2009

RESEARCH REPORT

College of **Engineering**

THE UNIVERSITY OF UTAH

From THE DEAN

The College of Engineering is proud to play an increasingly significant role in the research mission of the University of Utah. Since 2002, college research expenditures have more than doubled to $50.4M in 2008 (an average growth of 8% per year). Just as important as the dollars, though, is the spirit of inquiry and excitement that pervade the faculty. Visitors to campus are amazed by the interdisciplinary collaboration and entrepreneurial activity that characterize Utah's research environment.

The beneficiaries of such extensive research activity include our students who encounter a rich environment for creative learning. Professor Patrick Kiser's introduction to bioengineering class (page 5) has a focus on innovation, encouraging future inventors to develop solutions to biomedical problems. From the ranks of our students will come the next generation of engineers and technological leaders who are essential for U.S. leadership in a competitive international economy.

Society also benefits from university research as faculty teams address complex scientific challenges, such as developing alternative energy sources (pages 6 and 9) and detecting Improvised Explosive Devices (page 8) that demand multi-disciplinary strategies and state-of-the-art equipment and facilities. The U's nationally recognized Technology Commercialization Office helps move early stage research results into the marketplace. An example in this report is Professor Cynthia Furse's company, LiveWire Test Labs, Inc. (page 14), that focuses on detecting intermittent faults in electrical wiring in aging aircraft.

Our faculty also benefit from a culture of innovation that provides as a positive and supportive environment for building their careers. The size of the engineering faculty is growing by approximately 4.7% per year from 101 tenure-track positions in 2001 to 141 in 2008. The College of Engineering is continuing to flourish despite the current economy. Strong state support in the form of the Utah Science Technology and Research Initiative (USTAR) and the Engineering Initiative has provided the financial stability so essential for continued growth.

I hope you will enjoy reading more about some of our exciting research and the difference College of Engineering faculty are making in the world.

Richard B. Brown

Expanding the Engineering Campus

James L. Sorenson Molecular Biotechnology Building—a USTAR Innovation Center

Floyd & Jeri Meldrum Civil and Environmental Engineering Building

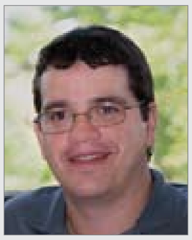
New FACULTY HIRES

Jake Abbott
Mechanical Engineering

EDUCATION:
Ph.D., mechanical engineering, Johns Hopkins University

PREVIOUS POSITION:
Postdoctoral research, Institute of Robotics and Intelligent Systems, ETH Zurich, Switzerland

RESEARCH INTERESTS:
Wireless magnetic control of microrobots, medical robotics, telemanipulation of novel systems, and haptics

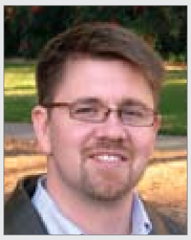


Adam Bargteil
School of Computing

EDUCATION:
Ph.D., computer science, University of California at Berkeley

PREVIOUS POSITION:
Postdoctoral research, Graphics Lab, Carnegie Mellon University

RESEARCH INTERESTS:
Computer graphics and animation, scientific computing, numerical methods, computational physics, and computational geometry



Alan Dorval
Bioengineering

EDUCATION:
Ph.D., biomedical engineering, Boston University

PREVIOUS POSITION:
Research associate, Pratt College of Engineering, Duke University

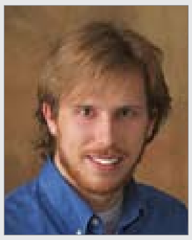
RESEARCH INTERESTS:
Neuropathophysiology, translational neuroscience, neuromodulation, and neuronal semiotics

Mary Hall
School of Computing

EDUCATION:
Ph.D., computer science, Rice University

PREVIOUS POSITION:
Research associate professor, Information Science Institute, University of Southern California

RESEARCH INTERESTS:
Automatic performance tuning, model-guided empirical optimization, interprocedural analysis and optimization, and parallelizing compilers



Matthew Might
School of Computing

EDUCATION:
Ph.D., computer science, Georgia Tech

PREVIOUS POSITION:
Start-up companies Diagis and yaplet.com

RESEARCH INTERESTS:
Static analysis of software systems, static analysis by abstract interpretation, security, parallelism, verification, and optimization

The College of Engineering is pleased to announce the building and expansion of two buildings that will enhance the engineering campus.

Earlier this year, officials broke ground on the $130 million James L. Sorenson Molecular Biotechnology Building—a USTAR Innovation Center, which is being funded by a $15 million cornerstone gift from The Sorenson Legacy Foundation, $100 million from the state of Utah, and private donations. USTAR (Utah Science Technology and Research) is a long-term economic development initiative to promote Utah-based technologies and research for commercialization.

The 200,000-square-foot facility will support 50 USTAR faculty members, their students, and administrative staff. It will include a vivarium, small-animal imaging, a microscopy and surface analysis core facility, and a nanofabrication laboratory.

The building will anchor a new 800,000-square-foot interdisciplinary research complex made up of four interconnected buildings, unifying work in the College of Engineering and the U's Health Sciences and Medical School. The project is anticipated to be complete in the fall of 2011.

Construction also began this summer on the new home for the Department of Civil and Environmental Engineering. A $3.3 million dollar donation from Floyd and Jeri Meldrum is the cornerstone gift for this 14,500 square foot addition to an existing laboratory building to provide space for new department offices, 22 faculty offices, student group space, a student design space, teaching assistant offices, two conference rooms, and a 45-seat auditorium.

The existing Energy and Mineral Research Lab Building will be re-named the Floyd & Jeri Meldrum Civil and Environmental Engineering Building once construction is complete in August 2010. Floyd A. Meldrum is a University of Utah alumnus and the retired owner of Southern Nevada Paving, Inc.

Kenneth Monson
Mechanical Engineering

EDUCATION:
Ph.D., mechanical engineering, University of California at Berkeley

PREVIOUS POSITION:
Assistant adjunct professor of neurological surgery, University of California at San Francisco

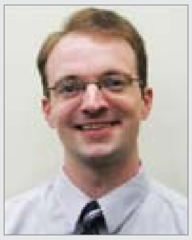
RESEARCH INTERESTS:
Traumatic brain injury, blast injury, cerebral vessel mechanics and mechanotransduction, solid mechanics, and dynamics

Valerio Pascucci
School of Computing and SCI Institute

EDUCATION:
Ph.D., computer science, Purdue University

PREVIOUS POSITION:
Computer scientist and project leader, Lawrence Livermore National Laboratory

RESEARCH INTERESTS:
Data analysis, topological methods for image segmentation, progressive and multi-resolution techniques for scientific visualization, and computer graphics

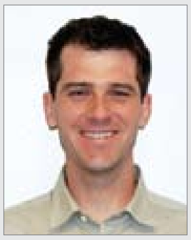


Leonard Pease
Chemical Engineering

EDUCATION:
Ph.D., chemical and materials engineering, Princeton University

PREVIOUS POSITION:
Postdoctoral fellow, National Institute of Standards and Technology

RESEARCH INTERESTS:
Structure of soft complex nanomaterials, biomanufacturing, reactions of macromolecular proteins related to disease, particle sizing, vaccines, and genetherapy vectors

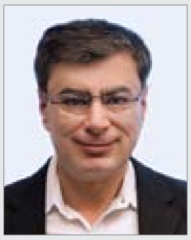


Michael Scarpulla
Electrical & Computer Engineering; Materials Science & Engineering

EDUCATION:
Ph.D., materials science and engineering, University of California at Berkeley

PREVIOUS POSITION:
Postdoctoral scholar, Molecular Beam Epitaxy Lab, University of California at Santa Barbara

RESEARCH INTERESTS:
Compound semiconductors, dilute semiconductor alloys, transparent conductors, and novel materials for thin film photovoltaics



