JACK BASKIN SCHOOL OF ENGINEERING
UNIVERSITY OF CALIFORNIA, SANTA CRUZ

ACADEMIC PLAN
(2013 Update to the 2006-2011 Academic Plan)
1) INTRODUCTION

The Baskin School of Engineering (BSOE) has achieved many significant milestones over the course of its first fifteen years. Working across department, division and university boundaries, our faculty have built education and research strengths in several important technology areas, including genomics, computer gaming, data storage research, network science, database research, rehabilitative technologies, biotechnology, robotics, sustainability engineering and nanotechnology.

Our reputation and visibility continue to rise regionally, nationally and internationally, as evidenced by increased external research funding, national rankings, growing graduate and undergraduate programs, increased recognition of the BSOE faculty, growing partnerships with Silicon Valley industries, and the increased number of domestic and international visitors to the school who come here to partake in collaborative research.

The vision for the BSOE as an engineering school for the 21st century has been strongly influenced by the National Academy report on *The Engineer of 2020: Visions of Engineering in the New Century*. Our goal is educate and graduate future leaders to participate in a world characterized by:

- Rapid technological innovation
- Intense global connectivity
- Diverse populations
- Social, cultural, political and economic forces determining the success of technological innovation
- Seamless, transparent presence of technology in our everyday life
- Increasing pressure for resources and heightened concern for the environment.

Because we are a relatively young school of engineering, it is often difficult to make comparisons to older schools, since the programs may not be identical and we are still quite small. For example, UCSD has the same number of departments that we do at UCSC, but their average department size is more than double ours and they have a wider distribution of expertise areas. They have 189 faculty in six departments: Bioengineering (21 FTE); Computer Science and Engineering (47 FTE); Electrical and Computer
Engineering (47 FTE); Mechanical and Aerospace Engineering (39 FTE), Nano-Engineering (13) and Structural Engineering (22 FTE). By contrast, the BSOE has been built largely around hardware- and software-based engineering: devices and circuits, genomics, bio-informatics, data storage algorithms, database theory, network theory and Bayesian statistical theory.

The reputation of public engineering schools is correlated with number of faculty and the age of the school. Frederick Terman (1990-1982) — Stanford professor, electrical engineer, academic administrator and considered by many to be “the father of Silicon Valley” — analyzed schools of engineering in the state of California, and concluded that the creation of a viable world class school of engineering would require a minimum faculty size of about 120-130 and that this could be done without addressing every engineering discipline. In fact, during his tenure at Stanford, Terman encouraged growth not in all areas, but in areas where the University could truly predominate. He knew that for the University to mature, it would have to focus on what it could do best, what he commonly referred to as “steeples of excellence.” Based on the now-realized limitations that stem from small size, we believe that Terman correctly characterized the “right-sized” engineering school for UC Santa Cruz. Thus, the BSOE’s desire is to grow from 78 to between 120 and 130 faculty by 2018. In choosing the engineering areas suitable for expansion, we have considered several factors: social relevance, intellectual vitality, existing core expertise, and applicability to the region’s industrial activity, particularly in Silicon Valley. Like Terman and the early days of Stanford, the BSOE will grow in areas where we believe we can be leaders.

2) OUTLOOK

The BSOE has grown dramatically over the last five years and is poised for continued growth at multiple levels.

- Between 2008 and 2012, external research funding grew by 65%, whereas the number of faculty increased by only 7%.
- During that same period, undergraduate majors and undergraduate degrees awarded doubled.
- In graduate education, the BSOE has played a major role in the campus growth of graduate education, working towards the campus goal of 15% graduate students. Between 2008 and 2012, the school maintained a 30-40% ratio of graduate-to-total degrees awarded.
- Graduate degrees awarded from the BSOE in the most recent year (2011-2012) comprised 21% of the campus total.
We plan to grow graduate student enrollment more rapidly than we previously forecasted, in response to both a revised long range enrollment plan for the UCSC campus and to rebenching activities across the UC campuses. We are positioning ourselves to nearly double our graduate student population through a combination of new M.S., Ph.D. and professional degree programs and new concentrations within established degree programs. Other venues for growth include online education, as well as geographic expansion into Silicon Valley.

