** are all important skills that today's engineering and science professionals need to possess, and adding these skills while maintaining strong educational basics will be a challenge and may result in the **Bachelor's degree being replaced by the Master's as the terminal degree for engineers**. Faculty also need to make these courses more attractive to our students and **interface better with Liberal Arts and Applied Human Sciences**.
- ✘ To prepare students for **careers outside the engineering profession**, there might be a need to add two more degree tracks in some disciplines. The traditional engineering track prepares students to be the designers that can solve future engineering problems by giving them the basics in math, engineering and physics. The first alternative track could prepare students to work in areas such as law, public policy and medicine; the second alternative track could add the business education that some students will need. The **Engineering Science degree may serve as an incubator** and offer the means to experiment with these alternatives, thus providing engineers with a more broad-based education that serves as the background for an MBA or advanced degree, similar to the various degree programs pre-law and pre-medical students obtain to prepare them for professional school in law or medicine.
- ✘ Several concerns were expressed about the above proposal. First, a concern that by splintering off into these alternatives, we will not have value to anyone. Second, that **we need to keep the fundamentals** so our students recognize that engineering is a commodity and will develop an **understanding of the industry and global processes**. It's also important that they have an **integrated approach to their job** and a broader context in which to manage people rather than operating in isolation.
- ✘ We also need to teach the students **applied creative design** aspects of engineering and not just analysis and pure science, although this may not apply to all disciplines. You have to **synthesize products and service**.
- ✘ **Creativity and design can be taught in undergraduate research labs** where you have to be creative to push the envelope. In labs we can **get students thinking and asking questions** that even the professors don't have the answer to. This experience should be started when they are in their first few years of college so that through their senior year they are getting experience with research projects, teams and presentations.
- ✘ **Foreign languages** could be considered as a requirement for undergraduate admission to the college. This is thinking outside the box to recommend a language over some of the core courses, but languages may be more relevant to tomorrow's workplace than some of the required courses.
- ✘ Use the **pipeline concept at the high school level** to reach out to young people who want a career that allows them to make a positive impact on society. Show these students that engineering is one way to make an impact on the environment and society.

- ✘ We need to rethink how we package our education. In Europe, students do not take classes outside their disciplines after reaching a certain point in their studies; instead, they take longer to graduate and have fewer courses, and are well educated in their fields of study.
- ✘ Another concern is making sure students are receiving the breadth of education along with the depth because there is so much more that students need to know today to do the work. We could expand our thinking beyond the standard credit-hour course in order to reach some of these goals; for example, using MIT's Independent Activities Period where the MIT community can organize, sponsor and participate in forums, lecture series, films, tours, recitals and contests (see website for more information: <http://web.mit.edu/iap/overview/index.html>). Other ways to do this include co-ops, Engineers Without Borders, or a more organized and project-focused Study Abroad program.
- ✘ Set up a summer job program for students that would apply directly to their specific educational programs. This would enable us to keep our curriculum focused on the basics while giving students relevant work experience and an opportunity to make contacts for future employment.
- ✘ NSF understands the need to involve students in all aspects of a research project early in their academic program to add value to their education. The National Science Foundation Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) has a strong K-12 outreach component. The University of Massachusetts, lead institution of CASA, has made K-12 experiences in engineering a mandatory element of the curriculum. There is also a strong industry component with the NSF ERCs, and CASA has achieved all of NSF's goals via an industry consortium linking faculty, undergraduate and graduate students from the participating universities with industry partners. There are also a lot of exchanges with Japan, Finland and Canada, providing international experiences to the participants. CASA is an example of how we can integrate all of these experiences into our curriculum. NIH does not currently emphasize this, however.
- ✘ Many students today cannot take fundamental knowledge and apply it to brand new information. They also are not retaining knowledge learned in basic classes. We need to make sure they can synthesize knowledge so if the problem is not identical, they will still be able to attack it. We need to force students to look at the examples and see how the fundamentals of each problem relate to other problems. Project work and lab work are the best way to do this.
- ✘ To prepare our students to work in the new global economy where they will see more offshore outsourcing of engineering jobs, we can provide more systems engineering in our curriculum as opposed to focusing on the engineering of parts. Engineers will need to understand the design, but the pieces may be engineered and manufactured anywhere, so we can also place more emphasis on creativity to help students make connections to the fundamentals of engineering and science.
- ✘ Our students must be trained to be flexible so they will be able to adapt to changing times. By putting more emphasis on communication, problem-solving and critical thinking skills in the classroom and labs, we will better prepare them for the challenges of 2020.
- ✘ The ability to be successful in a multidisciplinary environment will be increasingly important to future engineers and scientists as they work with people from a variety of educational backgrounds. New interdisciplinary programs at the undergraduate