Massood Tabib-Azar
Electrical & Computer Engineering

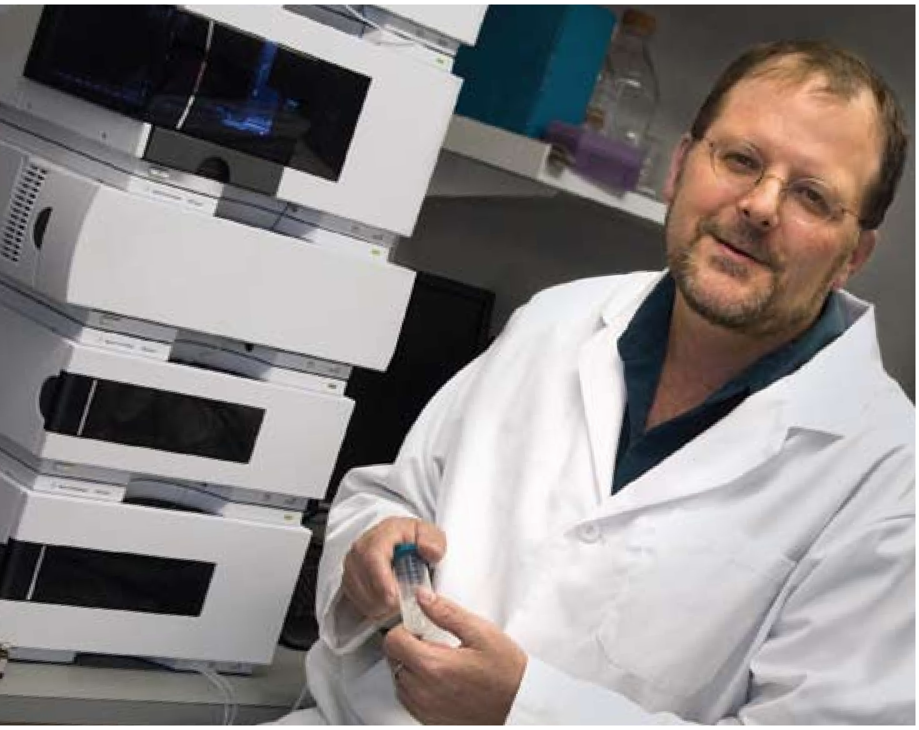
EDUCATION:
Ph.D., electrical engineering, Rensselaer Polytechnic Institute

PREVIOUS POSITION:
Professor of electrical engineering and computer science, Case Western Reserve University

RESEARCH INTERESTS:
Nanodevices and molecular electronics, metrology tools, microwave-AFM for bio-nano-info, and novel fabrication technologies

Stopping the Global Epidemic

NEW TECHNOLOGY TO PREVENT THE SPREAD OF HIV



LEFT:
Patrick Kiser

RIGHT TOP:
"Liquefied" anti-HIV polymer gel in an aciic (pH 4.2) state that mimics the environment inside a vagina.

RIGHT BOTTOM:
The gel solidifies and becomes impermeable to HIV when semen (pH 7.6) is introduced.

Every day more than 7,000 people around the world become infected with HIV (human immunodeficiency virus), most of them through heterosexual contact. HIV leads to the deadly AIDS (acquired immunodeficiency syndrome). In 2008 alone, there were two million deaths worldwide from AIDS.

The majority of new HIV infections occur between men and women. In Africa, HIV is the number one cause of death, and young women now represent more than half of all people living with HIV in sub-Saharan Africa — the hardest hit region, according to UNAIDS, the United Nations advocate on HIV/AIDS prevention.

"Women are more susceptible to HIV infection than men," says Patrick Kiser, assistant professor of bioengineering. "Because of poverty and gender inequality, many women in the developing world lack the power to protect themselves through abstinence or condom use. The development of safe and effective HIV technology is desperately needed in sub-Saharan Africa and elsewhere."

To address this problem, a team of bioengineers led by Kiser is designing new anti-HIV technology for women. Called vaginal microbicides, these drug delivery systems are vaginal products (gels, creams and films) that prevent the transmission of HIV and other sexually transmitted infections (STIs).

"The idea behind microbicides is simple," says Kiser. "Block HIV infection at any step in the viral life cycle by applying a protective material inside the vagina before intercourse."

A NEW TYPE OF ANTI-HIV TECHNOLOGY

Kiser has recently developed a new microbicide that is designed to coat the vaginal walls with a protective polymer gel barrier. When semen comes into contact with the polymer, the structure of the polymer changes and becomes impermeable to the HIV virus. Virus in the semen sticks to the polymer barrier and is unable to penetrate it or infect cells in the vaginal wall.

"The polymer acts like a molecular trap for small virus-sized particles," says Kiser.

Although a woman's natural immune function can eventually inactivate a virus, the gel barrier gives the body time to respond to the virus before it infects vaginal tissue. Antiviral agents — drugs that attack and kill a potential virus — would be added to the polymer to provide an additional layer of protection.

After 24 hours, the gel is designed to flush out of the vagina; therefore, a woman would need to apply the gel once every day to remain protected.

FUNDING FROM THE GATES FOUNDATION

Recently, Kiser was one of 30 applicants, from about 3,000, to receive a $100,000 grant from the Bill and Melinda Gates Foundation to further develop and test the polymer for effectiveness.

"We want to show that vaginal tissue does not become infected with HIV when this polymer is present," says Kiser. "We also want to demonstrate that the polymer can stop female-to-male transmission as well."

Kiser adds, "We will get testing done this year on human tissue, but I think we're looking at five years before this product could potentially be put on the market."

After working for many years in private industry, Kiser came to the University of Utah in 2002 to start his independent HIV research career. He is currently partnered with non-profits CONRAD (Contraceptive Research and Development Program) and the International Partnership for Microbicides to bring new HIV prevention technology to places like sub-Saharan Africa.

"One of the reasons I came to academia was to be free to work on HIV research that would not be funded by major pharma," says Kiser. "Most women who need these products in the developing world earn less than several hundred dollars a year. Because of this, the market for microbicides is big, but the potential profit is low."

Kiser says the ultimate reward for his research is not monetary, but to help prevent suffering from the disease. "The work we're doing gives women the chance to take control of their own bodies. The gel is designed for women in the developing world, but will also be useful in the developed world, particularly for other sexually transmitted infections."

Motivating Student Creativity

Patrick Kiser (left) with bioengineering undergraduate innovators.

Three years ago Assistant Professor Patrick Kiser asked his bioengineering students how many of them thought they would eventually become inventors and obtain patents. To his surprise, almost half of the 80 students in the class raised their hands. In response to the apparent interest, Kiser developed a class for bioengineering freshman to allow them to explore the process of inventing.

"My goal in the class is to help students realize their potential as innovators by working outside the safe and well-defined confines of a classroom and entering the unknown where creativity can occur," says Kiser.

Students are divided into teams of two or three members to identify important biomedical problems for which they can potentially invent a solution. The teams get ideas for inventions from speaking with professors and doctors or looking at medical journals and small business innovation research grants from the National Science Foundation. The teams choose several problems that interest them and, over the course of a semester, develop one idea for a workable invention.

Previous students have developed ideas for such inventions as reducing muscle atrophy in knee brace users, protecting patients from injury during seizures, and safely controlling bleeding after surgery. Several teams have entered their inventions in statewide innovation competitions and won against upperclass and graduate student teams.

"Through this class, students engage with engineering in ways that literally transform how they view the field," Kiser says. "They work hard on their inventions because they end up becoming the owners of their ideas."

Gasification

RENEWABLE ENERGY FROM BIOMASS

Fossil fuels — coal, oil and natural gas — are essential to the energy and economic health of the United States, supplying more than 85 percent of all the energy consumed. Fossil fuels also provide nearly two-thirds of the country’s electricity and virtually all transportation fuels, according to the U.S. Department of Energy.

But in the last half century, concerns about pollution, global warming, limited resources, and increasing costs have led to research into alternative ways to fulfill the country’s growing fuel and energy needs.