Over the next five years, the BSOE will grow strategically in areas that build on existing core strengths. Expanding research and education programs in specific “intellectual focus areas” will help address societal needs for renewable energy, clean environment, data management and cyber-infrastructure, cyber-physical systems and advanced robotics, advanced materials and improved health care. These areas are:

- Bioengineering/Genomics
- Data Science
- Engineering Management and Entrepreneurship
- Games and Playable Media
- Hardware Engineering
- Materials and Nanotechnology
- Mobile and Pervasive Computing
- Network Science and Engineering
- Robotics and Cyber-Physical Systems
- Software and System Engineering
- Statistical and Mathematical Modeling
- Sustainability Engineering

The BSOE remains committed to developing a substantial instruction and research presence at the UCSC Silicon Valley campus. The apex of high technology in the United States and perhaps the world lies in the Silicon Valley/South San Francisco Bay region. The BSOE continues to capitalize on the close proximity to this region by developing relationships with companies and institutions located there. The Silicon Valley professional population, and those students wishing to study and do research in Silicon Valley, is a market for advanced degrees. The BSOE has played a pioneering role in the development of academic and research programs on the Silicon Valley Campus. BSOE faculty drafted the first Silicon Valley Academic Plan, integral to both the strategic campus plan and the BSOE long-range academic plan.
3) **Guiding Principles**

**Excellence:** The BSOE strives for excellence in all areas of activity: instruction, research and operations. In instruction, we aim to provide students with a solid education that will open up a wide range of career options. We strive to give our students access to the latest techniques and tools afforded by technological innovation. In our research endeavors, we strive for preeminence in multiple disciplines by fostering an environment that creates leaders. In operations, we strive to exceed expectations of support for students and faculty by hiring the best staff and by developing workplace efficiencies.

**Diversity:** We believe that diversity fuels innovation and helps produce a rich and dynamic community for research and teaching. The BSOE embraces cultural diversity among faculty, staff and students, as well as diversity of ideas, research programs, intellectual outlook, and teaching styles. We will continue to support efforts—such as joint programs with minority-serving community colleges, the *MESA Engineering Program (MEP), Girls in Engineering, and Project Awesome*—that improve the ethnic and gender diversity of the school. Since 2003, MEP has served 261 students, 26% of whom were women and 58% of whom were Latino or African-American. We have successfully secured grants from programs such as NSF’s Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM), which provide assistance for academically talented but financially disadvantaged students. One such grant through the Applied Mathematics and Statistics department targets ethnic minority groups. Another grant, awarded jointly to the Computer Science, Computer Engineering and Electrical Engineering departments, targets female students.

We believe that efforts such as these will result in an increasingly diverse undergraduate population, where we lag somewhat behind the national average. Our undergraduate student population is currently 15% female (c.w. a national average of 18%) and 22% underrepresented minorities (c.w. a national average of 28%). In 2012, 14% of the School’s bachelor’s degrees were awarded to women, and while this lags the national average of 18%, it represents a near-doubling of degrees awarded to women over the past six years (from 18 to 35).

Our graduate student population is currently 28% female (c.w. a national average of 23%) and 8% underrepresented minorities (c.w. a national average of 6%). In 2011-2012, 26% of the graduate degrees were awarded to women, compared to a national average of 23%. Over the past six years, we have increased the number of graduate degrees awarded to women by 42% (from 12 to 17).
We will also continue to support a diverse range of teaching and learning activities, including online course development and the offering of professional degree programs in Silicon Valley.

**Interdisciplinary collaboration:** Engineering is a dynamic set of disciplines that integrates perspectives from various fields and naturally fosters interdisciplinary work. Engineering is the practice of new technology development, which almost always occurs in the interstices between mature technologies. Thus, interdisciplinary collaboration and instruction are essential components of a leading school of engineering. The BSOE faculty have collaborated across departmental, divisional and university boundaries to forge new programs for both teaching and research. For example, the Computer Science Game Design and Games and Playable Media programs integrate digital arts and new media disciplines, creating ties with the Arts division. The Program in Biomedical Sciences and Engineering is a collaboration between the BSOE and the Division of Physical and Biological Sciences, and our faculty form the core of the Bioinformatics and Computational Biology track for this program. BSOE faculty collaborated with faculty in the Division of Social Sciences to create a new curriculum in Sustainable Engineering and Ecological Design. The Center for Analytical Finance is a new collaboration between the BSOE and Economics. And the Center for Sustainable Energy and Power Systems, pioneered by the BSOE Electrical Engineering faculty, partners with other energy research institutes, both within the U.S. and abroad to develop an international approach to deployment of renewable energy resources.

Over the next five years, the BSOE interdisciplinary collaborations will increasingly focus on the nascent academic discipline of “data science” and its applications. Data science touches nearly every aspect of modern life—from architecture to zoology—and is relevant to a host of important research areas: earth and planetary sciences, genomics, medicine, national security, neuroscience, physics, quantum chemistry, robotics, sustainable energy systems design, and many other areas. Data science collaborations are possible among the BSOE faculty as well as faculty in other divisions.

