(E)lectrical (E)ngineering (K)aleidoscope

EE2K05

A PUBLICATION OF THE ELECTRICAL ENGINEERING DEPARTMENT UNIVERSITY OF WASHINGTON

ANNUAL RESEARCH REVIEW

A Look into the Future...

UWEE is building the future through education. Here are the ideas of three of our ambassadors to this new century of Electrical Engineering:

JEAN WANG

I am working in the field of photonics. Specifically, my research involves modeling and fabricating nanometer scale waveguides, which is important for creating high-density photonic integrated circuits. In particular, the waveguides are constructed through DNA-mediated self-assembly of quantum dots. This method seeks to capitalize on the advantages of high bandwidth and modulation speed inherent to optical waveguiding to transfer data below the diffraction limit. For the next 10-50 years, key work in my field will involve the discovery of a practical means for sub-diffraction guiding of energy, the development of increasingly compact photonic ICs and their integration with other components such as biological sensors and communication systems. Enhancing the computing capacity and capability of devices through nanoscale manipulation will advance our understanding of fundamental science and bring to life the possibilities we now imagine.

STEPHEN HAWLEY

I am working on the interface of control engineering, nanotechnology, and biology. My work involves developing a system using gene regulatory networks to obtain intracellular data over time, for the modeling and control of processes in the cell. This is engineering at the nanoscale, using biological components.

In the near term, the challenges in control engineering at the nanoscale are building inorganic components to sense and respond to their environment as gene regulatory networks are able to do. Longer term, the challenge will be controlling very large numbers of nanoscale components to form materials and devices at the macroscale.

MELISSA MEYER

I work on upper atmospheric plasma physics - particularly the remote sensing and characterization of turbulence in the Earth's ionosphere due to space weather (e.g., the solar wind). My work involves developing radar remote sensing techniques and technology to study these phenomena, as well as applying the resulting data toward a scientific understanding of plasma processes in our upper atmosphere.

The electrodynamic interaction of the Earth with its immediate space environment is important to understand for many reasons; notably, all communications with spacecraft are adversely affected by ionospheric turbulence, and once we can predict and accurately describe turbulent events, we will be able to perform error correction and make trans-ionospheric communication more robust. Furthermore, the radar techniques we are developing are at the cutting edge of remote sensing technology, and are useful for many other purposes, including aerospace and military applications.

A NOTE FROM THE EDITORS

Last year, EEK2004 examined the past 100 years of Electrical Engineering. EEK2005 is a look ahead into the future of Electrical Engineering. The opening article at the beginning of each section has been written based upon UWEE faculty answers to a questionnaire regarding future directions of research, over different time horizons.

PICTURED ON FRONT: THE HOME SYSTEM BY 2100. IT'S POSSIBLE THAT BOTH WILL SUPPORT HUMAN POPULATIONS.

EE2K005

ANNUAL RESEARCH REVIEW

WELCOME
TO EEK2005:
A pEEK INTO THE FUTURE

Past, Present, and Future is the theme of our Department of Electrical Engineering's Centennial Celebration to be held in the spring of 2006. EEK2004 chronicled our first century of leadership in education, research, and service at UW, one of the world's premier academic institutions. This fifth edition of EEK previews the future, our second century. It extrapolates our landmark successes in pioneering many multi-disciplinary research areas, in closely coupling our research and teaching programs, in providing service to our communities and our profession, and in striving for diversity among our faculty, staff, and students. As technology drives us towards a one-world economy, our department is uniquely positioned to maintain world-class leadership in fulfilling our mission: *Excellence in Education Through Cutting Edge Research.*

As we begin our second century, our department will continue its rapid growth. This year, we plan to add three outstanding new faculty members, increase our annual external research funding above $20 million per year, implement innovative curricula, and elevate the current top-twenty national rankings of our undergraduate and graduate Electrical Engineering programs.

Please plan to join us at our upcoming Centennial Celebration, as we welcome alumni, emeriti, friends and family to celebrate our past, present, and future with our students, staff, and faculty. Your support is vital to the continued success of our department as we look to the future.

DAVID J. ALLSTOT
Chair and Boeing-Egtvedt Professor
Department of Electrical Engineering

THE FUTURE OF Nanophotonics and Nanoelectronics

HOTTEST TOPICS: Research exploring interactions between photons and materials and building devices at the nanometer scale will create new ways to utilize light and build photonic devices. This will have impacts in computing, communications, sensing, and biomedicine. Professors Lih Lin and Babak Parviz are collaborating on quantum dot integrated circuits using DNA-directed self-assembly. Other hot topics include nanophotonic structures, bio-photonics (e.g., optical manipulation of biological materials and molecular imaging), and quantum optics (e.g., quantum cryptography, quantum imaging, quantum computing and communication). Professor Scott Dunham is developing a new generation of mathematical models and simulation tools that comprise a key enabling technology for many of these applications.

IN THE NEXT DECADE: We will see the rise of nanoelectronics, the creation through self-assembly of molecular-scale electronics. These systems require high degrees of regularity and fault-tolerance, which FPGAs can provide. Nanoelectronics can have orders of magnitude higher density, performance, and power efficiency, and will likely form the basis of most electronics in 10-20 years. Professors Babak Parviz and Scott Hauck are initiating research on these problems. In nanophotonics, the next decade will see the integration of photonic devices in nanometer scale. There will be further discoveries and advances regarding the use of light for early detection, diagnosis, analysis and treatment of disease. It is also likely that there will be a hardware realization of quantum communication that will provide enhanced security. Quantum computing will become practical, which will increase the speed and density of computation devices. Finally, organic optoelectronic devices will enter everyday use. Professor Larry Dalton (UW Chemistry and EE) is leading a large research effort in organo-electro-optics.

LONG RANGE FORECAST: Just as we advanced from copper wires and coaxial cables to optical fibers, photons instead of electrons will become the main information carriers and photonics will become the major tool in biomedicine. One advantage we have in EE is that we have developed a powerful arsenal of tools to describe and understand the behavior of signals in systems over the last century. There is a real opportunity emerging in coming decades to apply this arsenal to understand the storage, structure, and processing of knowledge and inference in biological computing systems, and eventually in people.

At some point, perhaps in the next 20-30 years, Moore's law will stop working, since fabrication would have to shrink to the single atom level. Eventually, we have to reassess all of electronics design and computer science, when the driver of ever-better fabrication techniques stops. The discovery of fundamental limitations (what is just never going to be possible) will be interesting.

NANOSCALE PHOTONIC INTEGRATED CIRCUITS

PROFESSOR LIH LIN

High speed and high integration density have always been the goals for advancement in computing and communication technologies. Over the years, steady progress in VLSI fabrication technology has continued to shrink the size of transistors, allowing technology to keep up with Moore's Law. Although state-of-the-art photolithography-based microfabrication technologies deliver devices with sub-100 nm critical dimensions, each generation of scaled devices face more challenging performance issues, especially regarding the leakage current and the allowed power density. As these challenges become more prevalent within the next decade, alternative device concepts, architectures, and methods of fabrication will be needed.

Photonics builds on the advantages of high-speed and broad-bandwidth nature of light and eliminates on-chip parasitic and electro-magnetic interference. Therefore using photons as a means of carrying information has been an appealing approach for future computing and communication. Although optical information technologies have been widely explored in optical-fiber communications, progress in computing and signal processing has been limited because most optical components developed to date are at micron-scale or larger. This makes the integration density far inferior to electronic VLSI. Furthermore, most all-optical logic gates require high laser power that is proportional to the device volume, which calls for 10's to 100's of mW for conventional optical components, making photonics integrated circuits impractical for computing.

Consequently, research efforts have been devoted to the development of nano-scale photonic integrated circuits, such as plasmonics, photonic crystals, and nanowires. At UWEE, Professor Lih Lin's and Babak Parviz's groups are constructing a generic platform for quantum dot (QD) integrated circuits. It consists of a collection of QDs that have been positioned on specific locations on the substrate via a DNA-directed self-assembly process. Various QD configurations are proposed to make waveguides, optical transistors/photodetectors, and logic gates. The platform allows for very large scale integration of nano-scale photonic components to yield a functional system. Low-loss optical energy propogation is achieved by energy coupling between adjacent QDs that are pumped optically or electrically in the sub-diffraction scale QD walvelguides. This results in high integration density. Furthermore, since QDs are semiconductor crystals with dimensions on the order of a few nanometers, the QD logic gates can, in principle, achieve a million-fold optical power reduction compared to conventional optical computing elements, due to a drastically smaller active volume. Electron tunneling between QDs, modulated by input optical intensity, is utilized to achieve an optical transistor, which can also function as a near-field photodetector. **EEK**2005

SCHEMATIC DRAWING OF THE QUANTUM DOT INTEGRATED CIRCUIT (QDIC).
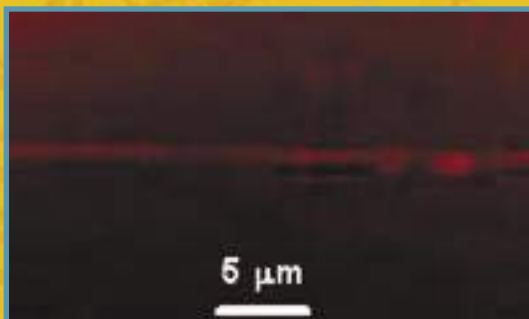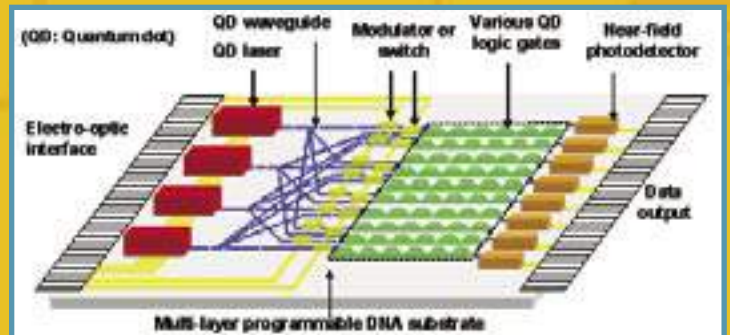
PHOTOGRAPH OF A QUANTUM DOT WAVEGUIDE.

A QD-ILLUMINATED ELECTRON-BEAM LITHOGRAPHY PATTERN, GENERATED BY A CREATIVE EE GRADUATE STUDENT JEAN WANG. THE PATTERN SHOWS THE PROCESS OF SPONTANEOUS EMISSION IN QUANTUM DOTS AND "UWEE PHOTONICS."

THE
FUTURE
Energy Systems OF

HOTTEST TOPICS: The onset of distributed generation involves many technologies and scales. The end of inexpensive energy supplies is driving research into renewable energy sources. The decreasing reliability of the power network and the deregulated energy market are motivating the development of new network control and operation strategies. Professor Kai Strunz is working on the integration of wind systems and Professor Rich Christie is exploring the effect of regulatory issues. Professor Alex Mamishev is leading an effort to develop crawling robots for power line maintenance. Professors Mark Damborg and Chen-Ching Liu are investigating larger scale power system issues. Professor Mohamed El-Sharkawi is investigating the vulnerability and the intelligent operation of the power system.

