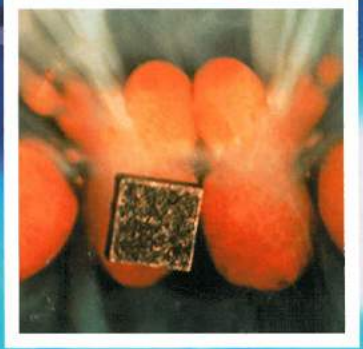
# EEK 2002

ANNUAL RESEARCH REVIEW

Electrical Engineering Kaleidoscope

A PUBLICATION OF THE ELECTRICAL ENGINEERING DEPARTMENT UNIVERSITY OF WASHINGTON



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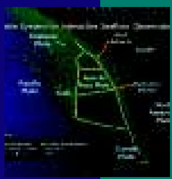







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## WELCOME TO EEK2002

The Electrical Engineering Department is the largest department in the College of Engineering at UW. We are dedicated to maintaining an atmosphere of cooperation that nurtures high-quality research and education, and which develops mature undergraduate and graduate engineers. Our department is in the midst of a period of dramatic growth and positive change. We moved into a new building in February 1998, and construction of an adjoining new CSE/EE building is underway. Since August 1998 we have grown through the addition of 14 outstanding new faculty. ALL of the assistant professors who have joined the department from 1998-2001 have received the NSF Early Career Development Award. Externally funded research in the department is increasing at a rate close to Moore's law—from $5 million in 1998-1999 to approximately $12.6 million in 2000-2001, and over $14M for the first six months of 2001-2002. Our goal is to become one of the very top EE departments in the world, through the delivery of outstanding and innovative education and the conduct of cutting edge research.

We are aggressively recruiting the very best graduate students. If you are a prospective graduate student, I encourage you to consider applying to our department. We have an extraordinary range of new and growing research projects that provide outstanding opportunities for graduate education and professional growth.

— Howard Chizeck,
Professor and Chair
Department of Electrical Engineering


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# HOW SWEET THE SOUND

## Scalable audio encoding provides new options for listening, sharing music

by Mary Ann Krug

Music lovers, take note: if fingernails scratching a blackboard sound better to you than music played over the internet, and the hefty cost of a high-speed connection keeps you buying CDs, stop despairing. A new method for processing audio files could change the way we share and enjoy music.

Professor Les Atlas and M.S. recipient Mark Vinton, both from the EE department's Interactive Systems Design Laboratory, recently made a patent application for their new audio-encoding technique, which they describe as fine grain scalable audio encoding. It produces a high quality sound even at low bandwidths.

Their success with this novel approach to audio encoding is based on a multi-university research initiative known as the Center for Acoustics and Auditory Research, funded through the Office of Naval Research.

The objective of the collaboration focused on "how our ears work, and using that understanding to improve and advance other areas of research," says Atlas.

Audio encoding was one of the areas that the research initiative was able to enrich. The popularity and convenience of sharing many kinds of files over the internet broadened interest in streaming media for sharing music and video images. Unlike other types of files, such as text or html files that can stand some delay while being accessed, streaming media files must be continually accessed during the download process.

Music must be encoded into digital format before it can be sent over the internet. As part of this signal transformation process, some qualities of the sound get lost. The qualities lost during this process vary with encoding software. Most encoders place information lost during the digitization step into frequencies that are the least perceptible to humans.

Since the human auditory system is most sensitive around 3000 Hz, this means lost information ends up in higher frequencies. When streaming media is sent over a typical phone line connection, the information transmitted at higher frequencies gets lost.

The new encoding technique developed by Vinton and Atlas is similar to MP3 files, but with one extra-and critical-step. That step is called modulation frequency analysis, which orders the elements of auditory recognition into a new level of abstraction.

"We pull sound apart ...from the slowest changes to the fastest changes, and we take the changes [too fast] for us to hear and don't transmit them," says Atlas.

The transmitted file ends-up devoting more content to the slower modulations that are more important for human auditory recognition, yielding music that sounds just a well with fewer bits. The

## HOW WE HEAR

A sound wave travels in longitudinal fashion, displacing air molecules as it travels. Some displacements cause air molecules to cluster together, while some spread air molecules apart, resulting in high and low pressure regions, respectively.

When sound travels down the auditory canal to the eardrum of the outer ear, high-pressure regions push the eardrum inward, and low-pressure regions pull it outward. This causes the eardrum to vibrate at the same frequency as the sound wave. Our ability to detect frequency enables us to distinguish the pitch of a sound.

Vibrations from the eardrum get transferred to the hammer, one of three tiny bones located in the middle ear. These bones serve as a system of levers that amplify and transfer vibrations to the inner ear. When the vibration reaches the stirrup, the smallest of the bones, the force acting on it becomes nearly 15 times that acting on the eardrum itself. This amplification allows us to hear very faint sounds.

The system of bony levers transmits vibrations to the inner ear, via the oval window, to the cochlea. The cochlea is a tiny coiled tube containing fluid divided into two chambers of roughly equal size. Inside the cochlea, thousands of tiny hair-like nerve cells exist, each varying slightly in size. The variations in size impart sensitivity to particular frequencies.

When the vibrations travel through the cochlea, they displace the fluid inside it, which causes the hair-like nerve cells to move. When a nerve cell encounters a wave with a frequency it is sensitive to, it responds by resonating with a larger amplitude of vibration. The amplitude of a wave allows us to distinguish the loudness of a sound.

This increase in amplitude is passed from the nerve cell to the auditory nerve and on to the brain in the form of electrical impulses. As these impulses travel up to the brain, they pass through structures called the "auditory midbrain." Auditory physiologists are finding that the concept of modulation frequency, where certain neurons signal slow changes and others signal fast changes, is common in the auditory midbrain.

The new encoding technique developed by Vinton and Atlas is similar to MP3 files, but with one extra-and critical-step. That step is called modulation frequency analysis, which orders the elements of auditory recognition into a new level of abstraction.

result? A remarkably clear, enjoyable musical experience over a dial-in connection.