Present plans for new interdisciplinary collaborations over the next five years also include those between genomics and storage systems, between networking and mobile computing, and between robotics and image processing.

**Academic freedom:** The BSOE is guided by the principles of academic freedom, which includes freedom of inquiry and research, freedom of teaching, and freedom of expression and publication. Faculty are encouraged to create classroom environments in which students have the freedom to express their own perspectives and
question those of others without fear of negative consequences. We also embrace the notion that in engineering, academic freedom also means that existing technologies, and their teaching, can be displaced by new technologies, both in research and instruction.

**Ethics:** Ethical behavior will guide all BSOE functions for faculty, students and staff. Ethical behavior includes demonstrating respect for colleagues and co-workers, as well as the appropriate treatment of data, property and the environment. As engineers, we also believe in the importance of responsibly confronting moral issues raised by technological activity, and therefore we will continue to expose students to ethical questions related to the technologies they are studying or developing.

4) **The BSOE Instructional Program**

The goals of the BSOE instructional program over the next five years are to:

**Goal #1: Create a transformative student experience that produces the next generation of engineers.**

This means introducing students to topics through various modalities that incorporate current thinking, hands-on learning, and modern tools, equipment and techniques.

**Goal #2: Contribute to the growth of UCSC’s graduate program.**

Through a combination of existing program growth and new M.S., Ph.D. and professional degree programs, we aim to nearly double the steady-state number of engineering graduate students (from 333 to 662 students) over the next five years.

**Goal #3: Respond to national, state and regional needs.**

National, state and regional research priorities set by current and anticipated future needs help shape tomorrow’s engineers. At the state and regional level, the Silicon Valley Economic Development Alliance and the California Department of Economic Development project growth and a corresponding labor need in several key areas:

- “Green” technologies, clean energy, advanced energy-efficient materials, smart buildings, power management, energy-control networking, and alternative fuels;
- Personalized healthcare technologies and software, medical devices, remote healthcare, and home healthcare engineering;
- Financial forecasting and actuarial science.

At the national level, the National Science Foundation and National Institutes for Health both articulate priorities in areas well represented in the Baskin School of
Engineering. The priority for research and development in rapidly evolving areas of science and engineering points to long-term, continuing and growing needs for graduates that are prepared for productive careers in industrial and academic settings.

National Science Foundation Acting Director Cora Marrett stated that while the NSF’s FY 2014 budget request provides increased support in all areas of research, there is particularly strong support for cyber-infrastructure, advanced manufacturing, and sustainability research. NSF investment priorities are in “areas where progress in basic research is vital to addressing key national challenges, such as spurring innovation in manufacturing, improving data storage and analysis (e.g., Big Data), securing critical infrastructure, and promoting innovation and economic growth generally.”

Some of the highest priority programs for NSF are:

- Cyber-enabled materials, manufacturing, and smart systems
- Cyber-infrastructure framework for 21st century science, engineering and education
- Science, engineering, and education for sustainability
- Secure and trustworthy cyberspace

In describing the National Institutes of Health FY 2014 budget priorities, Director Francis Collins stated, “The need to integrate and analyze massively complex datasets is referred to as the Big Data challenge—a challenge that we must overcome to gain a deeper understanding of disease and develop the next generation of therapeutic targets.” Specific initiatives the NIH will fund to accomplish this include facilitating the broad use and sharing of large, complex biomedical data sets through the development of policies and standards, developing and disseminating new analytical methods and software, and enhancing training of data scientists, computer engineers and bioinformaticians. Collins mentioned cancer genomics and stem cell research, both areas of strength in the BSOE, and both requiring expertise in biomolecular engineering and advances in computer science. A new NIH initiative in neuroscience includes the creation of tools to examine the activity of nerve cells, networks and pathways in real time.

Goal #4: Expand opportunities for online instruction

UCSC recently agreed to partner with education company Coursera to deliver online courses to the public, and the BSOE is committed to supporting these efforts. Some of our faculty are already incorporating web-based instruction and online activities into
existing courses, and other faculty are considering adding or expanding online offerings. A number of engineering courses are currently telecasting between the Santa Cruz and Silicon Valley campuses, and as the Silicon Valley campus grows, we expect to see an increase in the number of telecasted courses and an improvement in the telecast process.

