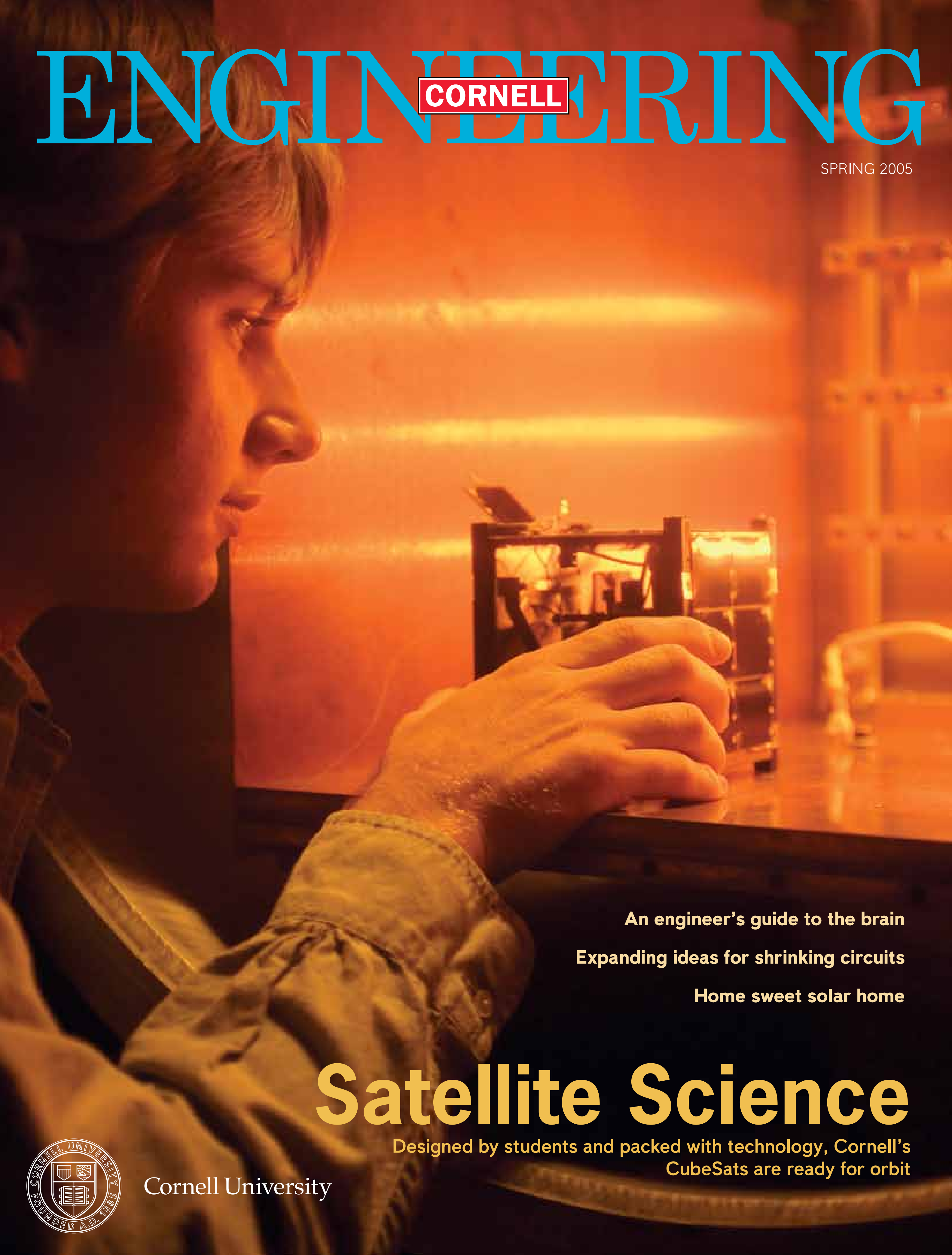

ENGINEERING

CORNELL

SPRING 2005

An engineer's guide to the brain

Expanding ideas for shrinking circuits

Home sweet solar home

Satellite Science

Designed by students and packed with technology, Cornell's CubeSats are ready for orbit

Cornell University

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Membership in the Cayuga Society is complimentary for those who have made a lifetime commitment to Cornell through planned gifts; Bob Cowie '55, BME '56, MBA '57, Cayuga Society co-chair, would be happy to welcome you into this special group.

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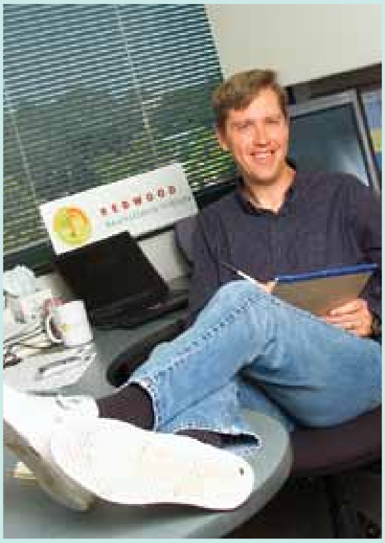
Professor Harry Stewart and David Ash in the new Civil and Environmental instructional facility.

