SECTION 3: RESEARCH EXCELLENCE

Introduction

Our reputation will be based on our research excellence. In the next five years, we seek to continue to advance and exceed our current level of research excellence. The School has an exceptional position in that its field of study naturally lends itself to key contributions to various fields of study throughout the campus. We have a unique spirit of collaboration throughout the campus, reflected in our interdisciplinary partnerships. As the area of engineering research grows, we will build upon our existing collaborative partnerships and venture into dynamic related fields where opportunities for further collaborations and new interdisciplinary connections will thrive. Total awards (not including $10.7 million in gifts) are anticipated to grow to $26.2 million by 2010-11, resulting in indirect cost recovery projections for the university of over $4.6 million by 2010-11.

The School plans to continue the expansion and support of focused research centers, such as the existing: Center for Biomolecular Science and Engineering, the Information and Technology Institute, and the proposed Center for Innovative Materials, Sensors and Systems which will evolve around interdisciplinary science and engineering. Each activity encompasses a set of collaborative and interdisciplinary research centers founded on our current and planned areas of excellence.

APPLIED MATHEMATICS AND STATISTICS RESEARCH PROGRAMS

AMS strives to achieve research excellence in two main areas: dynamic mathematical modeling of complex natural phenomena, and Bayesian statistical methods of inference, prediction, and decision-making, in both cases with applications in engineering and the sciences. Our focus is on modeling of the world around us, and our approach is computationally intensive (through the numerical solution of systems of partial differential equations in applied math and the use of Markov chain Monte Carlo methods and other techniques for approximating high-dimensional integrals in statistics). We are committed to full interdisciplinary collaborations in which we serve as co-PIs on grants with investigators from other fields, so that our publications are a mix of methodology articles in leading applied math and statistics journals and substantive articles in leading journals in the fields in which we collaborate.

In the disciplines of Applied Mathematics and Statistics, we have identified the following programmatic directions for research specializations of current faculty and future hires, by targeting sub-disciplines in these two fields that (a) are envisioned to be of paramount scholarly importance in the first half of the 21st century, (b) will lend distinction to the existing AMS faculty, and (c) are likely to promote fruitful interdisciplinary interactions at UCSC. Statisticians tend to work in more than one sub-discipline, so most of AMS's existing statisticians are listed below more than once, and there will be strong interactions among the research work in the three statistics sub-disciplines.

Each of the Applied Math (AM) and Statistics (S) groups naturally breaks down in research specialization into 3 sub-groups; because each of these groups is equally important and the SoE target for AMS of 8 faculty per Group is not divisible by 3, we have anticipated the possibility of at least 1 additional hire in each Group in the future beyond AY2011-12 (through a combination of increased central campus resources and/or extramural funding to support the future *Research Institute in Applied Mathematics and Statistics* (RIAMS) and/or non-RIAMS extramural funding and/or additional AMS workload), making at least 3 ladder faculty in each research subgroup. See the AMS appendix for details on current AMS faculty. (Abbreviations for interactions in the list below: COH = Center for Ocean Health; STEPS = Science, Technology, Engineering and Policy for Society Institute for Environmental Research; CSTAR = Center for Stock Assessment Research; EEB = Ecology and Evolutionary Biology; ES = Earth Sciences; MCDB = Molecular, Cell and Developmental Biology; OS = Ocean Sciences; CfAO = Center for Adaptive Optics; ETox = Environmental Toxicology; SCIPP = Santa Cruz Institute for Particle Physics.)

- (AM) Mathematical biology (3 faculty) (Mangel, Wang, 1 new; SoE interactions with Bioinformatics, BME; campus interactions with COH, STEPS, CSTAR, EEB, ES, MCDB, Physics (especially biophysics, if UCSC starts a new initiative in this field));
- (AM) Fluid dynamics (3) (Garaud, 2 new; SoE interactions with EE, CE; campus

interactions with OS, ES, Astronomy/Astrophysics);

- (AM) Optimization/control theory (3) (Cortes, 2 new; SoE interactions with EE, CE, CS, Bioinformatics; campus interactions with Astronomy/Astrophysics, ES, CfAO, ETox, Physics);
- (S) Bayesian nonparametrics (3) (nonparametric distributional modeling, nonparametric modeling of regression surfaces, connections with machine learning) (Draper, Kottas, Lee, 1 new; SoE interactions with CS, BME; campus interactions with CSTAR, Astronomy/Astrophysics, SCIPP);
- (S) Bayesian environmetrics (3) (spatial-temporal modeling, environmental risk assessment) (Draper, Lee, Sanso, 1 new; SoE interactions with CE, EE; campus interactions with COH, CSTAR, STEPS, ETox, OS); and
- (S) Computationally-intensive Bayesian inference, prediction and decision-making (3) (Markov chain Monte Carlo methods, stochastic optimization) (Draper, Kottas, Lee, Prado, Sanso, 2 new; SoE interactions with BME, CS, TIM; campus interactions with EEB, MCDB, SCIPP, CSTAR).

BIOMOLECULAR ENGINEERING RESEARCH PROGRAMS

The goal of the Biomolecular Engineering (BME) Department is to achieve a level of excellence that will place us among the top five similar departments nationally. Distinct from traditional bioengineering departments, the BME department will develop a new blend of engineering, computational biology and nanotechnology that draws on current strengths at UCSC, and reflects our vision of an important direction that biological and medical discovery should take. The target areas of excellence, highlighted below, intersect with all three areas of excellence identified for the Baskin School of Engineering—IT, BT and NT—and allow the department to play key roles in new campus initiatives, such as the biomedical research focus of Molecular, Cell, and Developmental (MCD) Biology, and Chemistry and Biochemistry.

Protein bioinformatics and engineering.
We currently have one of the leading groups in the world in protein structure prediction, but much of the future of the computational study of proteins will be in designing proteins. This is a natural direction for the Biomolecular Engineering Department to pursue. Our strength is in the computational end of things, and BME needs to add a faculty member who can lead the laboratory studies of protein structure and function.

Synthetic biology position
A new field in bioengineering is the engineering of existing biological systems by adding several genes to existing organisms to create new signaling pathways and new functions. The approach can be quite modular, reusing standard components, thus fitting in well with engineering design styles in other disciplines. This field promises to be a particularly fruitful area for 21st century bioengineering.