5) Research and Education Areas: Existing Strengths and Plans for Growth

The BSOE faculty have been successful in building world-class research groups in many different areas. Future opportunities abound. While federal funding in most areas is expected to be flat or to decrease in the coming years, we expect that several of our areas of strength — genomics, robotics, data science — will experience funding growth. In addition, we anticipate numerous opportunities to develop collaborative relationships with companies in Silicon Valley. The resulting research collaborations will serve our students’ ability to create and obtain jobs in high technology, support the growth of research on the UCSC campus, and serve Silicon Valley companies’ need for research.

Many of our research and education areas lend themselves to the creation of centers or institutes, of which we already have a few: the Center for Biomolecular Science and Engineering (CBSE), the Center for Information Technology Research in the Interest of Society (CITRIS), the Center for Games and Playable Media (GPM), the Center for Sustainable Energy and Power Systems (CenSEPS), the Storage Systems Research Center (SSRC), the W.M. Keck Center for Adaptive Optical Microscopy and the W.M. Keck Center for Nanoscale Optofluidics (CFNO). New centers and institutes will provide platforms for the ever-increasing group funding modality. In addition, such centers represent focal points for corporate involvement and graduate student training. Over the next several years, we expect to grow the number and impact of these centers/institutes. Below are the academic disciplines in which the BSOE presently has strengths to pursue research growth.

Bioengineering/Genomics. Bioengineering — the application of engineering principles and/or technologies to biological systems — includes macro-scale engineering such as the development of innovative tools for medicine and biology as well as engineering at the molecular and cellular levels, with applications in energy, the environment and healthcare. This engineering approach to biological and environmental research is an area in which UCSC could make significant contributions in both research and education.

The BSOE offers graduate degrees in biomolecular engineering and bioinformatics and undergraduate degrees in bioinformatics and bioengineering, with concentrations in
biomolecular bioengineering, bioelectronic bioengineering, and rehabilitation bioengineering. In addition to providing access to advanced instrumentation and fabrication shops, the BSOE offers several nano- and biotechnology courses such as bioinstrumentation, protein engineering, stem cell biology and applied circuits for engineers. These courses fill a growing gap between the knowledge offered by academic courses and the current technology used by the biotechnology field. Many provide students with hands-on experience with recently developed technologies.

The application of newly developed technologies to healthcare and biomedical research is an area of vibrant growth: locally in “Biotech Bay” as well as nationally and globally. As new questions, needs and ideas emerge in these research areas, new technologies will be required, and this presents a unique opportunity for UCSC. Faculty in the BSOE have developed innovative technologies for sequencing, analysis, single-cell manipulation, high-resolution sensing, biorecognition and adaptive optics for biological imaging. We anticipate that these innovations will undergo further enhancements and that new technologies will continue to emerge.

We also envision sustained growth within the BSOE in genomics, initially through new faculty hires in cancer genomics and evolutionary genomics. Investments in this area will help UCSC solidify our position as a recognized leader in genomics and will benefit the campus through increased extramural funding, additional graduate student enrollments, and partnerships with commercial genomics R&D in Silicon Valley.

**Data Science** is an emerging academic discipline that integrates tools from statistical inference, machine learning and computer visualization to transform data into information. Touching nearly every aspect of modern life, the applications of data science are as prolific and diverse as human activity itself. Data science is at the core of the business models of many old- and new-economy businesses (from Target to ESPN to Facebook) and underpins data-driven research in disciplines as diverse as earth and planetary sciences, genomics, humanities, medicine, national security, neuroscience, physics, quantum chemistry, robotics and sustainable energy systems design.

UCSC is in a unique position with respect to the emerging primacy of data. We are leading innovators in the development of both data analysis tools and the hardware that supports the acquisition and storage of large amounts of data. The BSOE possesses research acumen in the key areas that form the foundation of data science: statistical sciences, machine learning, computer visualization, database research, high-performance computing, data storage systems and network sciences. This, in combination with strong faculty leadership and motivation and proximity to Silicon Valley, positions us to take the lead in data science research and education.
The BSOE’s plans for growth in data science are ambitious. The nascent Data Science Leadership Initiative (DSLI), will help coordinate efforts that could propel UCSC into a position of national leadership. New hires will augment existing expertise and will include experts in statistics, machine learning, high-performance computing, and other related areas. Over the next five years, we plan to submit both undergraduate (B.S.) and graduate (professional M.S.) degree proposals, and to initiate a donor-funded Data Science Institute in Silicon Valley. We envision that within 10 years, the Data Science Institute will house approximately 40 faculty members and hundreds of research scientists and students.