Plan for Their Future

TOP, MIDDLE, AND BOTTOM RIGHT: FRANK DIMEO;
BOTTOM LEFT: NICOLA KOUNTOUPES/UP

Spring 2005

FEATURES



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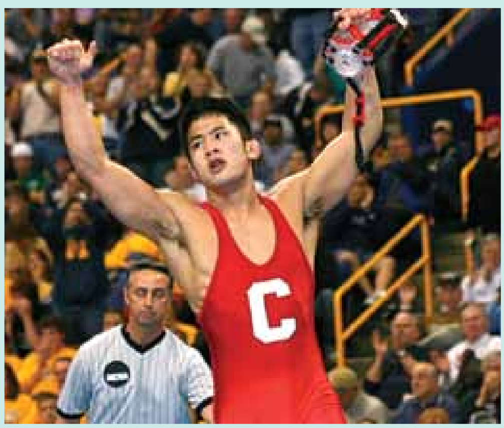


Wall of Water

Cornell tsunami expert leads scientific delegation into wave-ravaged Southeast Asia.

Philip Liu, professor of civil and environmental engineering, speaks to members of the press Jan. 21 in front of his wave tank in Hollister Hall.

He uses the 120-foot-long wave tank (right) to research the characteristics of ocean-wave climates and how waves interact with coastlines and coastal structures.

In a preliminary report about the Dec. 26 Indian Ocean tsunami's magnitude, Cornell Professor Philip Liu said three large waves engulfed Sri Lanka's coastal areas, and it was the second wave—the largest of the three—that cost people their lives.

Liu, a professor of civil and environmental engineering, led a group of U.S. scientists to the eastern and southern shores of Sri Lanka between Jan. 9 and 16 and then visited Thailand. He returned from his investigative trip, which was funded by the National Science Foundation, in late January.

A veteran of examining tsunami effects, Liu was struck by the power of this killer wave. "The destruction was more severe than I anticipated and the magnitude of destruction was beyond any imagination," he said. "The 1992 tsunami in Indonesia was severe, but it was nothing like this one."

Liu spoke to many eyewitnesses. They explained they saw three waves, and this corroborates the general belief that three earthquakes over a 10-minute period caused the tsunami series. The waves traveled at jetliner speeds—about 500 miles an hour—through the Indian Ocean and struck Sri Lanka about two hours later.

The waves measured between three and six meters (or 10 and 18 feet) high, he said. Because the coastal plain of Sri Lanka is relatively flat—that is, with a very slight slope—the ocean water poured inland between 500 meters (the length of five American football fields laid end-to-end) and two kilometers (about a mile and a half).

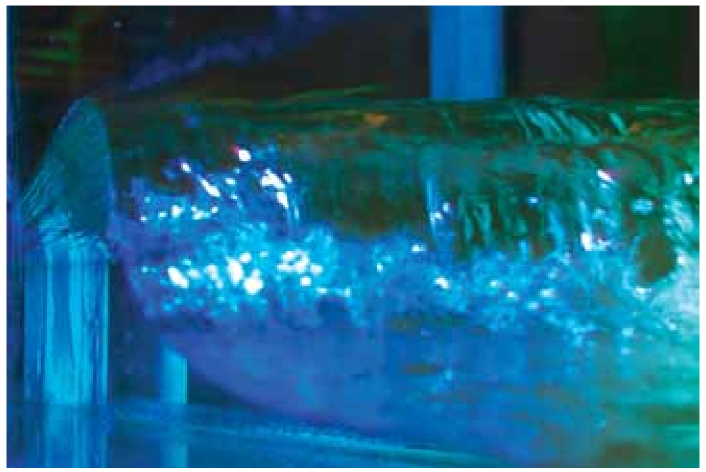
To learn the height of the highest wave, Liu and his team examined the trunks of trees in the vicinity of the shore. The wave was so powerful that it easily stripped away the bark and left a high water mark. He found ocean silt on the rooftops of structures still standing.

One hospital, built near the shore, had been obliterated. The waves overpowered the building, sweeping the patients, nurses, and doctors into the sea.

This tsunami, he said, points to a need for common sense when choosing where to build homes, schools, hospitals and commercial establishments. Even brick structures near the shore, thought to be solid, crumbled when the wave struck.

The purpose of the trip was to obtain information to further understanding of these waves to improve predictive capabilities and help future development of tsunami warning systems.

—Blaine P. Friedlander Jr.
Cornell News Service



TOP:ROBERT BARKER/UP; BOTTOM: FRANK DIMEO

A THOUSAND TIMES BETTER

The National Science Foundation (NSF) has awarded Cornell $18 million to begin development of a new, advanced synchrotron X-ray source, called an Energy Recovery Linac (ERL). The ERL, based on accelerator physics and superconducting microwave technology in which Cornell's Laboratory of Elementary Particle Physics (LEPP) is a world leader, will enable investigations of matter that are impossible to perform with existing X-ray sources.

"The X-ray beams produced by the new source will be roughly a thousand times better in brightness, coherence, and pulse duration than currently is possible," said Sol Gruner, Cornell professor of physics, who is the principal investigator of the ERL project.

It is important both to basic science and the pharmaceutical industry.

It also will make possible new study of advanced materials on a nano scale, giving more insight into how to make stronger metals and composites, better drug delivery systems, and more efficient optoelectronics. And the very fast pulses will make it possible to follow the structural changes that happen during important chemical reactions, both of life and chemical manufacturing processes.