level that include majors outside engineering, such as business students, could be developed to provide this background and training. We should also consider **expanding our senior design projects by blending in students from majors outside engineering to work on new cross-disciplinary projects and provide this level of interaction.**

- ✘ Molecular-level engineering including biomaterials and nanostructures are growing in importance, so **adding more science into our curriculum** will be necessary in order to educate students for these fields.
- ✘ A **program in international development** could be developed within CSU's College of Engineering, and provide opportunities for students to do interdisciplinary projects in an engineering system that is oriented to natural systems.
- ✘ The college culture where **faculty members are doing the majority of the teaching and conducting state-of-the-art**, cutting-edge research and bringing that knowledge into the classroom is a distinct advantage of a CSU education that we can market to students.
- ✘ **College-wide focus areas** that encompass both undergraduate and graduate education (not just in the classroom) as well as faculty research include: **bioengineering, robotics and automation, energy** (all aspects and sources), **water and the environment, advanced materials (including nanotechnology)**. The college could create concentrations or minors in these areas. Each of these areas would also be ideal as **interdisciplinary senior design projects**. Faculty could associate with the appropriate areas, create joint graduate-level courses, hold joint seminars, and work on group proposals such as IGERT at the graduate level or REU for undergrads. There are other possible areas, so the college should find a small set of topics where we can build on existing strengths, areas that we know will be important in the future – several of these match the University's strategic areas.
- ✘ **Engineering management** - an advanced degree in integrative engineering/engineering management may be one way to integrate graduate students at the master's level into the undergraduate research experience to better prepare undergraduates to manage projects.
- ✘ Identify faculty members who have an interest in developing a program that would use our talents to **promote peace in the world**. Maurice Albertson is one example of a faculty member who is still working towards world peace, beginning with his involvement in establishing the Peace Corps and continuing to his activities today (Village Earth).

THE ROLE OF A FACULTY MEMBER:

- ✘ Serving as an example and role model to all of our students and external constituents.
- ✘ Educating and graduating the highest quality students to take their place in society, by providing an environment where students can rise to the challenge and achieve their full potential.
- ✘ Building relationships with people who will eventually employ our students, from the small consulting firm to the large corporation or federal agency.
- ✘ Supporting students and researchers by broadening our research stakeholders beyond the federal agencies and enhancing the communication in order to enhance funding opportunities.
- ✘ Providing solutions to national and global problems such as the environment and homeland security.
- ✘ Educating the public, from the local community to Congress, about science and engineering by taking a leadership role and asking others to participate in the process.
- ✘ Providing a non-traditional educational experience to people from diverse backgrounds, with unique needs and goals.
- ✘ Creating research centers for emerging areas such as biosensors, or developing research clusters that can expand into superclusters.
- ✘ Providing accessibility to equipment and resources to industry and government partners.
- ✘ Capitalizing on the proximity of nationally recognized university colleges such as Veterinary Medicine and federal centers such as the Center for Disease Control to address new challenges and build new research programs.
- ✘ Reducing competition between colleges and departments in order to bring people together to solve global problems, e.g. incorporating people from business, sociology, anthropology or psychology as needed to address some of the broader problems.
- ✘ Communicating the benefits of engineering and science to both external and internal constituents, via both college and university leaders and tools.
- ✘ Educating people who live outside the U.S. in order to help other countries progress in their development.
- ✘ Stimulating economic development.
- ✘ Advancing society.
- ✘ Generating and applying new knowledge.
- ✘ Educating for tomorrow's needs.