**Engineering Management and Entrepreneurship** is the broad field concerned with engineering principles as applied to business practices, including information technologies, technology management, resource management, product development, technology transfer and organizational structures. At the BSOE, research and education in this field occurs in the space where three important themes overlap: *economics of information and technology*, *management of technology*, and *data science and engineering*. Within this space, a broad and diverse range of research projects takes place in the BSOE. For example, research related to information retrieval and knowledge management include healthcare analytics, assisted learning, and bug prediction analytics. Resource management projects include cyber security, energy analytics and network management.

Engineering management and entrepreneurship is also concerned with data science, as companies strive to improve their use of the data they have and to tap into new and growing sources of data. Government at all levels is making greater use of public and private sources of data. Consumers are simultaneously interested in new data-driven products and leery of loss of privacy and theft of information. All of this makes for a dynamic and expanding area of research and education, while also raising new questions about the role of government and business and their use of data.

We can explore these and other questions with the combination of existing intellectual resources in the Technology Management Department in the BSOE, as well as other campus departments (Economics, Psychology, Sociology, Environmental Studies, Electrical Engineering and Computer Engineering). Additional resources would help us build new research and teaching programs, including a graduate technology management program. With additional resources, we would also expand our expertise in the application of data science tools to management issues such as computational advertising and management of “smart cities.”
**Games and Playable Media** are emerging software-driven forms of interactive media with growing economic and cultural importance—and the potential to transform areas such as entertainment, education and health behavior intervention—in which California and UC Santa Cruz are current leaders.

At UC Santa Cruz, researchers and students have been setting the course for games since 2006, when the BSOE started the first undergraduate game major in the University of California system. A leader in game research, UC Santa Cruz also hosts three graduate programs with an emphasis on games, one of which ranked in the top ten game design programs by the Princeton Review. Another of these programs is the new professional M.S. degree launching in Silicon Valley. The undergraduate B.S. degree program in Computer Game Design currently has 400 students. The Center for Games and Playable Media, established in 2010, houses the School’s six games-related research labs including the Expressive Intelligence Studio — one of the largest technical game research groups in the world. Projects in these labs range from work on artificial intelligence and interactive storytelling to natural language dialogue systems, cinematic communication, procedural content generation, human computer interaction, rehabilitation games, computational photography, and level design. Currently, the group has more than 20 active research grants on games and is the only non-European university taking part in the European Union’s SIREN Project, a serious games initiative tackling conflict resolution.

In order for UC Santa Cruz to remain a leader in this fast-growing and increasingly competitive area of research and education, the BSOE plans to (a) establish a new interdisciplinary Ph.D. in Games and Playable Media, adding 40 more Ph.D. students and helping define graduate education in games on a national level; (b) hire new faculty in our core areas of strength (interactive narrative, procedural content generation) as well as faculty in key interdisciplinary areas, some of whom could be joint appointed across divisions (human-computer interaction, natural language processing, game design and game studies); (c) establish a new interdisciplinary department of Computational Media, providing an intellectual home for existing and new programs and faculty; and (d) continue to grow the Center for Games and Playable Media (which currently has positions for ten soft money researchers, as well as three professional staff) toward the formation of a field-leading research institute that remains deeply engaged with student education, from undergraduate research opportunities to helping graduating students found spin-off game studios in Santa Cruz.

**Hardware Engineering** involves the creation of materials, devices, circuits and systems that allow the realization of electronic systems in the physical world. As such it underlies and enables all of electronics and much of the industry in Silicon Valley. Faculty and facilities within the BSOE cover the main areas including crystal growth, enabling the
control of materials at the atomic level, nanomaterials and characterization, fabrication of devices, analog and digital circuit simulation and design. Our faculty have also developed an extensive array of both optical and electronic test equipment for circuit and system characterization.

Specific plans for growth in hardware engineering will expand our coverage into the following areas, all of which are good prospects for future research funding, take advantage of our proximity to Silicon Valley and allow us to offer a competitive graduate program: mixed signal circuit design, which involves the interface between the analog world in which we live and the digital world in which we compute; radio frequency circuit design and electromagnetics for wireless communication, a key area targeted for future growth by the national professional societies; micro-mechanical systems, aimed at sensors and actuators for environmental sensing, medicine and imaging in astronomy and biology; biophotonics, a rapidly growing area in which the significant technological advances in photonics over the last 50 years are now being used to develop therapeutic, diagnostic and research hardware in the realm of biology; bioelectronics, an area concerned with the development of implantable electronic systems for diagnosis, the development of research tools and to restore sight, hearing and movement; biomaterials to understand and develop the underlying materials needed for the realization of emerging devices in the areas of environmental monitoring, medical diagnostics, medical therapeutics and to interface with biological systems; and finally power electronics, an area identified as critical to future sustainability efforts as greater amounts of our energy and transportation systems become electrified, to support the burgeoning need for sophisticated power management strategies in portable wireless systems and the emerging “internet-of-things.”