The ability to provide CD quality sound with relatively little bandwidth provides several improvements for existing technologies, as well as new commercial applications.

Because bandwidth is not a critical limitation with this approach, an increase in channel capacity effectively results-users with broadband and DSL connections could now enjoy music without interruptions caused by increased connection traffic. The inherent scalability feature of the new technique enables internet-based radio stations to broadcast programming that accommodates users with slower connections without sacrificing quality for users with high-end connections and equipment.

"Scalability means that it's going to do the best it can, no matter what the available bandwidth is," explains Atlas. In other words as the amount of bandwidth shrinks, the encoder lowers the modulation frequency rate, and transmits only the most important elements for sound recognition. When more bandwidth is available, portions of the music with higher modulation rates (and less important auditory recognition qualities) are transmitted.

Other commercial possibilities include remote server access to audio files. A user could keep all music files on one central internet-based server, and retrieve them not only with computers, but cellular phones, beepers, and PDAs (personal digital assistants).

Atlas has high hopes for the new encoder, and is currently exploring commercial possibilities. EEK2002

Editor's note: *Mark Vinton has graduated and taken a position with Dolby Laboratories.*

# POWERING PROJECT NEPTUNE

## EE Researchers will Develop and Test Power Infrastructure for Seafloor Observatories

"Seafloor observatories present a promising, and in some cases essential, new approach for advancing basic research in the oceans."
—*National Research Council Report*

UNDER THE SEA. Submerged volcanic systems support a fragile microbial biosphere, hiding secrets to origins of life and even the formation of the earth and other planets.

Scientists everywhere are realizing that to understand the most complicated natural phenomena requires a cross-disciplinary approach to scientific investigation and discovery. Such realizations are prompting shifts in operational paradigms everywhere, including the earth and oceanic sciences. These new intellectual pursuits require longer, more extensive observations of deep-sea environments and natural events.

Technological advances in the field of electrical engineering help make these types of studies possible, providing "an extensive, remote, continuous and interactive sensor presence" within oceanic natural laboratories.

Such a presence requires a hefty undersea infrastructure.

A research team led by Bruce Howe and Tim McGinnis from the University's Applied Physics Laboratory, Harold Kirkham and Vatche Vorperian from the Jet Propulsion Lab of the California Institute of Technology, and EE Professors Chen-Ching Liu and Mohammed El-Sharkawi were recently awarded a 3-year, $2 million award from the National Science Foundation for the development of a power system for cabled ocean observatories, specifically Project NEPTUNE (North East Pacific Time-Series Undersea Networked Experiments). Their goal is to design a prototype for the NEPTUNE power system, including a 3,000 km fiber-optic/power cable that will lie on the sea floor.

The goal of NEPTUNE is to establish a submarine network of remote, interactive laboratories for experiments and observations on the Juan de Fuca Plate off the Pacific Northwest Coast. NEPTUNE will connect webs of sensors in, on, and below the sea to scientists, students, and the public on land. The NEPTUNE power system will deliver approximately 100kW to distributed science nodes on the seafloor with extremely high reliability. Their design of the new power system will incorporate standard telecommunications cable, regulated power supplies, and a multi-layered protection system. EEK2002


NEPTUNE cable system map. NEPTUNE will provide power and communications bandwidth via fiber-optic/power cables to junction boxes (nodes) on the Juan de Fuca Plate and surrounding areas. By connecting sensor networks to the nodes, with extensions onshore and offshore into the interior, scientists will, for the first time, have the capability to study a host of interrelated processes with high spatial and temporal resolution over long periods of time. (Graphic: *CEV*)

## F.I.R.S.T. ROBOTICS COMPETITION

Students working on Rainmaker II.

For the third year, UW EE will take part in the FIRST (For Inspiration and Recognition of Science and Technology) robotics competition. Most high school teams in this international competition have advisors from industry-but UW engineering students serve as the technical partners for our teams. On March 28th to 30th, UW will host the Pacific Northwest Regional competition. Approximately 34 teams will compete-including one from Brazil.

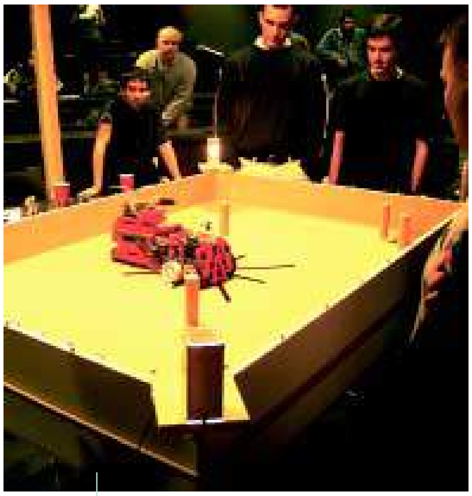
Last year students from UW and Bellarmine Preparatory High School designed Rainmaker II, which finished 25th out of 331 at the National Competition in Orlando. This was better than most university-backed entries. Our robot was dubbed "the six-wheeled wonder" on NASA TV. It received an award for "the most innovative locomotion mechanism." The faculty advisor of this activity, EE Assistant Professor Alexander Mamishev, reports that the students "considered this enterprise a very valuable learning experience of robotics, management, marketing, public relations, teaching, and life in general."

This year, UW engineering students will team with students from Roosevelt High School in Seattle. From the moment the rules are announced, the teams have only six weeks to imagine, design and build a mammoth 130-pound remote-controlled robot. For this reason, Team 824 calls itself: Students Working Against Time (S.W.A.T.) Robotics. For more information, go to http://swat.ee.washington.edu/

# BY POPULAR DEMAND:

## Robotics course sequence designed with students in mind

by Mary Ann Krug



Autonomous robots in competition.