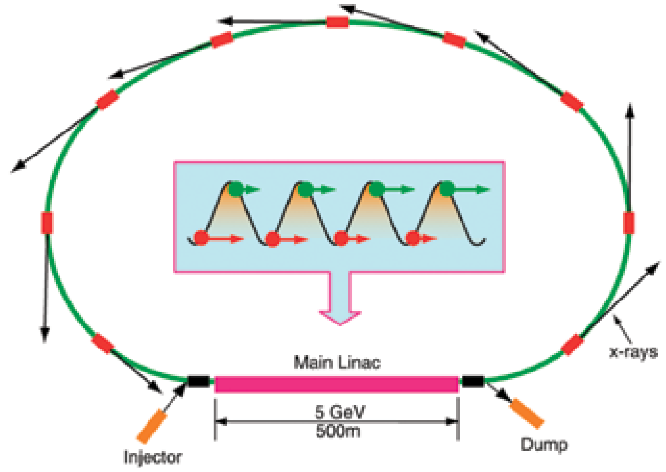


IMAGE: "REVIEW OF THIRD AND NEXT GENERATION SYNCHROTRON LIGHT SOURCES" BY DONALD H. BILDERBACK, PASCAL ELLEAUME AND EDGAR WECKERT, J. PHYS. B; PHOTO: ROBERT BARKER/UP

The facility will be a major upgrade of the national-user synchrotron radiation facility, Cornell High Energy Synchrotron Source (CHESS), which provides service to scientists and technologists from around the world, as well as to many departments at Cornell. The ERL will have value across the board, Gruner said, from research in biology and medicine to materials science and nanotechnology development.

Synchrotron radiation is generated when fast-moving electrons are forced to change direction. In the proposed facility, electrons will be pushed to within a fraction of the speed of light by a microwave beam in a linear accelerator (linac), made up of two straight tubes each about 1.3 kilometers long. The energetic electrons will be fed into the electron storage ring to make only one trip around the circle; then they will return to the linac where their energy will be recovered and used to push the next batch of electrons out.

The ERL radiation may be used to determine the structure of cells and biological molecules that cannot be determined with current sources, information important both to basic science and the pharmaceutical industry.

Cornell constructed the world's first beam line to study synchrotron radiation in the early 1950s. Today, CHESS, which is directed by Gruner, is one of five national hard X-ray synchrotron radiation facilities funded by the NSF and the National Institutes of Health and is the only such facility in the United States located on a central university campus.

—Simeon Moss
Cornell News Service

LIFE SCIENCES: DIG THIS

It was a happening worthy of late-night TV host David Letterman. The audience of trustees, alumni, and faculty had just finished watching a short video, specially produced for the groundbreaking ceremony for the Life Sciences Technology Building (LSTB) on March 11 at Phillips Hall Auditorium.

The last scene of the video showed six Cornell sweatshirt-clad students—with red shovels and buckets on a pile of earth on Alumni Field—leaping skywards and yelling, "Congratulations!"

At that instant, the same students echoed the word and rushed from the back of the hall wielding their shovels and earth-filled buckets, which they presented to the groundbreaking speakers, including renowned building architect Richard Meier '56.

"Cornell's first cross-campus groundbreaking," exclaimed President Jeffrey Lehman, receiving his bucket of ceremonial soil.

The virtual midwinter groundbreaking for the gleaming white four-story structure—and the ebullient presentation of Alumni Field soil—was created to celebrate the final stages of planning for the LSTB, which will begin to rise on the western end of the field in May or June, with completion scheduled for August 2007. The $140 million facility, the university's most ambitious building project yet, was described by Kraig Adler, vice provost for life sciences, as "the central capital element in the academic and economic leadership of Cornell."

The new building will be the centerpiece of Cornell's New Life Sciences Initiative (NLSI), a $600 million program involving seven colleges, hundreds of faculty members, and up to 60 departments in research across the biological, physical, engineering, computational, and social sciences. The LSTB will be home to the Cornell Institute of

Read more on these and other stories at www.engr.cornell.edu/news

From left: Richard Meier '56, Life Sciences Technology Building architect; Leti McNeil '05, government; Jennifer Zhao '05, engineering; Peter Meinig, chairman of the Cornell Board of Trustees; Sanford Weill, chairman of the Board of Overseers of Weill Cornell Medical College; and Steve Hohwald '07, engineering, celebrate at the indoor groundbreaking ceremony for the new life sciences building, in Phillips Hall, March 11.

A Star is Born

The documentary film "Cornell—Birth of the American University," produced by WSKG-TV, premiered on campus Dec. 3 before airing on the public television station several times the following week. At the reception prior to the premiere at the Statler Auditorium, from left, Carol Kammen, Cornell lecturer and historian, Brian Frey, producer of the documentary, and Elaine Engst, Cornell archivist, chat for a moment. Copies of the documentary may be purchased online from the station: http://www.wskg.com/cornell.htm.

Molecular and Cell Biology and the Department of Biomedical Engineering, as well as an incubator for start-up businesses.

New York state has provided $25 million to the building project, making the LSTB the largest life-science research facility in the state. It will be, said Lehman in opening the ceremony, a "building as large in scale and bold in design as the research to be conducted in it."

Ceremony speakers stressed the importance of the new building and the NLSI to the university and beyond. "Connectivity is the key. NLSI and the LSTB are important for Cornell, Ithaca, and the world," said Sanford I. Weill '55, chairman of the Board of Overseers of Weill Cornell Medical College in New York City and a university trustee emeritus. The building and the program have "already propelled Cornell to the forefront of life sciences, which will help millions of lives in many ways," said Peter Meinig, chairman of the Board of Trustees.

As Lehman noted, "Cornell's revolutionary genius has always been in making connections across disciplines that no group or institution has done before."

