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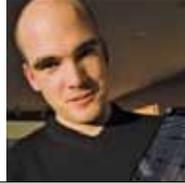
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## BIOENGINEERED SPINAL DISCS RESEARCH GETS \$100,000 FROM NFL CHARITIES



Scientists from Cornell and Weill Cornell Medical College have been awarded \$100,000 by NFL Charities, the charitable foundation of the National Football League owners, to research tissue engineering for spinal injuries. The research aims to create a living, bioengineered intervertebral disc (IVD) that may be implanted into patients with degenerated discs, either due to

injury or chronic wearing with age.

“We hope to create a living implant that is able to grow, adapt and integrate into the spine in order to completely repair the injury and restore function to the spine,” said Larry Bonassar, principal investigator of the study and associate professor of biomedical engineering and mechanical and aerospace engineering.

Bonassar and his lab are constructing engineered IVDs from sheep tissue and cells, molded into the shape and structure of naturally found discs. The IVDs consist of an inner nucleus surrounded by an outer annulus. The scientists grow the cells, which mature and multiply on a natural mold, to re-create a fully functional, implantable disc.

Each year, 40 to 60 percent of American adults suffer from

chronic back or neck pain. For patients diagnosed with severe degenerative disc disease, or a herniated disc, neurosurgeons perform surgery called discectomy—removing the IVD—followed by a fusion of the vertebrate bones to stabilize the spine. In spite of the surgery, the patient’s back will likely not feel the same as before their injury. Herniated discs are a common injury for professional athletes, who must often suffer with the side effects of currently available discectomy and spinal fusion.

“When a disc is herniated, the inner nucleus bursts, causing pain and discomfort to patients because the IVD is no longer able to maintain the correct pressure and alignment of the spine,” said co-principal investigator Dr. Roger Härtl, co-director of The Spine Center at NewYork-Presbyterian

Hospital/Weill Cornell Medical Center. Härtl is also the Leonard and Fleur Harlan clinical scholar, an associate professor of neurological surgery at WCMC, and the team neurosurgeon for the New York Giants.

Härtl is testing the engineered discs, made by Bonassar, by implanting them into the spines of animals that suffer from disc degeneration. A previous project shows that engineered IVDs, implanted into healthy animals, were able to maintain the proper pressure and support after one year. The researchers hope the next phase of research will show the same results in the injured animals.

“Our goal is to eventually test the bioengineered IVDs in human patients who are suffering from disc degeneration,” Härtl said. —Anne Ju

## CORNELL HELPING DEVELOP ALGAL BIOFUELS

Cornell scientists are playing a major role in a consortium of researchers led by Cellana, an algal biofuel research company based in Kailua Kona, Hawaii, to develop biofuels from algae, thanks to a \$9 million award from the U.S. Department of Energy.

The consortium—including Cornell, Duke University, San Francisco State University, the University of Hawaii, and the University of Southern Mississippi—will work out plans for developing by 2015 an 100-acre commercial-scale facility to produce fuels and animal feeds from microalgae.

“Relative to other fuels, algae produce at least 10 times more biomass per hectare than terrestrial land plants,” said Charles Greene, a Cornell professor of earth and atmospheric sciences, who is a principal investigator on the project.

Furthermore, algae use nutrients more efficiently than land plants, so there is no runoff of nutrients in the water; they are grown in seawater, so there is no demand for freshwater; and they don’t

require soil, “so you don’t have to compete with food plants for good agricultural land” the way terrestrial biofuels do, Greene added.

In addition, Cellana is analyzing the economics of extracting proteins as nutritional supplements for animal feeds from the byproducts of algal biofuel production. Such supplements could provide revenue to subsidize some of the biofuel production costs, especially in the early stages.

Cornell’s Xingen Lei, professor of molecular nutrition in the Department of Animal Sciences, is currently conducting feeding trials of such algal-based nutritional supplements in chickens and pigs.

Also, Greene is working with Jeff Tester, Cornell’s David Croll Professor of Sustainable Energy Systems in the School of Chemical and Biomolecular Engineering and associate director of the David R. Atkinson Center for a Sustainable Future, and his students to conduct life cycle analyses of the economics, energy costs, and carbon footprint of the project to determine its

commercial viability.

Challenges for developing cost- and energy-efficient algal biofuels include creating systems for processing the algae, including removing the water and extracting the lipids (oils). Cellana is researching novel ways to lower the energy costs of these processes.

Also, Beth Ahner, professor of biological and environmental engineering, and Ruth Richardson, associate professor of civil and environmental engineering, are researching lipid biosynthesis

and algal physiology to develop diagnostic tools to monitor algal cultures. To improve lipid production, the researchers impose stresses on the cells; Ahner and Richardson aim to identify biomarkers to help them understand those stresses and peak times to capture lipids.

The grant is funded through the DOE’s Biomass Program as part of the implementation of the agency’s National Algal Biofuels Technology Roadmap. —Krishna Ramanujan

*Raceway ponds at Cellana’s pilot facility in Kona, Hawaii, where the algae are grown prior to harvesting them for biofuels.*



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## CHEM E CAR WINS AGAIN

For the second time in three years, the Cornell Chemical Engineering Car team won the American Institute of Chemical Engineers student car competition, which took place Nov. 7 in Salt Lake City.

The car, which is required to travel a certain distance powered only by chemical reactions, defeated 31 other teams from universities across the United States. The 40-member undergraduate team powered the shoebox-sized car with two homemade, zinc-carbon dry cell batteries made of carbon, manganese dioxide, sodium chloride, water, and a zinc canister. This strategy replaced previous cars' power sources, including an aluminum-air battery and a hydrogen fuel cell.

Team co-captain Ivan Chua '11 noted that the car cost a mere \$150 to make—the cheapest among competitors.

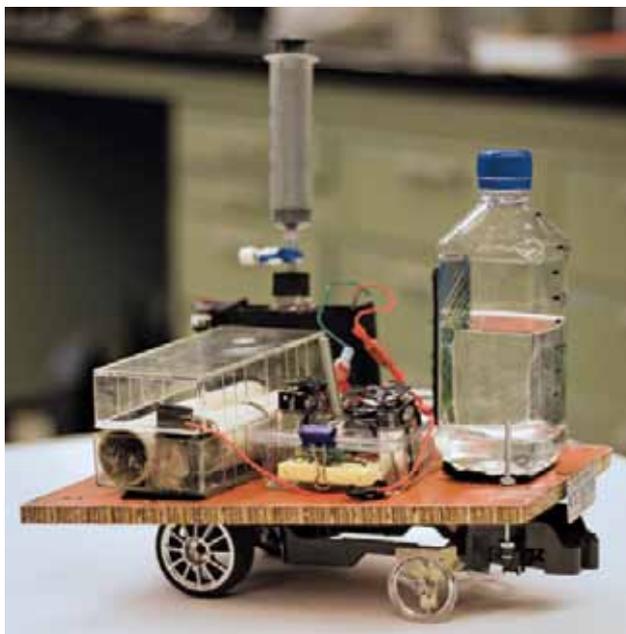
“Our car was far from fancy compared to many of the other cars at the competition, and I think most people did not expect us to win,” Chua said.

Like in years past, the students learned the competition's parameters about an hour before starting. Their car, named Zoidberg after the character from “Futurama,” had to travel 95 feet with a water payload of 250 milliliters. To stop the car, they used an old trick from previous years: an iodine clock, which turns opaque, trips a circuit and cuts power to the motor.

They finished within 20.5 inches of the target. Their closest competitor came within 29 inches.

“We were pretty confident going in there, but we had absolutely no idea we could come in first,” said team co-captain Woojin Kim '12. Kim added that the team performed close to 200 calibrations on the vehicle to balance speed versus power to ensure accuracy in the car's performance.

Chua also noted that teamwork and competition experience were crucial to the victory. Their game plan was disrupted early on when they realized they were missing an all-important electrolyte material. Instead of panicking, they split into two groups—one to search for replacement material, and the other to continue working on



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*The ChemE car, Zoidberg. On the left are the two batteries; in the middle is the circuitry that detects the iodine clock reaction; on the right is the water load required in the competition; and behind everything is the “black box” where the iodine clock reaction occurs.*

the car as if nothing had happened.

“We communicated with one another at every step, and every single member at the competition had a role to play in our win,” Chua said.

The students won a trophy and \$2,000. They plan to next participate in the Mid-Atlantic Regional contest, which will take place this spring.

—Anne Ju



*The ChemE Car team celebrates its win. From left to right: Woojin Kim '12, Brandy Risha '12, Qinyi Chew '12, Samantha Tierney '13, Ji Hoon Kim '11, Ivan Chua '11, Shreedevi Kumar '12, and Panpreedee “Pang” Laohapairoj '12.*

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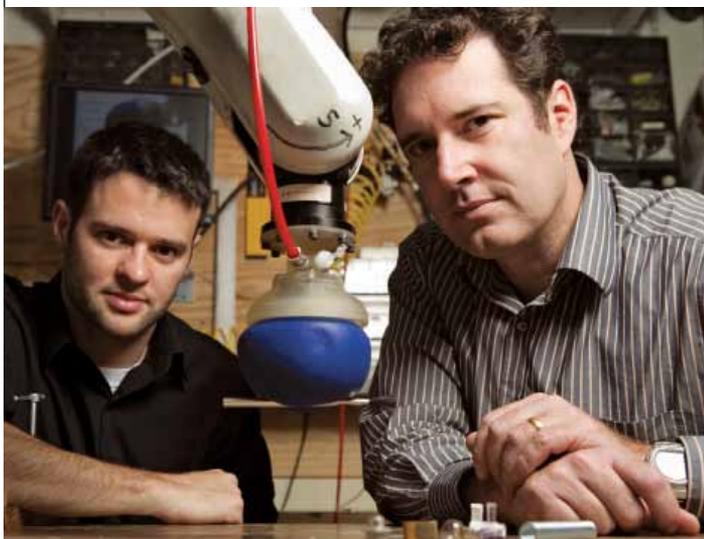
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## BALLOON FILLED WITH GROUND COFFEE MAKES IDEAL ROBOTIC GRIPPER



ROBERT BARKER/UNIVERSITY PHOTOGRAPHY

Graduate student John Amend, left, and associate professor Hod Lipson with the universal robotic gripper.

The human hand is an amazing machine that can pick up, move and place objects easily, but for a robot, this “gripping” mechanism is a vexing challenge. Opting for simple elegance, researchers from Cornell, the University of Chicago, and iRobot Corp. have created a versatile gripper using ground coffee and a latex party balloon, bypassing traditional designs based on the human hand and fingers.

They call it a universal gripper, as it conforms to the object it’s grabbing, rather than being designed for particular objects, said Hod Lipson, Cornell associate professor of mechanical engineering and computer science. The research is a collaboration between the groups of Lipson, Heinrich Jaeger at the University of Chicago, and Chris Jones at iRobot. It was published online Oct. 25 in *Proceedings of the National Academy of Sciences*.

“This is one of the closest things we’ve ever done that could be on the market tomorrow,” Lipson said. He noted that the universality of the gripper makes future applications seemingly limitless,

from dismantling explosive devices or moving potentially dangerous objects, to manufacturing, prosthetic limbs, and robots that could walk on walls.

Here’s how it works: A balloon filled with ground coffee is attached to a robotic arm. The coffee-filled balloon presses down and deforms around the desired object, and then a vacuum sucks the air out of the balloon, solidifying its grip. When the vacuum is released, the balloon becomes soft again, and the gripper lets go.

Coffee, Jaeger said, is an example of a particulate material, which is characterized by large aggregates of individually solid particles. Particulate materials have a so-called “jamming transition,” which turns their behavior from fluidlike to solidlike when the particles can no longer slide past each other.

This phenomenon

is familiar to coffee drinkers who have ever bought vacuum-packed coffee—hard as a brick until the package is unsealed.

“The ground coffee grains are like lots of small gears,” Lipson said. “When they are not pressed together they can roll over each other and flow. When they are pressed together just a little bit, the teeth interlock, and they become solid.”

Jaeger explained that the concept of a jamming transition provides a unified framework for understanding and predicting behavior in a wide range of disordered, amorphous materials. All of these materials can be driven into a “glassy” state where they respond like a solid yet structurally resemble a liquid, and this includes many liquids, colloids, emulsions, or foams, as well as particulate matter consisting of macroscopic grains.

“What is particularly neat with the gripper is that here we have a case where a new concept in basic science provided a fresh perspective in a very different area—robotics—and then opened the door to applications

none of us had originally thought about,” Jaeger said.