Materials and Nanotechnology. Nanotechnology is the understanding and control of matter at the nanoscale, where it often exhibits unique properties. By manipulating matter at these small scales, we can develop new applications and ultimately new products, such as medical devices and ultra lightweight materials. Because of its numerous applications and potential benefits for society, nanotechnology is likely to remain near the top of the most important fields of research and education for many years. The BSOE is in a position to help advance the field by leveraging its existing strengths in materials (bio and non-biomaterials), hardware (devices and sub-systems), and mathematics (modeling), each of which is a critical component for interdisciplinary nanotechnology.

The BSOE does not currently have any planned hires in this area, but this may change if campus elects to place a priority on this as an area of research and teaching. We expect that campus growth in materials and nanotechnology over the next five years will be led by the Division of Physical and Biological Sciences.
Leveraging existing expertise and resources, the goals for the BSOE are to (a) establish “basic nanotechnology” (e.g., understanding how electrons interact with light in a small semiconductor) to increase externally funded research for the benefit of both undergraduate and graduate education in this highly recognized field and (b) establish “applied nanotechnology” (e.g., developing batteries with ultra high capacity) to increase externally funded research and possibly to develop campus-originated businesses. While the former is a traditional pathway in academia, the latter offers exceptional advantage to the BSOE, given our proximity to the Silicon Valley. Exploring basic nanotechnology will allow us to tackle fundamental questions, while pursuing applied nanotechnology will bring breakthroughs to market.

**Mobile and Pervasive Computing.** Advances in wireless and sensor systems have fueled the growth and evolution of a new class of computing. “Mobile and pervasive computing” (MPC) is a rapidly evolving computing paradigm that will very likely transform the way humans interact with the world around them and with each other. MPC provides a platform for many novel applications: pervasive health monitoring, electronic learning, homeland security and electronic commerce, to name just a few. Mobile computer vision offers new entertainment (augmented reality), natural interface (gesture recognition), and information access (mobile barcode/tag/OCR) opportunities. In the future, sensors and actuators will become an integral part of interaction and computing. Contextual intelligence will be used to make services ever more efficient and customized. People will interact with one another through the environment in social settings supported and enabled by MPC, rather than working independently with personal computers.

MPC research is still in an early stage, and many research problems remain open, stemming from the enormous differences between it and traditional distributed computing and network computing. Defining the MPC systems of the future requires interdisciplinary knowledge, collaborative work, thorough investigation of diverse areas, and special attention human-centric design. In Silicon Valley, there is a high demand for engineers who are proficient in mobile sensors, architectures, networking and user interfaces. An article in the Silicon Valley Business Journal states that network engineers and mobile application developers are among the seven “hot jobs in demand.”

Specific plans for growth in the BSOE in this area include hiring new faculty with research expertise in mobile cloud and pervasive computing with emphasis on low-power and mobile architectures; human-computer interaction and user-centric design, with emphasis on wearable and pervasive computing; and embedded sensors and mixed-signal systems.
Network Science and Engineering. As of 2010, one third of the human population was connected through the Internet. By 2020, GSMA estimates that there will be 24 billion connected devices in the world, and connected devices will be a $1.2 trillion market. Large-scale applications of networking and information technologies are pervasive in education, healthcare, factory automation, Internet content distribution, the power grid, smart homes and tactical network deployments for the military or disaster relief. More recently, networking infrastructures are being applied at very small scales: on computer chips to improve performance; and nano-networks are beginning to be used to understand molecular-level constructs.

Research in network science and engineering at the BSOE consists of re-imagining and re-engineering networks and computer systems in general to be more meaningful and productive for people. The BSOE faculty members are well-known leaders in network science and engineering, and the results of their research have had an enormous impact in industry and the research community. The breadth and depth of our work, its cross-disciplinary applicability, and our proximity to Silicon Valley enable us to examine issues with an unrivaled scope and comprehensiveness in critical areas, including: new models that address the physical, social and information planes of networks; protocols and architectures to enable an Internet that can be everywhere and in everything; and interfaces and devices to enable an Internet and computing embedded in the ambient that are secure, efficient and simple to use by people as part of their daily activities.

Plans for growth in this area consist of complementing its strengths in wireless networking, sensor networks, formal analysis of communication protocols, and performance modeling of networks. We plan to hire two new faculty members whose research foci are mobile cloud and pervasive computing, and internetworking for big data and server rooms. We will also coordinate with the hiring of new faculty in Robotics and Cyber-Physical Systems and Hardware Engineering to address cyber-physical systems and mobile devices.