RECOMMENDATIONS TO PROMOTE ACADEMIC SUCCESS:

- ✘ Strive to ensure an **adequate number of faculty members** in the college to meet the educational needs of our students and address the research opportunities and societal challenges that are facing us. This proposal is backed up by the recent comparator analysis of peer institutions showing our low levels of faculty and staff in the College of Engineering.
- ✘ Provide **mentoring hierarchies for the student design teams**, getting graduate students involved in these projects. The new Engineering Science/ Engineering Education degree program could be used for this.

- ✘ Find new **seed money to support the development of new interdisciplinary research proposals** that align with the mission. This would assure faculty members that the funds will be there to support expansion into new areas.
- ✘ Putting together proposals for interdisciplinary projects can be very difficult and **the infrastructure** is needed within the university to assist faculty and provide adequate support for the amount of work involved. We can leverage off our strengths in different areas, but we need to put more efforts into **supporting the interdisciplinary research** to make us more competitive. This would enable us to build synergies that are supported not only by the CSU infrastructure, such as **superclusters**, but also by funding agencies, and enable us to address future challenges and opportunities that we can't even predict today. Another suggestion was to return RA/RSP money to the individual so the funds can be used to **travel to national funding agencies** to obtain new projects, as well as to **build other collaborations** on new projects.
- ✘ Establish a rewards system where the rewards can be shared across the college, and there is a way to **quickly move resources** to people showing promise. If we are serious about the undergraduate experience, we have to **change the focus of the rewards system** that currently exists with better metrics, particularly if faculty members are not always going to be the Principal Investigators on projects.
- ✘ Understand that excellence will be showcased naturally through **ongoing strategic planning and hiring the top people in their fields.**
- ✘ **Emphasize the strengths of CSU's College of Engineering**, which include the emphasis on applied teaching and research, the interdisciplinary nature of the research, the international orientation that exists today and is based on a history of internationally recognized teaching and research programs, the unique strengths that we can build upon, our excellent facilities including the Foothills and Main Campuses, as well as outstanding laboratories that have been set up in Fort Collins.
- ✘ **Utilize the services of a political lobbyist** to the extent permitted by the University and State in obtaining line item funding in budgets to support research and teaching programs.
- ✘ Develop **stronger ties with the emeritus faculty.**
- ✘ **Expand existing or add new facilities** as part of the strategic plan to aid in recruiting of faculty and students and promote interdisciplinary interaction between students, faculty and staff.
- ✘ **Capitalize on the existing natural resources in Colorado** – the land, agricultural economy, growing population, mountains, forests and water.
- ✘ Build a strong sense of community between the University and the College of Engineering so we can **play a larger role in our communities.**
- ✘ Bring CSU's status up and take steps to **raise the stature of our programs** within the state and nation so that we can eliminate the view that we are in "2nd place" among institutions of higher education in Colorado.
- ✘ **Develop collaborations with other top-notch departments** and programs at CSU by identifying students with a joint interest in both areas, thus giving them the incentive to collaborate and produce results.
- ✘ Think creatively about ways to **highlight and market our interdisciplinary activities.** CSU has not created specific "interdisciplinary schools" such as Duke and UC-Santa Barbara have done, but there is a lot of interdisciplinary work going on here and we need to market what we are already doing.

- ✘ There are national studies that show that the way universities currently deliver information to students is not the best way; a **change in our teaching methods** may be required in order to educate and train students to solve problems.
- ✘ **Change the stigma of engineering** by bringing graduate students from other colleges into the laboratories or onto project teams on a rotational basis.
- ✘ Broaden our faculty base to include **more interdisciplinary faculty**, if one of our goals is to bring more interdisciplinary focus into our teaching.
- ✘ If we are going to integrate biology, e.g., into our curriculum, one of the challenges we will face is that our **faculty will need to learn more about biology and other disciplines** and we have to have a strategy for that.
- ✘ If we integrate more IT into the curriculum, then that means our **faculty will need to learn more about information technology**.
- ✘ **Internships** are a reward that can be offered to bright students.
- ✘ CSU's College of Engineering has a history of world-class teaching and research, and this has attracted top-notch faculty who are willing to supplement the State's portion by earning half of their salaries through private support and external research grants. However, we have lost some faculty along the way because they were recruited to other schools that provided more financial support or better facilities. We need to continue to seek additional funding from the University to provide base support for faculty salaries so that we can **retain our excellent faculty members**.
- ✘ **Collaborations with agencies such as NREL** can be developed to help expand research into new multidisciplinary areas.
- ✘ Strategic hiring of new faculty to replace retirees has sometimes redirected positions to other research areas. This issue was discussed.