"We wanted to give students the opportunity to build robots for a specific task," said affiliate assistant professor Linda Bushnell of the newly designed EE course sequence in autonomous robotics.

Bushnell took up the challenge of modernizing the courses when she joined the department last year. A former U.S. Army Research Office Program Manager and former faculty member at Duke University, she approached the course design very pragmatically, seeking out and incorporating student feedback. While Bushnell admits experience in C programming is helpful, there are no formal prerequisites for her multi-disciplinary robotics course sequence.

Instead of traditional exams, the courses have competitions between class teams. Student teams build several robots for different purposes during the academic quarter. Each team member is responsible for a particular aspect of the project, such as system integration, mechanical design, digital imaging, RF, or control systems.

The hands-on opportunity to build and design robots, along with interpersonal communication and project management experience make the courses extremely popular, both inside and outside of the department. Students from aeronautics and astronautics engineering, chemical engineering, mechanical engineering, computer science, and physics frequently enroll. According to EE student Dinh Bowman, the best thing about the courses is that regardless of academic background students "get to work on a multidisciplinary project that is still in their area of interest." EEK2002

# NSF GRANT BOLSTERS VLSI/CAD TEACHING

by Mary Ann Krug

The University of Washington Department of Electrical Engineering (EE) was recently awarded a $1.1 million NSF grant that will bolster the research and teaching efforts of the VLSI/CAD group. The group will use the funds to purchase computers, FPGA boards, and other equipment for both VLSI/CAD teaching and research laboratories.

"This is strictly an equipment grant, intended for [equipment costs] not normally covered in other grants," explained Associate Professor Scott Hauck, the grant's principal investigator. Co-investigators include EE Professors David Allstot, Scott Dunham, Carl Sechen, Mani Soma, and Gregory Zick, EE Associate Professor Richard Shi, and CSE Professor Carl Ebeling.

The EE VLSI/CAD group teaches a large range of courses, including a rigorous 3 course sequence: VLSI I, VLSI II, and VLSI III. Typical enrollment is 120 students and remains high throughout the entire sequence. On the teaching side, VLSI is the heaviest consumer of computer resources in the department. In private industry the computing and software resources provided would cost close to $1 million per person.

The highly anticipated award required a substantial matching contribution: approximately $290,000 will come from the university itself.

Hauck is optimistic about the impact of the grant on the VLSI teaching program. "This [grant] will give a greatly needed boost to the VLSI teaching program for the next 5 years," he said.

# LIFE ON A CHIP

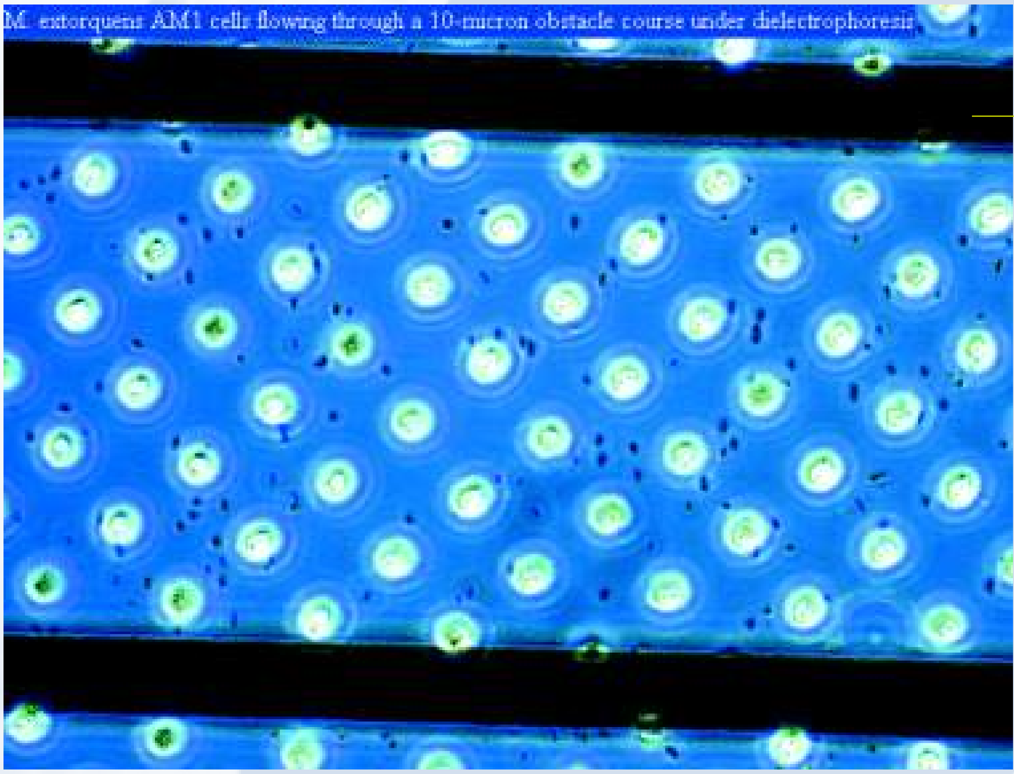
## The Continuing Saga of the Human Genome Project

Mary Ann Krug

Did last year's announcement that a draft of the human genome was complete leave you wondering "Now what?"

If so, then read on...






Bacteria (3-6 micron diameter) aligned in a dielectrophoretic field and separated by site in microsystem obstacle course.

Fettah Kosar, Mary Lidstrom
Deirdre Meldrum, Mark Holl

Photos by Fettah Kosar.

EE Professor Deirdre Meldrum (PI) and Associate Dean Mary Lidstrom (co-PI) received a $15 million award to start a Center of Excellence in Genomic Science (CEGS0 from the National Institutes of Health (NIH) National Human Genome Research Institute (NHGRI).

"It's a lot of money, but we have a lot to do," says Meldrum.

This CEGS grant is one of three that were awarded nationally, becoming part of the Human Genome Project (HGP) during its second phase, 1998-2003. The goals of the first phase, including a 'draft' sequence of the human genome, were accomplished on time or ahead of schedule. The full sequence, scheduled for completion in 2003, promises to give scientists massive amounts of raw data.