—Larry Klaes
Cornell News Service

PRI's mastodon tooth

A NEW BEGINNING

Eighty years after a disgruntled Cornell geology professor, Gilbert D. Harris, picked up his fossils and went home—to establish the Paleontological Research Institution (PRI) in an emphatically off-campus backyard—the science of ancient life at Cornell is set to expand significantly, with the signing of an affiliation agreement between PRI and Cornell.

For its part, Cornell gets another link in its network of "distributed museums," with the addition of the Museum of the Earth, which PRI built and opened about six miles northwest of campus in 2003.

"And PRI gets, among other things, the opportunity to reach more of the community and the wider world," said the institution's fourth director, Warren D. Allmon, of some highly successful educational-outreach programs PRI offers to persuade students of all ages that earth science is not as dull as dirt.

Cornell's Department of Earth and Atmospheric Sciences (EAS), the modern version of Harris's home department, is looking forward to increased connections to PRI's expertise in earth history education at pre-college and post-college levels, as well as its research opportunities, according to EAS chair Teresa E. Jordan. "Just as a central theme in PRI's Museum of the Earth is to illustrate that the biological, physical, and chemical systems interact," she said, "this is an important thrust of Cornell research, which can benefit from PRI's extensive collections of ancient and modern life forms."

The prolonged estrangement began with a dispute over fire safety. Harris, a Cornell professor from 1894 to 1934, was nearing retirement and intended to leave his extensive invertebrate fossil collection and library to the university—on one condition: that the university provide a suitable, fire-proof building with non-flammable furnishings.

When Cornell demurred, Harris built his own facility of concrete, with metal fixtures, next to his home in the Cornell Heights section of Ithaca. He filled it with many thousands of fossils, laboratories, books, and the offices of PRI, which was chartered as an independent educational institution by the state of New York in 1933. In 1968 PRI moved across the lake to a 12,000-square-foot stone structure on Trumansburg Road that was once an orphanage for the Odd Fellows fraternal organization.

The early rift notwithstanding, research accomplishments by Cornell faculty members are featured among the museum's exhibits. In addition, Cornellians are volunteers and work-study students at the museum, and PRI's board of trustees includes four Cornell faculty members, two staff members, and several prominent alumni.

And now the relationship will be official—or at least semiofficial.

"The affiliation agreement is defined more by what it is not than what it is," Allmon observed. It is not a financial arrangement of any sort, he says, and the words 'Cornell University' will not be attached to the institution's already-unwieldy, 13-syllable moniker. "It's really just a beginning, an opportunity to expand the connections that we already have with the university."

—Roger Segelken
Cornell News Service

TOP: LUKE WALKER/UP; BOTTOM: COURTESY OF THE PALEONTOLOGICAL RESEARCH INSTITUTION

PATCHING A HOLE

A Cornell research group has discovered serious vulnerabilities in a widely-used peer-to-peer file-sharing program. The weakness in LimeWire, a popular client for the Gnutella file-sharing network, would allow an intruder to read any file on a computer running the program, including confidential information and some password files. The problem occurs in both the free and paid versions of the program, in all operating systems.

As soon as members of his research group noticed the problem, Emin Gun Sirer, Cornell assistant professor of computer science, immediately notified Lime Wire LLC, the company that distributes the software. "Lime Wire responded immediately and had a patch ready within a few hours," Sirer reported. Patches are available for all versions except those that run on classic versions of the Mac OS, and the company is working on that, Sirer said.

The most serious vulnerability affects LimeWire versions 4.1.2 through 4.4.5. It enables intruders to connect to a computer even through a firewall. A second vulnerability affects versions 3.9.6 through 4.6.0, but can be stopped by a firewall.

Both vulnerabilities can be exploited without any special tools, Sirer said, through an ordinary telnet login. Like other Gnutella clients, the LimeWire program is designed to allow users to download music and video files shared through the Gnutella network, and also to allow the user to provide shared files to others. The glitch in the program unfortunately allowed remote users to retrieve other files, not just those in the user's sharing folder.

Sirer is a specialist in peer-to-peer systems. He and graduate student Kevin Walsh discovered the LimeWire problem while working on a new application, called Credence, that is intended to work with LimeWire to give users a way to determine how trustworthy upload sites may be.

Credence allows users to share ratings of objects, similar to the ratings on Amazon, but with features that discourage dishonest ratings. The idea has applications to many other types of peer-to-peer networks, such as those in which distributed workers collaborate. "As systems scale bigger and there is more collaboration on the net, we are going to need systems for evaluating the statements made by peers," Sirer explained.

—Bill Steele
Cornell News Service

Is wind energy feasible in Central New York?

DIGITAL VISION LTD.

IN THE WIND

Prompted by students from KyotoNOW!, Cornell is studying the possibility of producing wind-generated electricity for its campus and has opened discussions with its neighbors.

"Our investigation into using renewable wind energy is still in the study phase, and there still are a lot of issues to explore," said Harold Craft, Cornell vice president for administration and chief financial officer, "but, so far, the possibility looks promising."

In 2004 Cornell's Department of Utilities and Energy Management completed an investigation into whether locally produced wind-generated electricity would be cost effective for the Ithaca campus. This work was prompted by a request in the fall of 2003 by students from KyotoNOW!, an environmental advocacy organization on campus.