Kevin Whitty, associate professor of chemical engineering, is leading research to develop clean energy technologies from renewable feedstocks. He is building a unique system to convert biomass into synthesis gas (a gas rich in hydrogen and carbon monoxide), which can subsequently be converted into automotive biofuel, electric power and other useful chemicals.

Biomass — which includes trees, plants, and agricultural and animal waste — stores energy from the sun, either through absorption of the sun’s energy (photosynthesis), or by consumption of plant matter by animals. When burned as fuel, biomass releases heat and carbon dioxide (CO_2). However, since trees and plants absorb excess carbon dioxide from the air during their growing lifetime, they are considered a renewable energy resource.

“If we plant enough to replace the biomass we’re burning for fuel, there will be no net increase in biomass-based CO_2 emissions. This makes it cleaner than fossil fuels,” says Whitty, a member of the Institute for Clean and Secure Energy, which was organized from a long tradition of energy research at the University of Utah beginning in the 1950s to study energy, combustion and high-temperature fuel utilization processes.

BLACK LIQUOR AS BIOMASS

One biomass Whitty uses is a byproduct of the papermaking process called “black liquor.” To make paper, wood fibers that become paper are separated from lignin, a chemical compound that keeps wood fibers together. Paper mills use the lignin byproduct, or black liquor, for its energy value to power their facilities.

"Almost one percent of all energy production in the United States today comes from black liquor," says Whitty. "But you never hear about it because they make it in the paper mill and they burn it on-site."

He adds, "You could grow trees and plants specifically for energy production, but we're focused on using existing biomass resources. Rather than allowing waste biomass to decay in forests, fields or landfills, we can make use of its energy value to help displace energy that would otherwise be produced from fossil fuels."

In 2005, the U.S. Department of Energy and U.S. Department of Agriculture released results from a joint study that determined there are over one billion tons of readily-available biomass per year that could be used for production of biofuels, and that such fuels could meet more than one-third of the country's current gasoline consumption.

CONVERTING BIOMASS INTO FUEL

Whitty is converting biomass and black liquor to usable fuel through a high-temperature process called gasification, which involves converting solid fuel to synthesis gas. The gas is burned to produce electrical power in a manner similar to natural gas, or it is catalytically converted to transportation fuels or chemicals.

"Unlike fermentation-based processes such as corn-to-ethanol, gasification allows us to use all the biomass, not just the sugar or starch portion," says Whitty. "This lets us process fuels such as forest residues and energy crops much more efficiently, and with significantly lower water and fossil energy requirements, than conventional technology."

In his research facility, Whitty has two pressurized gasifier reactors that process biomass. One injects the biomass directly into a heated fluidized bed of sand, where it is converted into hydrogen-rich synthesis gas by reacting with steam. Ash in the fuel is removed through a cyclone or a lock hopper below the bed.

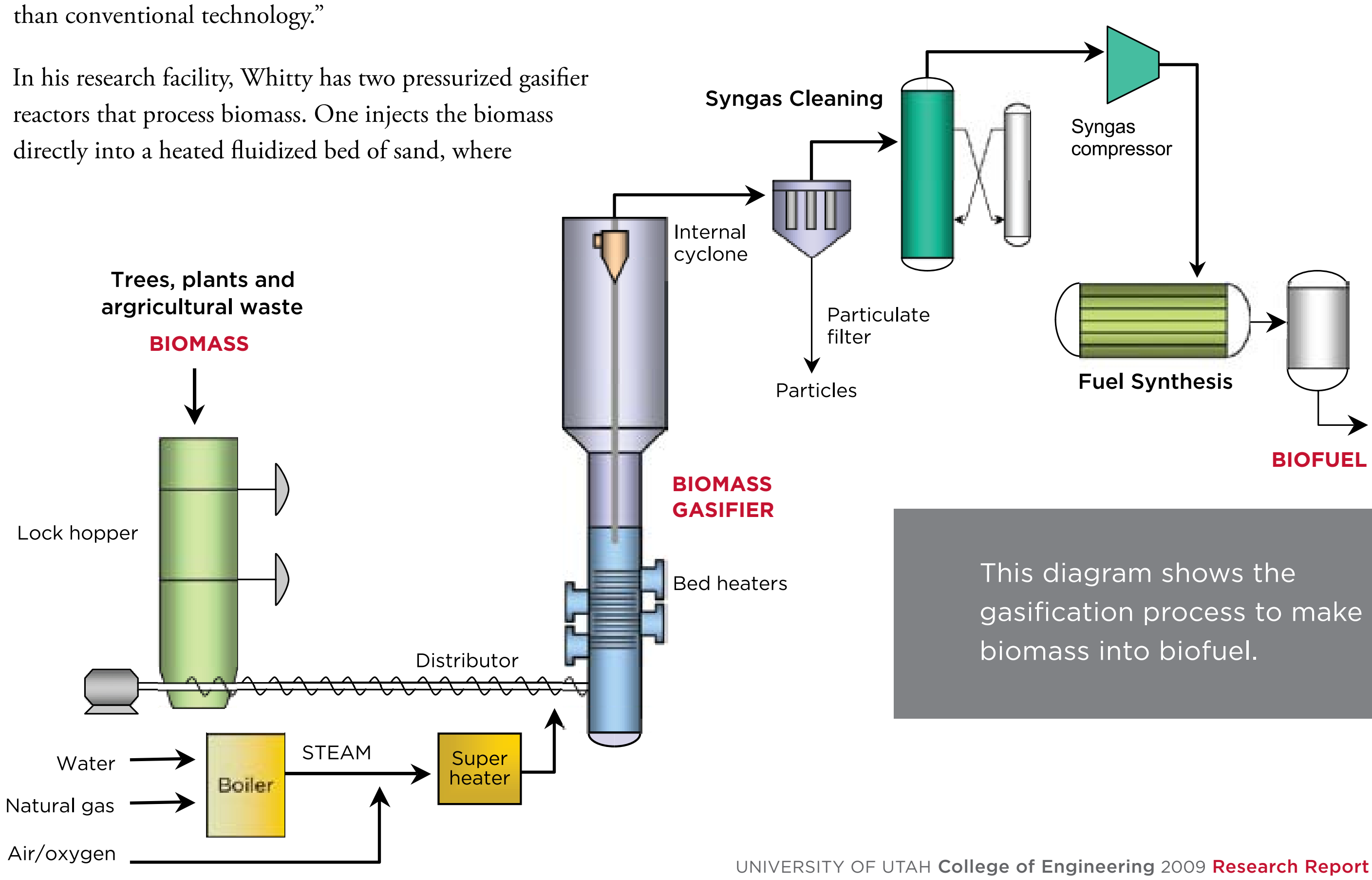
The other reactor is a pressurized entrained-flow gasifier that feeds the fuel and oxygen into the reactor to produce synthesis gas through partial oxidation. The high-temperature gas and molten ash exit the bottom of the reactor and enter a water-cooled quench system where the synthesis gas is separated from the condensed material.

Each gasifier has its advantages: The entrained-flow gasifier provides better conversion to synthesis gas, while the fluidized gasifier processes larger particles and is more energy-efficient.

"Both machines have the capacity to process about one ton of feedstock per day," says Whitty. "As this technology matures we will see these types of systems built on a much larger scale."

Whitty is collaborating with RTI, a research institute in North Carolina, to install a synthesis gas purification system in his facility that will remove tar, ammonia and sulfur that can contaminate downstream fuel or power production systems. There are also plans to construct a Fischer-Tropsch catalytic fuel production system to produce transportation fuel from the purified synthesis gas.