Data that needs to be digested, analyzed, and put to use.

Researchers want to correlate human sequence information with important biological processes, so that complicated activities such as cell proliferation, differentiation, programmed cell death (apoptosis), and disease progression and development (pathogenesis) can be thoroughly understood.

Current research protocols involve large cell populations containing individuals that vary greatly. When researchers measure cellular activity of a population, they essentially observe the average activity of its individual cells. This accounts for why biopsies and pap smears sometimes come out normal when they actually aren't—these tests use non-random samples of heterogeneous populations. Researchers need to account for the differences in activities of individual cells to understand the behavior of an entire population.

Since complex biological processes involve so many different events over time, the ability to study multiple activities of individual cells is needed. Such deep levels of understanding require technological capabilities that currently do not exist.

The CEGS co-directed by Meldrum and Lidstrom focuses on developing and enabling technology for the study of individual cells. Specifically, the center will build devices that detect rare cells within populations and perform real-time analysis of processes such as metabolism in individual cells.

These technological capabilities will take the form of individual modules designed to measure activity for single cells. Imagine a hypothetical protein X, associated with progression of a certain disease. A researcher might need to detect cells that produce the protein, and monitor activities associated with it. These activities might include DNA transcription, RNA translation, and numerous other factors before, during, and after the cell starts making protein X. The Center will design a module to study each of these events in real-time: life-on-a-chip.

According to Meldrum, the center intends to package these individual modules into kits, so researchers can select the characteristics they want to study and 'mix-and-match' the right modules to suit their needs.

Researchers want to correlate human sequence information with important biological processes, so that complicated activities such as cell proliferation, differentiation, programmed cell death..., and disease progression and development... can be thoroughly understood.

CEGS also serve as springboards for cross-disciplinary intellectual activity. At this CEGS, scientists from numerous life sciences and engineering disciplines collaborate. This CEGS currently draws on life science experts from genomics, proteomics, microbiology and analytical chemistry. It utilizes engineering experts from MEMS, nanotechnology, sensor fusion, detection, automation, and systems integration. EE faculty members Karl Böhringer, Denise Wilson, and Mark Holl currently collaborate with other CEGS scientists.

The feasibility of bringing this technology into existence is not so distant as it seems. Like many other high-technology fields, advances in electrical engineering and computer technology are driving progress in the Human Genome Project. Silicon chips that monitor cellular activity already exist (please see p.10 ). Meldrum's own EE research lab, the Genomation Laboratory, has developed microsystems that enable automation of large-scale DNA sequencing. The challenge will be to adapt existing areas of expertise to solving new problems.

Meldrum believes that efforts of this CEGS are "extremely" compatible with research going on in the Seattle area, which provides a host of potential collaborators.

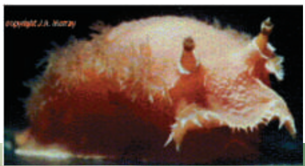
"We're bringing together a lot of groups that normally don't work together...as we move on and make progress, we want to bring in more researchers, applications and technology," explains Meldrum. EEK2002

Mary Lidstrom (L) and Deirdre Meldrum co-direct the College's new Microscale Life Sciences Center.

# Research Apprentices at Friday Harbor Help Devise Solutions to Understanding Brain Activity

Mary Ann Krug

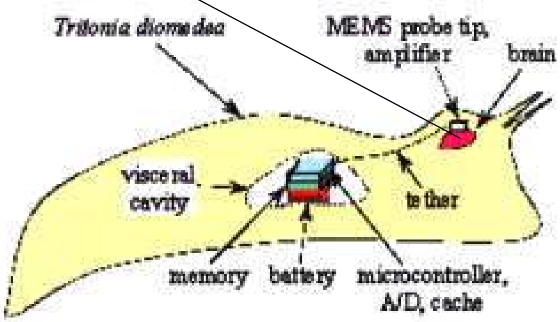
The inability of scientists to directly observe brain activity remains a major obstacle to an empirically based understanding of behavior.



This spring, EE undergraduates Nathaniel Jacobson and Jai Patel participated in a multidisciplinary research project aimed at providing new tools for solving this challenging research problem.

The goal of the project, which took place at the world-renowned UW Friday Harbor Research Facility, was ì to build a complete, stand-alone implantable microsystem for recording neural activity in freely behaving animals.î  EE faculty participation included Assistant Professor Karl Bˆ hringer, a MEMS expert, and EE Professor and Dean of Engineering Denice Denton, an expert in microfabrication and biocompatibility issues. Zoology Professors Dennis Willows and Thomas Daniel contributed their expertise on the animal species used in the project, while Computer Science and Engineering Associate Professor Chris Diorio contributed to chip design. Among the animal species selected to receive implantable sensors was Tritonia diomedea, a sea slug native to the Pacific Northwest. The selection of this animal was due to the extensive amount of knowledge that already exists about it; Willows has studied these creatures for years.

Conventional attempts to study brain activity involved sensors strapped to immobilized specimens, which prevented researchers from gathering authentic data on natural behavior. The sensors designed in this project are intended to be permanently implanted in animals, allowing neural data collection during normal activities. Unlike conventional sensors, which pierce cells with glass electrodes, the electrodes of the new chips are made of silicon. Researchers hope that the silicon electrodes will hold the sensors in place, so that the animals can be released into their natural environment for study. EEK2002




Above: A silicon chip implanted in the neural ganglia of Tritonia diomedea.

Top: Tritonia diomedea, a seaslug native to the Pacific Northwest and the model organism under study.

It looks like aerobics class, except these participants only move their hands. The instructor makes a rotating motion with his wrist and forearm, and his only pupil copies it closely.

Closely, but not perfectly.