"The students are aware of many of the benefits of wind energy, and we agreed that looking into that possibility for Cornell made sense," said Lanny Joyce '81 ME, Cornell manager of engineering, planning, and energy management in the Department of Utilities and Energy Management. He leads Cornell's Kyoto Task Team, chartered by Craft in 2001 to guide the university's effort to reduce energy use and carbon dioxide emissions. Wind energy could complement the many other conservation measures the campus utilizes, Joyce added.

Cornell's utilities and energy management department completed a wind inventory study for a 15-mile radius around Ithaca, and Mt. Pleasant, on university-owned property in the town of Dryden, has been identified as a possible wind resource site.

The next step for exploring the feasibility of wind energy generation on the Mt. Pleasant site is to install a temporary (24-month) meteorological station to better assess the wind resource, Joyce said.

Cornell's energy and other sustainability initiatives are described online at http://www.sustainablecampus.cornell.edu and http://www.utilities.cornell.edu.

—Cornell News Service

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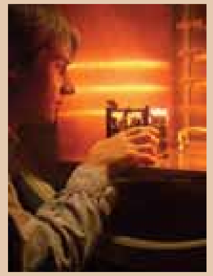
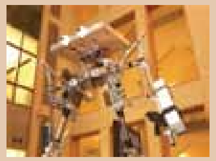


COVER
Andrew Welch '04 ME works with Cornell's Thermal Vacuum test facility.
Photo by Frank DiMeo
Story, p. 6



BACK COVER
BOOM 2005
Photo by Charles Harrington
Story, p. 26

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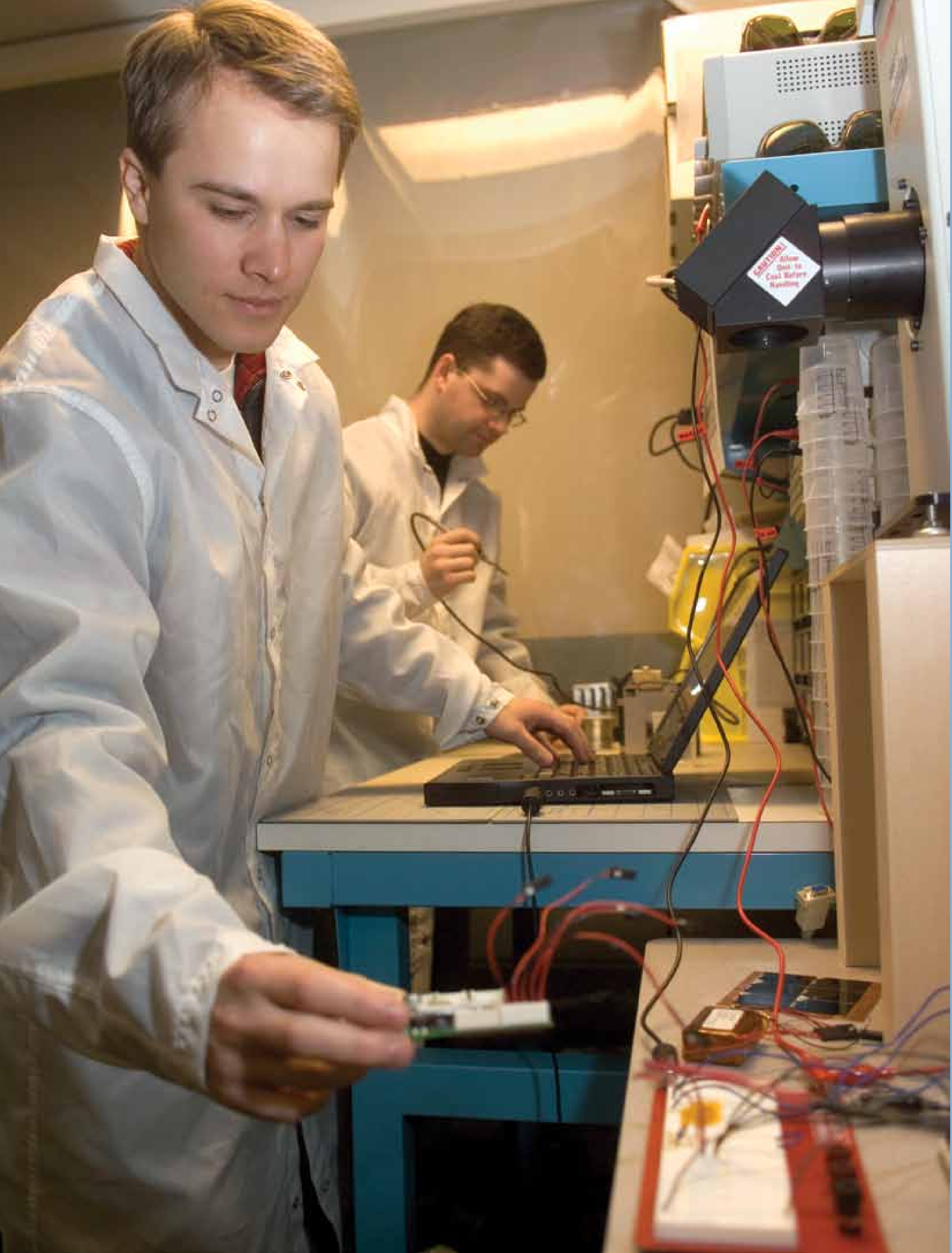


A student project to design, build, launch, and then communicate with 10-cubic-centimeter orbiting satellites is ready for blast-off.