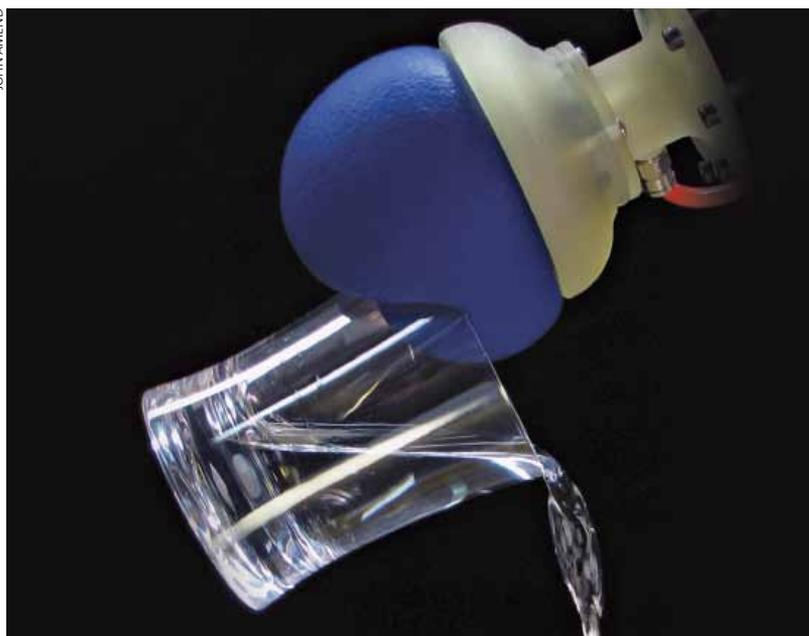
Eric Brown, a postdoctoral researcher, and Nick Rodenberg, a physics undergraduate, worked with Jaeger on characterizing the basic mechanisms that enable the gripping action. Prototypes of the gripper were built and tested by Lipson and Cornell graduate student John Amend, as well as at iRobot.

As for the right particulate material, anything that can jam will do in principle, and early prototypes involved rice, couscous, and even ground-up tires, Amend said. They settled on coffee because it’s light but also jams well. Sand did better on jamming but was prohibitively heavy. What sets the jamming-based gripper apart is its good performance with almost any object, including a raw egg or a coin—both notoriously difficult for traditional robotic grippers.

The project was supported by the Defense Advanced Research Projects Agency.

—Anne Ju

JOHN AMEND



The robotic gripper conforms to the shape of the item it is lifting.

## NEW DETAILS ABOUT ELUSIVE PROTEIN STRUCTURES COULD YIELD INSIGHT INTO PARKINSON'S DISEASE

Proteins perform almost every function our bodies require for life. But, they also can misbehave in myriad ways. By retracing the history of each abnormal reaction, biochemists aim to determine the events that lead to disease and to intervene in the process.

Collaborative research between Ithaca-based Cornell applied physicists and biochemists at Weill Cornell Medical College has yielded new clues into what happens when the Parkinson's disease-associated protein alpha-synuclein undergoes abnormal aggregation. These findings are published in the Nov. 2 edition of *Proceedings of the National Academy of Sciences*.

Parkinson's disease patients have dense lesions in their midbrains called Lewy bodies, which involve aggregates of alpha-synuclein. But it is still unclear whether Lewy bodies are a symptom of the disease or are themselves responsible for cell death. Many researchers surmise that smaller clusters (known as oligomers or aggregates) of alpha-synuclein protein could be responsible for initiating neurodegeneration.

The Cornell group, led by applied and engineering physics professor Watt W. Webb and Weill Cornell biochemistry professor David Eliezer, aimed to shed light on structural changes in alpha-synuclein. Using chemical solutions of fluorinated alcohol to trigger protein structural transitions, the researchers observed the formation of irregular, helical aggregates that may be similar to formations in the brain of Parkinson's disease patients. These structures, some long and thin, and others inter-wound or spooled, could suggest alternative pathways to alpha-synuclein

aggregation in the brain.

"These ringlike annular aggregates have been seen with atomic force microscopy before, and people have been interested in them for a long time," said Valerie Anderson, first author and a graduate student in Webb's lab. The research shows that the aggregates may be involved in infiltrating healthy cells and causing disease, which could result in toxicity.

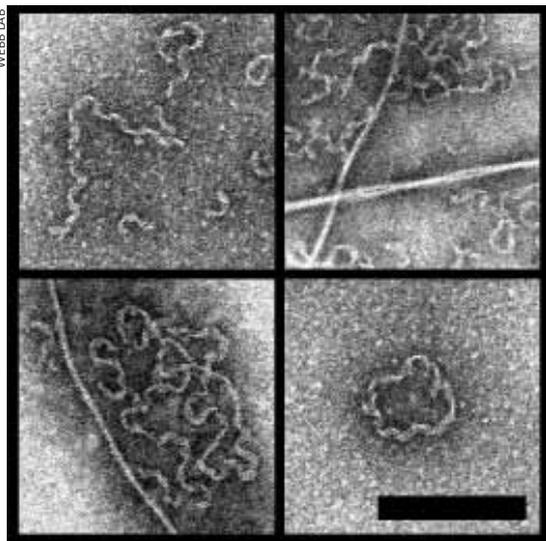
The new Cornell experiments paint stunning visual evidence of a wide array of protein aggregates with varying molecular structures, some of which might be key to understanding Parkinson's disease. In addition, the researchers identified early events in the assembly of these structures. By examining the interaction of types of polarized light with the alpha-synuclein protein, they observed rearrangements of the protein on the molecular level prior to aggregation. Additional changes in the molecular conformation occurred when the proteins stuck together; alpha-synuclein adopts a helical structure that converts to an aligned, sheetlike molecular assembly early in the aggregation process.

Understanding disease is like solving a mystery—a million clues yield nothing, but the right one could lead to new treatments. These latest results shed light on early events that occur when alpha-synuclein behaves badly, although more research must be done to determine whether similar events take place in the brains of Parkinson's disease patients.

The researchers made use of microscopy and spectroscopy equipment at the Cornell Center for Materials Research, which is supported by the National Science Foundation. The research was also funded by the National Institutes of Health and the NSF Science and Technology Center program.

—Anne Ju

*Transmission electron micrographs of classically rigid amyloid fibers and other, differently shaped aggregates formed from the Parkinson's disease-associated protein alpha-synuclein. The study of alternative aggregation pathways of alpha-synuclein may be crucial for understanding the initiation of the disease.*



WEBB LAB

## \$1 MILLION GRANT TO FUND BETTER VIDEO NETWORK RESEARCH



A team of electrical and computer engineering faculty have received \$1 million from Intel Corp., Cisco Systems Inc., and Verizon Communications Inc. for research on "video-aware networks."

Over the past two decades, research has focused on the art of coding to transport bits more efficiently and reliably over networks,

said Salman Avestimehr, assistant professor of electrical and computer engineering and project principal investigator.

"In contrast, we aim to understand how awareness from the content and users' perception of those 'bits' can revolutionize our networks," Avestimehr said. Among the team's goals is to explore video awareness at different parts of the network to engineer more intelligent communication infrastructures.

Other team members are professors Tsuhan Chen and Sheila Hemami and assistant professor Aaron Wagner, all electrical and computer engineering.

"There are many opportunities for efficiency improvements in current networks," said co-principal investigator Wagner. "For instance, two people watching the same video on their cell phones currently receive separate copies of the video. It is very inefficient."

The unique arrangement of the collaboration, with companies representing several different industries joining with an academic research team, promises opportunities for both fundamental research and technology transfer.

"We are very pleased to host this project, which will enhance people's experiences as people become more and more mobile," said Chen, who is also ECE director.

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## STUDENT NONPROFIT AIDS ZAMBIAN ORPHANS

In the city of Ndola, Zambia, 120 orphans each have a pair of brand-new, black leather shoes made especially for them. The shoes, which will complete the children's school uniforms, are their ticket to an education and were a gift from a nonprofit foundation started by two Cornell students last year.

Last spring, engineering student Ricky Panzer '13 and hotel student Alex Friedman '13 launched Signature Donations with a broad mission: to fight the causes and effects of poverty. Purchasing the custom-made shoes for children at Haven of Hope Orphanage—an effort dubbed Project Ndola—was their first fundraising venture.

After incorporating Signature Donations in March 2010, Panzer and Friedman led the effort to raise \$2,100 to have the shoes ordered, purchased and delivered by a local factory in Zambia. The children received their shoes in early September. Panzer and Friedman particularly wanted the shoes manufactured in Zambia, in order to help stimulate the economy.

The students chose the orphan shoe project after learning the dilemma that many Zambian children living in poverty face: To attend a government school, they need tuition, books and a uniform, which includes black leather shoes. For many, the shoes are prohibitively expensive—effectively barring them from receiving an education.

Panzer and Friedman began a relationship with the orphanage through its director, whom they met through Panzer's father, a health education professional. Panzer, a computer science major, spent the summer drumming up support at home in northern New Jersey, leading fundraising teams of high school students and also speaking to Rotary Clubs.

On the opposite coast in California, Friedman led such efforts as a charitable garage sale, in which neighbors donated

goods from which proceeds went to Project Ndola.

The organization's name reflects one of its main goals: To launch projects that address very specific needs. With regard to Ndola, Friedman explained, they wanted to do more than just collect or buy shoes and ship them to Africa, as many organizations do.

"We felt that if we didn't reach out to them, and they didn't tell us exactly what they needed, it might never have been addressed," he said. "So we felt, hey, this is a great opportunity to do good for a specific cause."

Panzer and Friedman lived in nearby rooms in Mews Hall freshman year. Panzer had led a service club in high school and knew he wanted to continue serving in college, but didn't know exactly how.

Friedman came into the partnership with an eye for business. He already had started a company in high school called Deuces Wild, and he was looking for more projects. Starting a nonprofit, he said, was an appealing challenge.

The duo hopes to grow Signature Donations and recruit more Cornell students. They have ambitions for more fundraising ventures, including building a K-8 school in Zambia. It's important to them that their projects can be sustained once their involvement ends.

"The theory is there is a finite amount of change that needs to be implemented in order to do good for people," Panzer said. "And we want to reach that goal, and it can only be obtained through sustainable projects."  
—Anne Ju

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After incorporating Signature Donations in March 2010, Panzer and Friedman led the effort to raise \$2,100 to have the shoes ordered, purchased and delivered by a local factory in Zambia.

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Children at Haven of Hope Orphanage receive shoes purchased by Signature Donations, a nonprofit started by two Cornell students.

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The students chose the orphan shoe project after learning the dilemma that many Zambian children living in poverty face: To attend a government school, they need tuition, books, and a uniform, which includes black leather shoes.

## NEW ACADEMY FOCUSES ON SCIENCE, TECHNOLOGY OF GEOTHERMAL ENERGY DEVELOPMENT

In step with the world's pressing need to explore alternative energy sources, Cornell is taking a leading role in the country's first National Geothermal Academy, expected to launch this summer.

Funded with a \$1.2 million U.S. Department of Energy grant, the multi-university academy will offer an eight-week, intensive summer training program for undergraduate, master's, and Ph.D.-level students in all aspects of geothermal energy.

The technology for harnessing geothermal energy, which captures heat from under the Earth's surface for generating electricity and direct thermal energy applications, is relatively underutilized in high-grade areas of the western U.S. and virtually unknown in the eastern states.

But the potential for geothermal energy to change the landscape of this country's energy use is becoming apparent, said Cornell's Jefferson Tester, the Croll Professor of Sustainable Energy Systems and a principal investigator for the geothermal academy grant.

"The neat part is that using geothermal energy is no longer just limited to the American West," Tester said. "Geothermal heat pumps can be deployed anywhere, as well as direct use of lower-temperature

geothermal energy for heating and cooling buildings."

The academy, to be hosted at the University of Nevada-Reno, will invite up to 35 students to attend the June 20-Aug. 12 seminars, and up to 20 of those students will be supported by a DOE fellowship. Tester, who is associate director of energy programs at Cornell's Atkinson Center for a Sustainable Future, will teach the first course module (June 20-24), "Introduction to Geothermal Energy Utilization." Other courses taught by faculty from various disciplines will cover such topics as public policy and permitting, resource assessment and exploration, and drilling and reservoir engineering.

Tester pointed out that the timing of the academy—the most comprehensive of its kind in the U.S.—ties in with Cornell's ongoing efforts to cut its carbon footprint and be a leader in alternative energy exploration and research.

In a paper presented in October 2010, Tester and several other faculty and staff at Cornell, Southern Methodist University, and the University of West Virginia formally discussed opportunities for utilizing lower-grade geothermal resources in the Northeast.

## RENEWABLE ENERGY TRAINEESHIP PROGRAM

This semester, several graduate students are being supported by a new National Science Foundation grant to Cornell that focuses on sustainable Earth energy. Cornell was awarded \$3 million over five years for an Integrative Graduate Education and Research Traineeship Program (IGERT) to support students seeking degrees in engineering and geosciences with particular focus on renewable and cleaner energy, including carbon management.