The instructor shakes his head, and repeats the motion. The pupil concentrates harder, trying to mimic the movement exactly. When he succeeds, the instructor stops and nods quickly. The pupil repeats the motion correctly one more time, and nods slowly in understanding.

This exchange occurred during a meeting between members of EE Professor Blake Hannaford's research team, including Prof. Jacob Rosen and graduate student Jeff Brown, and medical surgical residents who train under Dr. Mika Sinanan in the UW Medical School Department of Surgery. The two groups are collaborating on developing instrumentative surgical tools and algorithms for objectively evaluating surgical skills that will improve the teaching of Minimally Invasive Surgery (MIS) to surgical fellows.

(MIS) has been practiced on a large scale for about 10 years in the United States. MIS replaces traditionally more invasive procedures for common operations such as gall bladder removal, and provides tremendous benefits for patients. Unlike traditional surgery, which involves making large incisions in the patient to accommodate the surgeons hands, MIS incisions consist of small ports, through which long tools and a camera are inserted. Because of these smaller incisions, patient recovery times are much shorter: 1-2 days instead of 1-2 weeks with traditional surgery. The shorter recovery times and decreased incidence of complications result in reduced healthcare costs.

The differences between MIS and more traditional invasive techniques present a unique set of challenges for training surgeons. In MIS procedures, surgeons lack direct physical contact with patients,

Most improvement in technique was achieved during the first 2-3 years of the 5-year surgical residency. After that point, technical progress increases less dramatically and cognitive skills develop more fully.

The Blue Dragon, a device for measuring the properties of endoscopic tools and for objectively evaluating a surgeon's performance.

making it difficult to gauge the appropriate amount of force and torque to apply during the operation. Surgeons also lack a direct line of sight, watching their progress through images projected onto a television from a tiny camera inserted into the patient.

Consequently, teaching by expert surgeons necessarily becomes more abstract, and evaluations of student progress more subjective. Currently expert surgeons evaluate progress by commenting on videotapes of procedures done by young surgeons. Still another challenge is distinguishing between technical skills and cognitive development of young surgeons. For example, if a procedure has 30 steps in it, and an inexperienced surgeon is having problems completing the operation effectively, is it due to a lack of surgical skill, or is it because they have a hard time remembering the precise sequence of steps 21-24? Current training techniques make it difficult to evaluate these kinds of questions.

"We started out designing special surgical instruments that measure the forces a surgeon is applying during the operation," says Hannaford. The sensors on the instruments collect large amounts of data on the mechanical forces exerted by the surgeons. The data is evaluated using statistical techniques, including Hidden Markov modeling.

Hannaford's team collected data from expert and inexperienced surgeons, who operated on an animal model system, and created a quantitative basis for comparing their respective skill levels. Comparing data generated by surgeons of different levels of expertise provides a more objective method of evaluating skill level and progress.

Their preliminary data revealed some interesting facts about development of surgical skills. Most improvement in technique was achieved during the first 2-3 years of the 5-year surgical residency. After that point, technical progress increases less dramatically and cognitive skills develop more fully. The EE researchers and their collaborators in the department of surgery are currently planning a longitudinal study of surgical residents in the department of surgery.

Editor's Note: *Blake Hannaford, Jacob Rosen, and Mika Sinanan recently received a 4-year, $1.4 million grant to develop minirobots for telesurgery for battlefield surgery.*

# Reflection

by Howard Chizeck

We know now the "real" starting date of the twenty-first century. The terrorist attacks of September 11, 2001 changed our nation. Some experienced personal grief and pain. Most were shocked and shaken by a sudden loss of safety, by our vulnerability and the realization that some people want to kill us badly enough to sacrifice their own lives in the process.

On 9/15 a memorial was scheduled at the Seattle Center to honor the victims of the 9/11 attacks. There were no speeches or formal programs. Crowds brought flowers and stood vigil for 3 days and 3 candle-lit nights, accompanied by flutes, native drummers, Spanish guitars, and funeral trumpets. The vigil was scheduled for only 3 hours. (Photo by Carson Jones)

Initial responses to these events were followed by attempts to understand the meaning of the attacks and their consequences. We may not yet know how these events will change our individual lives and communities, but there has clearly been a change in national perceptions and in resource allocations. Any major change in perceptions and resource allocations is a turning point for our society.

We have been thrust into war by forces opposed to the globalization, free exchange of ideas and societal change that arise from technology. The use of commercial airliners and passengers as weapons of mass destruction was directed against a key component of global civilization-the air travel system. The initial attempt against LAX (aborted by quick thinking by border guard in Port Angeles, Washington), the destruction of 9/11, and the later attempt to use a shoe bomb to murder the passengers of a trans-Atlantic airliner were all attacks against the rapid movement of people across national and cultural borders.

The attack on the twin towers was also an attack on the system of world trade. It was meant to permanently impair the world economy. Ironically, our often-questioned y2k preparation greatly mitigated the systemic effects of this violence. Brokerage houses and financial institutions that were physically destroyed in the World Trade Center were quickly returned to operation because of backup and recovery procedures that were developed for y2k.

*We are engineers. Our business is knowledge, understanding, reason, and problem solving. How can we constructively respond to this changed world?*

Attention has turned to technological preventions, responses and countermeasures to terrorism. Many involve Electrical Engineering. Of course, the very best technology is useless if the training and management of those who use it is inadequate.

Sensor technologies under development to detect food-borne bacteria and viruses may be applicable for the rapid detection of bioweapons. Other sensors may identify chemical weapons, explosives and radioactive threats. Recent innovations in genomics and proteomics have the potential to facilitate rapid vaccine development, and may yield the broad-spectrum antiviral agents that will be needed to protect our population from unexpected attacks by biological weapons.

To prevent future use of civilian aircraft as weapons, a multitude of ideas for research and development have been proposed, including: hardened and alarmed cockpit doors; remote control of aircraft; emergency broadcast of cabin and cockpit information and images; video monitoring of planes while on the ground; and security scanning of passengers and luggage.