Bioinformatics position
David Haussler and Jim Kent have made the genome browser at genome.ucsc.edu the best resource for comparative genomics in the world. Dr. Haussler sees the grand challenge of the human genome as explaining the evolutionary history of every base of the genome. This requires comparison with many other genomes across a wide variety of organisms. The rate of new discoveries is exceeding what the current team can handle. Furthermore, since Dr. Haussler and Dr. Kent are not teaching (except by advising grad students), we are seriously short of faculty who train undergradutes and first-year graduate students in the techniques of comparative genomics. We need to add a faculty member to research, teach, and mentor in this new field to maintain our lead position. Since we already have the premier research group, recruiting in this field should be relatively easy.

Nanotechnology development/high throughput engineering
Our primary current expertise in Engineering for Biomolecules is in bioinformatics, a form of information engineering. We also have expertise in DNA microarray technology, but need to expand into additional high throughput techniques, such as micro fluidics, proteomic and microarray technologies, and robotics. Without such an expansion, it will be difficult to launch our academic programs in bioengineering and biomolecular

engineering. We expect these new faculty members to have strong collaborative potential with our existing research programs. Thus, proteomics or microarrays would be the most likely areas for the high-throughput technology position, and nanotechnology related to existing nanopore science or other areas in BME and collaborating programs.

Stem Cell Biology

Research in stem cell biology is opening doors to understanding fundamental problems in molecular biology, and BME seeks to recruit faculty members taking a biomolecular engineering approach to solving problems in stem cell biology. The differentiation of stem cells into specialized cells is a complex process involving networks of genes linked together by transcriptional regulatory circuits, intracellular signaling cascades, and cell-cell interactions. Our understanding about the detailed events and the genes involved in these processes is incomplete.

New developments in stem cell biology take a genome-wide approach to analyze the entire network of genes and how their function is modulated during development. New biomolecular engineering techniques in stem cell biology will contribute to our understanding of the causal genetic events underlying how cells specialize from stem cell progenitors. These approaches will greatly complement our strengths in genomics and bioinformatics, creating opportunities for new avenues of scientific investigation.

Systems Biology

We seek to recruit faculty members doing research in the area of Systems Biology. New high-throughput advances in molecular biology research are quickly changing how biological problems are being solved. Exciting research in this area lies at the interface between biology and engineering. To complement our expertise in computational analysis of genome-wide datasets, we seek colleagues that will develop new technologies for measuring molecular phenomena of entire cells or tissues on a global scale. These include but are not limited to techniques for measuring transcriptional changes, alternative splicing, protein abundance, protein modification state, genome-wide knockout studies, and synthetic genetic interaction mapping. We seek faculty that are applying existing technologies to new biological questions, especially those relating to stem cell research, as this is another one of our target areas.

Biosensors

We aim to recruit faculty involved in biosensor research for two reasons. First, biosensors can be highly specific, inexpensive and portable, therefore they will play an increasing role in disease diagnosis, forensics, detection of pathogens in food and water supplies, and detection of airborne pathogens released from bioweapons. Second, biosensors require research expertise at the interface between electrical engineering, nanoscale fabrication, data processing, control theory and biochemistry. Biomolecular Engineering (and the Baskin School of Engineering more generally) has already established effective interdisciplinary research between faculty in these areas. Therefore, we are optimistic that new faculty recruits working on biosensors will thrive in this environment.

Genomics/Stem cell biology

The priority here is determined by the same issues described above for seeking a stem cell biologist. Here the emphasis will be to complement that hire with a second hire using computational analysis of stem cell data. The differentiation of stem cells into specialized cells involves networks of genes, and signaling cascades. Understanding the genes involved in these processes can only be done using the methods of genomics and bioinformatics. We therefore seek colleagues who can train undergraduate and graduate students in this burgeoning field, as well as competing for Proposition 71 research grants.

Modeling

Computational modeling of biological processes is now an essential aspect of contemporary research in biomolecular engineering. Such modeling ranges from molecular dynamics simulations of individual molecules as they interact with other cell structures, to establishing interactomes that describe all protein-protein interactions occurring in a given cell type, to models of physiological and electrophysiological processes that underlie tissue level function. Expertise in modeling is therefore required for Biomolecular Engineering, and we will seek new faculty members who can bring their expertise to the UCSC campus.

Biomaterials

Virtually all of the advances in understanding biomolecules and their applications in research and biotechnology now involve novel materials. Examples of collaboration between the departments of Biomolecular Engineering and Electrical Engineering include the silicon nitride nanopores being developed for DNA sequencing, the ARROW waveguides that will be applied to single molecule detection devices, and implantable electrodes that will enable vision in the blind. All of these materials are being investigated on an ad hoc basis, and we do not have colleagues who focus on biomaterials in their research. For this reason we seek to hire a faculty member who will establish this area in BME, who can train undergraduate and graduate students in biomaterials and who will participate in the university's effort to establish biomaterial efforts between the SOE and the Division of Physical and Biological Sciences.

Microbial engineering

Synthetic biology relies in large part on devising "toolkits" of genetic information that can be used to program microorganisms and eukaryotic cells such as stem cells. A faculty member specializing in microbial engineering will therefore complement our new hire in synthetic biology that was described above, as well as providing expertise in growing an engineering live cells. We see this individual as an essential component of a complete department with the research theme of biomolecular engineering.

COMPUTER ENGINEERING RESEARCH PROGRAMS

We maintain a modified 10-year plan focus on five core areas of computer engineering, and are initiating a crosscutting emphasis on assistive technologies. During the coming 5 years, we will most particularly be emphasizing full development of the Embedded and Autonomous Systems area, in particular robotics and control, and the Assistive Technology emphasis. The growth in Autonomous systems will be one of many efforts in the SOE to develop Mechanical Engineering like programs within the existing departments of the SOE. Assistive Technology is one component of our growing interdisciplinary and interdivisional programs in bioengineering. In the longer term we wish to see at least five faculty members in each of our areas of excellence to provide critical mass for strong research programs able to present and fund focused large projects with multiple PIs. The areas include:

- **Computer System Design** studies the creation of computer and digital systems to solve problems. We currently perform work in parallel and distributed computation, performance modeling, field-programmable gate array (FPGA) and very large scale integration (VLSI) system design, and computer architecture. We are presently engaged in a recruitment in the area of VLSI and/or Reconfigurable System Design. Primarily the SOE area of Computer Systems, Storage, and Architecture. (Brandwajn, Hughey (in part), Renau, 2005-06 Recruitment);
- **Design Technologies** includes both the hardware and software technology needed to design and build complex digital systems. Our current research includes Computer Aided Design (CAD) for nanoscale system design, CAD for FPGA design, and CAD for VLSI design and testing. Primarily the SOE area of VLSI, Nanosystems, and Materials. (Chan, Ferguson, Larrabee, Schlag);
- **Computer Networks** includes the technology, software, and algorithms required to make large networks of computing devices. Research areas presently include design and evaluation of protocols for wired and wireless networks, network switching, sensor networks, and internetworking research. Sensor networks are collaborative networks of inexpensive sensors that enable, for example, smart highways and sophisticated environmental monitoring. We have developed several sensor networks in collaboration with EEB faculty to solve various environmental monitoring problems. This group collaborates with the faculty in Electrical Engineering and EEB, and includes graduate students from Computer Engineering and Computer Science. Primarily, the SOE area of Networks; and partially the SOE areas of Remote Sensing and Environmental Technology; and Formal Methods and Security (Garcia-Luna, Obraczka, Varma, 2008-09 Recruitment);
- **Digital Media and Sensor Technology** has an emphasis on computer systems and technologies for video processing, sensor networks, and distance education. Our current research includes image and video reconstruction and modeling, vision for robotics, visual tracking and surveillance, embedded vision systems,

and human-computer interaction. Research strengths in Electrical Engineering and in Computer Science complement several of these areas. Part of the SOE areas of Graphics & Visualization, Computer Game, Computer Vision, HCI; and of Communications, Signal and Image Processing. (Manduchi, Mantey, Tao); and

- **Embedded and Autonomous Systems** focuses on three related areas: embedded systems, control, and autonomous systems. Embedded systems include the ubiquitous computers in aircraft, automobiles, and consumer electronics. Control involves the use of mathematical models and algorithms to control complex mechanical or other systems. Autonomous systems are mobile embedded systems that are able to sense and interact with the environment. The integration of physical, electronic, and computer components into a working autonomous mobile system is a very difficult problem and a growing area of research. Autonomous systems will have a major social and technological impact, with applications encompassing medical robots, interplanetary exploration, aid for the motion-impaired, and unmanned rescue missions. Research strengths in Applied Mathematics and Statistics and in Electrical Engineering complement this area. Primarily the SOE area of Autonomous Systems; and partially the SOE areas of Formal Methods and Security; and of Software Engineering and Databases. (de Alfaro, Dunbar, Elkaim, 2007-08 recruitment, 2009-10 recruitment, 2010-11 recruitment).

  Finally, we have our cross-cutting emphasis of Assistive Technology. We expect that most of the Department's Assistive Technology research will take place within the Embedded and Autonomous Systems area and the Digital Media and Sensor Technology area.

- **Assistive Technologies** considers the use of computer and other technology to improve functional capabilities of individuals with disabilities. Growth of this emphasis will help enable the creation of undergraduate and graduate Bioengineering programs, and also define a new educational and training model for the engineer of the future, focusing on human—centered design. The National Academy of Engineering, in its 2005 report *The Engineer of 2020*, found one of the four primary challenges for the Engineer of 2020 to be creating and designing "technology for an aging population". We plan a unique and timely emphasis in this area, most strongly aligned with our Embedded and Autonomous Systems and our Digital Media and Sensor Technology groups. Research strengths in Electrical Engineering and Psychology complement this area. Primarily the SOE area of Assistive Technologies and Biomimetic Devices. (Manduchi, 2005-6 Recruitment)

During 2004-05, the CE research program generated nearly $3.5M among 16 resident faculty members, and has more than doubled its level of research funding per faculty member over the past five years.

COMPUTER SCIENCE RESEARCH PROGRAMS

The Computer Science Department carries out a substantial research program that focuses on selected key areas of computer science and strives for synergistic interaction with other disciplines in science and engineering. The Computer Science department already contributes strongly to the campus's research excellence in several key areas, including:

- Computer Systems (especially storage systems);
- Machine Learning;
- Software Engineering;
- Database Systems;
- Trustworthy Computing; and,
- Visualization, Graphics, and Human-Computer Interfaces.

In the 1980s much emphasis was placed on high performance computing, but the past decade has seen a shift in emphasis to what could be described as "information technology infrastructure". This encompasses the storage, maintenance, manipulation, transmission, and retrieval of information in an efficient and secure way. In addition to established areas like operating systems, distributed systems, relational database systems, and networks, the emerging areas of storage systems, heterogeneous databases, data mining, and computer security play a significant role in this information technology infrastructure area.

The Computer Science Department will build on its excellent Storage Systems Group led by Professor Darrell Long and on its security expert Professor Martin Abadi to become a top department in this information technology infrastructure area. This ties into the strong computer networks group in the Computer Engineering department. This information technology infrastructure area achieves synergy with the other research foci of the department and school, as well as between its component areas. Not only is the Bioinformatics Group interested in both genomic databases and data mining of genomic data, but data-mining and the machine learning area have significant synergy and many graphics applications can benefit from efficient large storage systems.

The Database Systems Group has three faculty led by Phokion Kolaitis. The two tenure track faculty, Assistant Professor Tan and Assistant Professor Polyzotis, have won NSF CAREER Awards. This group is important to both the Storage Systems interest in CS and to data-mining and data management issues in TIM.

The Machine Learning group is led by Professor Manfred Warmuth and is recognized as one of the leaders in developing and explaining some of the most successful machine learning algorithms and paradigms, such as: Boosting, On-line Learning Algorithms, Adaptive Algorithms, and Support Vector Machines. The Computer Science hiring plan includes adding applied learning faculty who will help put into practice the fundamental advances generated by our strong group of learning faculty and increase our visibility in the more empirical learning communities. In addition to the synergies between Machine Learning and the areas of Computational Biology, Bayesian Statistics, and Artificial

Intelligence, there is a strong synergy between the Machine Learning faculty and the Storage Systems group as the adaptive algorithms developed by the Machine Learning group can be used to improve performance on a variety of systems tasks.

Visualization has emerged as one of the most important ways to assimilate data or information that has traditionally been presented in the textual or tabular form. The importance of utilizing other senses such as sound, gesture, pose, haptics and smell, in order to create a compelling scenario for learning, exploring, and discovery has given rise to fervent research activities in the area of virtual reality interfaces. Related challenges spur research activities in visualization, graphics, human-computer interaction, collaborative/distance learning, user interfaces and digital media. The Computer Science Department currently has a group of three strong graphics faculty (Assistant Professor Jim Davis and Professors Alex Pang and Suresh Lodha), one of the best graphics groups in the UC system. This group has close working ties with several agencies within the Silicon Valley, and has worked with other groups within the department, e.g., visualizing protein alignment data and real time environmental data. Careful hiring in the sub areas of Human-computer Interaction and virtual reality along with the development of a top-notch display showcase/virtual reality lab will allow UCSC to become a national leader in this field. This also ties into Computer Gaming and Digital Media research.