A second "hot topic" is thermal cooling with electrostatics motivated by the need to avoid overheating in microelectronics. Professor Alex Mamishev is investigating this. A third major problem in power systems research is the increasing role of power electronics, and its many applications from high voltage DC transmission to high performance drives. Professors Mohamed El-Sharkawi and Kai Strunz are exploring these aspects.

IN THE NEXT DECADE: Thermal management and crawling robots will gain widespread use. The thermal management will be achieved at the microscale. Changes in energy economics and the increasing fragility of the core system will make distributed units important for reliability. There will be an increasing number of independent power producers, with many utilizing hydrogen fuel. It is not clear that the public will tolerate or invest in increasing the capacity of the base network. There are many operating challenges to incorporating these units into the interconnection, including technical and regulatory issues.

LONG RANGE FORECAST: There will be complete planet-wide management of air quality. Space-based energy production systems (for utilization on earth) will become practical. There will be a replacement of fossil fuels. Nuclear and renewable sources are the only likely candidates. Many of the renewable sources will be distributed; nuclear generation will involve large central stations. The resulting distribution and network issues will be made simpler by advances in power electronics.

THERMAL MANAGEMENT OF MICROELECTRONICS

PROFESSOR ALEXANDER MAMISHEV

AND NELS JEWELL-LARSEN (EE GRADUATE STUDENT)

The problems associated with thermal management in microelectronics are receiving increasing attention from academia, government agencies and industry. Rapid development of microelectronics has led to an immense component density. Though the size of a single component has decreased to 0.02 µm, each semiconductor component emits heat associated with the electrical resistance.

Recent advances in micro-elctromechanical systems (MEMS) and power electronics are also affected by the bottleneck of heat removal. High-speed MEMS applications generate heat mechanically from friction. The introduction of combustion processes in micro-devices is another new source of heat. In power electronics, high current applications require high operating temperatures, which will require dramatic improvements in heat dissipation.

Existing cooling devices are no longer sufficient in terms of energy consumption and heat removal. The decreased size of microelectronic components and their increased thermal output density requires a significant increase of thermal exchange surface. Incorporation of increasingly narrow airflow channels into heat sinks is no longer a viable option. Gases become viscous in narrow channels, and do not provide efficient heat removal. Elaborate cooling systems are being developed, including those using liquid nitrogen and helium, but the final step of heat exchange with the ambient environment always remains necessary.

NUMERICAL SIMULATION OF AN EFA BEING USED TO PUMP AIR THROUGH A MICRO HEAT SINK CHANNEL.
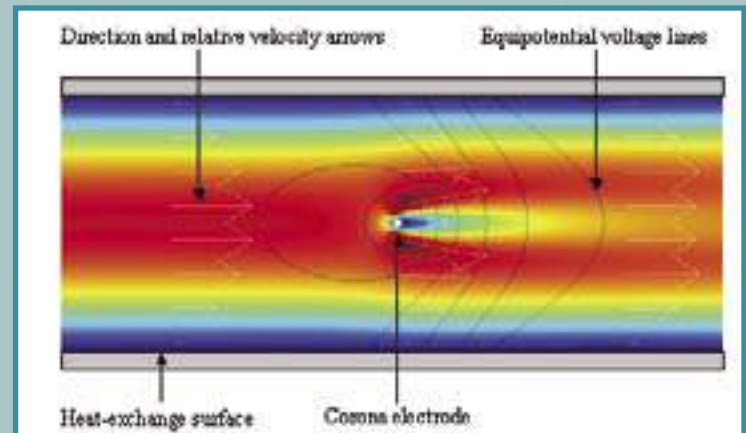
In the future, there are two new approaches to computation hardware that appear to be feasible. One possibility is to develop computing technology that minimizes heat generation through use of photonics or quantum dots. Another possibility is to develop three-dimensional chip architectures, but this approach makes the removal of heat even more difficult. Ideally, some sort of a micro-fan could reside inside the chip structure and move air through in an efficient manner. Research conducted by Professor Alex Mamishev's Sensors, Energy, and Automation Laboratory (SEAL), (in partnership with Kronos Air Technology and Intel) aims to produce novel solutions for this class of applications.

The Electrostatic Fluid Accelerator (EFA) is an emerging technology that employs an electric field to exert force on ionized gas shown. This approach will fundamentally change the design of heat exchangers used in microelectronics. The blades of rotary fans will no longer be used. Instead, the heat sinks will contain integrated micro-EFA devices that will create sufficient pressure difference inside the narrow channels of heat sinks and 3-D microprocessors. These micro-EFA devices will use low voltage for corona discharge and create high airflow with a desirable air velocity profile for efficient heat transfer from hot parts of electronic components and devices. Moreover, the ability to direct airflow at different angles will contribute to further development of need-based cooling, where the air is delivered only to the hottest part of the system. Ultimately, micro-EFA will become a natural inseparable part of any microelectronic and MEMS devices where heat transfer and withdrawal is necessary. EEK2005

THE FUTURE OF
Robotics and Control Systems

HOTTEST TOPICS: Robotics and Control research is undergoing a renaissance spurred by new applications. One topic involves autonomous robots to replace humans in risky environments. Professors Linda Bushnell and Alex Mamishev are developing autonomous robotic systems, and Professor Mohamed El-Sharkawi is part of a group investigating autonomous swarms of robots for undersea applications (see page 9). Swarm robots with emerging behavior are of particular interest. Another hot research topic is the control and programming of self-assembling systems. Professors Eric Klavins, Karl Böhringer and Babak Parviz are exploring this topic, along with many faculty in the UW Nanotechnology Center. The underlying question is: What makes simple matter become complex?

In the recent past, robotic surgery is beginning to be economically viable. This technology can provide better, less invasive surgical interventions for diseases. Remote surgery can provide better access to advanced medical care and specialists for people in remote locations. The application of telerobotics to surgery is driving major innovations in mechanization, control, and user interfaces. Haptic interfaces are being developed which will let people routinely touch and manipulate objects that exist only in the computer. This adds new realism and tactility (a "hands-on" quality) to training, entertainment, and appreciation of art such as sculpture. It will also enable new advances in computer-aided design. Professors Blake Hannaford and Jacob Rosen are developing new techniques and devices for haptic interfaces and telerobotic surgery. Professor Howard Chizeck is exploring the effects of randomly varying communication delays on these systems.

Professors Deirdre Meldrum, Mark Holl and others are involved in the applications of automation for genomics and proteomics (see page 23). In work building on the same technology base, Professor Chizeck is applying methods of systems and controls engineering to the analysis and design of cellular processes. This work concerns genetic circuits for intracellular sensors of metabolites in single living cells.

IN THE NEXT DECADE: Significant improvements in the efficiency of DC motors, new magnetic materials, superconductors and similar advances will make miniaturized robots and haptic devices possible. A broad and useful class of programmable self-assembling structures or devices at the molecular scale will be developed. High fidelity multi-finger haptic devices will become available (currently these are mostly limited to one finger touching). Low cost and widely available haptic devices with open software tools will become available in portable and hand-held devices for better user interfaces in cell phones, gaming systems and entertainment devices. The need for light-weight and powerful actuators is a major obstacle.

LONG RANGE FORECAST: In the next 50-100 years, ubiquitous autonomous and networked robots will become reality. We will be able to program and build reliable, robust and high performance molecular machines, which will have profound implications to the treatment and cure of disease. We may achieve the (ethically and religiously challenging) ability to reprogram ourselves.

ROBOTICS IN MEDICINE

PROFESSOR BLAKE HANNAFORD

Today, one company (Intuitive Surgical Inc.) is marketing an FDA-approved robotic surgical tool. Always in the surgeon's complete control, two tiny (10mm) mechanical hands manipulate inside the patient through tiny incisions. So far, the "Da-Vinci" robot is mostly a new technique looking for a compelling application, but two procedures are starting to show promise in terms of achieving better results than manual surgical techniques. These are the radical prostate-ectomy (in which the prostate gland is removed from an incision in the lower abdomen), and certain pediatric procedures. In both of these applications, the tiny mechanized hands give surgeons extra dexterity inside tiny body cavities.


THE OPERATING ROOM OF THE FUTURE. THE ONLY HUMAN PRESENT IS THE PATIENT.

During the next five years, look for robotic surgical technology to establish footholds. Improved operations will set a new standard of medical care in terms of outcome, patient recovery time, and safety. Remote surgery will let a surgeon be thousands of miles away from the patient, operating via a high-speed network connection. Image compression technology will send HD quality video to the surgeon and tools will respond to hand motions. Applications include care of combat casualties on the battlefield, and delivery of state-of-the art healthcare to underserved populations in rural and remote areas.

In the next decade, surgical robots will be extensively integrated with medical imaging. The surgeon will have combinations of a video image of the patient precisely overlapped with MRI, ultrasound, and x-ray images. Cancer cells will be visible directly in the operative field and thus it will be easier to extract them while sparing healthy tissue, vital nerves and organs. All operating room functions will become part of the system so the patient will be the only person in the OR. Operating room cleanliness will consequently improve to the level of semiconductor clean-rooms. Advanced sensors, integrated into the tools, will give the surgeon haptic cues about the composition and pathology of tissues being touched. Patient-specific rehearsal systems will allow the surgeon to practice an unconventional procedure on a patient with unusual anatomy.

In the next few decades, although many forms of treatment will be dramatically improved, the need for surgery will persist in treating trauma, cancer, and resistant infections. After two decades of clinical experience, understanding of the basic sciences underlying surgery (like biomechanics, histology of tissue damage, wound healing and human factors) will advance to the extent that autonomous software will begin to take over the simple steps of surgery such as suturing, preparing, and closing the patient. The robot will become a smart assistant by monitoring the surgeon's performance and raising alerts when it detects signs of tremor, suggesting steps when detecting hesitation, and keeping detailed records of every manipulative step in the procedure. Within a century, surgery will have new roles in addition to its evolving role in trauma repair. Installation of artificial organs will create new challenges for life support. The shrinking of surgical tools might stop as molecular approaches are able to repair capillaries, neurons, and other distributed micro-structures. Low cost and highly networked robotic clinicians could be deployed in villages with populations as low as 100 - distributing high tech healthcare to billions of people. Finally, surgical systems with a great degree of autonomy may allow small groups of humans to be launched in space flights lasting decades aimed at colonization of other planets. **EEK**2005
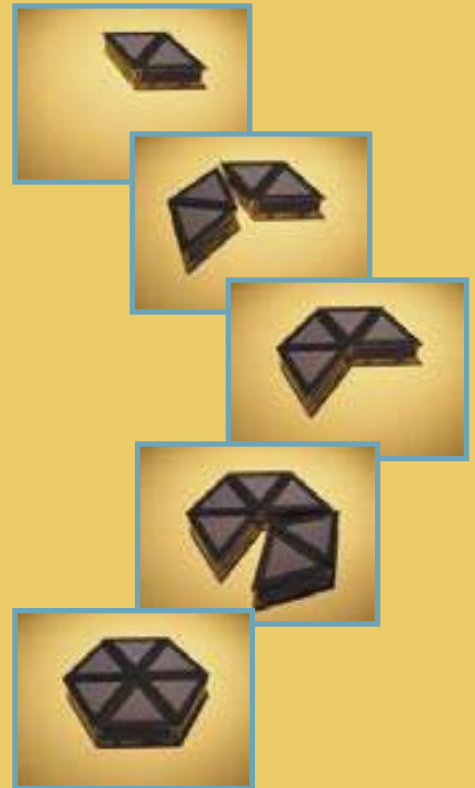
SELF-ASSEMBLING ROBOTIC PARTS

Professor Eric Klavins has developed a testbed for self-assembling programmable parts (pictured above). Each part is capable of binding to other parts, communicating with the parts to which it is bound, and detaching from other parts. The parts rely on the environment for mobility; they float on an air-table and are mixed by overhead fans. Thus, all interactions between parts begin with chance collisions. A sequence of events resulting in self-assembly into a hexagon is shown.