The interdisciplinary training program will meet growing national need for a new workforce to design energy solutions to take advantage of Earth's natural resources while remaining in balance with the environment's hydrologic and ecologic services, the IGERT proposal states.

The paper also made a strong case for exploratory drilling in Ithaca, where the geothermal resource grade is above average for the Northeast region. At Cornell, geothermal heat at temperatures of 120 degrees Celsius (248 degrees Fahrenheit) could be used in an advanced combined heat and power system in conjunction with other renewable resources such as biomass and lake source cooling, both of which are already in use.

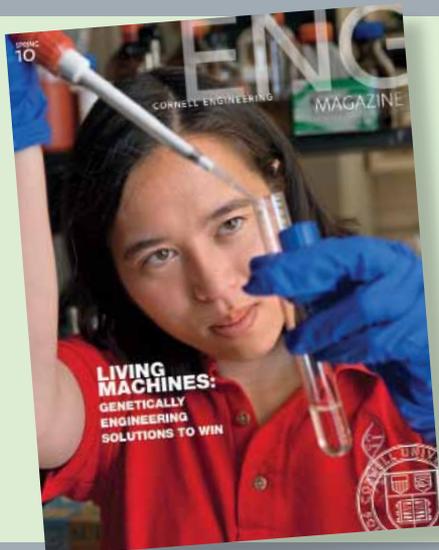
Furthermore, Cornell is also launching a graduate-level training program in sustainable energy recovery from the Earth, which includes a section on geothermal energy.

Lower-grade geothermal

energy is not widely used in part because of the cost of exploratory and commercial drilling, as well as public concerns about drilling in populated regions, Tester said. However, it could be a key component to a future free from dependence on fossil fuels.

The geothermal academy is led by faculty from the following institutions: University of Nevada-Reno, University of Utah, Stanford University, Massachusetts Institute of Technology, Oregon Institute of Technology, Southern Methodist University, and West Virginia University.

—Anne Ju



## Cornell Engineering Magazine GOES PAPERLESS

Alumni and friends of the college can now sign up to receive an electronic version of *Cornell Engineering Magazine* instead of a printed copy.

The college is encouraging this paperless option as a convenience to readers and to reduce its impact on the environment.

Anyone who would like to receive an e-mail notification when we publish a new issue of *Cornell Engineering Magazine* online can do so at [www.engineering.cornell.edu/paperless](http://www.engineering.cornell.edu/paperless).



## EARTH IS TWICE AS DUSTY AS IN 19TH CENTURY, RESEARCH SHOWS

If the house seems dustier than it used to be, it may not be a reflection on your housekeeping skills. The amount of dust in the Earth's atmosphere has doubled over the last century, according to a new study; and the dramatic increase is influencing climate and ecology around the world.

The study, led by Natalie Mahowald, associate professor of earth and atmospheric sciences, used available data and computer modeling to estimate the amount of desert dust, or soil particles in the atmosphere, throughout the 20th century. It's the first study to trace the fluctuation of a natural (not human-caused) aerosol around the globe over the course of a century.

Mahowald presented the research at the fall meeting of the American Geophysical Union in San Francisco Dec. 13.

Desert dust and climate influence each other directly and indirectly through a host of intertwined systems. Dust limits the amount of solar radiation that reaches the Earth, for example, a factor that could mask the warming effects of increasing atmospheric carbon dioxide. It also can influence clouds and precipitation,

leading to droughts; which, in turn, leads to desertification and more dust.

Ocean chemistry is also intricately involved. Dust is a major source of iron, which is vital for plankton and other organisms that draw carbon out of the atmosphere.

To measure fluctuations in desert dust over the century, the researchers gathered existing data from ice cores, lake sediment and coral, each of which contain information about past concentrations of desert dust in the region. They then linked each sample with its likely source region and calculated the rate of dust deposition over time. Applying components of a computer modeling system known as the Community Climate System Model, the researchers reconstructed the influence of desert dust on temperature, precipitation, ocean iron deposition, and terrestrial carbon uptake over time.

Among their results, the

researchers found that regional changes in temperature and precipitation caused a global reduction in terrestrial carbon uptake of six parts per million (ppm) over the 20th century. The model also showed that dust deposited in oceans increased carbon uptake from the atmosphere by 6 percent, or 4 ppm, over the same time period.

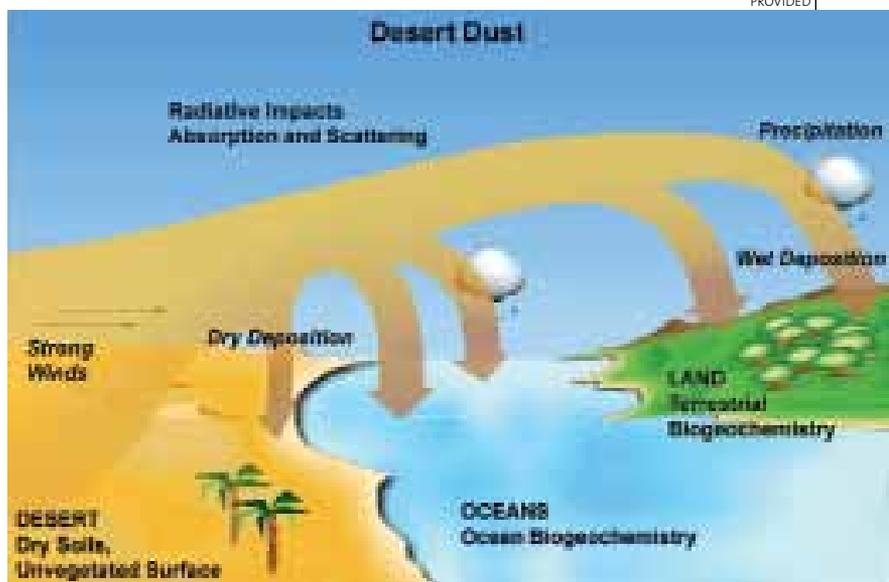
While the majority of research related to aerosol impacts

on climate is focused on anthropogenic aerosols (those directly emitted by humans through combustion), Mahowald said, the study highlights the important role of natural aerosols as well.

"Now we finally have some information on how the desert dust is fluctuating. This has a really big impact for the understanding of climate sensitivity," she said.

—Lauren Gold

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Desert dust and climate influence each other directly and indirectly through a host of intertwined systems.

## BOOK ON NETWORKS PROVIDES SIX DEGREES OF EXPLANATION

Are all film stars linked to Kevin Bacon? Why do the stock markets rise and fall sharply on the strength of a vague rumor? How does gossip spread so quickly? Are we all related through six degrees of separation? There is a growing awareness of the complex networks that pervade modern society—the links that connect us and the ways in which each of our decisions can have subtle consequences for everyone else.

"Networks, Crowds and Markets: Reasoning About a Highly Connected World" (Cambridge University Press, 2010) by David Easley, Cornell's Henry Scarborough

Professor of Social Sciences and chair of the Department of Economics, and Jon Kleinberg, the Tisch University Professor of Computer Science draws on ideas from economics, sociology, computing and information science, and applied mathematics to describe the emerging field of study at the interface of all these areas, addressing fundamental questions about how the social, economic, and technological worlds are connected.

The 736-page book is based on the interdisciplinary course, Networks, that the authors teach at Cornell. It is aimed

at practitioners in information technology, marketing, and related fields, and is suitable for use as a textbook. The book, like the course, is designed for readers at the introductory undergraduate level with no formal prerequisites, but most of the chapters are supplemented with optional advanced sections.

—Bill Steele



## MEDICAL TRANSPORT SYSTEM USED IN ONTARIO CUTS EMPTY FLIGHTS BY 21 PERCENT

A system for improving the logistics of medical transport in Ontario, Canada, developed through a series of Cornell master of engineering projects over the past three years, will soon be in use to help save lives.

Preliminary runs show that the new system may be cutting total travel distances by some 12 percent, and empty flights by 21 percent.

Since 2007, operations research and information engineering master's students have worked with Ornge, the nonprofit organization that provides medical transport for Ontario, to help improve the logistics of their service. Now a full-fledged system is in final testing phases and being rolled out for routine use.

Former graduate student Tim Carnes M.S. '08 OR and ORIE professors David Shmoys and Shane Henderson have worked together in advising the M.Eng.

medical transport projects. The Ornge project lead is Dr. Russell MacDonald, medical director for research and development and an associate professor at the University of Toronto.

After an early Cornell project focused on the basing of helicopters to be dispatched for emergencies, work shifted to the daily task of scheduling non-emergency medical transport planned for the following day. On an average day, Ornge flies or drives more than 10,000 miles to transport patients, and each year Ornge transports more than 20,000 patients.

The Flight Planning Optimization Tool developed by ORIE in partnership with Ornge uses operations research modeling as the basis for developing daily schedules from financial and aviation data. Doing so involves solving a challenging optimization

problem: to find the best routes for aircraft, some of which can carry two patients, escorts or family members, and to determine the sequence of pickups and drop-offs along the way.

Before the tool was developed, flight planners developed routes, relying on software that identified the cheapest aircraft for a specific route. Test runs of the new approach, using more than 30 sample days of historical data, reduced total travel distance by 12 percent and reduced the number of flight legs with no patients on board ("empty legs") by 21 percent, according to Mahvareh Ahghari, project supervisor at Ornge.

Using results from an M.Eng. project that supplied proof of concept, Carnes first redeveloped the code to make it run quickly. He came up with a way to enumerate possible routes to efficiently construct an auxiliary

optimization problem that can be solved, using commercial software, to obtain the desired optimal schedule.

"This made it conceivable for the first time to compute solutions to the scheduling problem that Ornge faces daily," Henderson said.

A follow-up M.Eng. project refined the cost data, after which computer science Ph.D. student Alex Fix added features to make the system more realistic (such as avoiding the transport of multiple patients when one of them is infectious) for putting the system into production at the Ornge headquarters near Toronto.

Carnes, who graduated in 2010 and is now a postdoctoral fellow at Massachusetts Institute of Technology, incorporated some of the results of his work with Ornge in his Cornell Ph.D. thesis.

—Mark Eisner

## STUDENT ENGINEERS DEVISE WAYS TO SOUNDPROOF LOCAL NONPROFIT

Students enrolled in Professional Practice in Mechanical Engineering (MAE 4300), taught by senior lecturer Alexander Deyhim, spent the fall semester working with Ithaca's Child Development Council to find a cost-effective solution to a critical problem: soundproofing.

The senior-level, required course for mechanical engineering majors features a project in which students must tackle an engineering design problem. Some projects are theoretical; for example, one group came up with a design for car tires controlled by a sensor that could change treads depending on weather. Others opted to help the Child Development Council improve their workspace by soundproofing their walls. And this semester, the theory might become reality.

Thanks to a grant being secured through the Cornell Public Service Center, the students will likely be able to return to the development council to figure

out which solution will work best, and volunteer their time to implement it.

Three groups worked on the development council project, which involved coming up with engineering solutions for making the nonprofit's conference room less susceptible to eavesdropping. The organization, located in downtown Ithaca, has occupied the same building for two decades. In 2000 they added a conference room, but since then they've had problems with sound leaking through the ceilings and paper-thin walls.

"We are [Health Insurance Portability and Accountability Act] compliant, and lots of the things we do require confidentiality," said Diane Feldman, fiscal manger of the development council. Feldman said she often finds herself whispering during phone calls in her office, which is located right next to the conference space.

Students tackled the problem in a variety of ways. One group

suggested putting in new ceiling tiles that would better contain sound and were also up to fire and building codes. Their project included pricing the different tile options and estimating time and implementation costs.

Others suggested that the council invest in sound and speaker systems to pump ambient noise through the building, helping to mask the sound.

"It's really rewarding to have a real client," said Alison Nalven '11 ME. "It was nice to work with the community and give back to Ithaca, and feel like we've made an impact after four years of engineering."

Kat Ingalls '11 ME, who worked with Nalven, said she plans to do product design, and gaining experience via the development council project was a welcome challenge.

Deyhim has been teaching the course for three years and is consistently striving to improve it. Every week he brings in a

guest speaker from industry to cover topics ranging from quality control to systems engineering, all of which are topics addressed in ABET (Accreditation Board for Engineering and Technology) certification, which most engineers must pass to practice in the field. For the ethics lesson, Deyhim made the unusual move of bringing in a pastor from a local church to lead the discussion.

Deyhim sees the course as a way to prepare students for careers in engineering, not only for the ABET certification, but also to expose them to different career options.

"Imagine you have a bunch of athletes who are brilliant," he said. "Now you have to help them figure out if they want to do the Tour de France or play in the Super Bowl. These engineering students have taken core courses over three years and are really intelligent and clever. It's actually a very exciting course."

—Anne Ju

# Teaching Excellence

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**New institute making Cornell Engineering education even better.**

BY LAUREN CAHOON

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IN DAYS GONE BY, LARGE CLASSES AT CORNELL, such as intro and organic chemistry, were a place to fade into the crowd—where students either furiously scribbled notes as the professor scrawled on the distant blackboard, or dazed off into day (or real) dreams.