THE CHANGING ROLE OF SCIENTISTS & ENGINEERS:

- ✘ The role of engineers in the U.S. will change because of the international dimension where **innovation, design and manufacturing are moving overseas**, especially to China and India.
- ✘ **Communication, leadership, and management** are all important skills that today's engineering and science professionals need to possess. Project management needs to be added to the definition of an engineer's skill set. This is partially needed due to the movement of some of the jobs overseas and also to the need for engineers to be more broadly educated and **able to solve complex problems on a global scale**. Corporations are asking engineers to become managers, and universities are not educating students at the graduate or undergraduate level to manage teams and projects.
- ✘ There is a **noticeable decline in the prestige of the engineer in the United States today**. Professionalism of the engineering field needs to be maintained so that the Professional Engineer registration is viewed as a high distinction.
- ✘ One of the reasons for the decline in stature of the engineering profession is the number of recent failures in engineering design that received national attention, such as the failure of the levees when Hurricane Katrina hit New Orleans. Engineers and scientists will need to be more proactive in **sharing the failures of some of the past engineering and science projects** in order to advance learning and build a better infrastructure for the future.
- ✘ The "**Dilbert**" image of the engineer is the one most people have today, and this must be changed in order to recruit students. Expanding our **outreach into K-12** by demonstrating the role of engineers in a positive and fun way similar to CSU's "Little Shop of Physics" would help attract more students to our programs.
- ✘ One definition of an engineer is someone who bridges science and society and makes science work for society. There will be more need for **adequate sanitation, housing, food, water, and sewer systems in developing countries**, and we must adjust our technologies to address the **growing populations**.
- ✘ There will be a need for engineers to **understand other cultures and how to work with them**. The **youth bulge in underdeveloped countries** will have a polarizing impact and affect the way we train engineers who will need to understand how to work with people from other cultures and be able to develop solutions for this changing population.
- ✘ **Ethics will be increasingly important** as we develop new innovations in science and engineering that can be used in both positive and negative ways, for good and for evil. Ethics training is needed across the board.
- ✘ Ethics also comes into play in **managing intellectual property** so that codes, for example, are not sold by someone working on a project. Understanding of engineering ethics is very limited today, and it might behoove us to develop **techno-ethics in engineering and science**.
- ✘ **Public policy** is another area of concern, and engineers should take more responsibility in the public realm, to understand how to interpret problems in an ethical way, to be leaders in making wise decisions, and to maintain high ethical standards in the face of increasingly formidable ethical issues. With the rise of **biotechnology, nanotechnology, and IT**, it is possible to do more things that aren't necessarily in the public's best interests.

- ✘ **Emerging opportunities and broader issues that need to be addressed on a global scale means we need to embrace chronic change and evolution**, and adapt our college culture to do that.
- ✘ **We have to be better and move faster** to stay ahead of the competition, **and stay in better touch with the community** to identify those opportunities.
- ✘ The **projected increase in the number of female engineers and scientists**, based on the projected increase in the number of female students enrolled in science and engineering in the next decade, was discussed. The question was raised on whether changes in our curriculum will be needed to meet the needs of this changing student population. This was a controversial topic and most faculty who stated an opinion were in disagreement with the need to adjust our textbooks or curriculum for the changing student demographics since female students did not appear to be falling behind men in class and many were excelling.
- ✘ **Innovations in science and technology** that no one could predict have produced dramatic changes in the way people work and spend their pastimes. **Our competitive strength will come from innovation, and significant research problems will be addressed by being innovative and making the connections to the basic sciences. No one can predict what the future holds and what innovations lie in store.** We need to be prepared, and to prepare our students for any number of new scenarios that will develop over the next decade.
- ✘ **There is a tradition in this country of innovation through collaboration, blending business with science and engineering to develop new products.** How can we capture that sense of confidence and enthusiasm again in the College of Engineering? **Applying engineering and science to societal problems** and solving some of the big problems is one way this can be done.