THREE YEARS AND COUNTING

By Jay Wrolstad

IT'S certainly smaller than a breadbox, but it holds the hopes and dreams of scores of engineering students who have labored over its construction for the past three years.

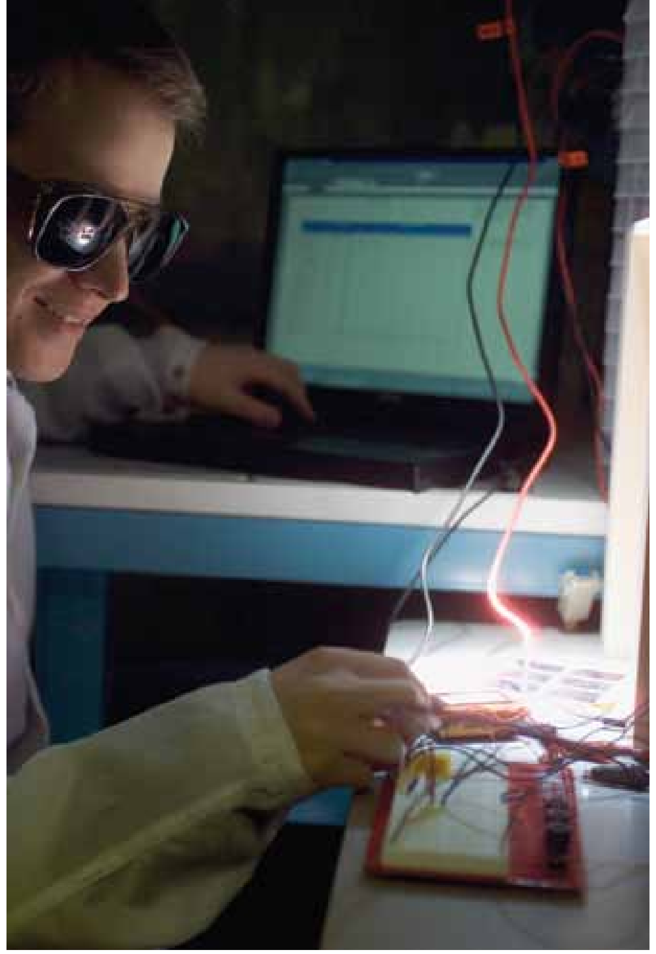
A group of some two dozen of those students this winter ran the final battery of tests on ICE Cube,

PHOTOS P. 6–11: FRANK DIMEO

Michael Willhoff '03 ECE, M.Eng. '04, left, and Bryan Doyle '05 ECE work inside the clean room on a power integration test with the custom power electronics board, solar panels, and rechargeable lithium-ion batteries.

Cornell's version of the CubeSat project run by Stanford University and California Polytechnic University with the express purpose of engaging students in the design, construction, and launch of "picosatellites" measuring just 10 centimeters on each side.

Cornell's ICE Cube (Ionospheric sCintillation Experiment CubeSat) satellites are packed tightly with technology, enabling them to examine a vast section of Earth's atmosphere and the effects of so-called "space weather" on widely-used Global Positioning System (GPS) transmissions, collect data, and send the findings back to the Cornell campus some 400 kilometers distant.



Michael Willhoff '03 ECE, M.Eng. '04, tests the solar panels of the CubeSat using a Xenon lamp to mimic the spectral energy from the sun.

"What's nice about this project is that it's so student-oriented," says Mark Campbell, associate professor of mechanical and aerospace engineering, who is the ICE Cube faculty adviser. "They were responsible for every aspect of this, from structural design to subsystems creation to budgeting."

Campbell compares the process to that of running a business, with participants handling all of the issues associated with creating a new product—including periodic setbacks—and eventually emerging from the lab as a close-knit team.

"There was a hierarchy, with graduate students and those who had experience with the project taking leadership positions in the subsystem groups," he says, "then other students and individuals who got involved were plugged in where they were needed."

Over the past three years, the composition of the ICE Cube team has changed continuously with some students graduating each spring and new ones added each fall. Still, the project is more or less on schedule, and everyone who played a part is anxiously awaiting (with fingers crossed) the July launch of the rocket that will carry ICE Cube into the outer reaches of the atmosphere.

Getting to the countdown wasn't without its challenges. While construction of the aluminum cubes was completed early on at the Cornell physics machine shop, creating the internal components, such as circuit boards, software, and sensors, was an on-going effort. Particular attention was paid to the size and weight of each component that had to fit inside the small container.

Teams working on the power subsystem integrated an electronics board, solar cells, and a rechargeable camera-type lithium-ion battery. The CubeSat takes 90 minutes to circumnavigate Earth, Campbell explains, spending about 55 minutes in the sun and 35 minutes in the shade, and is programmed to alternately absorb solar energy or run off the battery. The small power plant generates 1.3 watts of useable on-board power and weighs just 180 grams.

The Cornell Amateur Radio Club was enlisted to assist in developing a communications system comprising an on-board radio system, a ground station receiver at Barton Hall, software for sending and receiving data, and antennas. Eight separate iterations of the radios were custom-built by students, a task that took three years.

The communications system is designed to store at least 1 megabyte of sample data and to download that much information daily using amateur radio frequencies, which required approval from the Federal Communications Commission and international authorities.

The final distance test was conducted without a hitch, using a ground station set up at a site at Ithaca College on the city's south hill with a clear line of sight to Cornell's Barton Hall a few miles away.