Similar protective measures and responses can be developed for cargo transport. Detection of threats in shipping containers, transponders and satellite-based

Attention has turned to technological preventions, responses and counter-measures to terrorism. Many involve Electrical Engineering.

monitoring systems, remote control and other technologies will help to prevent the use of ships and trucks as weapons of mass destruction.

Research in computer face-matching, retinal and palm print recognition and DNA-based identification technologies all have the potential to avert future terrorist acts. But these technologies, as well as data-mining of credit and cash transaction information, monitoring of computer and communication systems and other new surveillance technologies raise challenging questions regarding civil liberties and privacy.

Advances in wireless and optical communications hardware and network design can enhance communication and data network security, reliability and resilience. We were fortunate that the attacks of 9/11 were not coordinated with attacks on our Internet infrastructure, communications systems, electric power and natural gas distribution, or our ground transportation infrastructure. The robustness and stability of these complex networks is now a critical issue. Recent trends toward "just in time" manufacturing and low inventory levels have heightened our vulnerabilities to disruption.

Beginning with World War II, American universities have been called upon to serve the national defense. The research and educational programs of engineering colleges have been profoundly shaped by the technological priorities of the military. Once again we are called to service. In the near term, the development of certain technologies will be accelerated. In the longer term, we must apply our skills to global human problems where we can make a difference. Victory in this war of the new millennium will ultimately rest upon our success in attacking the critical problems that generate despair on so much of our planet: the lack of economic security and opportunity, health and nutrition, environmental quality, understanding and tolerance of cultural differences, and individual freedoms.

We face new challenges for engineering education. There is critical need to teach our students the fundamentals of systems survivability. Education in engineering design methods must address the robustness and resilience of systems. In addition, the accreditation-mandated educational priority of "Engineering Ethics" now has an expanded meaning. EEK2002

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Dunham, Scott
Professor
Materials and Devices
Ph.D., 1985
Stanford University

El-Sharkawi, Mohammed
Professor
Intelligent Systems and Energy
Ph.D., 1980 University of British Columbia
IEEE Fellow

Hannaford, Blake
Professor
Biorobotics
Ph.D., 1985
University of California, Berkley
NSF Presidential Young Investigator Award,
IEEE EMBS Early Career Achievement Award

Hauck, Scott
Associate Professor
VLSI and Digital Systems
Ph.D., 1995 University of Washington
Sloan Research Fellowship
NSF Career Award

Helms, Ward
Associate Professor
Circuits and Sensors
Ph.D., 1968 University of Washington

Holl, Mark
Research Assistant Professor
MEMS. Micro-total analytical systems
Ph. 1995 University of Washington

Homola Jiri
Research Associate Professor
Photonic Devices & Optical Sensors
Ph.D., 1993 Academy of Science of the Czech Republic

Hwang, Jenq-Neng
Professor
Signal and Image Processing
Ph.D., 1988 University of Southern California
IEEE Fellow

Jandhyala, Vikram
Assistant Professor
Electromagnetics, Fast Algorithms, Devices
Ph.D., 1998 University of Illinois
NSF Career Award

Kim, Yongmin
Professor/Chair of Bioengineering
Digital Systems, Image Processing & Medical Imaging
Ph.D., 1982 University of Wisconsin-Madison
IEEE Fellow
IEEE EMBS Early Career Achievement Award

Kirchhoff, Katrin
Research Assistant Professor
Multilingual Speech Processing, Machine Learning
Ph.D., 1999 University of Biefeld

Kuga, Yasuo
Professor
Electromagnetics
Ph.D., 1983 University of Washington
NSF Presidential Young Investigator Award

Li, Qin
Research Assistant Professor
Electromagnetics
Ph.D., 2000 University of Washington

Liu, Chen-Ching
Professor & Associate Dean
Power Systems
Ph.D., 1983 UC-Berkeley
NSF Presidential Young Investigator, IEEE Fellow

Liu, Hui
Associate Professor
Communications and Signal Processing
Ph.D., 1995 University of Texas, Austin
NSF Career Award, ONR Young Investigator

Mamishev, Alexander
Assistant Professor
Electric Power Systems, MEMS, Sensors
Ph.D., 1999 Massachusetts Institute of Technology
NSF Career Award

Marks, Robert
Professor
Signal and Image Processing
Ph.D., 1977 Texas Technical University
IEEE Fellow, OSA Fellow

McMurchie, Larry
Research Assistant Professor
VLSI and Digital Systems
Ph.D., 1977 University of Washington

Meldrum, Deirdre
Professor
Genome Automation
Ph.D., 1993 Stanford University
Presidential Early Career Award (PECASE),
NIH SERCA Award

Nelson, Brian
Research Associate Professor
Plasma Physics
Ph.D., 1987 University of Wisconsin Madison

Ohlson, John
Affiliate Professor
Communications
Ph.D., 1980 Stanford University

Ostendorf, Mari
Professor & Associate Chair for Research
Signal and Image Processing
Ph.D., 1985 Stanford University

Peckol, James S.
Full-time Lecturer
Digital Systems
Ph.D., 1985 University of Washington

Poovendran, Radha
Assistant Professor
Communications Networks & Security
Ph.D., 1999 University of Maryland
NSF Rising Star Award, NSF Career Award

Ramon, Ceon
Research Scientist, Lecturer
Electromagnetics & Remote Sensing
Ph.D., 1973 University of Utah

Riskin, Eve
Associate Professor
Signal and Image Processing
Ph.D., 1990 Stanford University
NSF Presidential Young Investigator, Sloan Research Fellowship

Ritcey, James
Professor
Communications and Signal Processing
Ph.D., 1985 UC-San Diego

Rosen, Jacob
Research Assistant Professor
Biorobotics, Human-Machine Interfaces
Ph.D., 1997 Tel-Aviv University

Roy, Sumit
Associate Professor
Communications and Networking
Ph.D., 1988 UC-Santa Barbara