Software Engineering is one of the major programmatic initiatives of the School of Engineering; as such, it is a planned area of excellence of both the Computer Science department and the School of Engineering as a whole. The Computer Science department is taking the lead to successfully develop software engineering at UCSC with the help of the CE department. Our initial hire in the area, Assistant Professor Jim Whitehead, has an NSF CAREER award. More recently, Associate Professor Cormac Flanagan won a Sloan Fellowship. We see an opportunity for UCSC to achieve national eminence in this area by hiring outstanding software engineering faculty, developing first-rate graduate programs, and establishing a high-profile research and educational presence at the Silicon Valley Center.

We are currently recruiting faculty in Computer Gaming in order to create a new sub-major. This is important in that computer gaming is a fast growing research area that integrates existing strengths in the department. Graphics, AI, Software Engineering are critical to such an effort as is the Digital Media program making this an interdivisional initiative.

ELECTRICAL ENGINEERING RESEARCH PROGRAMS

Since its formal establishment in AY2000-01, the Electrical Engineering has endeavored to advance a research agenda in a few focused, but overlapping areas. These focus areas broadly include the following:

- Photonics and electronics;
- VLSI, MEMS, and nanotechnology; and
- Signal processing, communications and remote sensing.

Although we are still focused in these general areas at some level, there is significant overlap between these areas and we have begun to emphasize life science applications in most of the areas. We see the intersection of the life sciences with engineering (and particularly electrical engineering) as one of the intellectually exciting areas of the future. This is true not only for the instrumentation arena, but also in the biomedical, environmental and materials areas as well. The department is beginning to build up major foci in these application areas. Building on existing strengths, we are beginning to develop nano/microtechnology for a variety of bio/biomedical applications. A key strength of the department and a major distinguishing feature is the research focus on the underlying science necessary to solve important engineering problems.

Our faculty have key collaborations across divisional boundaries with colleagues in Applied Mathematics, Astronomy, Chemistry, Physics, Molecular, Cell and Developmental Biology, Earth Sciences, Ocean Sciences, and Education, both on and off campus, and with various medical schools. In addition, EE faculty not only have research ties with colleagues in all of the other engineering departments at UCSC, but also, faculty from those departments teach courses that some of our students are required to take.

EE faculty have played major roles (PI or co-PI) in large scale, externally funded, multi-investigator, multi-institution research centers. The NSF Engineering Research Center in Biomimetic, Microelectronic Systems (USC, lead; UCSC, CalTech) and the ONR Center for Thermionic Energy Conversion (UCSC, lead; UCB, UCSB, Purdue, Harvard, North Carolina State) are just two examples.

We also see the intersection of the environmental sciences and electrical engineering as another emerging area in which our faculty are getting involved. They are not only working on both developing novel forms of remote sensors for earth and ocean environments, but they are also investigating many aspects of the “physical layer” of wireless communications needed to tie networks of sensors (radar, sonar and optical) together in order to sense multidimensionally on a large scale.

With a significant program in opto-thermo-electric conversion devices, some faculty members in the EE department are also looking at alternative methods of energy conversion.

The other exciting area in which we plan to expand (and which overlaps with the other areas) is that of low power/analog/mixed signal circuit design. The need for such circuitry not only in biomedical diagnostics, but also in many other remote sensing and communication scenarios is enormous, and there is a pressing need for students skilled in that art in the industries of northern California and elsewhere.

A planned expansion in "materials for devices" is consistent with the university effort to build up a materials research core between physics, chemistry and EE and a biomaterials emphasis with MCD Biology; the ultimate goal being to propose to develop a NSF funded Materials Science and Engineering Center (MRSEC) at UCSC. There is a consensus among SOE and the Division of Physical and Biological Sciences that bringing together condensed matter science, materials chemistry and application development in a limited number of important focus areas is the most important approach in laying the groundwork for a MRSEC, provided that the applications drive the foundational science. Towards this end, the SOE and the Division of Physical and Biological Sciences will be putting together a committee to further explore the recommendations of the 2005 Materials Initiatives white paper.

If we are serious in carving a niche for nanotechnology at UCSC, we need to concentrate on bringing in external dollars for large-scale research centers where we can take advantage of the economy of scale and leveraging which such centers allow. EE faculty are deeply involved in building collaborations with the University Affiliated Research Center at NASA-Ames, not only in developing joint programs, but also in the planning of the Bio-Info-Nano Research and Development Institute (BIN-RDI) to be developed at the Ames Research Park. Such development will aid in our goal of creating large-scale research centers led by EE faculty and crossing departmental and divisional boundaries.

In addition to having EE play a major role in developing a materials research effort here at UCSC, we also are looking towards having an NSF funded ERC (or equivalent) led by EE faculty within the next half decade. We are exploring the idea of initiating a Center for Nanotechnology and Renewable Energies. An EE faculty member is looking at the possibility of proposing an ERC in Adaptive Optics as the successor to the NSF-funded STC Center for Adaptive Optics among several possibilities. Finally, we are bringing together faculty from diverse disciplines from UCSC and NASA-Ames to look at the possibility of putting together a proposal for a Center for the Exploration of the Limits of Life (CELL) in the next round of NSF Science and Technology Centers (2007). We see the cost-effectiveness of large scale centers not only from a research point of view, but also from the point of view of being able to allow students to participate in solving large scale, important societal problems, and in being able fund the resources to deliver more professional development opportunities to students (such programs are integral components of such centers). Furthermore, such centers are able to offer more outreach opportunities to students traditionally underrepresented in engineering disciplines. We will work closely with the Graduate Division as we begin to put together such center proposals such that we can leverage and augment the professional development programs already in existence at UCSC.

There are several key issues that the department faces in the near-term and long term. The most critical one is that of appropriate infrastructure. As the EE department has grown in the device and nanotechnology area, more materials processing needs and specialty spaces have become essential. Moreover, some of the areas of proposed expansion will also be heavily in such areas because those are the exciting interface areas of the future and there will be an increasing demand for students trained in those areas in Silicon Valley industries. Thus, there is a critical need in EE for wet chemistry, materials processing and characterization space (much of this needs to be in vibration and EM interference free environments). Please see the EE 5-year plan in the appendix section for specific recommendations.