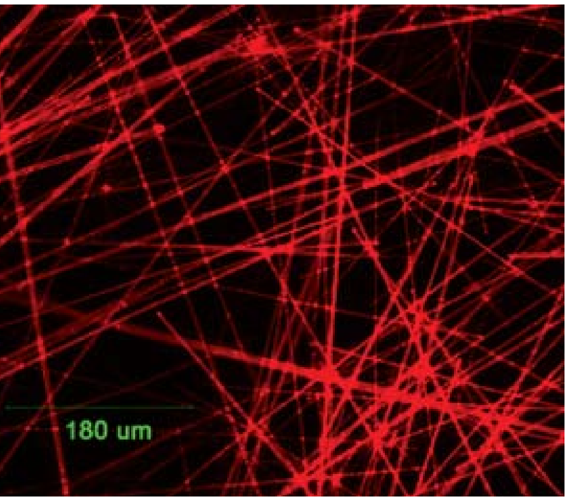
"This scale and cutting-edge technology makes our research unique," says Whitty. "No other university research facilities have the resources to go from start to finish, converting biomass to biofuel in the manner we are doing here."



This diagram shows the gasification process to make biomass into biofuel.

A Trace of Danger

SMALL-SCALE SENSOR TECHNOLOGY FOR BOMB DETECTION



LEFT TO RIGHT:

- Fluorescent glowing nanofibers used in optoelectronic nanodevices. Each strand is about one-fifth the size of a human hair.
- Used for explosives detection, the net of super-fine nanofibers are so tiny, the diameter of one fiber can be measured in terms of merely a few atoms.

Since the beginning of the Iraq War in 2003, nearly 60 percent of attacks against U.S. soldiers have begun with a homemade bomb, also known as an IED (Improvised Explosive Device). IEDs are widely used by insurgents to attack soldiers. They may be buried in the ground as roadside bombs or landmines, or used by suicide bombers.

"Our forces on the frontline in Iraq and Afghanistan need to be able to see the danger [from explosives] before it's too late," says Ling Zang, USTAR associate professor of materials science and engineering. USTAR stands for Utah Science Technology and Research, a legislative initiative to strengthen technological research and stimulate economic development in the state of Utah. Zang came to the University of Utah last fall from Southern Illinois University Carbondale, where he was associate professor of chemistry and biochemistry.

Electronic sensors — like the ones used in airports and other security checkpoints — detect explosives made with TNT (trinitrotoluene), but these sensors are expensive, not portable for soldiers on the go, and lack sensitivity to detect homemade chemicals used in IED explosives.

"The best sensor would detect even trace amounts of explosives from a long distance," says Zang. "It needs to be very sensitive, but also must be selective to minimize false alarms."

NANOWIRE SENSORS

Zang and his associates have developed and patented a portable sensor device that identifies the presence of TNT from many yards away. The sensor includes strands of fluorescent nanowires — infinitesimally small threads that act as super-fine filters — to catch molecules from explosives as they float through the air.

"These tiny nanowires are intertwined like a spider web," says Zang. "The threads capture single molecules from an explosive just like a web catches flies."

When TNT molecules are captured, the glowing nanowires go extremely dim. The decrease in fluorescent emission is used as the sensing transduction signal. Zang's group plans to combine an optical component with the electronic sensor to develop a dual-mode sensor that would provide unprecedented sensitivity and increased reliability (to minimize false positives) in explosives detection. The improved device will be used as long-distance standoff bomb detectors, minimizing the risk to soldiers and bomb squads. The Department of Homeland Security (DHS) and National Science Foundation are currently funding the research. More support for the sensor project is expected from the U.S. Army and the Department of Defense.

"The DHS requires the distance for detecting explosives to be from at least 50 meters away," says Zang.

COLORIMETRIC SENSORS

The government is also supporting one of Zang's projects to develop a special sensor for IEDs, which are not easily detected by traditional electronic sensors. The colorimetric sensor comprises highly porous, colorless material that turns bright yellow when a homemade explosive is detected.

"The colorimetric sensor is cheap, portable and easy to use," says Zang. "But as with the dual-mode sensor, we are working on improving its sensitivity."

Clean and Renewable: Harnessing the Sun's Energy

Arguably one of the great challenges facing society is the development of renewable energy sources. The supply of expendable resources, such as fossil fuels, is dwindling while the global demand for energy is growing.

Because it is abundant and renewable, solar energy may provide a significant contribution to the world's energy needs. One of the more promising ways to harness the sun's energy is through solar cells, which convert energy from the sun directly into electricity. For more than a decade Ling Zang, associate professor of materials science and engineering, has been developing solar cell technology.

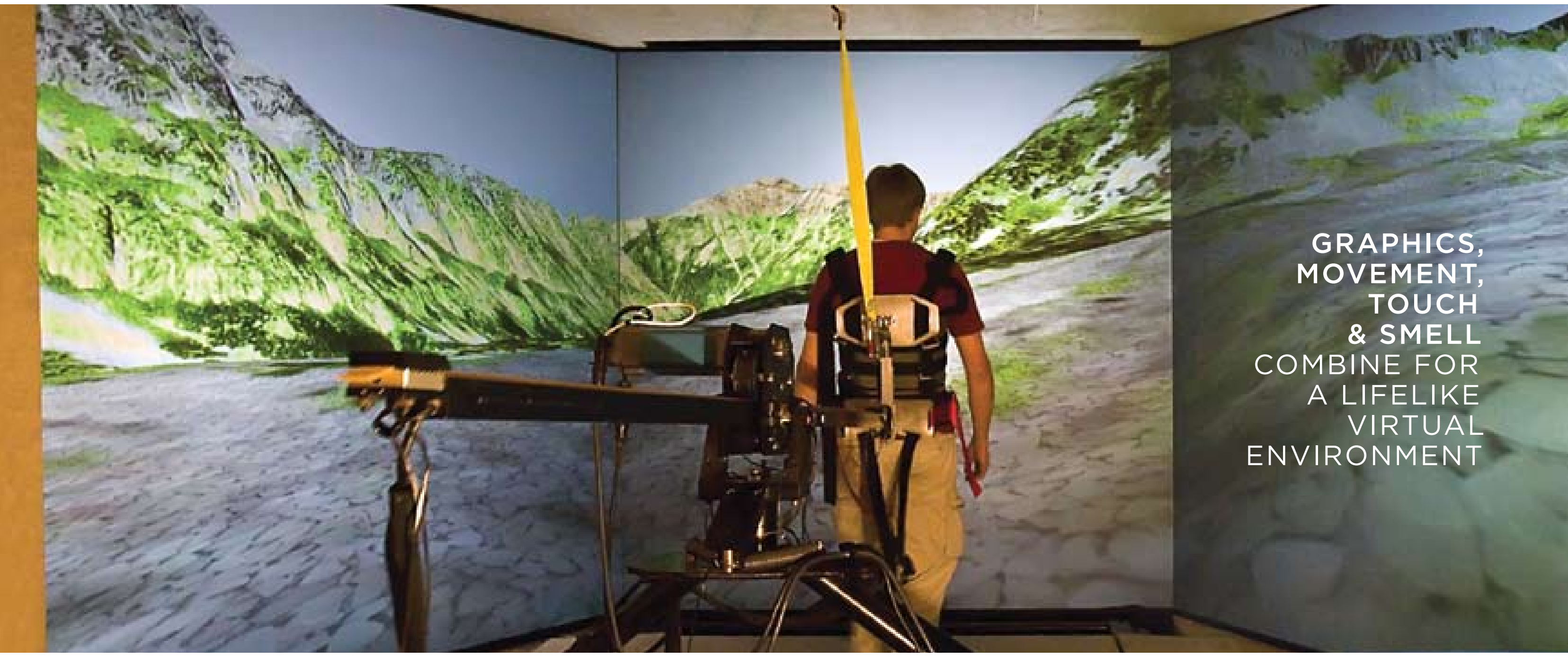
Most solar cells on the market are made from silicon, but the excessive cost makes widespread use prohibitive. "Silicon solar cells work well, but they are very expensive," says Zang. "That's why we can't just put them on our roofs to power our homes."

Zang and his associates are designing solar cells with nanocomposites—new nanotechnology materials made from organic compounds. These flexible, energy-generating materials are coatable, so they can be painted onto roofs, walls, or cars, whatever needs powering.

"We're trying to make the material more efficient and cost-effective," says Zang. "In the long-term, solar energy will be at least part of the solution to the energy issue."