"Students have designed all of this equipment from the ground up," says Mike Hammer, radio club adviser and director of data management for student services in the College of Engineering. The ground station at Barton will receive data collected in the ionosphere, with a communications window of opportunity of just three to twelve minutes during each orbit, he explains.

Those communications include verifying the temperature of the satellite, checking the status of on-board systems, and sending test results on the signal strength of the on-board GPS system.

Other systems for the diminutive spacecraft include attitude control to keep the antennas on the top and bottom pointed in proper directions to receive and transmit data and a gravity gradient boom to maintain its position.

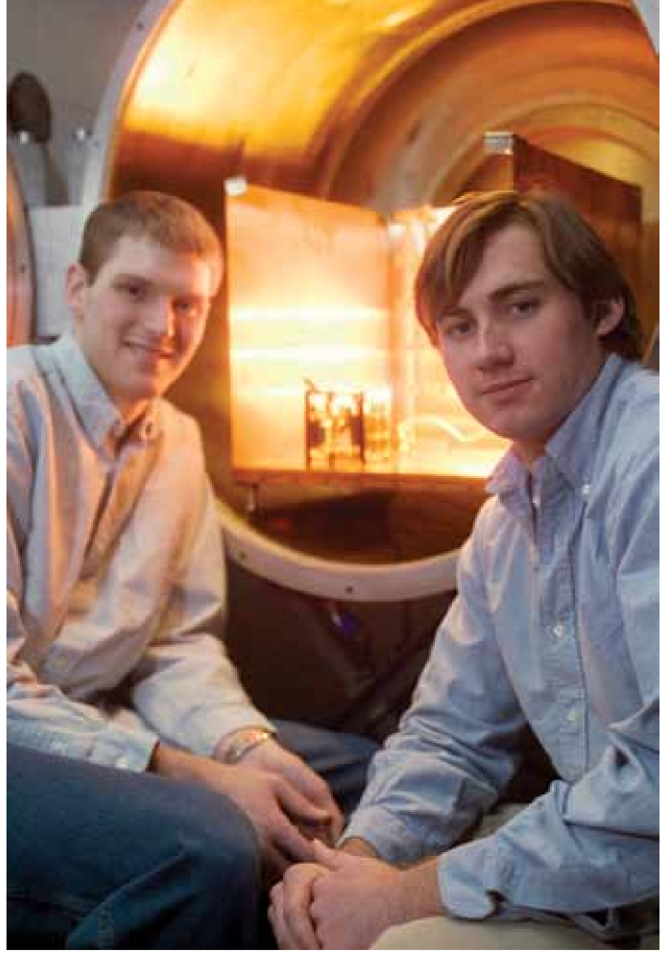
To cope with temperatures in the ionosphere that typically vary between 70 degrees and minus-30 degrees Celsius, the satellite has eight sensors and a tiny battery heater to maintain the optimum comfort level. "We can use the data from this mission to determine what worked well in controlling temp variations, which will be of use to future projects," Campbell says.

The brain of the cube is a main board that controls activation of individual components, samples internal systems data, and serves as both the central depository for scientific information and the agent for downloading those findings.

The finished product was put through its paces in a vacuum chamber on campus, enabling students to accurately replicate conditions found in space.

The nitty-gritty science gets underway after ICE Cube is deployed, with others of its type, from a rocket launched in Kazakhstan. The projectiles are loaded into a customized launcher, known as a P-POD (Poly-Picosatellite Orbital Deployer). When the rocket reaches the desired orbit, it ejects the P-POD, which holds up to three satellites. The CubeSats are then released to begin their missions.

Paul Kintner, professor of electrical and computer engineering, has worked closely with the ICE Cube team, seeking a closer look at scintillations in the ionosphere interfering with space-based global positioning systems used by the government as well as drivers, boaters, campers, hikers, outdoor sports enthusiasts, and others who want to pinpoint their location.



Terence Brauneis '03 ME, M.Eng. '04 (left), and Andrew Welch '04 ME use the Cornell Thermal Vacuum test facility to simulate the vacuum environment and the temperature fluctuations of space. Development of the test facility was made possible by a gift from Edwin W. Hewitt '54, B.M.E. '55.

There is "weather" in space, just as there is in the lower atmosphere near Earth, caused by charged particles emanating from the sun. These disturbances, or scintillations, in the ionosphere can effectively shut down GPS signals or other satellite communications. ICE Cube puts a pair of GPS receivers into the ionosphere and takes measurements as it flies through the "storm."

In certain positions on Earth, and at certain times of day, sunlight heats the ionosphere and causes severe turbulence. These disturbances have been measured from the ground, but not from where they originate.

"We can get a much better understanding of the effects of scintillation by taking measurements in space and eventually mapping the presence of these disturbances for future space missions," Kintner says. To do that, he and his research team provided a GPS package including a ground-based receiver and sounding rocket-based receiver that has been used in previous space missions. For students, the challenge was to modify their software for ground-based and space-based measurements.

Because of the sensitive nature of GPS technology, the ICE Cube project needed government clearance to send the satellite overseas, and Kintner notes that the equipment on board is built to be tamper-proof.

The decision to hitch a ride on an Eastern European rocket came down to dollars and cents, Campbell explains. "This is the most cost-effective option, since our cost is about $40,000 for each launch, while in the U.S. it would probably be a couple of hundred thousand dollars," he says. And that's if you can find someone closer to home who is willing to relinquish precious cargo room for a student experiment that has the potential to jeopardize an expensive launch.