Future Opportunities for Investment in New Endeavors

As mentioned previously, we plan to develop a coherent materials effort at UCSC in collaboration with the Division of Physical and Biological Sciences with the ultimate aim of being successful at bring an NSF funded MRSEC to UCSC. Coupled with the materials efforts going on at NASA-Ames and the development of a Bio-Info-Nano Research and Development Institute there and the potential of the TI building for further long-term expansion, we feel we are moving in the right track to have a successful end.

Plan for Extramural Research Support

As mentioned previously, the present external funding per faculty FTE in EE is about $320K per year (about $4.1M total last year excluding gifts). This external funding per faculty has been steadily increasing since the EE department's inception. Our goal is to increase the external funding level to be more like $500-$600K per faculty by 2010, consistent with the top ten EE departments to the country. We plan to do this by concentrating on several approaches:

- Developing interdisciplinary training program proposals to the NSF, NIBIB and DofED, to name a few. These proposals will allow for more multiyear promised financial support than we can do at present. (currently we can offer none!) Moreover, such programs will allow for student rotation in different labs the first year and will provide leverage for further research grants. This should increase the quality of our graduate students and make us more competive with other major research institutions in graduate recruitment;
- Concentration of efforts in developing large scale externally funded center grants, such as ERC's, STC's and NCRR resources;
- Increase the diversity of funding sources to include a wider range of federal agencies as well as private foundations;
- Develop closer ties to the national labs and NASA-Ames (through the UARC and the BIN-RDI); and
- By actively recruiting U.S. citizens and permanent residents to our graduate program. This will allow us to increase the number of students per research dollar, thus facilitating more ambitious programs to be undertaken.

As the department matures, we hope to be able to operate in the black and get the cash flow necessary to develop the administrative infrastructure to allow the faculty to more easily put together large scale research proposals. At present, we have faculty actively involved in investigating the possibilities of proposals for externally funded centers on the following topics:

- An ERC for Nanotechnology and Renewable Energy Resources;
- An ERC for Adaptive Optics;
- An STC for a Center for the Exploration of the Limits of Life;
- A training program in Imaging Across Scales;
- An Institute for Air Traffic Management (with the UARC);
- A Materials Science and Engineering Research Center; and
- A Center for Innovative Materials, Sensors and Systems.

It needs to be mentioned again, that a crucial aid in allowing to pursue these various pathways is the ability to be able attract esteemed research/adjunct faculty. UCSC needs to be able to streamline the process in which we get adjunct appointments. This is not only a problem for electrical engineering, and engineering as a whole, but will also be a program for the proposed School of Management.

TECHNOLOGY AND INFORMATION MANAGEMENT RESEARCH PROGRAMS

Research Overview

TIM faculty will carry out cutting edge research in business intelligence, service engineering, knowledge engineering, risk engineering, new product development, innovation management, enterprise integration, and application of knowledge and emerging technologies to business enterprises. More specifically, we have identified service science and knowledge engineering as the most exciting opportunities for the near future. Our prior research work and on-going collaboration with Silicon Valley companies, such as Cisco, IBM, Yahoo, and HP have given TIM a major advantage in business knowledge engineering. We will sustain our excellence in this area, especially in the context of service economy.

There are several future opportunities for investment in new endeavors including

- Robotics for business;
- Knowledge engineering in health system or biology;
- Information management in social networks; and
- Managing innovation.

These new endeavors provide significant opportunities for interdivisional collaborations with many departments within School of Engineering and Division of Social Sciences. We are extremely well poised to take advantage of campus schemes to promote interdivisional collaboration.

Plan for Extramural Research Support

The five TIM faculty are actively engaged in seeking extramural research support. With only 1 tenured faculty (mostly tied up with administration and service) and 3 tenure track faculty with average time at UCSC being less than 1 year, and 1 adjunct faculty (who is teaching 4.2 classes a year and shouldering several responsibilities including undergraduate directorship and SVC infrastructural development and outreach), we believe TIM has made excellent progress. Successful funding in the past couple of years include two NASA projects funded through UARC competition, and research projects funed by HP and Cisco.

2003-04 was the first year for TIM with Professor Ram Akella being the only faculty with the mission of building the program and no extramural funding was obtained that year. During 2004-05, Professor Akella obtained $64,000 from HP, $15,000 from Cisco and $132,000 from NASA for a total of $211,000. During this period, Prof. Kevin Ross obtained $31,958 from NASA/UARC funding. Thus, the total funding received by the TIM program during 2004-05 was $243,000 approximately. Prof. John Musacchio joined in January 2005 and Professor Yi Zhang has joined in Fall 2005.

TIM faculty is engaged in writing a NSF CAREER grant, two or three collaborative NSF grants, grants in collaboration with CE and Economics faculty. TIM has submitted a grant to Samsung in collaboration with the SOE Dean. TIM is interested in participating

in an IGERT grant and is looking to campus leadership to articulate some principles (such as no more than two chances to one group) so that every group can get a fair chance of participating in these grants which are limited to two per institution. TIM faculty is actively pursuing several industry contacts with many companies including IBM for research funding.

Campus funding for seed projects involving interdivisional collaboration will also prove very useful to TIM faculty.

FOCUSED RESEARCH CENTERS

Introduction

The purpose of the School's focused research centers is the fostering of interdivisional interactions through joint research projects, coordinated faculty hiring, and the development of joint academic programs designed for a better understanding of information technology, engineering and industry.

The School plans to have three organized research units: Center for Biomolecular Science and Engineering, Institute for Networking, Information Technologies Institute and the Center for Innovative Materials, Sensors, and Systems. These units will be centered on multidisciplinary science and engineering including materials engineering, life science engineering and environmental engineering. Each unit encompasses a set of research activities with focus on our targeted areas of excellence.

1. The Center for Biomolecular Science and Engineering (CBSE)

The Center for Biomolecular Science and Engineering is the most mature of the Focused Research Activities (FRA) housed within the Baskin School of Engineering. It supports interdisciplinary endeavors in engineering and science, offering unique opportunities for research and learning in bioinformatics and related fields. The blend of academic programs at UCSC allows students to pursue challenging avenues of study in biomedical research, bioinformatics, environmental toxicology, and related areas at the forefront of discovery. Community studies and philosophy programs address the ethical, social, and legal implications of today's scientific research.

Directed by Biomolecular Engineering Professor and Howard Hughes Medical Institute (HHMI) investigator David Haussler, the CBSE currently has 62 faculty members from 12 departments spanning the School of Engineering, the Division of Physical and Biological Science, and the Division of Social Sciences:

- Applied Mathematics and Statistics (4);
- Biomolecular Engineering (8);
- Chemistry and Biochemistry (16);
- Community Studies (1);
- Computer Engineering (4);
- Computer Science (3);
- Ecology and Evolutionary Biology (1);
- Electrical Engineering (3);
- Environmental Toxicology (5);
- Molecular, Cell and Developmental Biology (15);
- Philosophy (1); and
- Physics (1).