Ling Zang

Realism in a Virtual World



Although it may sound like futuristic science fiction, the pursuit of virtual reality technology—which allows a user to interact with a computer generated, simulated environment—has been around for years. In fact, in 1968 Ivan Sutherland, a former professor at the University of Utah, created what is widely considered to be the first virtual reality and augmented reality head-mounted display system.

Since then, researchers at the U of U continue to develop and refine such technology for purposes ranging from education and training to design and prototyping.

One project developed at the University began in 1995 initially with a first generation TreadPort, a unique device capable of simulating realistic locomotion through virtual spaces. The TreadPort was designed at Sarcos, an engineering and robotics firm founded by Distinguished Professor of Mechanical Engineering Stephen Jacobsen. The Office of Naval Research funded the project, called a "locomotion interface," for military training purposes.

"Back then it was smaller and had only one screen that projected visuals," says John Hollerbach, professor in the School of Computing and principal investigator of the project. "But it has been under continuous refinement ever since."

As he obtained more funding for the project, Hollerbach sought to create a more realistic virtual environment by adding more mechanical display aspects, such as a tilt mechanism and active vertical support and a stereo audio display for realistic sound.

"We continued to develop more virtual aspects that would engage multiple senses," says Hollerbach. "But one day in 2003, I heard Marc Watson, a chief ride developer at Universal Studios say, 'To get a sense of immersion in a virtual environment, you need a totality of sensory effects. All of your senses must be engaged to feel immersed and to suspend disbelief.' Then I wanted to do more."

ADDING ATMOSPHERIC AND WIND DISPLAYS

Since then, Hollerbach secured funding from the National Science Foundation (NSF) through its Information Technology Research Program. He put together an interdisciplinary team of computer scientists, graphics experts and mechanical engineers, including Mark Minor, associate professor of mechanical engineering, who heads design and control of the mechanical aspects of the system; Eric Pardyjak, associate professor of mechanical engineering, and Meredith Metzger, assistant professor of mechanical engineering, who are working on the flow design of the wind display; and Peter Willemsen, a former research assistant professor at the U of U currently at the University of Minnesota Duluth, who is building the graphics hardware and software.

Students building the system are drawn from mechanical engineering and computer science.

LEFT IMAGE:
Treadport Active Wind Tunnel at the University of Utah

FROM LEFT TO RIGHT:
- **Mark Minor** *Mechanical Engineering*
- **Eric Pardyjak** *Mechanical Engineering*
- **Meredith Metzger** *Mechanical Engineering*
- **John Hollerbach** *School of Computing*

Today, the project is called the TreadPort Active Wind Tunnel (TPAWT, pronounced "teapot") and is unique by virtue of adding a controllable two-dimensional wind tunnel to the existing TreadPort system.

The system houses a 6' x 10' computer controlled treadmill, surrounded by three projection screens that provide a 180 degree horizontal field of view. The treadmill can be tilted under computer control 20 degrees up or down to simulate walking uphill or downhill, allowing the user to walk or run to a maximum of eight miles per hour.

"Currently we have graphics simulating the Wasatch Mountains and we're working on making them more realistic," says Pardyjak. "We're also designing graphics to simulate a specific city, such as downtown Salt Lake City."

The wind component of TPAWT is an actively controlled wind tunnel that allows wind angle and speed to be regulated. Wind speeds can reach 20 miles per hour.

"We project a virtual world onto the screens, and the graphical environment displays artifacts of the wind, while the wind generation system creates and controls the wind flow," says Minor. "We can steer the wind along both sides of the screens, which creates the illusion for the user that the wind is literally coming from the screen."

NEXT STEPS

The research team is currently designing and adding displays for radiant heat and cold, and smell to enable users to engage in a completely immersing virtual environment.

"If you walk out of a shadow into the sun, you would be able to feel the heat of the sun," says Hollerbach. "Also, you could smell the trees while walking in the forest, or smell exhaust from a bus in the city and feel the whoosh of the air as it passes by you." The team has identified a number of possible uses for the completed TPAWT system.

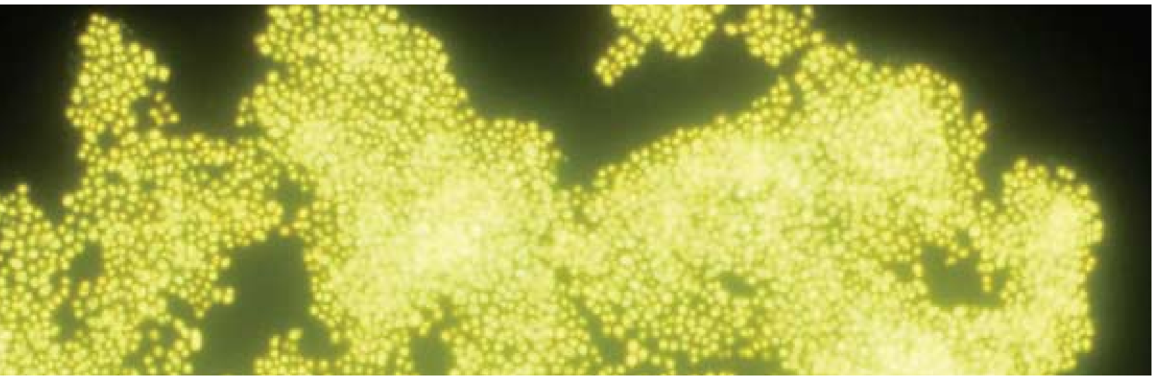
"If you have a faithful virtual environment, it would be used for all kinds of educational purposes," says Hollerbach. "If you can simulate reality, then you can use it for emergency response, rehabilitation for spinal cord injuries, training, psychological studies, exercise, and recreation."

"I think one of the main uses of this system is for training first responders how to locate contaminates, such as a dirty bomb or a chemical leak," adds Minor. "You can use the wind to simulate how chemicals would move through the air in order to contain a leak."

As part of an NSF follow-on project, Pardyjak and his collaborators plan to use the system to aid in city planning and building.

"We want to conduct simulations to optimize the design of cities for air quality and energy efficiency," says Pardyjak. "We will take technology we've developed for TPAWT and run simulations, allowing us to move buildings and create different designs to see how air quality and energy efficiency are affected."

Water Quality and Phosphorus



Polyphosphate-accumulating organisms (PAOs) involved in enhanced biological phosphorus removal.

Phosphorus is an essential plant nutrient and key element in all forms of life. Phosphate (a form of phosphorus) makes up part of the structural framework of DNA. Phosphorus is also involved in cellular processes that use energy.

Most humans consume about two grams of phosphorus per day through a normal, healthy diet. But most of that phosphorus is excreted by the body naturally and flushed away. This wastewater travels through a network of sewage pipes and pump stations to a wastewater treatment plant.

At the plant, various treatment processes are employed to remove debris, biological and chemical contaminants, and harmful pollutants. Once the water has been sufficiently processed, cleansed, and decontaminated it is eventually transferred to local surface water bodies (lakes, rivers and streams).

Until recently, many cities have not recognized the importance of removing phosphorus from wastewater, and instead allow the nutrient to pass through wastewater treatment, eventually ending up in the environment. But too much phosphorus in the environment can cause extreme overgrowth of harmful algae that can lead to an ecosystem imbalance.

Ramesh Goel, an assistant professor of civil and environmental engineering, who has been studying the effects of wastewater treatment on local surface waters in Utah. Surface waters generally serve as one of the primary sources for household and drinking water.

ALGAE TOXINS AND OVERGROWTH

In lakes and rivers, harmful algae produce a poisonous substance called cyanotoxin that hurts birds and other wildlife that drink the water in which it grows. Birds may also be harmed by eating fish or shrimp that feed on the algae. Goel says that tap water, however, is not affected because potential algal toxins are removed before water arrives at your home.

Excessive amounts of algae can also impede sunlight from penetrating through surface waters, which can be a problem for certain aquatic organisms that rely on sunlight to live.