Sahr, John
Associate Professor & Associate Chair for Education
Electromagnetics and Remote Sensing
Ph.D., 1990 Cornell University
NSF Presidential Young Investigator Award
URSI Booker Fellow URSI Young Scientist Award

Sechen, Carl
Professor
VLSI and Digital Systems
Ph.D., 1986 University of California, Berkley
IEEE Fellow

Shapiro, Linda
Professor
Signal and Image Processing
Ph.D., 1974 University of Iowa
IEEE Fellow, IAPR Fellow

Shi, C.J. Richard
Associate Professor
VLSI and Digital Systems
Ph.D. 1994 University of Waterloo
NSF Career Award

Soma, Mani
Professor
Mixed Analog-Digital System Testing
Ph.D., 1980 Stanford University
IEEE Fellow

Spindel, Robert C.
Professor
Signal Processing, Ocean Acoustics
Ph.D., 1971 Yale University
IEEE Fellow, ASA Fellow, MTS Fellow, A.B. Wood Medal, IEEE Oceanic Engineering Society Technical Achievement Award

Strunz, Kai
Assistant Professor
Electric Power Systems & Power Electronics
Ph.D., 2001 Saarland University

Sun, Ming-Ting
Professor
Signal and Image Processing
Ph.D. 1985 UC-Los Angeles
IEEE Fellow

Thorsos, Eric
Research Associate Professor
Surface Scattering, Underwater Acoustics
Ph.D., 1972 MIT

Troll, Mark
Research Associate Professor
Biophysical/Electronic Devices, Optics
Ph.D., 1983 UC-San Diego

Tsang, Leung
Professor
Electromagnetics and Remote Sensing
Ph.D., 1976 Massachusetts Institute of Technology
IEEE Fellow, OSA Fellow

Wilson, Denise
Associate Professor
Circuits and Sensors
Ph.D., 1995 Georgia Institute of Technology
NSF Career Award

Winebrenner, Dale
Research Associate Professor
Electromagnetic & Remote Sensing
Ph.D., 1989 University of Washington

Yee, H.P.
Lecturer
Electric Power Systems & Power Electronics
Ph.D., 1992 University of Washington

Yee, Sinclair S.
Professor
Circuits and Sensors, Photonics
Ph.D., 1965 UC-Berkley
IEEE Fellow

Zick, Gregory
Professor
VLSI and Digital Systems
Ph.D., 1974 University of Michigan

## EMERITI

Alexandro, Frank
Controls & Robotics
Ph.D., 1961 University of Michigan

Albrecht, Robert
Controls & Robotics
Ph.D., 1961 University of Michigan

Andersen, Jonny
Circuits & Sensors
Ph.D., 1965 MIT

Bjorkstam, John L.
Controls & Robotics
Ph.D., 1958 University of Washington

Clark, Robert N.
Ph.D., 1969 Stanford University
IEEE Fellow

Dow, Daniel G.
Ph.D., 1958 Stanford University

Guilford, Edward C.
Ph.D., 1960 UC-Berkeley

Haralick, Robert
Signal & Image Processing
Ph.D., 1969 University of Kansas
IEEE Fellow
IAPR Fellow

Hsu, Chih-Chi
Ph.D., 1957 Ohio State University

Ishimaru, Akira
Electromagnetics and Waves in Random Media
Ph.D., 1958 University of Washington
IEEE Fellow, OSA Fellow, IOP Fellow, IEEE Distinguished Achievement Awards: Geosciences and Remote Sensing Society; Antennas & Propogation Society

Johnson, David L.
Ph.D., 1955 Purdue University

Lauritzen, Peter O.
Power Electronics
Ph.D., 1961 Stanford University

Lytle, Dean W.
Ph.D., 1957 Stanford University

Meditch, James S.
Ph.D., 1969 Purdue University

Moritz, William E.
Ph.D., 1969 Stanford University

Noges, Endrik
Ph.D., 1959 Northwestern University

Peden, Irene
Ph.D., 1962 Stanford University
NSF "Engineer of the Year", Member, National Academy of Engineering, IEEE Fellow, IEEE Harden Pratt Award, U.S. Army Outstanding Civilian Service Medal

Porter, Robert B.
Ph.D., 1969 Northeastern University
ASA Fellow, OSA Fellow

Redeker, Charles C.
Ph.D., 1964 University of Washington

Sigelmann, Rubens A.
Ph.D., 1964 University of Washington

We apologize for any errors, omissions or misspellings in 2002 EEK. We would like to extend special appreciation to the faculty and staff who assisted in producing this publication and to the sponsors whose generosity made it all possible.

# MILESTONES AND INNOVATIONS

## LATEST CAREER AWARD RECIPIENTS ARE IN GOOD COMPANY

Congratulations to our latest NSF CAREER award winners!

Jeff Bilmes, Alex Mamishev, Radha Poovenderan and Vikram Jandhyala are the latest EE faculty members to receive this prestigious award. These new recipients are in good company: all 9 EE assistant professors hired from July 1998 through June 2001 are recipients of this national award, which is given by the National Science Foundation (NSF) in support of overall career development of young scientists. It combines extensive, broad based support for research and education of the highest quality. This level of support exemplifies the importance that the National Science Foundation (NSF) places on the early development of academic careers dedicated to stimulating the discovery process in a research environment enhanced by enthusiastic teaching and enthusiastic learning.

Congratulations to those faculty members who recently received promotions. Scott Dunham and Deidre Meldrum were promoted to full professor; Denise Wilson, Hui Liu, and Richard Shi are now associate professors with tenure. Jiri Homola was recently promoted to research associate professor. The department welcomes our newest faculty, assistant professor Kai Strunz in April 2002.

EE announces changes in leadership roles: Mari Ostendorf is replacing Les Atlas as Associate Chair for Research; John Sahr becomes Associate Chair for Education, taking over from Blake Hannaford; R. Bruce Darling takes over from John Sahr as Graduate Coordinator; Eve Riskin becomes our first Undergraduate Research Coordinator.