The resulting dynamics are nondeterministic and concurrent. Many interactions may occur simultaneously and the order in which interactions occur is not determined. Therefore, each part is provided with a rule book (i.e. a graph grammar) that prescribes the outcome of each possible interaction. In this example, each part has a microcontroller that can store both a rule book and an internal state value. Each rule in the book is of the form $L \Rightarrow R$. If the internal states and local topology of a pair of interacting parts matches L, then the parts rewrite their states and local topology with R. It can be shown that a rule book can be designed so that the parts assemble into any desired structure. Rules that produce limit cycles (i.e. processes such as sequences of global shape changes) can be generated as well.

NEPTUNE

North East Pacific
Time-integrated Undersea
Networked Experiments

NEXT GENERATION OCEANOGRAPHY

PROFESSORS JOHN R. DELANEY AND DEIRDRE R. MELDRUM

Historically, scientists have used ships and satellites for oceanic studies, but these approaches are limited. Ships can only be in one place at one time and satellites routinely survey only the upper portions of the water column, providing minimal information about processes at depth. Bad weather and cloud cover hampers the utility of both. Many portions of the oceans remain remote and hostile. Despite the limits of traditional approaches, the past four decades have fostered major discoveries in ocean and earth sciences. These include a newly discovered microbial biosphere in the rocks beneath the seafloor, life forms that thrive without sunlight under high pressure, high temperature, and low pH. Some estimate that this biosphere may rival that found at the ocean's sunlit surface, yet it was unknown until only a few years ago.

We now recognize that there are complex and extensive interactions among the atmosphere, the ocean, and the underlying seafloor. The global ocean may be viewed as the environmental "flywheel" of the planet in that it plays a major role in modulating long- and short-term climate change. Production of food on continents is directly linked to fluctuations within the oceans. As the world's population continues to increase, improving our ability to detect and forecast changes in oceanic processes may be the key to our survival.

The University of Washington is leading an international program that is developing and building NEPTUNE (North East Pacific Time-Series Undersea Networked Experiments), the world's first Regional Cabled Ocean Observatory. To be located off the coasts of Washington, Oregon, and British Columbia, NEPTUNE's 3,000-km network of fiber-optic/power cables will encircle and cross the Juan de Fuca tectonic plate in the northeast Pacific Ocean.

PROPOSED NEPTUNE NETWORK IN
THE JUAN DE FUCA AREA.

AN ARTISTIC VIEW OF A SMALL
PART OF THE NEPTUNE SYSTEM.

Ultimately, NEPTUNE cables will deliver up to 100 kW power to nearly 20 seafloor nodes (~5 kW each) and provide greater than 10 GB/sec bandwidth connectivity between land and thousands of sensor packages distributed across the seafloor, below the seafloor (in drill holes) or in the overlying water column. Entirely new approaches to oceanography will evolve based on the power-bandwidth availability in situ. The network will enable regional-scale, real-time, interactive observations and experiments with the ocean, the seafloor, and the biological communities that thrive in these environments. Hardwired to the Internet, NEPTUNE will provide scientists, students, educators, and the public with virtual access to remarkable parts of our planet, rarely visited by humans.

NEPTUNE will also provide a unique facility for improving our understanding of potential earthquake and tsunami hazards along our coastline. The ocean sciences are now in a transformational period leading to entirely new ways of accessing the oceans. Scientists, educators, decision makers, and the general public will soon reap the benefits of new approaches that provide interactive and continuous access to the oceans, the seafloor, and the sub seafloor.

The NEPTUNE infrastructure, and the science that it enables, offer tremendous opportunities for interdisciplinary research at UW and beyond, including robotics; telemanipulation; automation; controls; power; chemical, biological, and physical sensors; radar; acoustics; photonics; imaging; data compression; biomaterials and biofouling; self-assembly; computing and communication systems; network security; genomics and proteomics; ecogenomics; nanotechnology; microbiology; chemistry; ecology; and geology.

NEPTUNE will have profound ramifications for the manner in which scientists, engineers, and educators conduct their professional activities. However, the most far-reaching effects may well be a significant shift in public attitudes toward the oceans and the scientific process. The real-time data and high-speed communications inherent in remote observing systems will open entirely new avenues for the public to interact with the natural world. Public access to science will be transformed by enabling participation in the journey of scientific exploration and discovery. EEK2005

HARDWIRED TO THE INTERNET, NEPTUNE WILL PROVIDE SCIENTISTS, STUDENTS, EDUCATORS, AND THE PUBLIC WITH VIRTUAL ACCESS TO REMARKABLE PARTS OF OUR PLANET, RARELY VISITED BY HUMANS.

NEPTUNE POWER AND CYBERINFRASTRUCTURE

PROFESSORS MOHAMED A. EL-SHARKAWI AND JOHN R. DELANEY

We can install permanent observatories in outer space where energy is continuously available from the sun. But in the deep ocean, technology has not matured enough to provide the continuous electric energy needed for permanent observatories. Present technology allows the deployment of battery-operated instruments, or instruments powered from shore or ship. Carrying out scientific experiments on the ocean floor for an extended time will require a permanent source of energy. NEPTUNE will involve a network of about 3,000-km of fiber-optic/power cables covering an area of roughly 500 km by 1,000 km. Submarine cable will be used to serve two purposes; its hollow core will carry fiber optics for communications, and its copper sheath will be used to transmit electric power. The ocean provides the return path for the current, so only a single conductor cable is needed.

NEPTUNE's power system is significantly different from terrestrial power systems. It requires completely different switching, protection and control strategies. The network is composed of approximately 30-40 evenly distributed branching units (BU), which are like the switching yards in terrestrial systems. The branching circuits are cables connecting the BUs to "science nodes" on the seafloor. The length of the branching cables can be as long as 100 km. Each node provides standard power to scientific equipment, and Internet communication interfaces between this equipment and the shore. The communication network has a capacity of about 10 gigabits per second, and the power network will deliver 200 kW with a design life of 30 years. Two shore stations will provide the energy of the network; one is located on Vancouver Island, Canada, and the other on the Oregon coast. Each of these stations is capable of providing 100 kW. A redundant power supply will be located at each of the shore stations.

The engineering power system prototype is a parallel power system utilizing flexible DC/DC power supplies that auto adjust to changing load conditions with a multi-layered, reliable protection system. The backbone voltage is 10kV DC, and the cable will have a current rating of 10 A. The anode of

the system is at the shore station, to limit the corrosion of the equipment in deep water. Hence the voltage of the shore station is negative with respect to ground. At each science node (30+ locations), a DC/DC converter will be used to reduce the incoming voltage from ten kV to a more conventional level of 400V (and 48 V). In the event of component failures or cable fault, a protection system inside the BU isolates the fault as soon as possible and minimizes the loss of load. This is done without any communication from the shore station or coordination between the BUs. Furthermore, if a fault occurs, its location can be identified to within one km to minimize the cost of search and repair in deep water.

The goals of NEPTUNE can be achieved only if the at-sea portion is complemented by an information technology cyberinfrastructure that can fully utilize and ultimately automate interactive ocean observatories. This will involve a strong collaborative effort between computer and ocean scientists. A working prototype will be built linking, via experimental wireless, optical networks, and grid technology, a series of facilities located off the Pacific coasts of Mexico, the United States, and Canada. The prototype will allow development of essential middleware to facilitate and enable instrument and infrastructure control, data generation and distributed storage, data assimilation and ocean simulation, analysis, visualization, and collaboration. The prototype infrastructure will be a large distributed data grid, driven by a variety of instruments, and will be capable of interactively analyzing and collaboratively visualizing multiple data objects. EEK2005

NEPTUNE SENSORBOTS

PROFESSORS JOHN R. DELANEY AND DEIRDRE R. MELDRUM

The power and bandwidth that NEPTUNE can deliver would enable the deployment of an adaptable array of small, semi-autonomous sensor-robots or "sensorbots" capable of moving, either independently or under remote control, in a 3-D geometric formation through precisely controlled volumes of seawater. In such a system, the operator (on land) might specify the spacing of the sensorbots, the rate of movement through the water, the types of sensors that are activated and the repetitive patterns of flight that would be utilized. Swarms of sensorbots could be used to record spatial and temporal variations in aquatic environmental parameters, permitting effective monitoring of changes in controlled ocean volumes near volcanic or seismic activity, near mass-wasting events, within primary-secondary plankton blooms, or associated with any other dynamic process operating within the ocean. When programmed to operate in an autonomous mode, these sensor swarms would have the ability to function in complex, harsh, and remote environments. For example, spatially and temporally indexed genomic analysis of microbial communities may be possible with the appropriate micro-analytical systems mounted on the sensorbot platforms in the swarm mode.
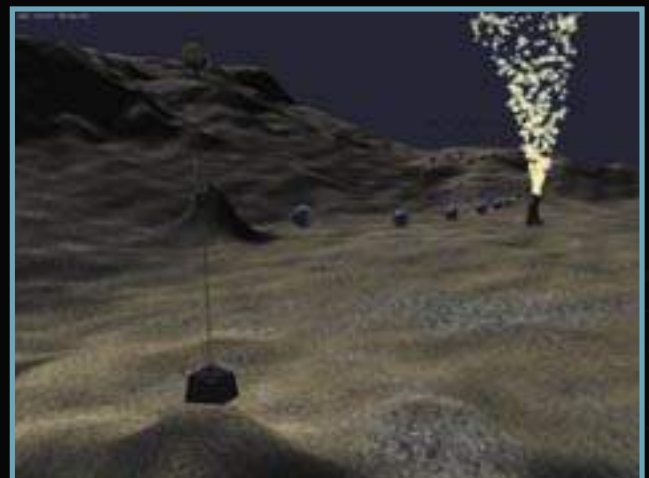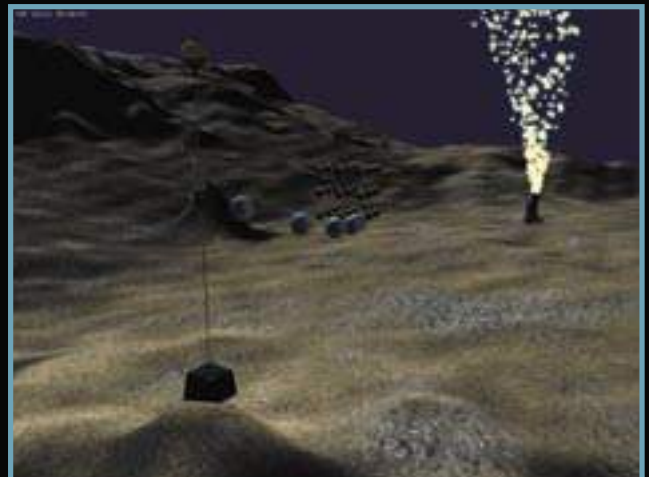
SENSORBOT ARRAYS TO MONITOR SPATIAL AND TEMPORAL VARIATIONS IN AQUATIC ENVIRONMENTS: SENSOR-ROBOT SWARM INTENDED FOR USE IN THE DEEP OCEAN. THE SCENE IS AT THE FLOOR OF AN ACTIVE SUBMARINE VOLCANO (2000 M DEEP) SHOWING AN ACTIVE HYDROTHERMAL VENT. THE YELLOW MOORING (FOREGROUND) IS HARDWIRED TO A BURIED ELECTRO-OPTICAL CABLE CONNECTED DELIVERING POWER AND COMMUNICATIONS TO SHORE. THE MOORING COMMUNICATES WITH THE YELLOW SENSOR-ROBOT SWARM BY OPTICAL MODEM, WITH ACOUSTIC BACKUP, THROUGH THE SINGLE CHAIN OF BLUE COMMUNICATION-NAVIGATION MODULES. FIGURE A SHOWS THE TIGHTLY CLUSTERED SENSORBOT SWARM NEAR THE MOORING. FIGURE B SHOWS THE EXPANDED SENSOR SWARM DOWNRANGE. THE SENSORBOT SWARM MAKES SELECTED MEASUREMENTS IN TIME AND SPACE AS IT MOVES, USING TONS OF DIFFERENT MICRO-SENSORS. POWER IS FROM RECHARGEABLE BATTERIES SERVICED ROUTINELY AT CHARGING STATIONS NEAR THE BASE OF THE MOORING.