The CBSE first took shape in 1999 and became an official FRA early in 2001. Contrary to the original plan, the CBSE will not apply to become an Organized Research Unit (ORU), because UCOP no longer funds these entities.

The CBSE mission
CBSE fosters interdisciplinary research and academic programs that address the scientific questions of the post-genomic era—the scientific opportunities resulting from the completion of the human genome project and the sequencing of other model organisms. It serves as an umbrella organization to promote the exploration of new biological and biomedical questions resulting from genome sequencing and advances in biomolecular science. Its affiliates blend cutting-edge computational approaches with new research in biology, chemistry, and engineering.

CBSE takes advantage of our location in the San Francisco Bay Area and proximity to Silicon Valley to foster research collaborations between UCSC and other world-class institutions (Stanford, UC Berkeley, UC San Francisco) and leading biotechnology and high tech companies.

Goals:
- Promote interdisciplinary research in areas that encompass the study of genomic information and structural biology;
- Support the UCSC Genome Browser, a crucial resource for the international scientific community;
- Support a core of facilities, such as the KiloKluster data processing system and microarray facility;
- Help meet the need for trained professionals in industry and academia by developing courses, curricula, and internships leading to degrees in the areas of bioinformatics and biomolecular engineering;
- Attract research funding for the center, for affiliated faculty, and for students from federal, state, and private agencies; and
- Cultivate and maintain mutually beneficial relationships with industry through research collaborations, internship opportunities, and gifting programs.

Participation in multi-campus organizations
The CBSE serves as the contact point and administrator for UCSC's involvement in two multi-campus organizations, the California Institute for Quantitative Biomedical Research (QB3) and the Bioengineering Institute of California.

- QB3: The CBSE coordinates UCSC's participation in QB3, one of the first California Institutes of Science and Innovation (Cal ISI). A cooperative effort between UCSF, UCB, UCSC, and industry, QB3 endeavors to harness the quantitative sciences to create fundamental new discoveries, products, and technologies for the benefit of human health. The CBSE also served as primary consultant in the design of QB3-funded space in the new Engineering 2 building, completed in summer 2004 and in the new Physical Sciences building, which is nearing completion.

- Bioengineering Institute of California: The CBSE coordinated UCSC's participation in a proposal for the Bioengineering Institute of California, a UC-wide Multi-Campus Research Unit (MRU). This proposal was accepted in 2003, and CBSE now represents the campus in this institute. The institute focuses on intercampus research in the area of biomedical engineering. It facilitates an annual symposium on bioengineering that brings researchers from throughout the University of California together with scientists from California industry. The institute also directs itself toward providing the infrastructure for intercampus communication, data sharing, and broadcasting of teaching materials.

Accomplishments and focus areas

The CBSE first took shape in 1999 and became an official FRA early in 2001. Rather than pursuing a defined academic vision, the CBSE has worked in support of departments and faculty affiliates to help bring to fruition academic objectives that are in line with our mission, such as training grants and the development of new departments and facilities. For example, the interdisciplinary research and faculty recruitment efforts of the CBSE paved the way for the creation of the new Biomolecular Engineering department in the School of Engineering. The programs and projects described below further illustrate the role that CBSE plays in the academic fabric of UCSC.

- First working draft sequence of the human genome: On July 7, 2000, Jim Kent and David Haussler posted the first working draft of the human genome sequence on the internet at www.genome.ucsc.edu for free and unrestricted access by all people. Within 24 hours, the scientific community downloaded one-half trillion bytes of information from the UCSC genome server, their first access to the assembled blueprint of our human species.

- The UCSC Genome Browser: Soon after the initial posting of human genome on the UCSC website, Haussler and Kent developed an interactive genome browser, now used by thousands of biomedical researchers every day. The publicly funded UCSC browser allows researchers to view all 23 chromosomes of the human genome at any scale from a full chromosome down to an individual nucleotide. Since releasing the human genome, they have performed related work for the mouse, the rat, other mammals, and more distantly related species. This unprecedented tool opens up a deeper understanding of the origins of disease and the evolution of our species. It is used extensively in biomedical research, accessed by thousands of researchers from around the globe every day. The Genome Browser project now employs a staff of 20, which is expected to grow by half over the next five years. The browser forms the basis for many graduate and postdoctoral research projects focused on understanding the nature of the human genome and how its code translates to organism development and function.

- Bioinformatics graduate programs: CBSE developed and submitted the proposal for the Bioinformatics M.S. and Ph.D. programs, which became formal in fall 2003. UCSC has developed one of the top bioinformatics research programs in the country under the leadership of David Haussler, Kevin Karplus, and Richard Hughey. UCSC

is now the only UC campus and one of just seven universities in the United States to offer all three degrees in bioinformatics. From the time they arrive on campus, bioinformatics M.S. and Ph.D. candidates participate in cutting-edge research.

- Department of Biomolecular Engineering (BME): CBSE developed the proposal for this new department, launched In February 2004 within the School of Engineering. The BME department features an interdisciplinary blend of engineering, biology, and chemistry designed to foster collaboration with other departments. This interdisciplinary department reflects our vision of the direction that biomedical discovery will take over the next two decades. The department has 8 faculty members to date and is expected to grow to 14.

- NIH training grants: CBSE assisted the departments of biomolecular engineering and of molecular, cell, and developmental (MCD) biology in applying for and receiving NIH training grants designed to support graduate students involved in specified areas of biomedical research. In addition to directly supporting graduate students, the grants also provide flexible funding departments can use to support graduate training programs. The five-year grants amount to $850,000 for MCD biology and $800,000 for biomolecular engineering. Under these grants, student training includes a rotation program in which they spend time working in different laboratories with faculty in both biomolecular engineering and MCD biology.

- Stem cell training grant: CBSE coordinated and submitted a proposal to the California Institute for Regenerative Medicine (CIRM) for a 3-year, $1.2 million training grant to establish a new training program in the systems biology of stem cells. This grant will fund the training of three graduate students and three postdoctoral fellows each year. CBSE will support this program in a number of ways, including administering the budget, hiring staff, establishing the laboratory facility, coordinating the development of the curriculum, and the selection and disbursement of fellowships. David Haussler will serve as program director, and 11 other faculty from the departments of biomolecular engineering, electrical engineering, and MCD biology will serve as mentors. This program reflects our commitment to interdisciplinary research and education at the interface of science and engineering, and it takes advantage of the fact that many of our faculty regularly work across the divisional boundaries. The program will underscore the value of stem cell research in developing therapies and cures for human disease and establish UC Santa Cruz as a stem cell training and research center.