Because of special treatment required to remove phosphorus and a lack of awareness about its effects over time, many wastewater plants do not attempt to remove phosphorus during the treatment process. Consequently, phosphorus from human waste passes through into surface waters. And after years of collecting extra phosphorus, rivers and lakes are hard hit.

Goel is working with the Utah Water Quality Board and several local wastewater treatment plants to devise a workable solution. Although phosphorus can be removed through a process called chemical precipitation, which involves the use of aluminum sulfate, the process is costly and creates chemical sludge waste that must be disposed of.

"You do actually remove the phosphorus this way, but you end up with chemicals that you have to get rid of," says Goel. "Chemical sludge is more difficult to deal with than the original phosphorus."

BIOLOGICAL REMOVAL OF PHOSPHORUS

Goel says a more cost-effective, environmentally friendly method of removing phosphorus is through polyphosphate-accumulating organisms (or PAOs), a group of bacteria already present in most wastewater treatment facilities. PAOs can remove large amounts of phosphorus from wastewater.

In a process called enhanced biological phosphorus removal, wastewater passes through a special sequence of aerobic and anaerobic environments in the presence of PAOs. These bacteria accumulate large quantities of phosphorus within their cells, which are then separated and removed from the treated water at end of the process.

Goel is currently investigating the presence and role of PAOs in many full-scale wastewater treatment plants in Utah. The ultimate objective of Goel's ongoing research is to help plant operators and district managers achieve safe and effective biological phosphorus removal without much capital cost.

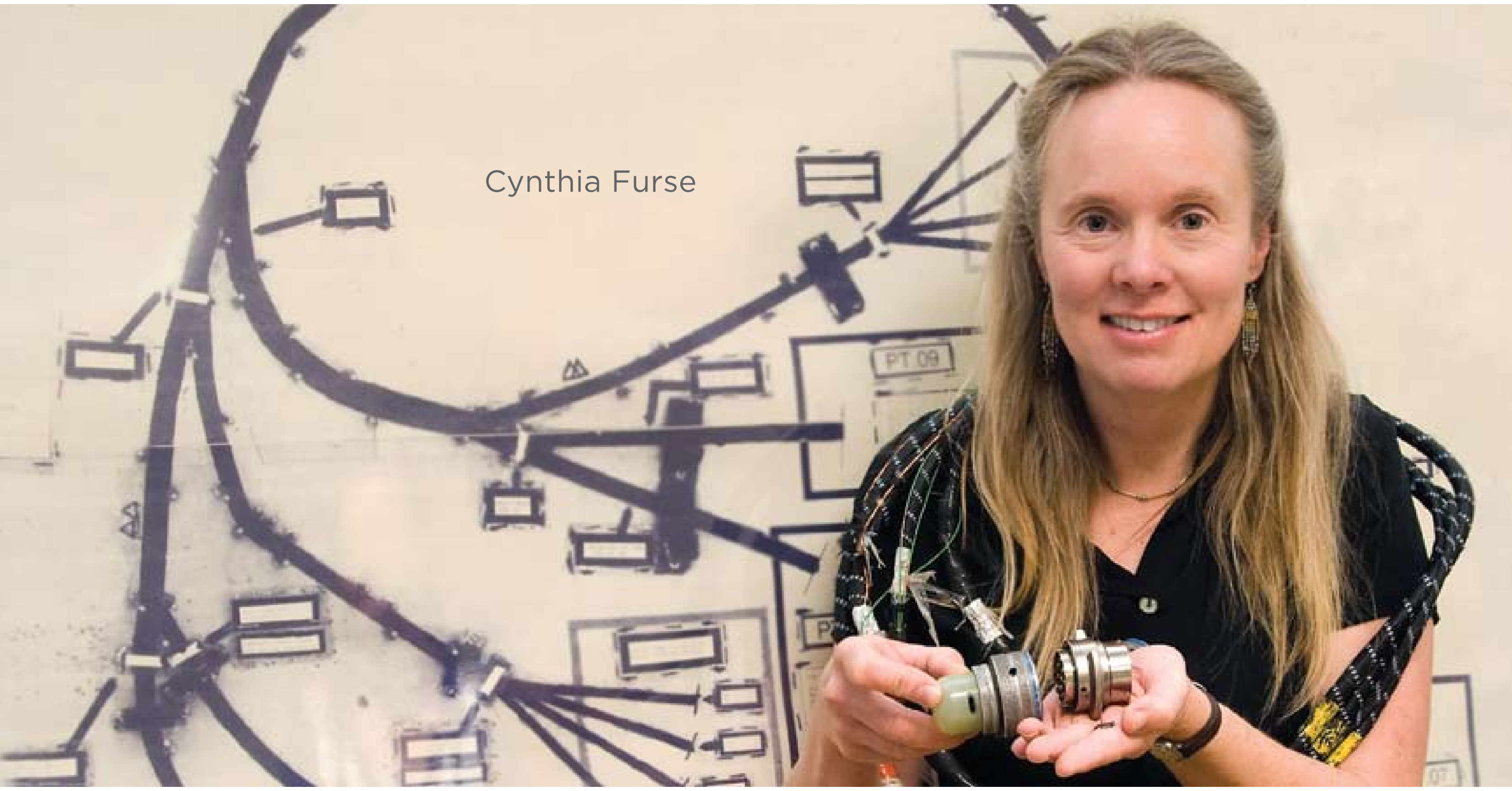
"I tell them they won't need to construct a new plant or spend millions of dollars on upgrading," he says. "The cost would be minimal to treat wastewater with PAOs." Goel is also bringing early awareness to the problem. "Down the road, the Environmental Protection Agency will require us to do something about the presence of phosphorus in our lakes and rivers," says Goel. "With water quality being affected, we should begin correcting the problem now."

“Because phosphorus already exists in the sediments of many surface water bodies, we don’t want to be adding more of it to our rivers and lakes through wastewater.”

Ramesh Goel

InFlight

DETECTING INTERMITTENT ELECTRICAL WIRING FAULTS IN AGING AIRCRAFT



Cynthia Furse

Flying is considered one of the safest forms of transportation. Airplane crashes make national news at least in part because they are relatively rare compared to accidents from other forms of transportation.

Still, as airplanes age, more problems can occur. One of the biggest issues is with the many kilometers of electrical wiring buried deep in airplane structures. Electrical faults are one of the main causes of maintenance problems with planes.

As wires age, the insulation may become brittle and crack, or chafes may appear as wires vibrate against each other. Airplane maintenance or even flying in general causes natural wear and tear on wires. A typical airplane has hundreds of wire cracks and frays.

"Commercial and military fleets are only getting older," says Cynthia Furse, professor of electrical and computer engineering. "Many are 20-years-old or older. As technology improves, computers that run an airplane's systems get upgraded, but not the wiring. Electrical wiring goes with the skeleton of the airplane."

Furse and her associates are developing a novel intermittent live wire fault location system that can precisely pinpoint electrical faults. The technology is being commercialized through a University of Utah spin-off company, LiveWire Test Labs, Inc., which Furse co-founded with her then-PhD student Paul Smith in 2003.

THE CHALLENGE OF DETECTING FAULTS

During flight, condensation forms in wheel wells and other areas of the plane that can affect already brittle or cracked wires. Electrical faults may give rise to short circuits, arcs (electrical currents that jump gaps in circuits), and electromagnetic emission and interference—particularly when wires get wet.

"Moisture creating a short circuit between compromised wires can cause a tiny arc, gradually carbonize the insulation, and result in a flashover and fire," says Furse. The challenge with detecting faults is that some show up only during flight. Once a plane lands, the problem is 'gone' and it is often impossible to find the fault.

"Unlike obvious cracks in a wing or an engine, damaged wire is extremely difficult to detect, but the resulting arcing and failures can be serious," says Furse. "In fact, any densely wired system is vulnerable—the space shuttle, nuclear power plants, subways and railroads, large industrial machinery, homes and business buildings, communication and power distribution networks, and even the family car."