Today, there's a decidedly different feel in courses such as Analysis of Mechanical and Aerospace Structures (MAE 3250), a large lecture course for junior mechanical engineering students.

Professor Yingxin Gao, in a tailored skirt and blazer and short-cropped hair, explains how to calculate the stress concentration of a plate with a circular hole in its center. As she lectures, a bright projector screen shows computer-generated examples and illustrations of the concept. Gao frequently walks to an adjacent blackboard to write out equations. As she writes, she asks the students questions about the problem—her voice crisply amplified by the microphone clipped to her blazer. The students call out answers, and she plugs in the correct ones accordingly.

Periodically, she stops to ask them to solve an equation in their notebooks, and discuss it.

Finally, Gao pauses to put up a PowerPoint screen with a multiple choice question on it. "Which of the following statements about sigma is correct?" she asks. Options A through D are available. Students reach into their bags for small white devices called iClickers that resemble TV remotes. Quickly, their answers filter in—a small meter at the top of the screen instantly shows how many students have chosen each option as they press the corresponding buttons on their iClickers. Once choices are in, Gao brings up a bar graph showing what percentage of the class picked each answer—86 percent picked A, which turns out to be correct. Not



one student is asleep—not even in the back.

This class's lively and engaged atmosphere is in large part thanks to the Teaching Excellence Institute. The College of Engineering created the institute in 2008 to improve the quality of teaching and learning within the college. Director Kathryn Dimiduk, '79, formerly a senior lecturer in physics at the University of New Mexico, works closely with faculty. "We're looking to get the maximum amount of impact with

our efforts," she says, noting that one of the major goals of the institute is to "reduce the frustration of the faculty, and reduce the frustration of the students."

Dimiduk finds out exactly what faculty want to help them teach better—the results range from simple to state-of-the-art solutions. Improving the audio-visual quality of the rooms was a basic, but huge, step towards improving the experience for students and professors. Renovations, which started last summer and continued over winter break, vary by room. Some include wide-screen projectors with split-image capability, a document camera to display text or demos, and new, larger screens that display the full image that appears on the professor's computer. Previously, rooms such as Olin 255,

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## This class's lively and engaged atmosphere is in large part thanks to the Teaching Excellence Institute.

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The institute awards McCormick Teaching Innovation and Course Improvement Grants that faculty can use to purchase new tools like the iClickers and smart tablets, which allow them to make notes on a slide or actively work out an equation with the students. The institute works with faculty as needed to develop innovative teaching strategies that incorporate these technologies.

Tobias Hanrath, assistant professor of chemical and bioengineering, was wary at first of the new technology. "To be honest, I was skeptical about some aspects of this technology in the beginning because I am not a fan of multiple choice questions," he wrote in an e-mail to Dimiduk. "But the combination of concept-tests to test the students' fundamental

understanding of the underlying thermodynamics and the clicker system has proven to be a very effective improvement to the course." Now, Hanrath's students, who have been hugely in favor of the technology, use the clickers routinely in recitation session and in lecture.

Chris Schaffer, assistant professor of biomedical engineering, is an advocate for the technology. As a physics graduate student at Harvard University, he studied with Eric Mazur, who has studied the way science and technology is taught. The Mazur group pioneered and studied the Peer Instruction method, which encourages student participation and interaction in



Susan Daniel, assistant professor of chemical and biomolecular engineering, overwrites a presentation slide during lecture using a smart tablet. She piloted the device for the Teaching Excellence Institute.

large lecture classes. According to Mazur's Web site, "[Peer Instruction]...involves students in their own learning during lecture and focuses their attention on underlying concepts. Lectures are interspersed with conceptual questions... designed to expose common difficulties in understanding the material. The students are given one to two minutes to think about the question and formulate their own answers; they then spend two to three minutes discussing their answers in groups of three to four, attempting to reach consensus on the correct answer. This process forces the students to think through the arguments being developed, and enables them (as well as the instructor) to assess their understanding of the concepts even before they leave the classroom."

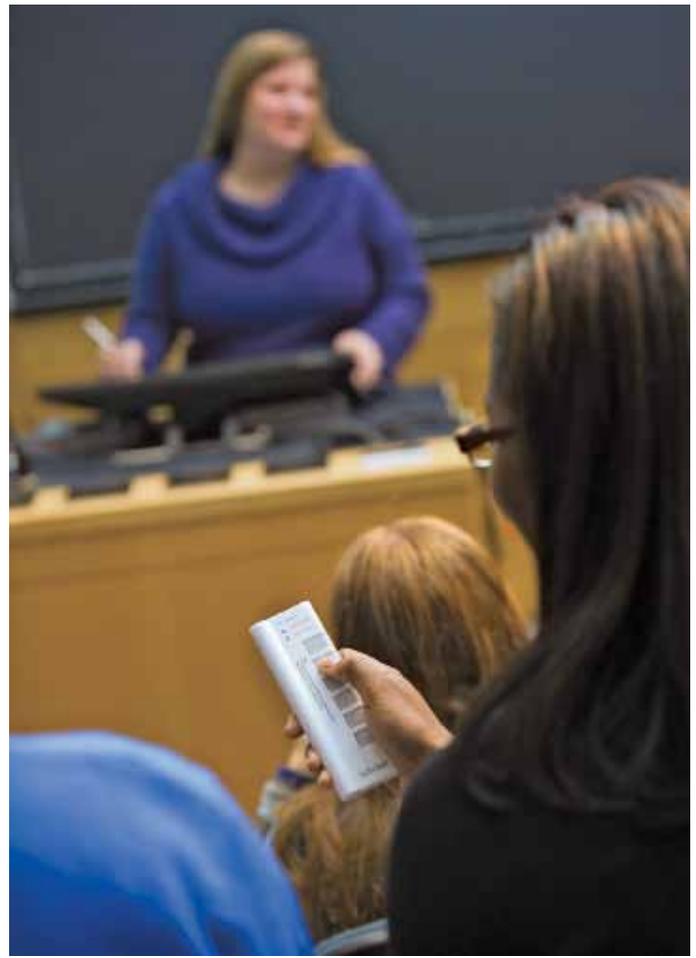
This method can be used in conjunction with iClickers, so that students can discuss, and then vote on the answers they arrived at after working with their peers. Mazur introduced the iClicker method to Schaffer, who then continued to use it when he came to Cornell in 2006, before it had been widely adopted. Schaffer explains that the value of the iClicker method goes beyond a simple test to see if students understand a concept. "If a teacher designs a question that all the students get correct, they're just patting themselves on the back saying, 'Wow I did a good job teaching them.'" Instead, he says, teachers should provide students with questions that challenge their own conceptual misunderstandings.

The trick, Schaffer says, is in designing the questions correctly, which is not always easy. Crafting the 'right' wrong answers that get at common misjudgments is also important for getting students to think more deeply about a topic. "These questions can be extremely effective teaching tools," says Schaffer.

To better facilitate the use of iClicker questions, Dimiduk is creating a database for faculty to upload and access the multiple-choice questions for various courses and subjects. Thus, faculty that are new to the format and may not have the time to compose new questions can access the database and use ones that have already been tested in the classroom. They can also use questions from the database as models as they design questions for their own courses.

The institute was founded with a partial endowment and continuing support from Michael Goguen '86 EE, a member of the Engineering College Council. James '69 OR, M.Eng. '70 and Marsha McCormick '70, have also supported the institute. John Swanson '61 ME, M.S. '63 is the lead donor for the classroom renovation project (other major donors include Bob '63 AP, M.S. '64, and Anne '64 Shaw).

Swanson recently visited the college to view the latest improvements and talk about why he chooses to donate to



The value of the iClicker method goes beyond a simple test to see if students understand a concept.

efforts like this one. He says he focuses on improving engineering education because "there is a desperate need to fill the gap" of vacant engineering positions opening up. "Education is important in my life. I'm looking for places to make a positive effect in education," Swanson adds. His beliefs in education technique align nicely with that of the institute. "The best way to learn something

is to teach it," he says.

Teaching excellence has always been important to the College of Engineering. If the Teaching Excellence Institute's goals are achieved, teaching will be even better in updated classrooms that further support innovative, engaging teaching. "It can really change the feel of a class," says Dimiduk, "and I have been impressed with faculty willingness to try new technology and approaches and how much they care about teaching." **CEM**

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**T**eaching has always been important to the College of Engineering. If the Teaching Excellence Institute's goals are achieved, teaching will be even better in updated classrooms that further support innovative, engaging teaching.

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A



# CONVERSATION

## WITH KATHI WARREN

### assistant dean for Alumni Affairs and Development

*Kathi Warren became assistant dean for Alumni Affairs and Development in the College of Engineering June 1. As chief development officer for the college with responsibility for the college's alumni affairs and development program, Warren works closely with Dean Lance Collins, directors, chairs, faculty members, and staff to ensure the college achieves its fundraising goals. She came to Cornell after serving as campaign director and director of corporate relations at the Robert H. Smith School of Business at the University of Maryland. Previously, she held positions as a major gifts officer at Johns Hopkins University's Krieger School of Arts and Sciences and at the Smith School of Business.*

**Cornell Engineering Magazine:** You've been here for about seven months now. How's it going so far?

**Kathi Warren:** It's going well. It's a very exciting time having a new dean (Lance Collins) here. We've been very busy on the road and thinking about the future of the college and how alumni resources can be brought to bear on that. We've been to Boston, Washington, the Northeast, the West Coast, and, of course, New York City. We're focusing on the dean's priorities, which will be further articulated as a function of the strategic planning process the college is undertaking.

**CEM:** Will changes be made to the college's strategic plan?

**KW:** Lance is building on the great leadership of former dean Kent Fuchs (now provost) and former interim dean Chris Ober, but the last strategic plan was written in 2004. When Lance

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*responsibility for the college's alumni affairs and development program, Warren works closely with Dean Lance Collins, directors, chairs, faculty members, and staff to ensure the college achieves its fundraising goals. She came to Cornell after serving as campaign director and director of corporate relations at the Robert H. Smith School of Business at the University of Maryland. Previously, she held positions as a major gifts officer at Johns Hopkins University's Krieger School of Arts and Sciences and at the Smith School of Business.*

talks about the strategic planning he calls it an update and simply says, 'I'm asking us to think about how we build on it.' He is not changing the research areas we are focusing on, but he recognizes that within them there are areas where we are already great to preeminent while in others we are just emerging. Lance is working with the schools and departments to identify opportunities to truly go to the next level in those areas. His goal is to position the college among the top five in engineering.

**CEM:** What sort of reception are you getting from alumni?

**KW:** I'd say a very warm welcome. When we went to San Francisco in November, Autodesk, a company where most of the leadership is Cornelian, hosted an alumni event for the dean. There were over 100 alumni in this fabulous gallery where they have the products people

have made with Autodesk software, everything from designing the Avatar movie to the new bridge that spans over the East Bay to the new Tesla car. There were alumni, parents, friends, prospective students. It was a really great gathering and it happened to coincide with game five of the World Series, in which—of course—the San Francisco Giants were playing. Lance's presentation on the future of the college started somewhere around the bottom of the eighth. Even when everyone knew that the game was ending, they listened in rapt attention. Then, maybe halfway through the talk, it came through that the Giants had won and there was a little cheer. Lance said 'OK—phew—they didn't lose the game.' and then he finished the talk. I've seen that kind of interest in the college replicated across the country.

**CEM: What are the college's fundraising priorities?**

**KW:** Our focus right now is on faculty renewal. We recognize that there's a talent bubble out there in the marketplace as well as the significant retirements that will be happening in the college. We estimate that a third of the faculty will retire in next five to 10 years. That's why Cornell has established a \$100 million Faculty Renewal Fund. The university has asked the college deans and

**We recognize that there's a talent bubble out there in the marketplace and that significant retirements that will be happening in the college.**

the department chairs to develop hiring plans for the next five years and to reallocate monies from their budgets to focus on faculty hiring. These reallocated monies will comprise half of the faculty renewal fund. The other half will come from philanthropy; we are asking donors to make faculty renewal their priority.

Lance wants to ensure that we aren't just replacing faculty, but hiring in the research fields that align with our strategic priorities and position the college for success. If you don't have great faculty you don't have a great institution—you can't do great research; you can't do great teaching.

Another key area is graduate fellowships. We'd love to have fellowship funds available for every first-year Ph.D. student, and we're off by more than half. That would make us much more competitive in terms of getting the best graduate students and it would actually allow us to enhance our teaching and faculty research.