If the position, control, and mobility parameters on these sensorbots can be designed to be sufficiently precise and accurate, as a swarm they would have the ability to detect and respond to specific stimuli such as motion, turbulence, thermal variations and other physical processes operating in the deep ocean. These robots might be programmed to respond to events such as submarine volcanic eruptions and earthquakes. Bioluminescence will be tested as a biological (non-electrical) medium for intercommunication between adjacent sensorbots, which does not require high-speed communication or high optical intensity. Once in full operational mode, all data would be continuously downloaded to the NEPTUNE network and data archiving and analysis system. These capabilities will allow oceanographic and geophysical phenomena to be explored with entirely new research strategies. EEK2005

THE NSF OCEAN OBSERVATORIES INITIATIVE

As a result of recent discoveries about the ocean, scientists are asking new questions that cannot be answered using only traditional approaches. To address the next generation of questions and problems, the National Science Foundation's Ocean Observatories Initiative (OOI) will support the development of novel strategies to allow for remote, routine, and continuous operation within the oceans. These will enable better understanding of our planet's crucial fluid engine of global change and moderation, and will help us to eventually learn to manage major components of our ocean space.

The OOI merges technological advancements in sensor technologies, robotic systems, high-speed communication, ecogenomics, and nanotechnology with ocean observatory infrastructures that will meet the needs of both science and society. One of these next-generation facilities, a regional cabled observatory, will provide instantaneous and remote surveillance of thousands of square kilometers of seafloor and the overlying volume of ocean. Vast sensing arrays, coupled with new classes of robots and autonomous vehicles, will respond to unexpected events as well as continuously collect information from microbial to global scales. High-bandwidth communications will transmit data directly from instruments the oceans to any user with an Internet connection.

THE PEOPLE OF NEPTUNE

Members of the multi-institutional NEPTUNE consortium are the University of Washington, the University of Victoria, the Woods Hole Oceanographic Institution, the Monterey Bay Aquarium Research Institute, and the California Institute of Technology's Jet Propulsion Laboratory (JPL).

The University of Washington's Applied Physics Laboratory and the department of Electrical Engineering are teaming with the Jet Propulsion Laboratory of California Institute of Technology to design the NEPTUNE power network. The first prototype, named MARS is scheduled for deployment during the second half of 2005. It is a scaled down version of NEPTUNE, which will be installed at Monterey Bay Aquarium Research Institute in California.

Canada has begun work on the northern portion of the NEPTUNE network, led by the University of Victoria, with support ($62.4M Can) from federal and provincial governments. In the US, the National Science Foundation has formed the Ocean Research Interactive Observatory Networks program to oversee the comprehensive national development of the Ocean Observatories Initiative (OOI). The OOI is slated to begin in FY2007 with a 6-year budget of $268M US, to be funded through NSF's Major Research Equipment and Facilities Construction Account. The NEPTUNE consortium will compete for participation in that program.

The NEPTUNE Power System is being developed by an engineering research team led by Bruce Howe and Tim McGinnis from the UW Applied Physics Laboratory, Harold Kirkham and Vatche Vorperian from JPL, and UW EE Professors Mohamed El-Sharkawi and Chen-Ching Liu.

UW Oceanography (Professor John Delaney), Computer Science and Engineering (Professor Ed Lazowska), and UW Computing and Communications (Dr. Ron Johnson) have teamed with Oregon State University (Professor Mark Abbott), and the University of California, San Diego (Professors John Orcutt and Larry Smarr) to initiate the design of the NEPTUNE cyberinfrastructure.

The "sensorbot swarm" concept is being developed by Professor John Delaney of UW Oceanography, Professors Deirdre Meldrum, Mani Soma, and Lih Lin of UWEE, and Professor Mary Lidstrom of UW Microbiology and Chemical Engineering.

For further information on this project, please visit the following sites:
http://www.neptune.ocean.washington.edu
http:// www.neptunecanada.ca
http://www.neptune.washington.edu/
http://neptunepower.apl.washington.edu/np_home.html
http://cialab.ee.washington.edu

THE FUTURE OF

Radar, RF and Computational Electromagnetics

HOTTEST TOPICS: As the experience with passive radar (or "passive coherent location") grows, its potential rests on the development of networked systems. Professor John Sahr is developing passive radar instruments and he is currently engaged in developing a truly distributed network of five passive radar receivers in the Pacific Northwest, in conjunction with five more in New England (operated by MIT-Haystack Observatory). A second area of current radar research is in the application of ionospheric physics, as part of new remote sensing instruments, which are capable of capturing the daily variability for remote sensing. A series of new ESSP remote sensing satellites will be launched to monitor oceans, land and atmosphere. Large-scale computational methods will be used to model the interactions of waves (electromagnetic waves, optical waves, electron waves, acoustic waves) with large-scale structures. This is important for studying issues such as global climate change, and for the monitoring of natural resources and evaluation of natural disasters. More generally, large scale problems of multiple scattering of waves by structures is not adequately understood, but is important in applications ranging from electron scattering from nanostructures, disorder effects in photonic crystals, scattering of surface waves and wave scattering in outdoor and indoor wireless communications. Professors Leung Tsang, Yasuo Kuga and Vikram Jandhyala are investigating these topics.

Computational electromagnetics is being applied to new materials, meta-materials and nanotechnology, and to future systems-on-a-chip. This enables innovations in functionality, size, speed, and reliability for defense, communication, and biomedical applications. Professor Vikram Jandhyala is leading an effort in this field. Professors Richard Shi, David Allstot and Mani Soma are involved in this field and related efforts.

High-frequency test methods for digital RF, analog RF, and mixed-signal electronic systems in computing and communication are current topics of great interest. These methods enable test equipment to keep up with new product designs. Recently several companies have had to cancel or delay products because they are unable to test them to verify performance. Professors Mani Soma, Richard Shi and David Allstot are conducting research aimed at addressing these problems.

IN THE NEXT DECADE: Parallel methods, fast hierarchical methods, and design techniques will enable real-time design of future systems. Issues of the complexity of cross-physics simulation and telescoping or changing the physics depending on simulation speed requirements will be successfully resolved. Embedded distributed simulation within circuit-level simulators will allow multi-physics design with the same ease with which digital VLSI is designed now.
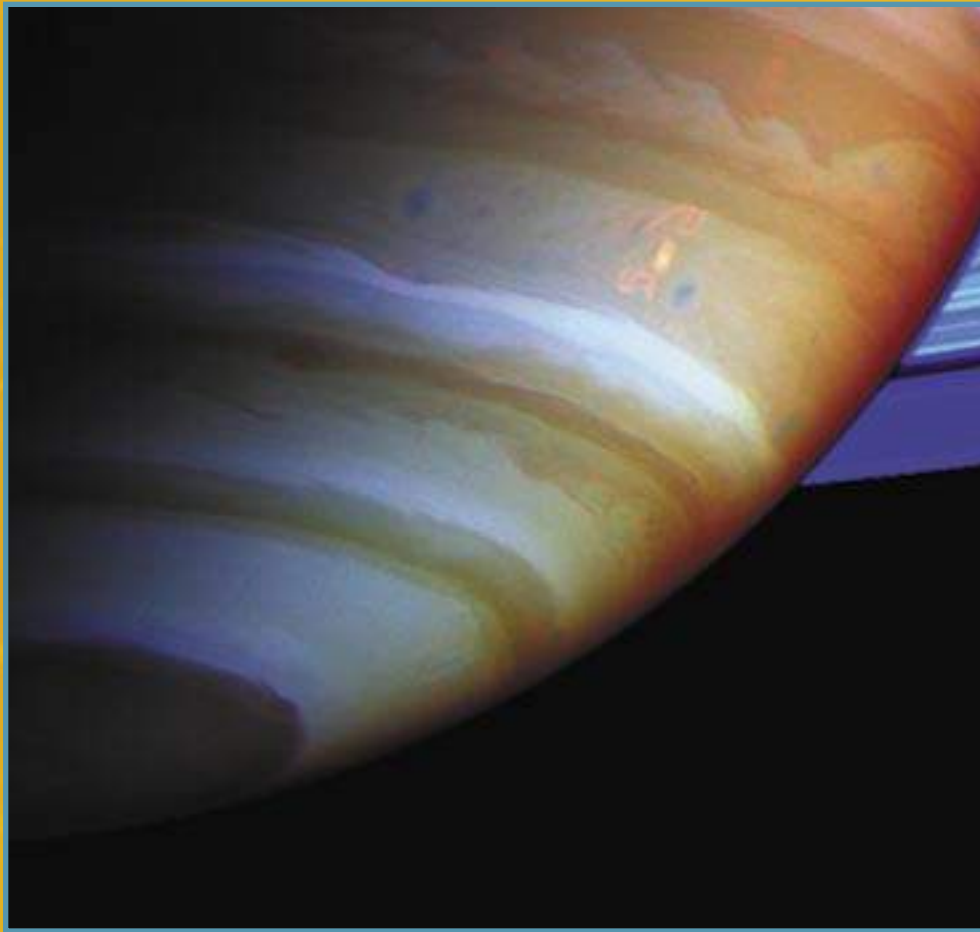
ELECTROMAGNETIC ACTIVITY IN THE ATMOSPHERE OF SATURN.