Robotics and Cyber-Physical Systems combines several technical areas spanning mechanical, software and control engineering in the service of creating real devices that interact with the world in a full or partially autonomous way. The economic and societal impact of this autonomy is enormous. Factory automation, for example, gives us better and lower-priced goods, and is advancing how supply chains can be streamlined. In aviation, autopilots increase safety by reducing the impact of pilot fatigue. In biotechnology, automation in the delivery and preparation of biofluidic samples has advanced many important biomedical technologies. Advances in the Robotics and Cyber-Physical Systems field also promise better and more timely data using unmanned
vehicles, better medical outcomes using robotic surgery and elder-care robotics, and fewer lives lost in traffic accidents using autonomous consumer vehicles.

Areas of expertise among faculty in the BSOE include air traffic management, autonomous vehicle guidance, biomedical instrumentation, game theory and optimal control, guidance navigation and control, medical robotics and optimization. As Robotics and Cyber-Physical Systems research continues, the BSOE has an opportunity to play a leading role in defining and developing these systems. Already one of the few institutions to offer a Robotics Engineering undergraduate degree, growth leads to a larger educational effort, more large-scale research projects that combine our existing talents with other departments and institutions, and puts the BSOE is a leadership role in this important area.

The BSOE’s specific plans for growth in this area are to (a) expand our expertise to include robotic artificial intelligence (AI) and perception, autonomous robotics, and design and application of biomorphic robots; and (b) establish a graduate degree program in Robotics Engineering.

**Software and System Engineering** is the study of how to construct reliable, large-scale, software-intensive systems, often involving custom computer hardware and devices. Already pervasive in our society, software increasingly controls safety-critical systems ranging from anti-lock brakes to air traffic control, and mission-critical systems such as the campus cloud-based email and calendaring services.

Research and education in software and system engineering in the BSOE focus on the analysis and design of programming languages used to construct systems; data mining of software history to understand and predict patterns of bug incidence in software; analysis of concurrency errors in software; and crowd-sourcing techniques used in large scale web applications.

Additional faculty with focus on large-scale web engineering, large-scale software analysis, and hardware/software systems engineering would allow UC Santa Cruz to leverage its location on the doorstep of Silicon Valley and have substantial impact on the engineering practices of the valley. Since neither Stanford nor Berkeley have made substantial investments in software and systems engineering, this is an area of opportunity for the campus.

**Statistical and Mathematical Modeling.** Many natural phenomena share fundamental underlying processes. For example, turbulence is a common and crucial process in aerodynamics, astrophysics, environmental fluid dynamics, meteorology, oceanography
and many other areas. Mathematical modeling and the construction of mathematical methods for investigating cross-disciplinary basic processes such as turbulence are research strengths within the Applied Mathematics and Statistics (AMS) department in the BSOE. The fundamental research our faculty perform to distill understanding of crucial processes is then leveraged by other disciplines for their specific application, creating true interdisciplinary collaborations.

The most important modern asset for the development of these process models is high performance computing (HPC). Through its massively increased efficiency, HPC has allowed models to become much more realistic and to explore much larger parameter spaces. However, the efficiency of HPC comes at a cost. HPC is now so complex that it requires particular new skills in order to be able to formulate algorithms and models that use the machines at their maximum efficiency and to cope with and analyze the massive datasets generated.

BSOE faculty already have expertise in HPC algorithm and model design, HPC optimization and HPC implementation and use. We envision adding capacity in these areas, which could propel the BSOE to the forefront of the field and would facilitate collaborations with other departments and campuses. Growth in the areas of high performance computing and statistical and mathematical modeling is also important to UCSC’s expanding presence in Silicon Valley. HPC is an essential component of any data science initiative and will enrich collaborations with data scientists and discipline-specific researchers in a variety of companies in the high-tech and internet sectors. Finally, given that the newly developing and quickly evolving HPC skill set is not generally taught formally, growth in this area will also provide an opportunity for UCSC to offer unique professional training in HPC.

Statistical modeling is the study of learning from data, and making good decisions in the presence of uncertainty. Our faculty are internationally renowned for their development and application of Bayesian statistical methods to a wide variety of interdisciplinary collaborations, including bioinformatics, econometrics, engineering, environmetrics, and other biological, physical and social sciences. Statistical modeling will continue to play a key role in scientific discovery, and it is also has a key role in UCSC’s data science initiative.