Current fault-finding technology uses a measurement technique called "time domain reflectometry" (TDR) to trace wiring problems. A short, rectangular voltage step function pulse is sent down the cable, and the cable impedance, termination, and length give a unique signature to the reflected signal. But this method is not able to locate the tiny faults left after an arc fault event during flight because the impedance discontinuity is too small to create a measurable reflection, and it can't be used during flight.

"The voltage step function that is TDR's input signal would interfere with the aircraft, particularly on digital signal lines," says Furse. "And the noise on the aircraft on both the power and signal lines would interfere with the TDR. So we have developed a method for locating faults on wires while the plane is flying that doesn't suffer from interference with or from the plane."

THE INNOVATION

Furse and her associates have developed a fault-detection chip that uses spread spectrum TDR to accurately find faults during flight. The method uses a high-speed pseudo noise code —similar to a code from a typical cellular phone—that spreads the spectrum, thus increasing the number of non-interfering simultaneous users on the line, and reducing the effects of noise and jamming.

Fault-detection chip that tests live wires in flight.

The ability to reduce interference with other users and to resist jamming provides the ability to test live wires in flight without interfering with the avionics signals or being corrupted by them.

"The magnitude of the signal can be so small that it is well below the noise margin for the aircraft, and it can still be correlated to determine the location of the fault on the wiring to within a few milliseconds. This can give an accuracy of a few inches over hundreds of feet of wire," says Furse.

Furse and her group are now testing the second version of the tiny detector chip. They plan to develop a third, smaller version to make the chip fully commercial. Within about two years, Furse expects some aircraft to begin integrating the chip into wiring systems.

"It's so rewarding to take this idea for finding electrical faults, and make it into something real that will have a significant impact," says Furse.

Recruiting New Engineers

Cynthia Furse, professor of electrical and computer engineering, has always taken an interest in young students and their potential to make an impact on the world. In 2007, Furse received a five-year $2 million grant from the National Science Foundation to recruit and retain more engineering students to the University of Utah. The project provides programs that go into Utah high schools to introduce students to engineering, as well as bring many young students to campus.

"Few students in high school know what engineers do," says Furse. "We need more young students entering the field. Engineering is so broad that there are applications in every aspect of our world. If only a small number of students enter engineering, we miss out on a lot of contributions others could have made."

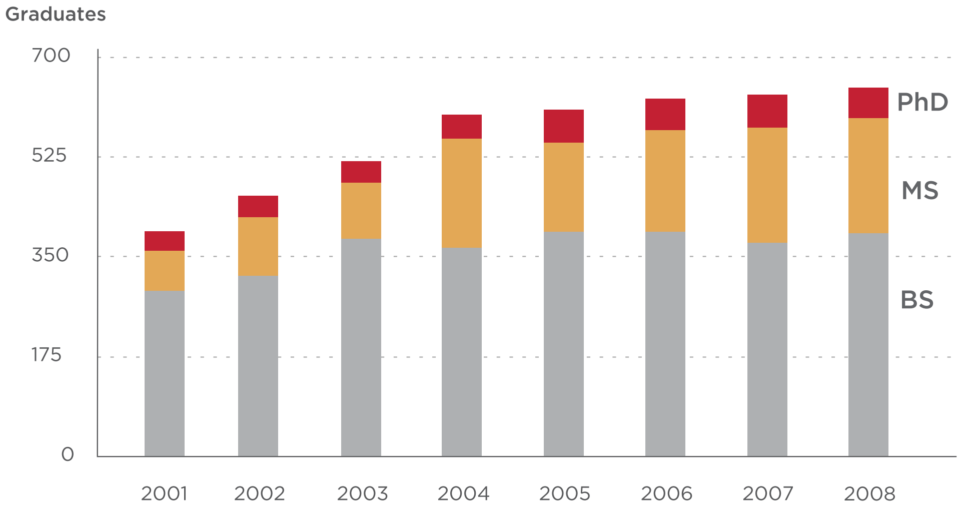
Furse has recently been appointed associate vice president for research at the University of Utah. She will facilitate interdisciplinary research with different groups, both inside and outside the University.

"It's an exciting time to be involved at the university level," says Furse. "I hope to encourage research that will be socially impactive."

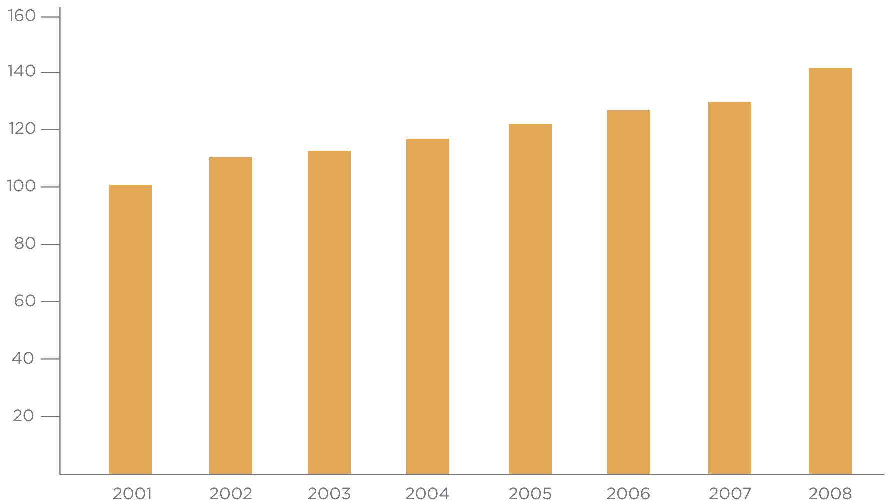
Facts and Financials

- The number of PhD students enrolled per faculty has increased by 42% in past two years.
- Research expenditures per faculty increased by 58% over past six years.

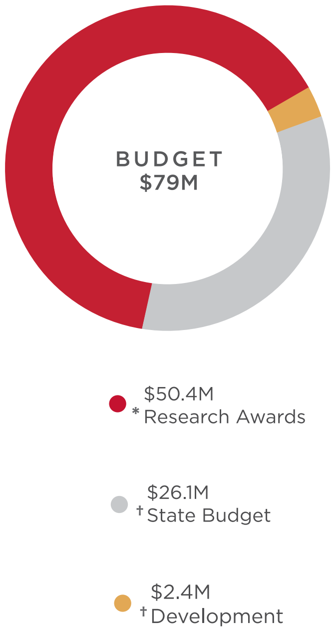
Degrees Awarded: 2001–2008



Tenure-track faculty growth: 2001–2008



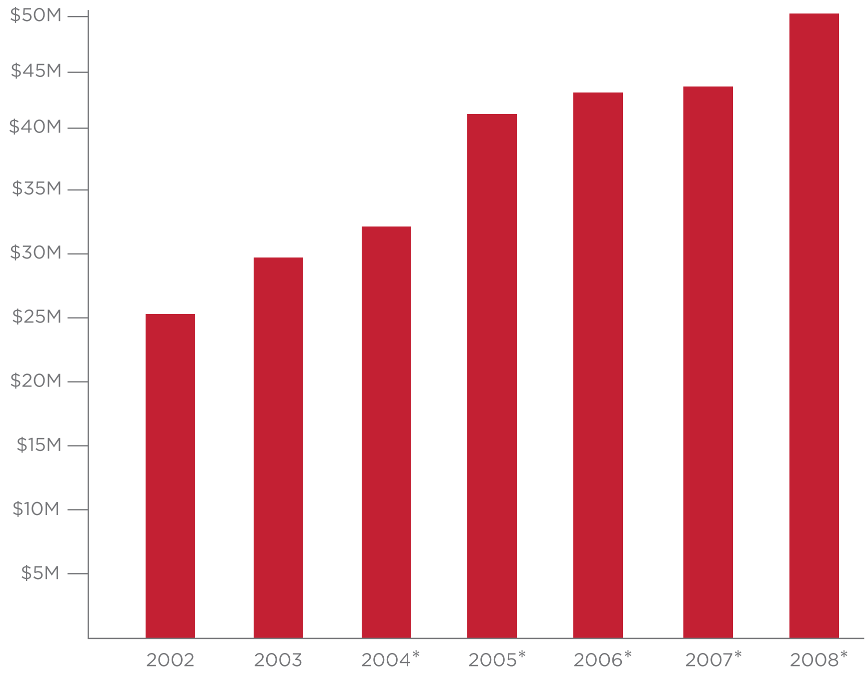
Budget: 2007–2008



***COE data reported to ASEE**
American Society for Engineering Education

†COE
College of Engineering, University of Utah

Research Expenditures: 2002–2008



With $50 million annually in external research funding, the College of Engineering is a vital component of the University of Utah's growing research enterprise. Faculty members are nationally recognized for their innovation and entrepreneurial spirit.