Another priority area for us is providing support for some of the experiential learning activities that our students undertake such as student teams. The dean has said "This is something I want to hang my hat on." Around 20 percent of our undergraduates participate, which is quite unusual for a college like ours. It's quite



rigorous and prepares them to hit the ground running when they leave this place in a way that no other experience that they have here does. We want to celebrate that and provide the support that will allow those programs to continue and grow to the next level. That's preparing entrepreneurs. That's developing leadership skills, providing them with an experience that can't be learned in the class.

Of course, I'd be remiss if I didn't highlight annual support for the College of Engineering. The university has seen support for the annual fund increase in a sustained fashion in recent years resulting in back-to-back record-breaking years. We'd love to see our alumni continue that. Unrestricted support to the college is of incredible importance. It's basically giving where the dean's need is greatest. If you can't give a gift to create a professorship or endowed fellowship—which 99 percent of people can't—what you can do is provide unrestricted support. The dean can use that money for everything from a faculty startup package or a new faculty line to graduate fellowships.

**CEM: Why do engineering alumni give?**

**KW:** They tell us over and over again about how important their education was. It doesn't matter that many of them are not practicing engineers. They could be on Wall Street, or in a venture capital firm, or an entrepreneur, but they tell us that the principles that they learned here are what gave them the wherewithal to be successful, period, end of story. That motivates them because they know that that quality has only improved, the rigor has only improved.

Our alumni also know that Cornell is actually answering global challenges and they believe that we are positioned to do that in a way that's unique amongst colleges and universities across the world. When they give, they're not just thinking about helping their alma mater, they're thinking about solving some global challenges too.

**CEM: What's the toughest part of your job?**

**KW:** Our alums are some of the smartest people on the planet. I've had some of the most intriguing, but daunting conversations with some of these folks. I'm learning a whole new language. What it comes back to is they are at the heart of solving challenges. I'm a scientist. I look at myself as the person who would try to understand what they did. I'm on the end game. They are on the front end. To me being an engineer is the definition of being a pioneer.



**CEM: What has surprised you about Cornell?**

**KW:** I'm consistently surprised by how deep the culture of collegiality goes here. Whether that's within the college, when I'm engaging with a faculty member or chair or director trying to understand how I can help them obtain resources for a program, or whether it's with my colleagues in Alumni Affairs and Development trying to think about how I can engage an alumnus to support a program, people here really want the organization to succeed and it just plays out over and over again.

I'm struck by how the minds here are fluid and there really is interdisciplinary collaboration happening all across the quad here and you see it exemplified in so many ways and that's exciting. As I said before, I'm a scientist by training, not an engineer, but I can at least talk about faculty research with a sense of understanding and certainly the passion—that's the thing—the passion these folks have for what they are doing is palpable, it's infectious.

**CEM: Do Cornellians identify with their alma mater more than other alumni?**

**KW:** There's something in the water here. You come here and you spend years in this freezing cold, you get a connection and a passion for this place and somehow you infect another generation. There's nothing like Cornell so it breeds an affinity and connection to it like no other institution. I've worked at land grant schools; I've worked at private schools. There's something different about being a Cornellian, and it's more than academic excellence. I don't have the words to describe it. It's truly a community and its very inclusive and supportive. People's livelihood and connections are woven in and through Cornell. And they're genuinely passionate about it. **CEM**



BY MICHAEL GILLIS

M.Eng. student Kevin Meissner '10 ME (left) and Stuart Jackson '12 EP inspect the core structural assembly of the Violet satel

INSIDE AN AIR FORCE “CLEAN TENT” AT KIRTLAND Air Force Base in New Mexico is a small collection of hardware easy to overlook. Stacked there are two hexagonal structures weighing about 110 pounds, easily lost in the dizzying array of sophisticated military hardware. But to hundreds of Cornell students, staff, and aerospace professionals, that small package represents a real shot at advancing satellite technology.



## One student satellite is set to launch; another may fly.

lited in a dedicated clean room in Rhodes Hall.

The two pieces of equipment are CUSat. This matched pair was Cornell's 2005 entry in the University Nanosat Program's Nanosat-4 competition, sponsored by the U.S. Air Force and the American Institute of Aeronautics and Astronautics. CUSat won the competition, which, in addition to a \$110,000 grant to make the satellites spaceworthy, includes a ticket into space. The program aims to foster student satellite research and design, construction, and flight.

Mason Peck, associate professor of mechanical and aerospace engineering, said the time between victory and the launch pad can be years, a long and anxious wait to test a spacecraft's mettle. But the wait is nearly over for the CUSat team. The experimental spacecraft is now booked—or manifested—for its one-way flight later this year aboard a SpaceX Falcon 9 rocket. That's exciting news for Peck and the team that has spent years working on the project.

invaluable to a host of future manned and unmanned missions.

"What's important here is how CUSat does the inspection," Peck said. "It doesn't just circumnavigate, just fly around the other spacecraft—it does do that—but it does so using GPS. In space, what GPS offers is relative position knowledge. CUSat has some innovative algorithms developed by Mark Psiaki, another professor at Cornell, that allow CUSat to know its position remote to something else to within millimeters of accuracy, which is an extremely fine precision."

The implications of that level of precision are significant.

"If you had a satellite that could go from one to another geosynchronous satellite, for example, you might have the means to evaluate the health of, and maybe even fix, what amounts to very expensive assets," Peck said.

That could include everything from commercial satellites to manned spacecraft.

There's also a financial incentive.

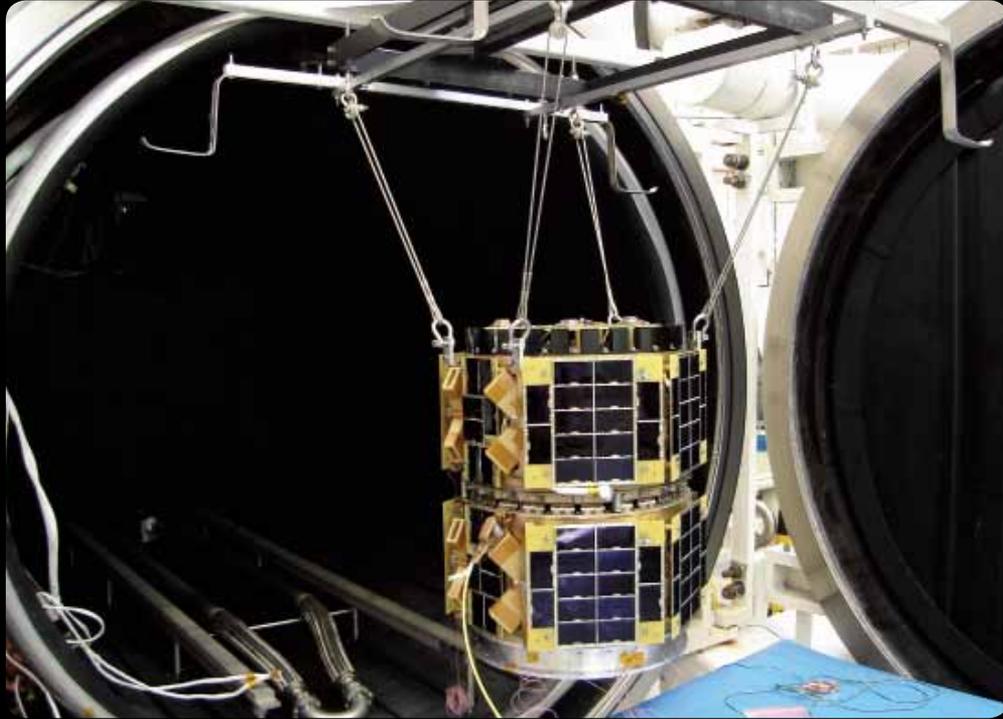
"Geosynchronous satellites can cost hundreds of millions of dollars to build and tens of million dollars to launch," he said "They make their operators millions of dollars a day, so there's a lot of money at stake."

CUSat was one of the first proposals Peck wrote when he arrived at Cornell in 2004. He said the project was envisioned as a way to

### AN IDEA TAKES FLIGHT

Once in orbit, CUSat's two identical satellites will navigate with the help of global positioning satellite data to inspect each other with cameras and beam that data back to Cornell for evaluation. Peck said that kind of precise inspection of spacecraft could prove

PROVIDED



The CUSat spacecraft hangs from a crane before being moved into a thermal vacuum chamber for testing at the Air Force's Aerospace Engineering Facility in Albuquerque, N.M.

produce spacecraft in such a short time and for such low cost, that are then able to compete side-by-side with satellites from other organizations in the industry," said Justin Hahn '08 ME, M.Eng. '08 AE, who was CUSat's propulsion subsystem lead, responsible for the design, assembly, and testing of CUSat's pulsed plasma thrusters. He also led the entire CUSat team during his final year at Cornell. "Building a spacecraft that can stand up to these industry reviews is significantly different from many other student projects, so the success of CUSat indicates how well the rigorous space systems processes have been applied to the program. Although CUSat has demonstrated numerous other technical achievements in their various subsystems, I'm most impressed with the overall

merge some of Cornell's faculty strengths, including those of Psiaki, a professor, and Mark Campbell, an associate professor, both in mechanical and aerospace engineering.

Psiaki's unique GPS algorithms will help CUSat navigate precisely. Campbell's design of pulsed-plasma thrusters to move the spacecraft were specially modified for CUSat, and each satellite contains eight of the thrusters.

That kind of expertise allowed CUSat to evolve and now, near the eve of the launch, the team can size up their success so far.

Peck said there are few university projects of this scope and its accomplishments reach a wider audience.

"CUSat turns out to be the most densely packed spacecraft the Air Force has ever seen," Peck said. "It really is chock-full of good stuff. It's two spacecraft merged together, so it's two for one to begin with. Each spacecraft has eight thrusters. That's a total of 16 thrusters for the entire package, a large number. Each spacecraft has three reaction wheels. Each has three GPS receivers, two radios, two antennas, and eight solar panels. The pair tolerates any single failure of its hardware. So, we've created a very robust space system."

Just as significant, though, is ownership and student and faculty pride in the project.

"It's very impressive that the CUSat program is able to

ability of the program to deliver flight-ready hardware."

Once in orbit, Cornell's role with CUSat will be far from over. "It's very much a Cornell-owned, self-contained project—we build it, we send it to the Air Force who launches it, we operate it, and we get the data," Peck said. "So it's very much a Cornell spacecraft."

In 2006, Campbell's ICE Cubesats were the first Cornell spacecraft to be launched. Unfortunately, the launch vehicle exploded. So, if CUSat makes it to orbit, it will be Cornell's first satellite.

A radio antenna on Mt. Pleasant in Ithaca, adjacent to the Hartung-Boothroyd Observatory, will link CUSat with

the mission control center in the basement of Ward Hall. The CUSat team operates another ground station on the Kwajalein Atoll in the Pacific Ocean, which had been created for a previously planned CUSat launch that never happened.

Peck points out that enthusiasts won't be able to spot CUSat in space—it's simply too small—but can listen in.

"These will not be visible from the ground, probably not even with telescopes," he said. "Instead, they'll be in a low enough orbit that you'll be able to pick up their transmissions using off-the-shelf radio equipment. Any radio hobbyist can easily listen in and pick up the transmissions."

**“CUSat turns out to be the most densely packed spacecraft the Air Force has ever seen.”**

MASON PECK, ASSOCIATE PROFESSOR  
MECHANICAL & AEROSPACE ENGINEERING

## NOT YOUR TYPICAL HOMEWORK PROBLEM

There's no denying that hands-on or experiential education is invaluable. However, that level of experience on a project such as CUSat can be daunting and challenging to even the most disciplined students.

"This is much more than simply a set of homework problems or even a garage mechanic's kind of project," Peck said. "This is the kind of activity where students get experience they're not likely to get at any other university, and one that prepares them for a career in a way they won't get elsewhere. They are learning the professional context for the more abstract engineering. They also get the sense of ownership, beyond simple interest, which helps mature them."

That maturity, he added, is shaped by a recognition that if students fall short of their work on the project, there isn't time for someone else to pick up the slack.

Graduate student Dan Milavitch '10 EP, who is lead systems engineer on CUSat's successor project, Violet, explains the challenge.

"Working with a group of young, inexperienced students is difficult for any project," he said. "Working with a group of young, inexperienced students on the design and fabrication of a spacecraft is much harder. Now add a Cornell engineering workload to the mix and you start to see what we have to deal with here."

However, Milavitch said that because the projects look to industry standards, the work directly relates to sought-after skills in the professional aerospace industry.