In ionosphere research, we will see a robust, ubiquitous networking of autonomous/semi-autonomous ionospheric sensors. Progress in understanding the Earth-Ionosphere-Magnetosphere system will rely critically on improving the quality of data ingested by the big models. Here, "quality" does not mean "better resolution" as much as it means "better coverage." One of the key challenges to the field is to get the scientists to build lots of "low quality" instruments rather than a few "high quality" instruments. The former will actually lead to better science product in conjunction with the models.

LONG RANGE FORECAST: In the coming century, conventional ionospheric physics methods will become mature. New work will involve increased contemplation of the ionospheres of other planets. The Gas Giants (Jupiter, Saturn, Uranus, Neptune) have spectacularly complex ionosphere/magnetosphere systems. Near Jupiter's moon Io, a process akin to a welding operation exists with spectacular auroras generated at the base of the field lines passing through it. To understand the scale of this, if you could see the magnetosphere of Jupiter with your naked eye, it would be four times as wide as the Sun! Jupiter will present significant radiation hazards for both electronic equipment and human visitors — a formidable technical challenge on many fronts.

THE NEW RENAISSANCE IN COMPUTATIONAL ELECTROMAGNETICS

PROFESSOR VIKRAM JANDHYALA

Computational Electromagnetics (CEM), as the name suggests, deals with the numerical solution of electromagnetics. It is elegantly captured by Maxwell's equations, which govern the behavior of electric and magnetic fields. Compared to fluid dynamics and quantum mechanics, these equations are relatively simple (albeit they are still coupled vector partial differential equations). Nevertheless, the art of finding computational methods for these equations has motivated individuals trained in physics, EM, signal processing, applied mathematics, computer science and programming to produce simulation methods for this field.

CEM has been driven by the emerging needs in defense, space and communications. Antennas are the common link in all these areas, from simple television and radio antennas to modern complex, adaptive, multiple-input multiple-output antennas for digital communication. Stealth and radar cross section reduction techniques were developed using filters, called frequency selective surfaces, which required the use of large computers. Several biomedical applications, including magnetic resonance imaging (MRI) also need these methods. Remote sensing (from satellites) is another active area where CEM has been applied, dealing with scattering from soil, rough surfaces, ice and water and was a useful method to ascertain remote conditions from satellites.

Over the last decade, the major emphasis of CEM has shifted to microsystems. Computer chips and the related packaging and boards now operate at higher frequencies and speeds, while packing density of components has dramatically increased. These trends result in substantial EM effects at the chip, package and board levels. When signals propagate on metal lines inside these microsystems, they also interact with each other through EM effects. The design of these systems can take this into account by obtaining equivalent inductance, capacitance, resistance, mutual effects and impedance to model EM effects, or by deriving designs that mitigate them. Both are actively used to design the present generation of microsystems, such as the Pentium, the microelectromechanical (MEMS) chips found in flat screen TVs, in analog and mixed-signal systems for radar processing, and in the wireless communication chips found in cell phones. The Applied Computational Electromagnetics (ACE) Lab led by Professor Vikram Jandhyala is very active in developing methodologies in these areas (with support of the National Science Foundation, the Semiconductor Research Corporation (SRC), the Defense Advanced Research Projects Agency (DARPA), and Intel Corporation, amongst others). Current interest is now shifting towards developing robust and commercial-strength simulation tools for these areas.

In the last few years, microsystems have become more complex. As packing densities have increased and feature sizes have diminished, quantum effects have become more pronounced. More varied technology is now being integrated into these microsystems, such as optical devices, thermal devices, MEMS systems, mixed-signal systems, and microfluidic systems. Hence multi-physics multi-technology simulation and design is becoming critical. These multi-physics systems will involve EM, ranging from on-chip antennas and receivers, wireless interconnects and parasitics, to electrostatic actuators and more esoteric quantum control. Problems in microfluidics and thermal simulation can be recast into forms that look very similar to EM. Hence CEM will play a critical role in the development of algorithms and techniques to design these systems using new technologies for computing, communication, control and sensing. The physics encountered in such systems will cross several scales. CEM can be used to bridge these levels. Developing these simulation and design tools will require the simultaneous development of new parallel simulation methods and enhancements to the class of "fast algorithms" in CEM.

AN EXAMPLE OF WHAT CEM CAN DO NOW: VISUALIZATION OF 3-D CURRENT THROUGH AN INDUCTOR AND CAPACITOR STRUCTURE IN A HIGH-FREQUENCY RADAR CIRCUIT.

In the next ten years, such systems will become even more integrated, complex and diverse. The bio/nano/quantum interface will become a key area. Within nanotechnology, molecular electronics and bio-particle manipulation are both strongly dependent on EM and quantum effects. Biological applications at the manipulation, DNA and cell levels are also dependent on several low-frequency EM effects. Quantum computing also relies on highly accurate electromagnetic field generation for classical control of quantum states. All three areas will directly be affected by future CEM methodologies, based on the development of multi-physics paradigms.

In the next 50 years, space exploration and fusion technologies will rely on several CEM-related advances for design, communication, energy generation and control. In the next century, the narrow "silo-based" thinking of the past half-century will no longer be adequate. Like the Renaissance, a more holistic approach to knowledge will be required. It will become possible to scientifically tackle problems that have been with mankind for all of time: the human mind, social science and interactions, and even consciousness and spirituality. By then, a silo-field like CEM will have no relevance on its own. A combination of complex networks, nonlinear systems theory, quantum mechanics and field theory (with CEM addressing the last two areas) will form the basis of a future scientific framework for areas now considered to be outside science. That will indeed be an exciting and satisfying time. **EEK**2005

THE MANASTASH RIDGE OBSERVATORY, NEAR ELLENSBURG, WA, IS OPERATED BY THE UW ASTRONOMY DEPARTMENT. THE RADAR REMOTE SENSING LAB AT UWEE USES IT ALL YEAR, AND EVEN SKI TO IT IN THE WINTERTIME.

PASSIVE RADAR

PROFESSOR JOHN D. SAHR

Professor John Sahr, EE graduate students Melissa Meyer and Andy Morabito, and several undergraduate students are currently working on the Manastash Ridge Radar (MRR), which is operated out of the Manastash Ridge Observatory near Ellensburg, WA.

MMR is a bistatic passive radar system that uses commercial FM broadcasts as a signal source. By carefully analyzing these broadcasts, faint echoes can be detected from many different objects including mountains, aircraft, meteors and turbulence in the upper atmosphere. Because FM broadcasts are very powerful, and have other nice properties, MRR's data is among the very best in the world.

Turbulence in the lower ionosphere called Auroral Electrojet Irregularities can degrade the quality of radio services which depend upon paths through the ionosphere. Because the altitude of this turbulence (100 km) is too high for balloons or aircraft, and too low for satellites, radars provide the only means for regular study in this region.

In the coming year, the radar system will be expanded in a collaborative project with the MIT. Dr. Frank Lind and his colleagues at the Haystack Observatory are building powerful new receivers which will be deployed in Washington State as well as New England. Two sites in Canada will be added as well. **EEK**2005

THE FUTURE OF

Sensors

HOTTEST TOPICS: Developing sensors for the real-time monitoring of trace biological and chemical analytes, down to of nano- and pico- molar concentrations. This capability is important for a number of applications. New sensors for chemical and biological toxin/warfare agent detection based upon surface plasmon resonance are being developed by Professors Sinclair Yee, Tim Chinowsky, Denise Wilson and R. Bruce Darling, in collaboration with Chemical Engineering Professor Shaoyi Jiang. Sensors for environmental monitoring of emissions control are also research topics of Professors Wilson and Darling. Tim Chinowsky's project to develop new instrumentation for saliva-based medical diagnostics is part of a collaboration that includes Bioengineering professor Paul Yager, Genome Sciences Professor Clement Furlong, and Chemistry Professor Patrick Stayton.

IN THE NEXT DECADE: Significant advances will occur in on-chip reagent storage, fluidic control, and temperature control for sensor systems. To produce reliable devices in quantity, microfluidic systems need to be small, dependable, and easily integrated. In order to use specific recognition and binding chemistry, which is often the first step in transduction, the reagents need to be retrievable and stored without damage, and thermal fluctuations that can cause signal drift must be mitigated.

Biochemistry research will lead to the development of specific binding chemistry for targets of interest. Designer molecules that perform the first level of transduction will drive these applications over the next ten years. For example, to design a real time monitoring system for detection of picomolar concentrations, we might rely on the ability to specify monoclonal antibodies and required binding proteins to meet a specific need. Work in UWEE, in collaboration with Professor Clement Furlong's group in the Genome Sciences Department is addressing this issue.

LONG RANGE FORECAST: In the next 50-100 years, it is likely that ubiquitous, networked, "seamless" sensors systems will be developed for monitoring and interpretation of the global environment, and for the entire individual humans.

THE ENOSE TOOLBOX:
SNIFFING OUT EVOLVING SOLUTIONS TO CHEMICAL/BIOLOGICAL SENSING PROBLEMS

PROFESSOR DENISE WILSON

Editor's Note: The following entry arrived by transtemporal email. It appears to contain the reminiscences of a future major donor to the department.

I sat down at a workstation for what seemed like the first time in years, with Jeff, our latest summer intern, who was tasked with redesigning a sensor system for monitoring a site just outside the city limits. Environmental pollution was an increasingly sensitive issue as more information about the contents of the soil, water, and air in our everyday lives became available and distributed to the public eye. The expectations of the public for safe air to breath, food to eat, and water to drink prompted a spiraling series of new regulations that required broader and more capable sensing systems in order to be enforced properly. The site that we were addressing focused on bioremediation of an old

military installation where jet fuel leaked into the soil, over long years of use. Immense progress had been made in the development and use of natural bacteria to convert toxic compounds into more environmentally benign byproducts. However, the bacteria continued to have a rather persnickety view of the optimal conditions to do their clean-up work; the traditional means for sampling a few points in the area and transporting the samples back to the laboratory for analysis and subsequent adjustment of nutrients and other growth conditions was no longer fast or efficient enough for a demanding public eye.

In retrospect, it wasn't so long ago, only ten years, when my partner and I were the only ones here, in my company now of 100 plus employees, and growing at a rate that simultaneously filled me with daunting trepidation and immense excitement. I was quite skeptical when the market research for our idea for a consulting firm exceeded even the optimistic expectations of my partner. After eight years, though, it wasn't hard to see that the demand for a middleman to convert the intimidating number of choices for chemical and biological sensor technologies into coherent, optimized, and cost-effective systems was and promised to remain high.

When it first started, the ENose Toolbox was little more than a solid education tool that I was first introduced to in a senior electrical engineering class in my days as an undergraduate at the University of Washington. As part of a broad survey of sensors and sensing systems, my study group and I were tasked with designing and optimizing a sensor system of our choice. Intrigued by the mission of the newly created Homeland Security agency, we chose to take on the design of a vapor-phase system for monitoring large public spaces, such as subways and sports arenas for lethal chemical agents. At first, the task seemed quite straightforward. With models and a common language to describe sensor technologies from surface plasmon resonance to polymer chemiresistors, we engaged in the optimization of an array of sensors to detect the toxic agents at sufficiently low levels to protect a vulnerable public.