- Bioengineering symposium: In June 2005, UCSC hosted the 6th annual UC System-Wide Bioengineering Symposium for the Bioengineering Institute of California. The CBSE coordinated every aspect of this annual event, a three-day symposium entitled, "Envisioning the Biomedical Future." The symposium had 172 participants from the biotechnology industry, the National Institutes of Health, and all of the UC campuses. It brought together a broad range of scientists and students to exchange ideas and share recent advances in the field of bioengineering. Speakers throughout the symposium showed how advances in biomolecular engineering are shaping the

biomedical future. And UCSC researchers are among those at the forefront of these developments.

- Diversity outreach activities, fellowships & awards: CBSE works to increase the diversity of students and researchers involved in genome research and in exploring its surrounding ethical, legal, and social implications. Through an NHGRI-sponsored program, the CBSE actively recruits students at national conferences hosted by SACNAS, SHPE, NSBE, and SWE, and through programs such as MESA, CAMP, MARC/MBRS, MEP, ACE, and ACCESS. The CBSE hosts an annual summer workshop on genome-related research for students and teachers. We offer diversity fellowships to graduate students and awards to undergraduates at UCSC who are working on genome-related research projects. We also increase public awareness of the potential benefits and risks of genome research through talks offered to schools and community groups.

- Research collaborations among faculty in different fields. Here are a few notable examples:
    - The CBSE coordinated and obtained a $1 million Packard Foundation grant, "Bioinformatics and Microarray Expression Analysis of Nervous System Function," that allowed UCSC to build and staff a state-of-the-art microarray facility, directed by HHMI Professor Manny Ares in MCD biology. This grant ran from 2000 to 2004, with an extension to 2005;
    - Recent research characterizing a potential drug target on the SARS virus that began with the development of a genome browser for SARS in the Center for Genomic Sciences and was conducted by two different laboratories in the MCD biology department and the chemistry & biochemistry department; and
    - Nanopore detectors, instruments built around a tiny pore in a membrane or thin, solid-state wafer, hold promise for genome sequencing. This project resides in the biomolecular engineering lab of Mark Akeson and David Deamer (chemistry and biochemistry). Early on, a computer science graduate student developed a machine-learning algorithm capable of identifying the DNA base pairs in real time as they enter the nanopore, creating an interdisciplinary collaboration that continues today, now that he is an assistant professor at another institution. This device, when fully developed, should have many possible uses such as DNA fingerprinting, detection of disease genes, and pathogen identification.

Funding and operating expenses

Most of the major funding agencies and private foundations allocate substantial portions of their budgets to research awards in areas relevant to the CBSE—bioinformatics, proteomics, and various types of technology development. The CBSE faculty affiliates are strong candidates for such awards, and individually and through collaborative projects organized by the CBSE, they have had extraordinary success in obtaining extramural funds.

CBSE operates entirely from extramural sources. David Haussler's NHGRI award covers most of the genome browser staff, postdoctoral scholars, graduate students, undergraduate researchers, some administrative staff, and our outreach coordinator. Further funding for research staff and postdoctoral students is derived from Haussler's grant from the National Cancer Institute. The Howard Hughes Medical Institute (HHMI) directly employs some of our staff, and covers much of the operating budget for the CBSE office and for the Haussler wet lab. QB3 funds some administrative staff and capital projects and will soon begin to offer funding for postdoctoral scholars and graduate students to be distributed among QB3 affiliates at UCSC.

The CBSE currently has 28 staff members associated with the Haussler laboratory and the UCSC Genome Browser: 5 administrators and 23 research and technical staff members. We expect this staff to grow further within the next 5 years. The CBSE also funds 6 postdoctoral scholars and about a dozen graduate students.

2. The Information Technologies Institute

The Information Technologies Institute (ITI) is a Focused Research Activity (FRA) and is operationally within the Baskin School of Engineering (SOE). Via its research centers, ITI focuses research in an inter-related set of areas of interest to faculty in Computer Science, Computer Engineering, and Electrical Engineering (as well as some from Physics, Chemistry, and Applied Mathematics).

Areas of emphasis include:

- Design and development of complex networked systems and software technologies;
- Storage systems and databases;
- Multimedia systems and applications in education and business management;
- Communications;
- Opto-electronics (including nanotechnology devices);
- VLSI design, packaging, testing;
- Sensors, sensor systems and Internet appliances;
- Visualization and computer graphics;
- Knowledge management / data mining; and
- Decision support tools.

For ITI, advanced "Internet" applications provide the impetus and focus that bring together the components of research related to the rapidly expanding world of networks, distributed computing, "smart" sensors and Internet appliances. As electronics and packaging developments lead to low cost and powerful sensors, resulting in a broad array of instruments, these become Internet devices, bringing a significant increase in the data captured, transmitted, stored, managed, and displayed. ITI also promotes research in applications of the emerging capabilities of the Internet to such exciting areas as distance education and telecollaboration, environmental monitoring, and resource management.

Directed by Computer Engineering Professor Patrick Mantey, ITI has faculty from throughout the School of Engineering, and also has participation from the Division of Physical and Biological Science, the Division of Social Sciences and the Arts.

ITI was proposed as part of the campus initiatives in 2000, and was organized as an official FRA early in 2001. Contrary to the original plan, the ITI has not pursued becoming an Organized Research Unit (ORU), as an ORU appears to bring no new funding nor other apparent advantages over an FRA.

The ITI mission

ITI functions as an umbrella organization, providing the organizational and management structure to support large and interdisciplinary projects. It also facilitates the management and sharing of resources and staff (including administrative support and also technical staff).

A major function of the ITI is the coordination and management of interactions and cooperation with industry. These include arrangements for industry research staff working at ITI on cooperative projects with industry. A major focus of ITI is facilitating the developing partnerships with the information technology industry, especially in Silicon Valley.

Goals

- Promote leading-edge research in information technologies and applications;
- Provide staff and facilities for large, multi-year and multi-disciplinary research projects;
- Attract research funding for the center, for affiliated faculty and staff, and for students from federal, state, and private agencies; and
- Cultivate and maintain mutually beneficial relationships with industry through research collaborations, internship opportunities, and gifting programs.

Participation in multi-campus organizations

The ITI serves as the contact point and administrator for UCSC's involvement in the Center for Information Technology Research in the Interest of Society (CITRIS).