**Sustainability Engineering** is the science and technology of designing and building sustainable systems; i.e., systems that maintain their own viability by using techniques that allow for continual resource recycling and reuse. It is multidisciplinary, encompassing not only “traditional” systems engineering and optimization, but also *materials science* (developing new materials that are themselves renewable and designing
materials used to build renewable technologies such as solar panels), *data and computer science* (modeling energy use and managing the electric power grid given intermittent energy sources such as solar and wind), *sociology* (understanding human behavior and how this plays out with respect to energy use patterns), and *biomolecular engineering* for developing more efficient ways of producing biofuels with minimal carbon emissions.

Research and education in sustainability engineering is quickly becoming a differentiator for UCSC. The BSOE’s Center for Sustainable Energy and Power Systems (CenSEPS) conducts fundamental research on renewable and sustainable technologies and systems; and the School has led the very successful effort to develop new curricula in this area. The SEED (Sustainable Engineering and Ecological Design) effort has received more than $1.5M in external funding to develop new courses, many of which have been adopted on other campuses. We are also part of a national consortium to revamp the “power engineering” curricula in the United States.

Located on the Monterey Bay, near Silicon Valley and not far from the Salinas Valley, UCSC is in a unique location. Within a 50-mile radius are diverse geographic and environmental conditions: rural, urban, agricultural, coastal and mountainous environments. This provides the opportunity for studying renewable energies and sustainable engineering systems in diverse sites and to understand how to couple new high technology (originally developed for communications) to agriculture; for example, wireless technology applied to food safety, to water and soil sensing, to create “Smart Farms” and to regional water supply systems.

This is an enormous area of growth in both research and education, and UCSC could become one of the nation’s leading institutions in the field of sustainability engineering. We emphasize the integration of engineering and social sciences, a practice to help ensure that new technologies will be accepted by society. Our research and education programs are already tied to local community colleges, and we are thus poised to be the leading local provider of a skilled “sustainability workforce” in this region. Our recent multimillion dollar award from the National Science Foundation in the area of community-scale renewable energy sources will allow us — with our Danish colleagues from the Technical University of Denmark and Aalborg University — to develop international academic programs in renewable energy on the UCSC Silicon Valley campus.

Over the next five to seven years, we envisage the development of Masters and certificate programs in the area of sustainability and sustainable power engineering at the Silicon Valley campus as well as on-line programs that could be integrated into programs in the Salinas Valley. We will also explore whether or not developing a B.A. degree in
Sustainable Technology is viable and makes sense for students who want more technical training than the one offered by Environmental Studies but do not want an engineering degree.

New faculty lines in engineering are essential to campus sustainability initiatives since technical aspects – new devices, efficient control strategies, better utilization of existing data and development of new data sources – are a critical part of a sustainable future. The BSOE faculty engaged in this area will work across divisions, with other Engineering, Social Sciences, and Physical and Biological Sciences faculty.

6) THE BSOE GROWTH PLAN

The BSOE has tremendous research growth potential. We remain significantly below our original targeted size, and our desire to grow by up to 50% over the next five years is in keeping with our long-term strategy as well as the campus’s goal to establish a presence in Silicon Valley. Currently at 78 FTE faculty, we envision growing to 125-130 by 2018 (see table below).

We envision growth in several areas, as described in the previous section. These represent areas of existing strengths, as well as important engineering areas underrepresented at UCSC, and emerging new areas of importance. Our primary goal is to grow our research and external reputation in support of regional, state and national interests with an instructional focus on graduate studies, while maintaining excellence in our undergraduate programs. To meet this goal, the growth plan for the BSOE focuses on enhancing the excellence, vitality and scope of our academic research programs, growing our graduate programs, and addressing curricular capacity and student retention.

**BSOE Projected Faculty Hiring Plan**

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1 Current projections: Actual hires may differ from the numbers presented in this table.
2 Total hires minus separations

BSOE Academic Plan: 2013 Update
7) CONCLUSION

This update to the 2006-2011 Academic Plan represents our current vision for the growth and evolution of the Baskin School of Engineering over the next five years. As the changing technology landscape alters the instructional and research needs both on the Santa Cruz campus and in Silicon Valley, the school will respond with new programs to address these needs. We are committed to growing the graduate student population while retaining excellence in undergraduate education. We are committed to expanding interdisciplinary collaborations between BSOE and other divisions. Because we intend to continually re-assess our role in technology development, this plan will be updated on an annual basis. The latest version will be available through the BSOE Dean’s office.

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1 http://www.nae.edu
4 http://www.nih.gov/about/director/budgetrequest/fy2014testimony.htm
6 projections by GSM Association, 2012
7 http://planning.ucsc.edu/academicfuture/docs/DivPlans2006/SOE.1-17-06.pdf