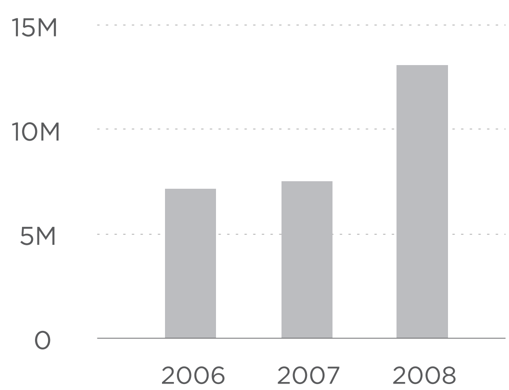
Technology Commercialization: 2006–2009

For the second year in a row, the University of Utah was ranked number two in the nation only to MIT at starting companies, according to the Association of University Technology Managers, which ranks public and private research institutions throughout the country. The U of U's accomplishment is made more significant because MIT receives over four times as much research funding.

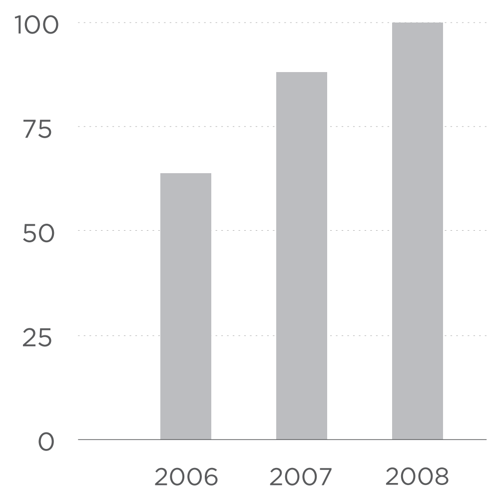
The U of U launched 20 new companies from technologies developed at the University in 2006, 17 in 2007, 23 in 2008, and 23 in 2009. The College of Engineering is responsible for 35 of these spin-off companies.

The University of Utah's intellectual property is managed by its Technology Commercialization Office (TCO). Since 2005, TCO has focused on economic development in the state of Utah. TCO has set up a satellite office in the College of Engineering to direct the College's extensive technology commercialization activities.

†INDUSTRY-FUNDED RESEARCH



†PATENT DISCLOSURES



ENAC

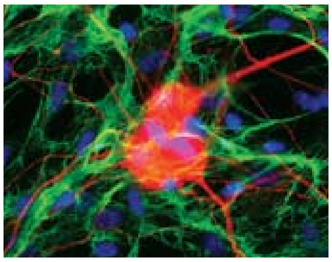
ENGINEERING NATIONAL ADVISORY COUNCIL

Edwin E. Catmull spoke at the College of Engineering last December to discuss lessons he has learned as president of Walt Disney and Pixar Animation Studios. Catmull told the audience how he learned that animation teams had to be empowered to figure out solutions without compromising the creative process. He also said that the key to success is getting "the right people and the right processes."

A member of the Academy of Motion Picture Arts and Sciences and the National Academy of Engineering, Catmull chairs the University of Utah Engineering National Advisory Council. He earned B.S. degrees in computer science and physics and a Ph.D. in computer science at the U of U. He won a 2008 Academy Award for lifetime achievements in computer graphics.

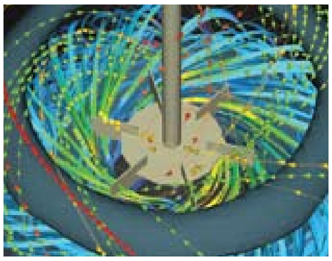
Our highly interdisciplinary research environment has enabled faculty to respond to emerging needs in such diverse areas as visualization and graphics, energy, robotics, software engineering, advanced electronics, neuroprosthetic development, new construction and transportation technology, photonics, and nanotechnology.

COLLEGE OF ENGINEERING DISCIPLINES

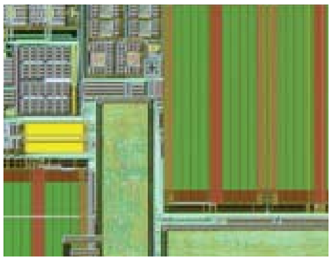


Bioengineering

Chemical Engineering



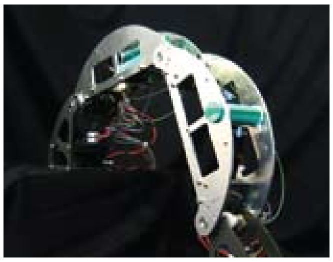
Civil & Environmental Engineering



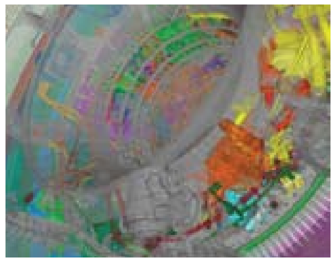
Electrical & Computer Engineering

Materials Science & Engineering

Mechanical Engineering



School of Computing



RESEARCH INSTITUTES

- The Brain Institute
- Institute for Clean and Secure Energy (ICSE)
- Scientific Computing and Imaging (SCI) Institute
- Energy and Geoscience Institute (EGI)
- Cardiovascular Research and Training Institute (CVRTI)
- Center for High Performance Computing
- Nano Institute

RESEARCH CENTERS

- Center for Excellence in Nuclear Technology, Engineering, and Research (CENTER)
- The Keck Center for Tissue Engineering (KCTE)
- Nanofabrication Laboratory
- Center for Integrative Biomedical Computing
- Center for Controlled Chemical Delivery
- Petroleum Research Center
- Rocky Mountain Center for Occupational and Environmental Health
- Quality and Integrity Design Engineering Center
- Utah Center for Advanced Imaging Research
- Moran Eye Center

City
LIVING IN THE MOUNTAINS

PHOTO CREDIT: Downtown Alliance and the University of Utah

Salt Lake City

Situated in the beautiful Wasatch Mountains, the University of Utah is mere minutes from vibrant downtown Salt Lake City. Residents and visitors enjoy the rich urban environment with its many cultural amenities, including restaurants, ballet, symphony, opera, museums, stage theater, movies, shopping, and historic Temple Square—Utah's most popular tourist attraction. Salt Lake City also hosts portions of the annual Sundance Film Festival, the largest independent film festival in the United States. The headquarters of the event is in nearby Park City.

Salt Lake City is home to the Utah Jazz basketball team of the NBA, Real Salt Lake of Major League Soccer, as well as two minor league teams: AAA Salt Lake Bees Baseball and the Utah Grizzlies Hockey Team of the ECHL.

A commuter-friendly city, Salt Lake's mass transit service includes an extensive bus system, light rail, and a commuter rail line that links the University of Utah with valley neighborhoods and downtown. Salt Lake International Airport is located four miles west of downtown.

1 Summer Concert Series in downtown Salt Lake 2 TRAX, Salt Lake's light rail system 3 University of Utah campus 4 Ice skating at the Gallivan Center
5 First Night Salt Lake 2009 6 Race for the Cure at the Gateway Mall 7 Salt Lake Farmer's Market 8 Downtown Public Library

THE UNIVERSITY OF UTAH

College of **Engineering**
2009 RESEARCH REPORT

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