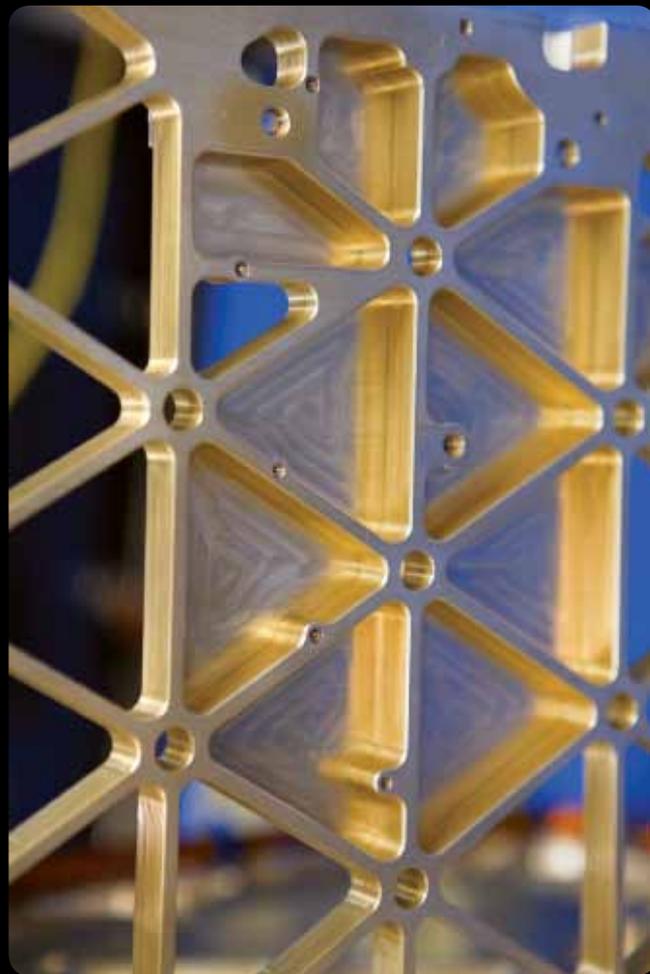
Simmie Berman '06 ME understands. Berman worked on CUSat during her junior and senior years. She said the project was hard work, long hours, and a lot of fun. It was also some of the best practical experience she had, which helped plot a career course.

"Working on CUSat has had a direct impact on my current position," she said. "I'm currently working as a mechanical engineer in the Space Department at the Johns Hopkins University Applied Physics Laboratory on the Radiation Belt Storm Probes. My experience on CUSat was a lot like my work experience, just on a smaller scale. We faced similar challenges on CUSat and on my current program, and I have been able to draw from that experience to help me figure out how to solve problems in my current work. Being familiar with a lot of the terminology, processes, and requirements of designing a satellite definitely was to my advantage when applying for my current position."

Hahn, who is also at Johns Hopkins' Applied Physics Laboratory, agrees.

"Working on CUSat directly prepared me for the job I have now and allowed me to come in with a 'running start' when I began work," he said. "At a minimum, working on the project familiarized me with the basics of spacecraft engineering. When I started working here, I was already familiar with the process for designing and building a spacecraft as well as the subsystems involved. I also had a grasp of the terminology and vocabulary of spacecraft design and build."

Hahn added the leadership experience gained from working with the team was a direct benefit to his professional career.



A close-up of the 'isogrid' pattern machined into Violet's structure. This gives the structure a high strength-to-weight ratio, necessary for surviving launch.

## A BRIGHT FUTURE

Cornell was not allowed to enter Nanosat-5 because of the victory in the previous competition. Violet, Cornell's Nanosat-6 entry, won second place after a Flight Competition Review in January. Peck says the Air Force was impressed enough with the project that it may launch Violet regardless of the outcome of the competition.

Violet shares very little in common with CUSat, Peck said, the exception being the GPS receivers, built by Paul Kintner, the well-respected professor of electrical and computer engineering who died in November, 2010.

"It's disappointing he never got to see his receivers on the satellite, but we'll be doing that in remembrance of him," Peck said.

Peck said Violet's mission is to achieve unparalleled agility in space to improve imaging. Violet's science team, led by astronomy Assistant Professor Jamie Lloyd, focused on ultraviolet astronomy.

"The ultraviolet data we'll gather with the spectrometer will tell him information about the Earth's atmosphere in a way that he can then use to calibrate how he might look at extrasolar

planets,” Peck said.

And it will be fast.

“Violet will conduct experiments that show a very small satellite can actually move much faster than a larger satellite,” he said. “Violet, when you stretch its capabilities, should be able to rotate about 40 degrees per second. That’s faster than a race car and as fast as an athlete rotates in gymnastics.”

Violet will reach such speeds through the use of control moment gyroscopes (CMG) and the application of next-generation steering laws. CMGs have been used in spacecraft for decades, but not on such a small scale in nanosatellites, which, if successful, will increase efficiency and agility.

That kind of speed and agility could also provide financial benefits.

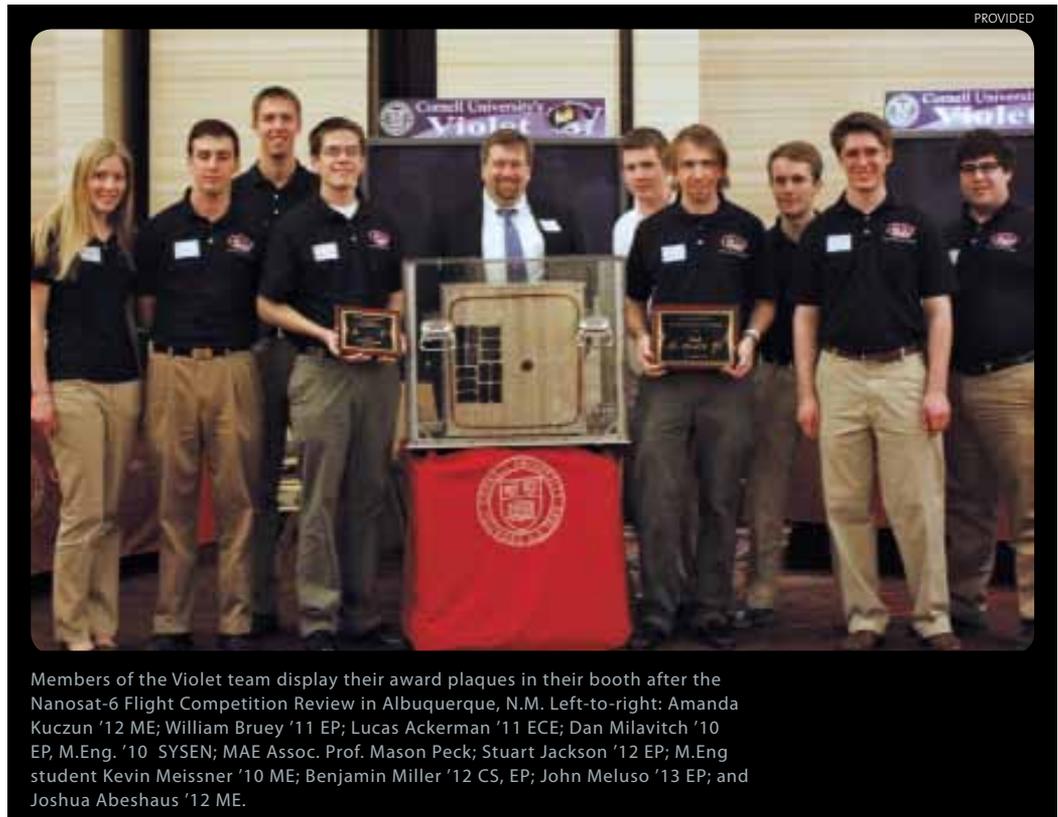
“I’ll give you an example,” Peck said. “Google Earth uses imagery from a spacecraft called GeoEye. It’s a spacecraft that moves as quickly as it can to point its cameras at different places on the earth and take as many relevant pictures as it can as it passes overhead in orbit. The GeoEye spacecraft moves only about a tenth as fast as Violet. So, because time is money, Violet represents a much more cost-effective use of those camera resources.”

Although the Violet mission differs from CUSat’s, it does share a critical component: teamwork.

M.Eng. student Kevin Meissner ’10 ME, the project lead for Violet, said the team’s showing at Nanosat-6 depended on coordination and teamwork.

“The team has been required to evolve as we’ve reached different stages in the project’s lifecycle,” he said. “When the team started, we had about

18 members, mostly underclassmen, all focusing on developing requirements, performing trade studies, and designing a spacecraft that can complete our mission. Since then, for the past year, the team has been deeply involved in design and analysis, fleshing out the detailed subsystem designs and performing the analyses required to ensure that our spacecraft can survive launch and the space environment. During that time the team has steadily grown in size. This semester the team moved into integration activities, and there were up to 55 members working nonstop to prepare our satellite for the flight competition review in January. Typical activities of the team included soldering, machining, writing software, and lots of testing.”



Members of the Violet team display their award plaques in their booth after the Nanosat-6 Flight Competition Review in Albuquerque, N.M. Left-to-right: Amanda Kuczun '12 ME; William Bruey '11 EP; Lucas Ackerman '11 ECE; Dan Milavitch '10 EP, M.Eng. '10 SYSEN; MAE Assoc. Prof. Mason Peck; Stuart Jackson '12 EP; M.Eng student Kevin Meissner '10 ME; Benjamin Miller '12 CS, EP; John Meluso '13 EP; and Joshua Abeshaus '12 ME.

**Violet, when you stretch its capabilities, should be able to rotate about 40 degrees per second. That’s faster than a race car and as fast as an athlete rotates in gymnastics.**

MASON PECK, ASSOCIATE PROFESSOR  
MECHANICAL & AEROSPACE ENGINEERING

Even with such camaraderie on a project, the challenges remain. “The most challenging thing for student satellite teams is typically just training the team in aerospace design and build practices,” Meissner said. “The problems you encounter and need to design for in space are very different from what you would encounter when designing something for terrestrial use, and it takes a while for new

members to become familiar with these nuances. For that reason we started out with a very young team, mostly freshmen and sophomores, who we were able to thoroughly train. Since then the young team has matured and we were able to retain many of those early members. The continuity this provides is very important to building an efficient, knowledgeable team.”

Violet and CUSat clearly benefit students, but others benefit, too. For instance, Violet’s attitude control actuators—the CMG hardware that moves the spacecraft—are being manufactured by an Ithaca firm, Ithaco, just outside the Cornell campus.

“The fact that Ithaco is building these high-agility actuators is a big deal,” Peck said. “This is their first entry into this market. It’s a multimillion dollar a year market, so Violet is also complementing the local business environment with commercial and research applications.”

Several former students now work at Ithaco, Peck said.

With CUSat heading for the launch pad and Violet’s strong showing, Peck said it’s an exciting time for Cornell students and faculty, but also for the advancement of the aerospace industry. **CEM**

# TAKING OUT THE OUCH

## **Antje Baeumner partners with SensiVida to build painless glucose meter.**

BY BRIDGET MEEDS

FOR 171 MILLION DIABETICS ACROSS THE GLOBE, MANAGING THEIR chronic illness is a pain, literally—they need to monitor the glucose level in their blood with a finger prick test several times a day, for years. That’s a lot of pain, and a lot of dirty needles going into landfills.

Antje Baeumner, a professor in biological and environmental engineering, thinks there’s a better way. She was recently awarded a \$5,000 JumpStart grant, funded by the New York State Foundation for Science, Technology, and Innovation and administered by the Cornell Center for Materials Research, to collaborate with SensiVida Medical Technologies Inc. in West Henrietta, N.Y. on a painless glucose biosensor that provides more accurate results than currently available tests.

Baeumner and the scientists at SensiVida (led by chief technology officer John Spoonhower M.S. '75 AP, Ph.D. '77), are developing a sensor that uses nanobiotechnology and optical engineering to monitor glucose.

“There are many sensors that are being used for glucose detection in the marketplace and in the patent literature,” says Larry DeMejo, the materials scientist and engineer at SensiVida who is supervising the project. “We’re trying to come up with a concept that involves not just the chemical sensor itself but also the measurements with the digital image processing and the optics, which are very unique and will provide higher accuracy measurements of glucose.”



Antje Baeumner, center, working with visiting master's students Christian Willrodt and Vanessa Kurth.



Antje Baeumner, professor of biological and environmental engineering, has previously created biosensors for dengue virus, *E. coli*, and toxins.

He notes that even commercially available state of the art continuous glucose monitors, which are worn all the time and have internal needle sensors that need to be replaced every few days, have only adjunct approval from the Food and Drug Administration. because their data need to be corroborated by finger stick tests.

“Their data fall outside a very accurate range,” says DeMejo. “This is dangerous for people who are trying to ascertain if their blood glucose goes too high or too low. These continuous glucose monitors are not sufficient to give you the results you need to determine the amount of insulin you should take.”

One version of the SensiVida monitor, which is small enough to be worn on the wrist, contains a clock-shaped cartridge in which

12 microneedles are mounted in a rotating circle. (The needles are conical, 600 microns from the base of the cone to the tip, and five to 10 microns in diameter.) They are programmed to prick the patient at user-defined time intervals, barely entering the skin and sampling interstitial fluid, which is found directly beneath the dermis and contains the same components as blood plasma.