What followed was a deflating of the ego, to understate our reaction when we received midterm feedback on our project. We had optimistically left out considerations of real-world conditions in our analysis, including humidity and interferent vapors that would result in the equivalent of at least a dozen evacuations of our targeted public space a day, something the public was sure to lose patience with rather quickly. Daunted, but nevertheless energized by the "realness" of the engineering problem at hand, we went back to the drawing board, prioritized our interfering effects, and redesigning the system to accommodate them.

In those days, many of our fellow students as well as industry skepticists and researchers alike, doubted the ability of the ENose toolbox to adequately represent the many complex influences on chemical and biological sensor technologies in real-world environments. No doubt, the ENose toolbox could well initiate students to the multidisciplinary complexities of designing chemical and biological sensor systems. At first, it seemed like the impossible task, to tame the innumerable classes of these sensor technologies into a set of coherent models without the luxury of through and across variables that aided the development of simulation tools for sensor types outside the chemical and biological realm. Using the "you have to start somewhere approach," its developers hoped to create a common language for researchers around the world to contribute input to evolving models of chemical and biological sensor technologies that became increasingly more complex and useful as the momentum of the Toolbox developed and evolved.

Over the years, aided by the common language, a growing database, and access to the Toolbox over the public domain, the capacity and capability of it grew, until we could simulate the impact of a wide variety of real-world inteferents and influences on chemical and biological sensing systems. Using the ENose toolbox, we started our designs by selecting the technologies and material types that could detect our targeted analytes at concentrations relevant to our application. We came up with a preliminary set of optimized designs that detected our analytes in the presence of common interferents to the known sensing environment that we were addressing. Then we evaluated each design, in terms of cost, power, and complexity weighted against its resilience and robustness to fluctuations in the real-world, real-time sensing. Distilling our possible designs to a short list, we then contracted out to the appropriate research laboratories or companies to fabricate the sensors in the desired hybrid configuration. Playing the middleman in this way, we had grown our company at an astonishing rate over the past decade, addressing sensing needs that ranged from monitoring bioremediation in environmental clean-up sites to the detection of toxic agents in subway stages leaning on the power and infrastructure provided by the optical telecommunications networks. **EEK**2005

THE FUTURE

Signal Processing

and Communications

OF

HOTTEST TOPICS: In the broad area of signal processing and communications, a current topic of intense interest is improved methods of speech recognition for human-machine communications. Professors Mari Ostendorf and Katrin Kirchhoff are working on automatic translation and speech recognition in multilingual conversations. Professor Jeff Bilmes is leading the "Vocal Joystick" effort to provide a "sound recognition" (rather than speech recognition) system that provides computer access to individuals with severe physical disabilities. He is also a leader in the development of a "graphical models" formalism that combines high-level domain knowledge with a formal mathematical/statistical approach of this type of problem.

PROFESSOR MAYA GUPTA AND UWEE GRADUATE STUDENT NATHANIEL JACOBSON HAVE DEVELOPED A METHOD TO DISPLAY HYPERSPECTRAL IMAGES IN A WAY THAT MATCHES HUMAN VISUAL PROCESSING AND OUR NEED FOR RAPID INTERPRETATION AND UNDERSTANDING OF SCENES. THIS EXAMPLE SHOWS A 224-BAND IMAGE OF MOFFETT FIELD ON A STANDARD CRT MONITOR.

Professor Maya Gupta is developing nonparametric statistical learning theory, and applying new theory to problems in protein engineering, as well as assisting graphic artists to create custom color image enhancements.

UWEE and CSE Professor Linda Shapiro is developing methods of video analysis, including object and event recognition, to both military and industrial surveillance problems. Professor Greg Zick is engaged in transferring image and multimedia database technology to the commercial sector.

The research of Professor Les Atlas involves time-frequency signal processing and novel methods of modulation spectral analysis. These techniques could revolutionize the way large data sequences are handled in applications ranging from speech and music, to movies and the interpretation of DNA genomes.

Multimedia research, which combines these different types of content, is an active topic of contemporary research and development. Professor Jenq-Neng Hwang is working on problems of Embedded Wireless Multimedia, which satisfies the growing demand for ubiquitous multimedia content and information/entertainment access using handheld devices (through either WLAN or 2.5G/3G mobile connections). This work requires the application of several research disciplines, including multimedia coding and signal processing, wireless networking, embedded programming, real-time operating systems, and systems-on-chip development.

Hwang and Professor Jim Ritcey work on improving networking performance by categorizing the packet loss as either Internet routers or wireless fading. Professor Ming-Ting Sun is developing new technology for broadband wireless networks, and Professor Sumit Roy is working on the design and analysis of next generation digital networking infrastructure. This research embraces a wide variety of issues pertinent to both wireless and wired/fiber networks, that includes and integrates the design of physical, data-link layer and the transport layers. Next generation digital wireless networks must

accommodate growing numbers of mobile users requiring high data rates (multimedia services) and greater mobility support in a physical environment that is both power/bandwidth limited. Professor Radha Poovendran is conducting basic and applied research in the security of critical networks and network components. This includes issues of secure multimedia multicast, secret sharing schemes, and energy-aware secure group communications in wireless/sensor networks.

Critical to all of these applications is the issue of hardware realization. For example, how do you support floating point computations in FPGAs, required by many signal processing and scientific computing applications? Floating point requires a large area in a FPGA, limiting how much can be done. Professor Scott Hauck is exploring how to improve performance and power efficiency in this area, which will lead to significant improvements in a wide array of applications.
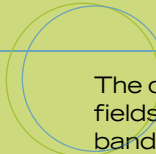
IN THE NEXT DECADE: RFID (radio frequency identification) technology is currently being introduced—this will profoundly change the tracking, ordering, delivery and production of physical items. Soon, we will see ubiquitous information/entertainment access with wireless handheld or wearable devices sensor in a pervasive and secure network. It is rapidly becoming possible to communicate and access networked information from any place, at any time. This includes intelligent transportation access and scheduling, which is captured in the work of Professor Dan Dailey. One aspect of these new technologies will be in novel use of human-computer interfaces. Speech, haptic (sense of touch) interfaces such as those developed by Professor Blake Hannaford, and possibly direct electrical connection to intended motion through EEG ("brainwave") will become feasible. Friendly human computer interfaces based on natural language recognition/understanding, free handwriting inputs, and hand/body gestures will all enter the marketplace.

LONG RANGE FORECAST: In the next 50-100 years, algorithms that appear to make computers and other appliances intelligent will become common. This will require fundamental advances in our abilities to compute quickly. Quantum computation, or any other methods that make computing possible in five-ten orders of magnitude higher with lower power will be required for the anticipated changes in communication.

A personal multimedia (video, photo, sound, health sensing) recorder of everyone's daily life events (24/7), with systematic indexing, retrieving and information sorting will be technically feasible (although perhaps not politically or socially desirable).

FILTERS OF THE FUTURE

PROFESSOR LES ATLAS

The concept of frequency filtering is common across electrical engineering and many other technical fields. For example, every time we change a television channel we are adjusting the center of a bandpass filter to match the broadcast or cable channel that we wish to watch. Even modern video delivered over the Internet uses extensive frequency filtering to reduce the amount of raw data in the sequence of images and accompanying audio. This concept of frequency filtering is based upon the mathematical concept of time-shift invariance, which says the filter acts exactly the same whenever it is applied. So, if a filter is designed to remove all signal power at frequencies above 1000 Hertz, this happens whenever the filter is applied. Concepts such as linearity, convolution, and transfer functions allow us to predict how the filter will behave for any reasonable input. Modern advances like cellular phone receivers use filters to make channel selections while suppressing all kinds of undesired wireless radio signals and noise. Frequency filtering is a mature concept with many software tools available to design and implement filters.

Are there any new research opportunities in filtering? Over the years, researchers have been dropping the requirements of linearity and time invariance. Modern research concepts such as sequential learning and inference methods are important in many applications where data arrival is inherently sequential. These methods and related concepts such as particle filtering vastly extend the notion of filtering. Recent developments in applied statistics have also stimulated advancements in the field of sequential Monte Carlo simulation. Current research is investigating these methods on a large number of interesting problems such as computer vision, econometrics, medical prognosis, tracking, communications, blind deconvolution, statistical model diagnostic tools, automatic control and navigation.

Another new filtering possibility, which keeps the assumption of linearity but drops time-invariance, arises from graduate student research in modulation frequency theory supervised by UWEE Professor Les Atlas. This linear form of filtering is based upon frequency-shift invariance. A modulation filter acts the same no matter where it is applied in frequency. Instead of specifying cutoffs in frequency, they can be specified in the modulation rate. For example, a modulation filter, which removes all modulation energy above a two Hertz modulation rate, would presumably remove the fastest talkers from a conversation while leaving the slower talkers. This form of filtering would potentially be useful in areas such as audio coding and hearing aids. For example, the blurring of competing conversations is a common problem for people who have lost some of their hearing. A modulation filter, which is trained with some previous speech samples from a desired speaker, (such as one's spouse, child or friend), could select the desired individual while suppressing others. Modulation filters could also improve the efficiency of wireless networks, allowing us to carry even more conversations or data over existing networks. EEK2005

THE VOCAL JOYSTICK

PROFESSOR JEFF BILMES

The Vocal Joystick (VJ) is a novel human-computer interface mechanism that enables individuals with motor impairments to control objects on a computer screen (buttons, sliders, etc.) by using only vocal control. Ultimately, electro-mechanical devices such as robotic arms and wireless home automation devices will be controllable as well. The VJ project involves a combined effort in a variety of research areas including computer science, electrical engineering and signal processing, phonetics, cognition and perception science, machine learning, and human computer interaction.

A working VJ system has recently been implemented and currently runs on a standard laptop computer. The system works by simultaneously recognizing a user's vowel quality, voice pitch, and voice amplitude to produce four continuous parameters that can be used to control devices such as mouse movement on a screen. In this case, each of four vowels corresponds to one of four different mouse movement directions (up, down, left and right). By uttering each vowel, the mouse moves in the appropriate direction. Additional vowels for more directions are currently being developed. Moreover, vocal loudness is used to control mouse acceleration so that users can both rapidly move long distances and maintain fine-grained control for short distance movement. The VJ system can also recognize discrete sounds, so the combined and simultaneous coordination of continuous vocal control and discrete sound recognition is analogous to a physical joystick used to control video games.

The currently working VJ system is already quite useful. A recent video demonstration of the VJ system can be viewed at: http://ssli.ee.washington.edu/vj/. The ultimate goal of this project is to provide a new useful human-computer interface methodology for individuals with motor impairments who otherwise would not have as fluent a technology available.

The VJ team consists of UWEE Professors Jeff Bilmes (PI), Katrin Kirchhoff and Howard Chizeck, Computer Science and Engineering Professor James Landay, Linguistics Professor Richard Wright, and Speech and Hearing Sciences Professor Patricia Dowden along with graduate students Xiao Li, (EE), Jon Malkin (EE), Kelly Kilanski (LING), Amar Subramanya (EE), and Susumu Harada (CSE).