EE undergraduate students Rejo Jose, Hans Isern, and Jeff Chen received the "AT&T Labs Student Enterprise Award," given by IEEE through AT&T labs and the AT&T foundation to support IEEE student branch programs. Their project, "High Voltage Energization Status of Underground Cables" safely determines the energization state of underground cables using non-intrusive methods.

Associate Professor Jeff Bilmes received a $650,000 equipment donation from IBM, which includes 10 RS/6000 44P Model 270 workstations. The machines will be used for computationally intense forms of computer speech recognition.

The Electrical Engineering department proudly congratulates its 2001 doctoral degree recipients: Al-hussein Abou-zeid, Ph.D., Selim Aksoy, Ph.D., Hamed Alazemi, Ph.D., Supavadee Aramvith, Ph.D., Mohammed Azadeh, Ph.D., George Barrett, Ph.D., Mark Billinghurst, Ph.D., Todd Chauvin, Ph.D., Aik Chindapol, Ph.D., Timothy Chinowsky, Ph.D., Georgios Chrysanthakopoulos, Ph.D., Mark Curry, Ph.D., Giri Devarayanadurg, Ph.D., Randall Fish, Ph.D., Jihun Joung, Ph.D., Jae-Byung Jung, Ph.D., Changick Kim, Ph.D., Seongwon Kim, Ph.D., Gang Liu, Ph.D., Ravi Managuli, Ph.D., Desik Echari Nadadur, Ph.D., Garet Nenninger, Ph.D., David Palmer, Ph.D., John Rockway, Ph.D., Kalev Sepp, Ph.D., Tatjana Serder, Ph.D., Izhak Shafran, Ph.D., Xinyu Wang, Ph.D., Dongxiang Xu, Ph.D., Hujun Yin, Ph.D., Jongtae Yuk, Ph.D.,

The IEEE has announced that Professor Carl Sechen has been named an IEEE Fellow, effective January 2002. His citation reads *"For contributions to automated placement and routing in integrated circuits."* The UW EE Department now has 19 IEEE Fellows. A list, including their citations, appears at http://www.ee.washington.edu/welcome/IEEE_Fellows.htm.

Congratulations to our recently appointed Professors Emeriti: Robert Albrecht, Frank Alexandro, Jonny Andersen and Robert Haralick.

Congratulations to Sang-Il Lee and Sermsak Jaruwatanadilok who took 2nd and 3rd prize at the recent International Union of Radio Science US National Meeting in Boulder CO. Mark Curry, who took 2nd prize the previous year. Half of all the students winning these URSI awards in the United States for the last two years have been from our department.

We are pleased to report that our new building performed admirably during the 6.8 magnitude earthquake of February 28, 2001. There was no significant damage and there were no injuries. The old EE building did suffer damage, but not enough to accelerate its demolition one month later (as planned). That site will soon be the Paul G. Allen Center for Computer Science & Engineering. The building will provide 75,000 square feet of new space for the Department of Computer Science & Engineering and 10,000 additional square feet of space for the Department of Electrical Engineering.

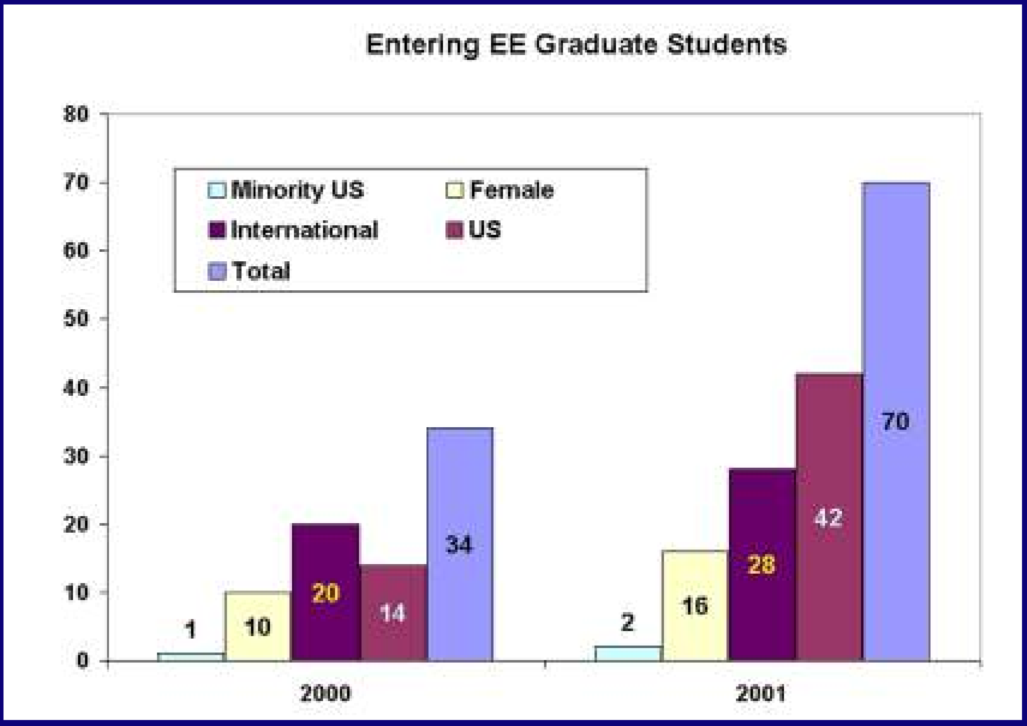
## ENROLLMENT (AUTUMN 2001)

- 268 Graduate Students (19% female, 14.2% minority, 47.6% US)
- 545 Undergraduates (20% women)

## DEGREES GRANTED IN 2000-2001

- Ph.D. 26
- M.S. 53
- B.S. 164

## GRADUATE ENROLLMENT TRENDS




## EXTERNAL FUNDING