Each needle is coated with a non-toxic enzyme-based chemistry sensitive to glucose, which reacts with the glucose in the interstitial fluid, creating a colored reaction. A light sensing system in the transparent needle reads the color and calculates the actual concentration of glucose in the fluid. This data is then captured digitally and can be displayed, stored, or transmitted wirelessly.

“We focus on the accurate measurement of the piece that corresponds to glucose, and digitally subtract out all of the other noise,” says DeMejo. “That is one of the unique features of our technology.”

The device is being designed to be inexpensive to manufacture. Once perfected, it will greatly improve the quality of life for millions of diabetics worldwide—people will find it easier to test, will have better results to plan their care, and ultimately be healthier.

Baeumner’s role in developing this device is to test materials that will coat the needle. “The people at SensiVida are not biosensor development researchers. They’re coming more from the mechanical and physical side,” says Baeumner, who has been at Cornell since 1997. “They approached me because of my expertise in biosensor development.”

Baeumner, who previously has created biosensors to monitor for dengue virus, *E. coli* bacteria, and toxins, is focused on the chemistry of the device.

“We are evaluating what type of polymers and starches can be used in their sensors that are capable of performing the biochemical reactions to actually detect the glucose,” says Baeumner. “We do all of the fundamental and applied studies so that they can then afterwards decide which of the materials that are biochemically optimal will perform best within their device.”

DeMejo indicates that Baeumner’s help is speeding the project along, “because she has the technology with the microtiter plates that enables us to look at many different combinations of polymers with the chemistry. If we had to do it sequentially, it would take a long time. We can look at batch to batch

Once perfected, (the device) will greatly improve the quality of life for millions of diabetics worldwide—people will find it easier to test, will have better results to plan their care, and ultimately be healthier.

reproducibility aspects, different starches, different polymers, and the effect of interferences very rapidly.”

Baumner is being helped on the project by two visiting master’s students from the Technical University of Dortmund in Germany, with which she has had a three-year long exchange program. The students, Christian Willrodt and Vanessa Kurth, are doing the hands-on microassay investigations of materials.

“They both bring to the project their chemical and biological knowledge, which is extremely important, especially for the current phase, because we look at all of the chemical interactions that take place in the polymers,” says Baumner.

“The sensor is based on a color-forming reaction, and we are screening some different polymers and starches,” says Willrodt. “We investigate them for reproducibility and stability of the signal, trying to find the optimal candidate for this reaction.”

“It is very exciting to work with a company,” says Kurth. “The progress we’ve made is thrilling for everyone, because it’s one step forward to the actual production of the glucose monitor. Dr. Baumner really trusts us, and she helps whenever we are uncertain what would be the best next step. She’s very supportive in kind ways.”

“She is taking us really seriously and lets us work independently,” agrees Willrodt. “It’s important to develop your own research personality, so you can think on your own and later get the feedback from her.”

“I give the students a lot of freedom,” says Baumner. “And sometimes this means that they progress much slower, but at the same time I always think they have a much deeper understanding of what they do. And also, we discover new things.”

“We have been very pleased with the two grad students that she brought on board,” says DeMejo. “They both have been very productive; they’re very smart. They have great careers ahead of them.”

Teaching is very important to Baumner, who has won teaching awards in both the College of Agriculture and Life Sciences and the College of Engineering and directs the biological and environmental engineering graduate program. So she’s glad she could involve the visiting students. She makes an effort to have all her research group members work on real-world projects.

“For students it is so exciting to work on a project where they understand why they are doing it,” says Baumner.

“I’ve grown from this experience,” says Kurth, “because I have worked independently on something that’s so huge and really has meaning to it.”

JumpStart is funding Baumner’s collaboration on only a small part of the prototype development process. But it has gone so well, both parties are hoping to continue to work together.

“My hope is that we will continue to be part of their team,” says Baumner. “We want to continue to help with biochemical and nanofabrication assistance, so that we can look at certain aspects of that prototype and make sure that it is a solid device.”

“This is the beginning of what we hope to be a longer term

(Top) A rendering of a wearable glucose monitor with microlancets mounted in a rotating circle. Baumner will test the glucose-sensitive, non-toxic enzyme that will coat the tiny needles, shown in the microscope images below.

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“I have the perfect job. I love teaching, I love research, and I love working with people. And being able to do all of this also with research is a perfect combination.”

ANTJE BAEUMNER, PROFESSOR OF BIOLOGICAL AND ENVIRONMENTAL ENGINEERING

collaboration with Professor Baeumner,” says DeMejo. In the future, he’d like to see if they could work together on other devices to detect analytes in blood such as cholesterol, illegal drugs, or toxic bioagents.

Baeumner’s work integrating nanotechnology into a glucose meter fits well with her career, one in which she has always been pushing the envelope of how nano-devices can improve medical care. “I think I was interested in nanobiotechnology before it even existed,” she laughs, noting that she was dreaming about functional devices even as child, when she drew a picture of a machine which made gold from dust for her father’s Christmas present.

But at Cornell, she discovered the path to making her dreams a reality. “When I came to Cornell, I was handed the ability to actually go into a nanofabrication facility and make devices that

are small enough that we could actually combine them with our biological systems and make biosensors,” says Baeumner. “It fascinates me because we use nature at its own scale in order to get an analytical answer.”

Baeumner, the daughter of two medical doctors, knows that she wouldn’t be satisfied doing pure science without altruistic aspects. “I have always wanted to contribute to society to make it better,” she notes. “For me, the ability to actually create something that will have an application has always been important.”

“I have the perfect job,” she concludes. “I love teaching, I love research, and I love working with people. And being able to do all of this also with research is a perfect combination.” **CEM**



Working with Baeumner, two visiting master’s students from TU Dortmund, Christian Willrodt and Vanessa Kurth, microassay polymers and starches for reproducibility and signal stability.

## SKORTON ELECTED TO INSTITUTE OF MEDICINE OF THE NATIONAL ACADEMIES

Cornell President **Dr. David J. Skorton**, a professor of biomedical engineering, has been elected to the Institute of Medicine of the National Academies. IOM membership is considered one of the highest honors in the fields of health and medicine.

Announced Oct. 11 at the IOM's annual meeting in Washington, D.C., Skorton is among 65 new members and four foreign associates elected this year, including Dr. Joseph J. Fins, chief of the Division of Medical Ethics at Weill Cornell Medical College. "Each of these new members stands out as a professional whose research, knowledge, and skills have significantly advanced health and medicine and who has served as a model for others," said IOM President Harvey Fineberg.

"I am deeply honored to be a part of the Institute of Medicine, with its timely and critical focus on evidence-based advice to the nation on health and health care," said Skorton, also a professor of medicine and medicine in pediatrics at Weill Cornell. "To be able to recognize at the same time

the election of Dr. Joseph Fins, an esteemed colleague and friend at Weill Cornell Medical College, makes this a double honor."

The IOM recognizes individuals who have demonstrated outstanding professional achievement and commitment to service. With this year's election, the institute counts 1,610 active members, 75 emeritus members and 93 foreign associates. The IOM is recognized as a national resource for independent, scientifically informed analysis and recommendations on health issues.

## PHOTONICS PIONEER MICHAL LIPSON NAMED A MACARTHUR FOUNDATION FELLOW

The John D. and Catherine T. MacArthur Foundation has named **Michal Lipson**, associate professor of electrical and computer engineering, one of 23 MacArthur Fellows for 2010—the so-called "Genius Awards." She will receive \$500,000 in no-strings-attached support over the next five years.

"I was completely stunned when they notified me," Lipson said. "It was very dramatic. They said, 'Are you sitting down?'"

Lipson is a pioneer in the



*Michal Lipson*

development of photonic circuits, in which beams of light flitting through tiny waveguides on a silicon chip replace electric currents. The MacArthur Foundation cites her as one of the first to work with such circuits on a silicon base, where they can be manufactured with the same technologies used to make electronic microchips. She demonstrated methods to guide, filter, bend, and split light on silicon chips at much smaller dimensions than attained by previous researchers, offering the promise of photonic circuits as small as current electronic chips.

"We were one of the first to show it could be done," Lipson said. "At the time it was considered very risky, but there has been a lot of follow-up." These days, she said, papers in the field almost always cite her early work.

"Michal Lipson's scientific rigor, coupled with her creative vision, has made her a pioneer in nanoscale photonics," said Provost Kent Fuchs. "We are very proud of all her achievements and delighted that the MacArthur Foundation has recognized her in this way."

The MacArthur Fellowships are awarded to writers, scientists, artists, social scientists, humanists, teachers, and entrepreneurs based on "exceptional creativity, promise for important future advances based on a track record of significant accomplishment, and potential for

the fellowship to facilitate subsequent creative work." The grant is paid in quarterly installments over five years, and the foundation requires no reports. Recipients are expected to use the funding for work that might be too innovative to earn conventional support.

Lipson's research since joining the Cornell faculty in 2001 has led to many innovative methods to reproduce with light what is commonplace in electronics: modulating, amplifying, switching, and otherwise processing optical signals. Photonic circuitry has the potential to speed communication over optical fiber networks, where information carried on pulses of light currently must be converted to electrical signals for processing, then back into optical signals for transmission. It can also lead to circuitry that is faster than electronics—signals move at the speed of light—while using less power.

Lipson studied physics at Technion-Israel Institute of Technology in Haifa, Israel, receiving her B.A. in 1992, M.S. in 1993 and Ph.D. in 1998. From 1998 to 2001, she worked as a postdoctoral researcher at the Massachusetts Institute of Technology. She is a member of the Institute of Electrical and Electronics Engineers and the Materials Research Society and is a fellow of the Optical Society of America.

Her early research at Cornell was bolstered by a National Science Foundation Faculty Early Career Award, the most prestigious award for new faculty members, given to those teacher-scholars who are considered most likely to become the academic leaders of the 21st century.

—Bill Steele



*David Skorton*

## CU AWARDED TWO LUCE FELLOWSHIPS FOR WOMEN IN ENGINEERING

The Clare Boothe Luce (CBL) Program, part of the Henry Luce Foundation, has awarded Cornell two two-year fellowships, including tuition and stipend, for women graduate students studying engineering, the foundation recently announced.

The recipients will be drawn from this year's graduate school applicants, according to Rick Allmendinger, associate dean for diversity and faculty development in the College of Engineering. The fellowships will be awarded to female students in electrical and computer engineering, materials science and engineering, or mechanical and aerospace engineering.

"The College of Engineering has moved successfully over the last decade to diversify its student body," Allmendinger said. "These prestigious fellowships from the Clare Boothe Luce Program will help us extend that progress into the new decade by providing yet one more reason for talented women to pursue graduate studies in engineering at Cornell."

The receipt of the CBL fellowships falls in line with the college's ongoing efforts to increase the presence of women Ph.D. candidates and faculty members in the traditionally

male-dominated engineering fields. Efforts have paid off: From 2000 to 2009, enrollment of female Ph.D. students in engineering at Cornell increased from 20.4 percent to 26.5 percent, according to the graduate fellowship proposal.

The remarkable turnaround, according to the proposal, can be attributed to two equally important factors: An increase in the number of women faculty (from 18 to 28 since 2000) in the college, and the emergence of strong women graduate student groups across the college. Among them are the Women@ECE programs, including Women's Travel Conference Grants, Women's Professional Development Grants, and Women's Technical Exposure Grants. Also, Women in Materials Science and Engineering provides career development, social events, and mentoring; and the Sibley Women's Group, which includes social and professional development as well as a well-attended annual dinner.

The increased priority of diversity in the college's strategic objectives has also helped bolster this trend, beginning with leadership by former Dean Kent Fuchs (now provost), who encouraged departments to examine their gender breakdowns and institute changes to address inequities when appropriate.

In addition, Cornell has several institutional initiatives dedicated to increasing diversity, including the National Science Foundation-

funded ADVANCE grant awarded in 2006. The five-year grant funds efforts to increase the recruitment, retention, and promotion into leadership positions of women in engineering and the sciences.

The CBL program first awarded such grants in 1989 and has since become the most significant source of private support for women in science, mathematics, and engineering.

Clare Boothe Luce, the widow of Henry R. Luce, was a playwright, journalist, U.S. ambassador to Italy, and the first woman elected to Congress from Connecticut. In her bequest establishing this program, she sought "to encourage women to enter, study, graduate, and teach" in science, mathematics, and engineering.

—Anne Ju

## THREE WIN AIR FORCE YOUNG INVESTIGATOR AWARDS

Two engineering faculty members—**Salman Avestimehr**, and **Peter Frazier**—are among this year's 38 winners of the Air Force Young Investigator Research Program.

The program, administered by the Air Force Office of Scientific Research, is open to U.S. scientists and engineers who have received a Ph.D. or equivalent in the last five years and have shown "exceptional ability and promise for conducting basic research."