CITRIS is one of the California Institutes for Science and Innovation (Cal ISI), and ITI coordinates UCSC's participation in CITRIS. Professor Patrick Mantey also serves as director of CITRIS at Santa Cruz. CITRIS has provided funding for the research space on the 5th floor of the new Engineering 2 building, completed in summer 2004, and housing ITI / CITRIS activities.

Cooperation with other campus organizations

The ITI has on-going partnerships with:

- STEPS (Science, Technology, Engineering, Policy) Institute for Innovation in Environmental Research;
- UCSC Center for Remote Sensing;
- University Affiliated Research Center of UC and NASA Ames;
- Monterey Bay Aquarium Research Institute;
- Center for Integrated Marine Technology / UCSC Institute of Marine Science;
- UCSC Environmental Toxicology Department;
- UCSC Center for Biomolecular Science and Engineering (CBSE); and
- California Institute for Quantitative Biomedical Research (QB3) at UCSC.

Accomplishments

The ITI has supported the creation of and/or the work of a number of research centers and projects.

Included are:

- Storage Systems Research Center (SSRC);
- Dynamic Ad-hoc Wireless Network Center (DAWN);
- Thermionic Energy Conversion Center;
- Biomimetic MicroElectronic Systems (BMES);
- Quantum Electronics Group;
- Computer Communications Research Group (CCRG);
- Inter-Networking Research Group (i-NRG);
- UCSC Scientific Visualization Laboratory;
- UCSC Visual Computing Laboratory; and
- Information Retrieval / Knowledge Management Center.

ITI / CITRIS has also supported the work of:

- Digital Arts and New Media Program (DANM);
- CARNIVORES (partnership with STEPS);
- MicroArchitecture at Santa Cruz (MASC);
- Assistive Technology;
- Multidimensional Signal Processing Group;
- Enterprise Cockpit;
- Santa Cruz Agent Technology & Environments Research (SCATE);
- Center for Stock Assessment Research (CSTAR);
- Real-time Environmental Information Network and Analysis System (REINAS);
- HF Radar Project; and
- Sea Labs.

3. Center for Innovative Materials, Sensors and Systems (CIMSS) -- Proposed

The Center for Innovative Materials, Sensors and Systems (CIMSS) will promote research in both biomaterials and novel functional materials critical for biotechnology, information technology, nanotechnology, smart sensor development, environmental sensing, and environmental technology, nanoelectromechanical systems, microarrays and microrobots. Technology development for sustainable products can also be an important research mission in order to ensure that future industrial products and services are ecologically balanced, environmentally sound, and socially responsive to ensure a collective future for all mankind. The SOE anticipates playing a leading role in the development of a proposal to establish a NSF-funded Materials Science and Engineering Research Center at UCSC. This fits in with our long-term goals of establishing CIMSS. We plan to build multidisciplinary academic research programs in materials science and engineering, biomedical instrumentation and environmental engineering following the example of the biomolecular engineering program through the Center for Biomolecular Science and Engineering (CBSE). Furthermore, CIMSS would also be synergistic with our nascent proposal to develop a Center for the Exploration of the Limits of Life (CELL), which would bring together engineers, microbiologists, chemists and other disciplines to explore the fundamental limits of living organisms.

Potential participants could include professors Ali Shakouri, Holger Schmidt, Michael Isaacson, Wentai Liu, Joel Kubby, Ken Pedrotti, John Vesecky, Claire Gu and others in the EE Department: Susan Carter, and Sriram Shastry in Physics; David Deamer, Jin Zhang, and Shao-wie Chen in Chemistry; Todd Lowe in Biomolecular Engineering; and, Russ Flegal in Environmental Toxicology. Additionally, the new tenured hire in EE in materials devices will also play a key role.

4. Institute for Scalable Scientific Data Management

Institute for Scalable Scientific Data Management (ISSDM) will address looming issues of data storage and management for projects that involve large-scale simulation and computing. The University of California, Santa Cruz, and Los Alamos National Laboratory have agreed to establish a new collaborative institute for research and education in the area of scientific data management. The institute will provide opportunities for UCSC graduate students to gain specialized experience and expertise in scientific data management by working on large-scale computing projects at Los Alamos. In addition, the students who take advantage of these opportunities will provide a pool of potential employees for the laboratory with skills in key areas of computer science and data management where the lab foresees significant staff needs in the future. It is anticipated that annual LANL funding of this activity will be in excess of $1M over the next five years.

5. Research Institute in Applied Mathematics and Statistics (RIAMS) -- Proposed

Research Institute in Applied Mathematics and Statistics will enable UCSC to bring together a sufficiently large critical mass of researchers in Applied Math and Statistics

required to tackle large, difficult and important collaborative problems in fields such as astronomy/astrophysics, computational genomics, environmetrics, mathematical biology and robotics. As the West Coast center of excellence in these highly important research areas, RIAMS will greatly increase UCSC's visibility in the mathematics sciences.

6. Storage Systems Research Center (SSRC) is composed of faculty from the Computer Science, Computer Engineering, and Electrical Engineering departments. SSRC research focuses on caching, storage systems hierarchies, large-scale distributed storage systems, security and performance.

7. Dynamic Ad-hoc Wireless Networks (DAWN) is a collaborative effort to develop the technology for complex wireless communication networks that can be set up in rapidly changing environments such as battlefields and emergency situations. The Baskin School of Engineering will head a multidisciplinary team of scientists at seven major universities. The project also includes researchers at UC Berkeley, UCLA, Stanford University, Massachusetts Institute of Technology (MIT), the University of Maryland, and the University of Illinois at Urbana-Champaign (UIUC). It is funded by a five-year grant from the U.S. Department of Defense that will provide an average of $1 million per year spread among the seven institutions.

8. Thermionic Energy Conversion (TEC) Center is a collaborative and multidisciplinary project involving researchers at seven major universities working to develop new technology for direct conversion of heat to electricity. The researcher team is comprised of experts in mechanical engineering, electrical engineering, materials science and physics. With UCSC as the lead institution, the TEC center also includes researchers from UC Berkeley, UC Santa Barbara, Harvard University, Massachusetts Institute of Technology, Purdue University and North Carolina State University. It is funded by a five-year, $6M grant from the Office of Naval Research.

9. The Engineering Research Center for Biomimetic Electronic Systems (BMES) is part of a multimillion dollar NSF funded Engineering Research Center consisting of USC, CalTech and UCSC. The UCSC portion of this center emphasizes the development of the low power, mixed signal electronics necessary for development of biomimetic prosthetic devices for vision, memory and muscle function.