RECOMMENDATIONS ON HOW UNIVERSITIES CAN ADDRESS CHANGING ROLES IN THE PROFESSIONS:

- ✘ In the civil engineering discipline, some educators recommend the **Master's degree as the professional registration degree**. Having a Master's degree as the terminal degree would give students an **opportunity to specialize, and to delve deeply to solve problems**. However, **does it give them the skills set they need to get hired in other disciplines?**
- ✘ Civil Engineering might also consider separating into **two tracks**. One track would provide **a basic education to produce engineering technicians**. The second track would be for those interested in **advanced degrees and higher-level positions** in the company. Fellowships and Internships would be deferred until the students are enrolled in the graduate program and could receive practical training in industry to enhance the theoretical knowledge they gained at the university. These tracks may not be needed in other disciplines.
- ✘ **Ethics, communication, teamwork, management skills, legal issues such as intellectual property rights, working across cultures, and other issues named above can be taught college-wide** so the departments are not responsible for staffing these courses. This would be a return to former days when there was more cooperation across general engineering courses than exists today.

- ✘ **Collaborations and expanded communications with industry will keep us informed of the constantly changing skill sets** that will be required of our students in order for them to be successful over their lifetimes.
- ✘ **We should train students who can compete with people from the top schools in the nation.** If by raising quality we end up reducing numbers, that just means we will not be producing graduates who are unlikely to get a job in the new global marketplace, which is especially important since it is predicted China will graduate one million engineers a year by 2010.
- ✘ **Cooperative education programs, fellowships and Internships with industry** are a good way to obtain research experience to go along with the theoretical knowledge students receive in class.
- ✘ During their first year as undergraduates, the **college should actively counsel students and engage them in the process** of identifying what it is they need to know for the particular field they wish to enter and what it is they need to do in order to succeed at the university and obtain the jobs they intend to seek.
- ✘ Research experiences for undergraduate students are excellent recruitment and retention tools. The brightest students are attracted to challenges, and are drawn to top-ranked institutions where they have the opportunity to **work in laboratories from their freshman through their senior years, and go on to top-notch industry positions.** These university laboratory jobs are not always paid positions but that doesn't seem to be a critical factor for the intellectually curious students who just wish to gain laboratory experience. At CSU, too, we have seen that laboratory experience has a strong positive impact on the recruitment and retention of students. **Undergraduate laboratory experience also has a positive impact on our research programs, making them more agile and able to respond quickly to emerging areas.**
- ✘ We should also attempt to hire **undergraduates for research projects across disciplines to prepare them for interdisciplinary research and development work they will see in industry.** It would be very beneficial to have **scholarships to support students as they worked with faculty on research projects.** We have seen that external scholarship funds can be unstable, and university support should be sought for these scholarships.
- ✘ Our students need to gain experience outside the U.S. **in order to work in the global marketplace; we should expand our international efforts** so that we can provide a majority of our students that opportunity. This means developing new programs that go beyond the typical experience students receive through **Study Abroad.**
- ✘ The college should look at the education paradigms all the way from the Bachelor's to the PhD degree, training our students in fundamentals and then introducing them to **real engineering problems they will see in industry.** The students could **rotate through the disciplines and then choose their specialization and concentration.**
- ✘ In today's global economy where we are seeing routine analytical functions and design work being sent overseas by some of the major U.S. companies, we need to **educate students to be creators and innovators, to manage and lead, and to sell the products. This includes the ability to write proposals and papers** and present their ideas via formal presentations. CSU's **ECE students take a special composition course as undergraduates** which helps develop some of the writing skills they will need; other departments might want to follow their lead.
- ✘ Each department has different experiences and needs when it comes to educating students. However, they all share the **need for more resources for teaching**

assistantships, modern laboratories, research experiences for undergraduates, paid internships and scholarships.

- ✦ Every university has areas of strength and programs of excellence. The College of Engineering should **identify nuclei of excellence that can be nurtured**. Rather than develop completely new areas, start with areas of strength that can be used to attract people and build up the programs. We should **support research areas that have achieved levels of international excellence** to facilitate future growth and excellence, and make use of these successes to build for the future.