Avestimehr, assistant professor of electrical and computer engineering, was awarded \$360,000 over three years to support his research on the impacts of local network-state information on the design of distributed communication networks for military applications. He plans to develop a unified framework to mathematically model local network views and investigate their impacts on information transfer in networks.

Frazier, assistant professor of operations research and information engineering, received \$360,000 over three

years to explore decision-theoretic methods in simulation optimization. This OR field involves testing different courses of action by simulating them on a computer. For example, Frazier's research could identify which configuration of a hospital emergency room would be able to treat patients most effectively and efficiently.

Another Cornell faculty member, Kyle Shen, assistant professor of physics, received \$700,000 over five years for a project developing new superconductors in artificially engineered correlated materials. The approach will combine cutting-edge materials science through state-of-the-art oxide molecular beam epitaxy synthesis with advanced new tools.

This year the Air Force received 202 proposals in such areas as aerospace, chemical and materials sciences; physics and electronics; and mathematics, information and life sciences.

—Anne Ju

## MICHAEL KING NAMED VP OF BIOMIMETICS SOCIETY

**Michael King**, associate professor of biomedical engineering, has been appointed vice president of the new International Society of Bionic Engineering (ISBE).

The ISBE was established at the Third International Conference of Bionic Engineering in Zhuhai, China, Sept. 14-16, and comprises 500 researchers in biomimetics, or bionics, from 15 countries. The field consists of the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology.

King's primary research interest is the study of adhesive interactions of flowing cells in the contexts of blood clotting, inflammation, and cancer.

—Anne Ju



Salman Avestimehr



Peter Frazier



Michael King

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**MAHOWALD TAPPED AS LEAD AUTHOR FOR INTERGOVERNMENTAL CLIMATE REPORT**

**Natalie Mahowald**, associate professor of earth and atmospheric sciences, has been tapped to be a lead author on the next Intergovernmental Panel on Climate Change (IPCC) Assessment Report. Established by the United Nations Environment Programme and the World Meteorological Organization, the IPCC is charged with providing the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences.

Mahowald will lead Chapter 1 of Working Group I, which will cover

the physical science basis for Assessment Report 5. The IPCC's first four Assessment Reports are at the core of today's scientific and policy debates regarding climate change. The new Assessment Report is scheduled for completion between 2013 and 2014.

"The last IPCC Assessment Report was very influential in getting the U.S., especially, on board with the idea that climate change is a real threat, and that we need to assess what we will do about it," said Mahowald, who is one of 831 experts around the world who will contribute to the report. "It's an honor to be asked to serve on the IPCC Assessment Reports, and I look forward to working on it."

The first lead author meeting will take place in November, when stakeholders will start on outlines and drafts.

Another Cornell faculty member, **Jefferson Tester**, already serves as a

lead author on the IPCC's Special Report on Renewable Energy Sources and Climate Change Mitigation, which will be completed this year. Tester is the Croll Professor of Sustainable Energy Systems in the School of Chemical and Biomolecular Engineering and associate director of energy programs in the David R. Atkinson Center for a Sustainable Future.

—Anne Ju

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**TWO ENGINEERING FACULTY RECEIVE NSF CAREER AWARDS**

**Tobias Hanrath** and **Cynthia Reinhart-King** have received National Science Foundation Faculty Early Career Development Awards, which support early career development activities of teacher-scholars. The awards support research and outreach components.

Hanrath, assistant professor of chemical and biomolecular engineering, has received \$328,000 over four years to study semiconductor nanostructures as artificial solids with controlled connections in multiple dimensions that balance quantum confinement and quantum coupling. The project aims to significantly advance knowledge and understanding of tunable extended electronic states in nanocrystals. Objectives include mapping the electronic phase diagram of semiconductor nanostructures with precise

experimental control over disorder and coupling; applying the understanding of correlated properties in the creation of artificial solids with electronic and optical properties by design; and transforming fundamental understanding into technological reality by developing and testing prototype photovoltaic structures. The educational activities of Hanrath's project will integrate research and education of students from high school to graduate school and engage students in impending energy issues.

Reinhart-King, assistant professor of biomedical engineering, has received \$400,000 over five years to develop a research and education plan focused on cellular migration. Reinhart-King uses novel tools to uncover the mechanisms of endothelial cell chemotaxis, which is how cells move according to certain chemicals in their environment. In particular, she studies how cells respond to vascular endothelial growth factor, which is a specific protein that promotes the growth of blood vessels. Her work also has implications in the field of tissue engineering, where controlled, directed endothelial cell migration could enable the engineering of vascular networks in tissue engineered scaffolds and in cancer research, where a better understanding of angiogenesis could enable development of more targeted therapeutics to prevent endothelial cell



Natalie Mahowald



Tobias Hanrath



Cynthia Reinhart-King



Rowena Lohman

chemotactic response. The broader impact of Reinhart-King's proposal is the development of an interdisciplinary learning environment that connects biology and engineering across multiple length scales (molecular, cellular, and tissue level). New teaching methodologies and outreach activities will introduce middle and high school girls in the local, underserved rural community to concepts in biology and engineering.

Itai Cohen, assistant professor of physics; William Dichtel, assistant professor of chemistry and chemical biology; and Eun-Ah Kim, assistant professor of physics, also received NSF Career Awards.

—Anne Ju



## ROWENA LOHMAN RECEIVES NASA GRANT

Rowena Lohman, assistant professor of earth and atmospheric sciences, has received a three-year, \$318,000 grant from the NASA New Investigator Program to study subsiding deltas and sea level rise worldwide with space-based geodetic observations.

Lohman's primary research interests are: earthquake physics, satellite remote sensing, finite element modeling, ground displacements from human and natural causes, and the tectonics of southern California, Louisiana, the Cascadia subduction zone, and Iran.

The NASA grant also supports the development of a new undergraduate course aimed at attracting the next generation of scientists who will use data from the diverse range of satellites to be launched by NASA over the next decade.

—Anne Ju

# A Problem of Proofreading

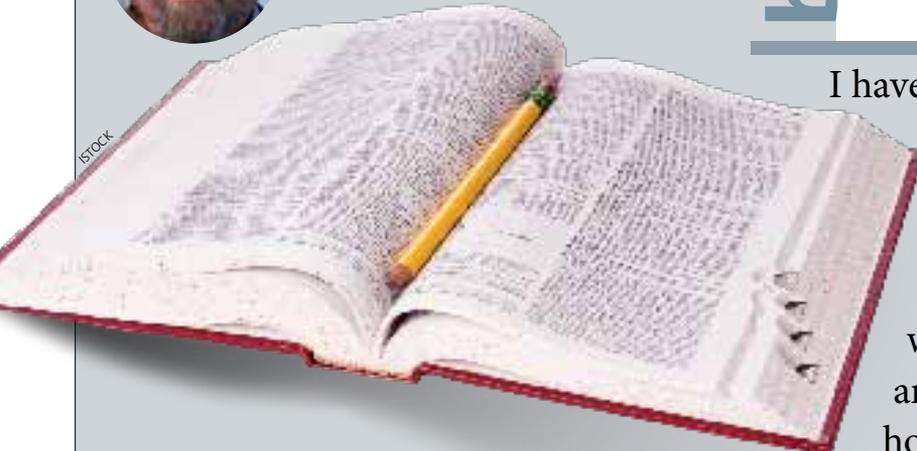
brainteaser

Professor Andy Ruina,  
Mechanical and  
Aerospace Engineering



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ISTOCK



## SOLVE THIS TO WIN CORNELL ENGINEERING GEAR

We will draw three winners from correct entries submitted by July 1. They will receive a Garland gift pen, a stainless steel water bottle, or a Cornell Engineering car decal. Congratulations to Christopher Cheek '98 EE M.Eng. '99, James Couillard M.S. '91 AP Ph.D. '96, and Kristof Toth, a freshman student of David Wootton '87 ME at The Cooper Union, for correctly solving the fall brainteaser! You can see the solution and submit your answer to this brainteaser at [www.engineering.cornell.edu/brainteaser](http://www.engineering.cornell.edu/brainteaser).



I have a book. I ask two people to proof read it. They both read random and independent parts of it. One finds 100 errors, the other finds 200 errors 50 of which were already found. After these are fixed what is the best estimate of how many errors remain?

## Kill Drill

**Emeritus professor's company aids at BP disaster.**

**T**he BP oil well blowout in the Gulf of Mexico mushroomed into an environmental and economic disaster after an explosion on a drilling rig less than 50 miles off Louisiana killed 11 workers on April 20, 2010. The next day, an emergency call was made to a small Ithaca-based company.

Arthur F. Kuckes and his team were waiting for action. "While the last surface attempts to finally kill the well were being attempted, our equipment was on standby for a few months, deployed, downhole

in the relief well a few feet from the proposed kill location in the problem well," said Kuckes, founder and chief executive officer of Vector Magnetics, and a professor emeritus of applied and engineering physics. "After receiving the final go-ahead, we essentially killed it in a week."

Drilling a relief well is a last resort and Vector Magnetics has become a first name in a small group of experts around the world with the technical know-how. Using its specialized suite of guidance and measurement tools and software, Vector Magnetics tracks a relief well to a point where it can intersect the troubled well to close it.

A mile beneath the sea and more than two miles under the seabed, the Deepwater Horizon well posed unique pressure and temperature challenges for the company Kuckes established 25 years ago. Still, Kuckes said that, operationally, it was not much different from the hundred relief and directional wells Vector Magnetics has worked on around the world.

The Deepwater Horizon project showcased drilling and measurement expertise that otherwise gets little attention. It stands out for Kuckes for its social and environmental importance—an estimated 4.4 million barrels of oil spewed into the Gulf.

"It was very satisfying in terms of its significance," he said.

Kuckes, who came to Cornell in 1968, began experimenting with electromagnetic sensing and guidance in the early eighties. In 1985, he took a leave of absence to start Vector Magnetics. Two years later, with business taking off, he took an early retirement from the university.

Vector Magnetics also works wells in coal-bed methane production and horizontal drilling of underground pipelines. The company, with more than 20 employees directed from its office on Cherry Street in Ithaca, performs half its work around the globe. "You name it," Kuckes said, "we've probably been there."

In December, a Vector Magnetics team was working two relief wells in Nigeria in addition to another problem well 50 miles away from the Deepwater Horizon site. It is highly specialized work. Oil and gas companies will always try to control a blowout from the surface because it is faster and cheaper.

"Essentially it's not a good business to be in because it's feast or famine," Kuckes said with a laugh. "You're a fireman, waiting for the phone to ring."

When Vector Magnetics employees reached the platform from which one of two relief wells was being drilled, it was a busy stage of oil and gas industry workers. The three engineers set up shop in a small room packed with equipment and electronics and waited to get to work.

When drilling a relief well, the drill operator bores it to the desired depth and location, then the crew pulls the entire drill pipe out of the hole, cleans the hole, and pulls out the drill string. Then the hole is turned over to Vector Magnetics, which readies its sensing and measuring equipment for deployment. The self-contained package is attached at the drill bit, and lowered down to the bottom of the well where the measurements are taken. A series of measurements using electromagnetic sensing

will be taken at various intervals in a "homing in" process that is refined time and again. After the intercept, BP pumped heavy drilling fluid and cement into the well for the final kill.

In the end, half of the runs used "open hole" equipment Vector Magnetics has used successfully for years. The other measurements utilized its new generation of tools which had to be adapted to meet the challenge of higher pressures and temperature.

"Each time you go about this the horizon gets a little higher, the fence gets a little higher," Kuckes said.

—Dan Tuohy



Two Vector Magnetics engineers prior to lowering one of the company's "wellspot at bit" tools into a relief well.

## Bone Mechanics

The human body's structural underpinnings are subject to the same mechanical laws as bridges and buildings, but unlike steel or concrete, bone heals. "If you get some cracks in the bone, some cells will come in and repair it," explains Chris Hernandez, assistant professor of mechanical engineering. "That's how we think most of us can survive our whole lives without ever breaking a bone."

Clinical studies have shown that high levels of this "bone remodeling" can in some cases predict osteoporosis-related bone fractures—which cost \$17 billion per year to treat—better than the conventional indicator of fracture risk. "Why is a measured biological activity telling us more about fracture, which is a mechanical event, than a bone scan?" asks Hernandez. "The hypothesis that we're working with is actually that the repair process is part of the problem. It doesn't sound right, but that's what it looks like."

When cells are sent in to make repairs, they dig out the old or damaged bone leaving a divot before refilling it with new bone. The entire process can take six months. "One theory is, all these little patches added up weaken the bone and put someone at increased risk for fracture," said Hernandez.

To determine if his theory is correct, Hernandez has created new imaging approaches to get extremely high-resolution images of bone. "This," he said, holding up a model of a bone showing a cross section, "is a 20 times blow up of this piece of trabecular bone and it was created from data collected at a 10 micron resolution, but our system gets down to submicron scale."