SPEECH RECOGNITION WITH GRAPHICAL MODELS

PROFESSOR JEFF BILMES

In Arthur C. Clark's 1968 novel, *2001: A Space Odyssey,* computers such as the HAL9000 had feelings and could reason just like people. They could also easily recognize and understand human speech. Here we are in 2005, four years after the time that story took place. One might wonder: can computers now recognize and understand human speech? A quick check on Google® reveals that many companies advertise computer programs. However, speech recognition by computer is based on something entirely different than the HAL9000.

The technology behind most of these speech recognition systems is the hidden Markov model (HMM), a statistical technique that has been around since even before 1968. A hidden Markov model is a random time-series model that allows for variability in time and also between a sequence of words and the way in which that sequence of words might be spoken. However, as anyone who has tried speech recognition knows, HMM-based speech recognition methods fail to properly recognize speech in a variety of important cases. This includes situations where there is background noise, such as when driving in a car with the radio on or with the window open, or when at a party or meeting with many background speakers. Moreover, these methods can fail to account for the variability in speech due to regional accents and dialects or even when a person has a cold.

UWEE is one of the world leaders in a new technology for speech recognition and natural language processing that addresses some of the shortcomings of the HMM approach. The technology is based on the concept of 'graphs,' which was invented by the mathematician Euler in 1736. In a nutshell, graphs are a two-dimensional visual and mathematical formalism that can be used to describe many different phenomena. Graphs can describe the outcome of a season of baseball games, the schedule of a chess tournament, the rules of puzzles, the workings of an electrical circuit, or social and interpersonal relationships. The popularity of graphs is due to their ability to explain extremely complex situations in a concise, intuitive, and visually appealing way.

Statistical graphical models are a family of graphical abstractions of statistical models, where important aspects (namely factorization) of such models are represented using graphs. A fundamental advantage of graphical models is rapidity—with a graphical model, it is possible to quickly express a novel and complicated idea in an intuitive, concise, and mathematically precise way, and to speedily and visually communicate that idea between scientists. With the right software, it is possible to rapidly test that idea on a standard desktop workstation. In recent years, it has become apparent that graphical models offer a mathematically formal means for solving many problems encountered in speech recognition. Graphs are able to represent events at the very high level (such as the relationship between ideas), at the very low level (such as the relationship between acoustic events), and at every level in between (such as words and syllables).

A graphical model is a representation of a set of random variables and the dependence relationships between those variables. Nodes in a graph represent the variables, and the relationships are represented by the edges connecting those nodes. In fact, anytime there is not an edge between two nodes, the graph is indicating that there is some factorization property that holds true among all probability distributions that obey the rules of the graph. Factorization is an important property because it allows the distributed law to vastly reduce the amount of computation required to compute probabilistic quantities of interest. For example, if an unknown speech signal is represented by a set of random variables, which randomly relate to a set of word variables, it is important to be able to efficiently compute the most probable word variables once the values for the speech signal variables becomes available.

The set of possible models expressed by a graphical model is far richer than just the HMM. For speech and language research, graphical models may allow scientists to rapidly express and evaluate their ideas in this domain, quickly evaluate new methods, rule out those that do not work and advance those that work well. Without the graphical model framework, one must re-implement each idea over and over to some programming language. Equally important, graphs provide a visual representation of a problem, so it becomes possible to intuitively verify that assumed properties are the desired ones. Graphical models augment a set of equations with a representation that humans are good at contemplating. Equations alone do not always provide enough of an intuitive feel about whether a statistical representation of a problem is correct. Graphs provide a picture that is worth a thousand equations.

Graph-based methods can be used in a speech recognition system only if there is suitable software available. Professor Jeff Bilmes and his graduate students Chris Malkin (EE), Mukund Narasimhan (EE), Gang Ji (EE), and Karim Filali (CSE) are developing the Graphical Modeling Toolkit (GMTK), which is in active use worldwide. The goal is to provide researchers with a set of abilities to express models in terms of graphs, but hide many of the technical details regarding the graphical algorithms at the same time. GMTK is highly optimized for speed and ease of use; its development has resulted in the creation of a number of novel techniques. Graphical models hold great promise to be the "next big thing" in speech and language processing. **EEK**2005

THE
FUTURE OF
Interaction of Electrical and Biological Engineering

HOTTEST TOPICS: Many of the core methods of Electrical Engineering, including techniques of automatic control, system modeling, communications, and signal processing are increasingly being applied to the engineering of biological systems. This is a two-way exchange of information. Biological designs are inspiring new approaches to the synthesis of devices in Electrical Engineering. There are a number of "hot topics" on the hard-to-define boundary between these fields. One area is the combination of electronic devices with biological components. Professor Mani Soma is investigating the integration of microorganisms in artificial systems on the cellular level, in collaboration with Chemical Engineering Professor Mary Lidstrom and colleagues from several departments. Professors Babak Parviz and Eric Klavins, and several colleagues in the Materials Science and Engineering Department are exploring methods of self-assembly systems of molecular electronic and nanoscale photonic devices using DNA, or using genetically engineered polypeptides to guide self-assembly processes.

A second "hot topic" along the interface between Electrical Engineering and Biology involves advances in genomics and proteomics, using automation techniques at both the micrometer and nanometer scale. One particular focus is "single molecule DNA sequencing," a potentially inexpensive and rapid way to sequence many genomes. This might allow sequencing of each individual person, potentially leading to tailored treatment of disease.

A third area of current interest is real-time multi-parameter dynamic single cell analysis. This is important to improve our understanding of how cells work. This work includes the development of microfludic systems, a research focus of Professors Deirdre Meldrum and Mark Holl of the Microscale Life Sciences Center (MLSC). Professor Howard Chizeck is investigating the development of mathematical models and simulation tools for these systems. The combination of new data about single cell dynamic processes and mathematical representations of systems and control mechanisms may be useful to improve understanding of disease processes, and the rapidly developing field of synthetic biology.

At a larger physical scale, problems relating to human/machine electronic interfaces for devices such as neural prosthetics (to replace damaged portions of the nervous system) or as command and sensory interfaces for prosthetic limbs or eyes are of great interest. Professor Karl Böhringer is working with Biology Professor Tom Daniel on the development of electrodes for some of these applications. Blake Hannaford, Howard Chizeck, Alex Mamishev and Jacob Rosen interact with colleagues at the Puget Sound VA Medical Center, as well as other UW departments on some of these types of problems.

IN THE NEXT DECADE: Significant advances in using nano-structures and micro-structures to collect information from biology will begin to change medical diagnostic techniques and treatment methods. Other likely advances are improvement in DNA sequencing with speed and cost reduction due to microfabrication, new sensing mechanisms for infectious diseases, integrated systems that do biological sensing and data manipulation, and the introduction of intelligent artificial drugs/devices that will detect disease and provide treatment when and where needed.

LONG RANGE FORECAST: The next century may see the deployment of integrated bioelectronic systems at the nanotechnology level. These will be used for communication (implanted network access?), real-time diagnosis and repair of medical problems, replacement parts for human organs and sensory capacities, and possibly augmentation of physical and mental capabilities. Advances in genomics and molecular/nano medicine will revolutionize our lives, providing humans with the ability to extend our lifetimes and simultaneously improve our quality of life.
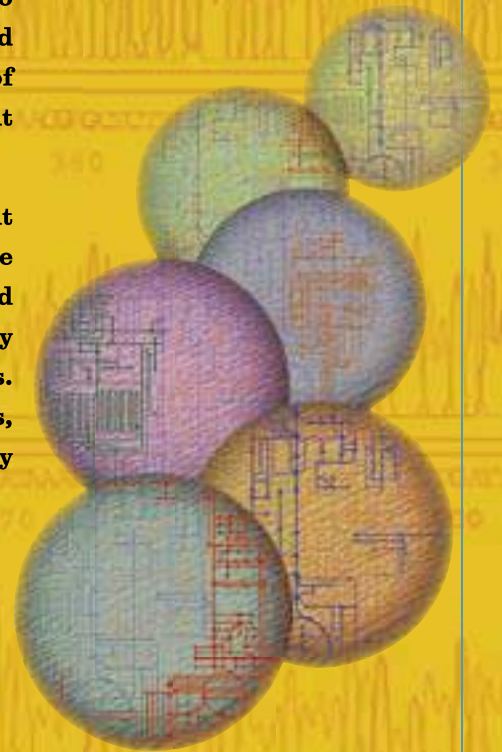
THE FUTURE OF GENOMICS

PROFESSOR DEIRDRE MELDRUM

It is the year 2020. It costs $1000 or less and only two hours to sequence an entire human genome. Research to understand gene function has elucidated numerous human diseases. Personalized medicine enabled by human genome sequence information makes it possible to predict and prevent or minimize genetically based diseases. Prevention is possible in some cases with gene therapy that corrects the genomic or molecular basis of disease. The interplay of genetic and environmental factors that determine health or disease is well known, making it possible to improve health with personalized modifications of the environment (e.g. diet, drugs, etc.) [3]. Treatments are optimized with individual drug design and the ability to ascertain drug responsiveness. The average life span of a human has increased to over 100 years.

How do we get to this scenario by the year 2020? It took over 13 years and cost $3 billion to sequence the human genome by April 2003, the 50th anniversary of the discovery of the double helix structure by James Watson and Francis Crick [8]. It currently costs $10-50 million to sequence an entire mammalian-sized genome. Predictions are that in the next 10 to 15 years, it will cost $1000 or less and only two hours to sequence a human genome. This would be 50,000 times cheaper and a year faster than we can do today [9].

Current high-throughput sequencing technology relies on amplification of DNA, incorporation of labels, and capillary electrophoresis. Fluorescently labeled DNA molecules that differ in size by one base are loaded into arrays of capillaries. An applied voltage causes the DNA fragments to separate by size as they migrate through the capillaries. A detector reads the color of the fluorescent dye specific to the base at the end of each DNA fragment [4].

The National Institutes of Health (NIH) National Human Genome Research Institute (NHGRI), as a part of its vision for the future of genomics research [2], launched a program to develop technology that achieves the "$1000 Genome"[10]. Challenges to achieving this goal are speed, integration and accuracy [11]. The most promising approaches to achieve the $1000 genome are to read out the linear sequence of nucleotides without copying the DNA and without incorporating labels, relying instead on extraction of signal from the native DNA nucleotides themselves. One such approach is nanopore sequencing that would allow direct analysis of individual DNA molecules (which are negatively charged) at rates of up to 1000 bases per second [6]. Bases on a single-stranded DNA molecule are forced single-file through a nanopore, less than two nm in diameter, under an electric potential difference. An integral detector in the pore translates the characteristic physical and chemical properties of a base or sequence of bases into an identifiable electrical signature. When no DNA is present, the pore exhibits an ionic current of 120 pA at 120 mV potential (see figure below). When the pore is occupied by polynucleotides (multiple base-pairs), the ionic conductance decreases in a manner related to the nucleotide composition of the DNA. To achieve the ambitious goal of single nucleotide sequence resolution, several improvements are needed. The movement of DNA through the pore must be slowed down and more sensitive detectors must be coupled to the pores to discern single nucleotides in the electrical signature [4].
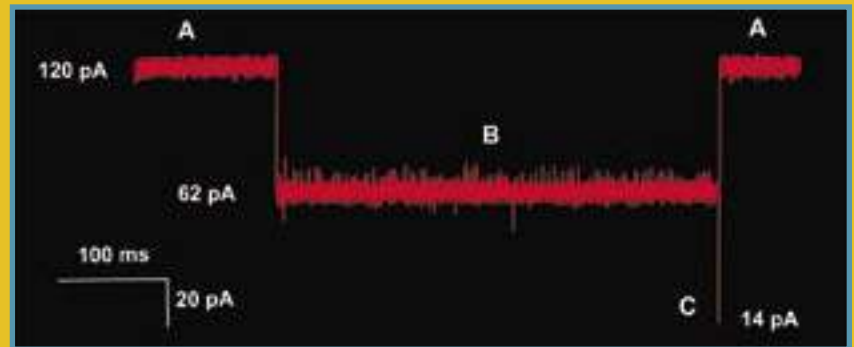
NANOPORE DETECTION OF DNA.

Nanotechnology is playing a key role in advancing technology for DNA sequencing. Research and technology development recently funded by NIH NHGRI to achieve the $1000 genome focus on high-speed nanopore gene sequencing, nanotechnology for the structural interrogation of DNA, and rapid sequencing nanotechnology using electrodes spaced two to five nanometers apart and electron tunneling [12,13].

Advancing the state-of-the-art in DNA sequencing is very competitive as evidenced by the number of companies investing in development of new single-molecule-based methods: Amersham Biosciences, 454 Life Sciences, Helicos BioSciences, LI-COR, Solexa, US Genomics, and VisiGen Biotechnologies, to name a few ([1,7]). The J. Craig Venter Science Foundation announced a $500,000 Technology Prize for advances leading to the $1,000 Human Genome [14].

UNDERSTANDING GENE FUNCTION

It is becoming increasingly apparent that understanding, predicting and diagnosing disease states is confounded by the inherent heterogeneity of in situ cell populations. At the UW, the Microscale Life Sciences Center is focused on solving this problem by developing microscale technology for genomic-level and multi-parameter single cell analysis, and applying that technology to fundamental problems of biology and health. Microscale instrument modules to measure multiple parameters in living cells in real time to correlate cellular events with genomic information (e.g. gene expression and genomic rearrangements) are being developed. These modules comprise a low-cost, flexible, reconfigurable, benchtop toolbox with state-of-the-art detection and analysis features to enable scientists to pursue and solve scientific questions that require analysis of heterogeneous cell populations. The microsystem modules are used for real-time quantitative assessment of expression of different genes and the resulting phenotypes as a function of environmental (and cell-to-cell) interactions. Progress to date includes the development of microsystems with multiple sensors, environmental control, and cell manipulation capability. To ensure broad applicability, experiments have been performed with yeast, macrophages, T-cells, and bacteria. Current capabilities in live cells include measurement of substrate-dependent O_2 consumption rates and measurement of expression from multiple genes using fluorescent reporters, while in fixed cells we are developing the ability to carry out quantitative Polymerase Chain Reactions (qPCR) and quantitative reverse transcriptase qRT-PCR on multiple genes simultaneously and to generate single cell proteomics profiles.

As we expand technology capabilities, we are focusing this technology on a set of interconnected problems involving in situ cellular heterogeneity that link genomics to phenotype to health. These interrelated challenges all have the common theme of pathways to cell damage and cell death and include pro-inflammatory cell death (pyroptosis), programmed cell death (apoptosis), and avoidance of cell death (neoplastic progression). The disease states represented by this suite of problems include cancer, heart disease, and stroke.

MLSC cancer research is focused on correlating progression to cancer with increase in cell-to-cell heterogeneity in Barrett's Esophagus, a precursor to esophageal adenocarcinoma (0.5-1% annual progression rate). This is the fastest growing cancer in the U.S. With MLSC technology and Dr. Brian Reid at the Fred Hutchinson Cancer Research Center, we will analyze crypts from patients during progression and analyze abnormal cell lines derived from patients. The experiments will determine the kinetics of change in multiple parameters (genomic, genetic, physiological) during and after exposure to an agent that induces oxidative damage in single epithelial cells. Measured parameters will include respiration rate (mitochondrial function), mitochondrial membrane potential, viability, reactive oxygen species, cell membrane integrity, nuclear DNA content, loss of heterozygosity for key markers, and specific genome rearrangements. With detailed understanding of Barrett's Esophagus, we may one day be able to prevent esophageal adenocarcinoma.

SUMMARY

We are going to see a revolution in genomic medicine over the next 15 years that will improve the quality of life for humans. Low-cost, rapid whole human genome sequencing could become a routine, in-office diagnostic test [15]) or be performed at birth and stored in silico for testing as needed and as more treatments become available (Robertson 2003). Consideration of the ethical, legal, and social implications of whole genome sequence information is essential. Issues include privacy, discrimination, security, ownership, use, and rights [5,16]. EEK2005

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Congratulations to John Sahr and Richard Shi
who were promoted to Full Professors effective
September, 2004.

Electrical Engineering as a discipline is like a tree because we keep growing new branches. For example, at most universities, Computer Engineering and Bioengineering grew out of Electrical Engineering, and often Computer Science as well. Some universities now have departments of Optics, Photonics, and/or Nanotechnology, which largely emerged from EE, Materials Science, Chemistry and Applied Physics. On the other hand, most contemporary engineering research is interdisciplinary and there is a push toward reunification of the various engineering disciplines that have separated during the past century. These somewhat contradictory trends present curriculum design challenges and also complicates faculty recruitment decisions.

Over the last century, Electrical Engineering has developed a powerful arsenal of tools for describing and understanding the behavior of signals in systems and their control. There is a real opportunity to apply this arsenal and to understand the storage, structure, and processing of knowledge and inference in new materials at new size scales, and in self-organizing and biological systems. We have progressed from using electricity, to microwaves, to light as a medium for signal transmission—and new possibilities are emerging.

FUTURE STUDENTS The demographics of our potential undergraduate and graduate students are changing. This presents both opportunity and challenges for the future. On the positive side, we live in a state and a country that is increasingly more diverse. This will bring strength to our future educational programs, as our students will bring a wider variety of points of views and life experiences to the University. Unfortunately, the percentage of elementary and secondary students who are considering a career in engineering or science is steadily decreasing. This is a problem that must be addressed at every level of the educational system if our society is to maintain technology leadership.

For engineering departments, it is important to "grow our own." We must help influence future students to consider engineering and science careers. UWEE and the UW College of Engineering are engaged in outreach programs for elementary and middle school students, summer programs for high school students, a yearly Engineering Open House, the sponsoring and advising of FIRST Robotics (high school) teams, and other many other activities.

STUDENTS OF ALL AGES PARTICIPATED IN THE VARIOUS EE EXHIBIT ACTIVITIES AT THE COLLEGE OF ENGINEERING OPEN HOUSE.

FUTURE FACULTY The most important decision that any academic department makes is in the hiring of new faculty. Ideally, these individuals will have successful careers of many decades at the institution. Hence wise hiring decisions will reap tremendous rewards. But what kind of person will be a member of the EE faculty in our future?

In a word, our goal should be diversity. The common usage of this term concerns the gender, racial and ethnic background of an individual. But there is another kind of diversity as well. The "field" of electrical engineering is becoming increasingly diverse in the topics that it spans, and in the type of education that we must provide our students. Our research is becoming more interdisciplinary. Thus, there will be an increasing premium on recruiting new faculty who can communicate and work well with specialists in other disciplines, and who can rapidly adapt to changes in technology. To any and all undergraduate and graduate students who read these words: We hope that you will seriously consider a career as an Engineering Professor if you resonate with the description above.

HOWARD JAY CHIZECK
April 2005

WOMEN FACULTY IN UWEE

UWEE has been a national leader in recruiting excellent women faculty. Our first woman professor, Dr. Irene Peden, was hired in 1961. Peden has achieved a long record of firsts and distinguished awards. She was the first woman ever to earn a Ph.D. in an engineering field from Stanford University. She was the first woman engineer/scientist to conduct fieldwork in the interior of the Antarctic continent as a Principal Investigator (1970) and was elected "Man of the Year" by the IEEE Antennas and Propagation Society. In 1993, she was NSF's Federal Engineer of the Year and inducted into the ASEE Engineering Educators Hall of Fame (40 selected in 100 years). She is an IEEE Fellow and winner of numerous major IEEE awards, including the 2000 Third Millennium Medal. Irene Peden is also a Fellow of the AAAS, ASEE, ABET and the Society of Women Engineers, as well as a member of the National Academy of Engineering. She has not only set a high standard for women in electrical engineering, but she has been an active mentor and a role model to women students and faculty, both in EE and outside the department.

Currently, UWEE has seven tenured and tenure-tracked women faculty. This number reflects a percentage of 16%, which is significantly higher than the average of 6.5% women faculty in the top 50 EE departments. Over half of these women are full professors and three are IEEE Fellows. Women faculty in EE head two of the largest research programs and interdepartmental centers. They also play an important role in teaching in the department. In Spring 2004 alone, three women faculty taught undergraduate introductory courses and women faculty are taking a driving role in undergraduate curriculum revision efforts this year. It is no longer unusual for UWEE students to have female faculty teaching their courses or on their thesis committees.

In October 2001, the University of Washington received a $3.75 million National Science Foundation ADVANCE Institutional Transformation Award to increase the representation and advancement of women in academic science and engineering careers. Professor Eve Riskin directs the Center for Institutional Change (CIC) that was initiated with this award. Its primary goal is to transform and improve the climate in engineering and science departments so that more women can advance in academic careers and move into positions of leadership. In addition, ADVANCE is providing recruitment strategies that will continue to increase the representation of women faculty in EE. Also as part of ADVANCE, UWEE received a Departmental Transformation Grant which will be used to establish mentoring programs for faculty and graduate students aimed at supporting new faculty and also developing women students for faculty positions elsewhere.

UW ELECTRICAL ENGINEERING
CENTENNIAL

In Spring 2006, the Electrical Engineering Department will be celebrating its 100th anniversary. This exciting event, scheduled for April 28-29, 2006, will include historical, career and future perspectives of our graduates and faculty. Please mark your calendars and watch for future announcements.

Also, if you are an alumnus or affiliate of the department and have any historical stories, momentos or pictures of UWEE, please contact the Centennial Committee Chair, Professor Les Atlas at atlas@ee.washington.edu.

DURING THE WARTIME — SUMMER OF 1943

PICTURED ABOVE: A JUNIOR CLASS IN ELECTRICAL ENGINEERING AT THE UNIVERSITY OF WASHINGTON, IN THE WARTIME SUMMER OF 1943. BACK ROW, LEFT TO RIGHT: T.J. CROSS, F.C. BRUYA, G.R. REHKOPF, M.W. ROSEN, I.J. STAMPALIA, E.F. MAGNUSSON, R.E. HULL, AND K.C. ANDERSON. FRONT ROW, ALICE JOHNSON, R. BACCHI, W.J. SMITH, D.E. FISHER, M.L. GIBBS, E. PECK, D.C. ROGERS, AND PROFESSOR GORDON R. SHUCK.

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