Nevertheless, a long-term goal of the CubeSat project is to conduct launches in the United States, and negotiations are underway with all major launch providers to assess that possibility.

ICE Cube's launch, originally scheduled for October 2004, was pushed back to July 2005. Campbell says that ISC Kosmotras, the Kazakhstan-based firm providing the Dnepr rocket in which ICE Cube will reside, delayed the launch at the request of the customer providing the primary payload and footing most of the bill.

"That gave us more time to iron out the wrinkles through testing, although delays can cause problems because the optimal launch time available each year is limited," Campbell says. Cornell's two CubeSats are among a dozen to be deployed during the July launch.

Participants are grateful for the opportunity to explore the final frontier—an opportunity of immeasurable value according to their mentors.

"I got involved because I was looking for something different than my major. The project has made some of my coursework easier," says Bryan Doyle, a junior studying electrical and computer engineering, who has toiled since fall 2003 on the ICE Cube power systems. "With this project I got exposure to new areas of engineering, like systems and mechanical engineering. It was a lot of work, but it was enjoyable," he says.

Lucy Cohan, a senior majoring in mechanical engineering, was drawn to ICE Cube while working with Campbell on a different research effort and has contributed her knowledge as systems engineer since last summer, conducting tests, making structural changes, and putting the entire package together.

"I always wanted to do aerospace research. It's gratifying to know that something I worked on will actually be launched into space," she says. "This is important work in that we can detect errors in location technology."

Both students will help deliver the ICE Cube satellites to California, and then monitor its progress from campus. They're confident the space probes will outlast the expected lifespan of three to six months.

"This gives students an experience that is not lecture-based, or problem-set driven," Campbell says. "They now have one foot into the world of industry, and they have established camaraderie with a group of their peers."

Kintner concurs, saying that the chance to put into practice the knowl-

Mark Campbell (left), Terence Brauneis, and Bryan Doyle '05 ECE (right) discuss design and testing issues regarding the CubeSat.

edge they gain from textbooks and lectures prompts students to address an array of research variables and develop solutions to challenges they wouldn't typically face.

Steve Powell, a senior engineer on staff in the School of Electrical and Computer Engineering who works with Kintner and helped build the ICE Cube GPS receiver, cites practical experience in software development and equipment testing as benefits of the CubeSat program. "It's valuable hands-on work that students might not otherwise get in school. It enables them to be more effective engineers when they graduate and makes them more attractive to potential employers."

Radio club adviser Hammer says Cornell is better than most institutions in providing hands-on opportunities to students. ICE Cube is a prime example of that effort, he says.

"They have to make this work. When they are finished, it will be as if they have already been at their first job before they graduate," he says. Hands-on work is done in electrical engineering design, testing, and verification, Hammer says, which contributed to one student landing a job at NASA's Jet Propulsion Laboratory and another finding work with a defense contractor doing satellite research.

Initiated in 1999, the CubeSat project provides guidelines for the design of small satellites that can use a common deployer, with the ultimate objective being a low-cost space program with frequent launches. Program participants must design and construct a satellite conforming to the CubeSat standard created by California Polytechnic and Stanford. The standard describes the outer dimensions, offers recommended materials, highlights restrictions, and describes schedules pertaining to systems integration and launch. To date, some 40 colleges and high schools throughout the world have developed, or are working on, CubeSats.

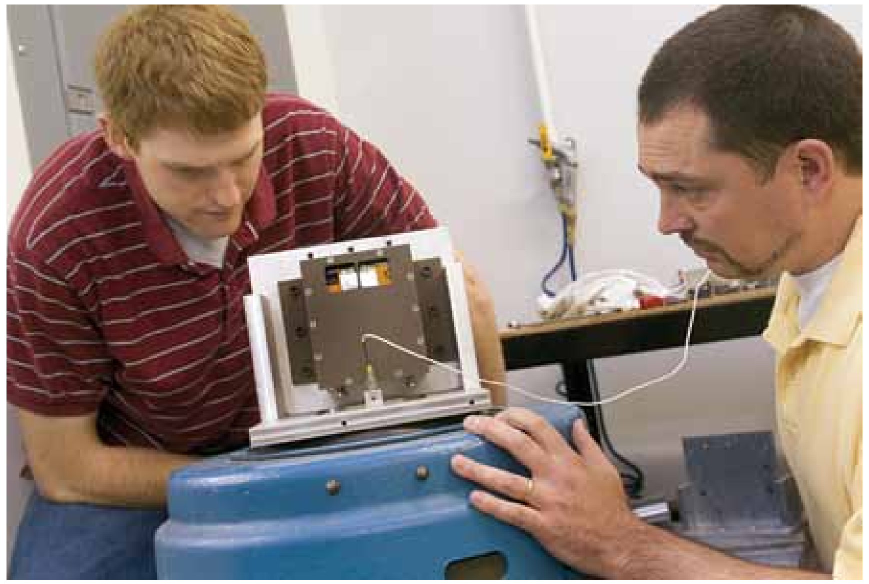
Developers benefit from the sharing of information within the community, and resources are available to all by networking with others creating satellites and attending CubeSat workshops.

Beyond delivering small payloads into orbit, the project may well lead to groups of satellites flying in formation. Future mission concepts are expected to multiply exponentially, with educational institutions linking with private companies to offer services based on the little boxes, perhaps some as low-tech as carrying ashes into space as an alternative to burial.

"This has been a real challenge, but all of the hard work has paid off," says Campbell. "We were able to bring on board new members, replacing a majority of students on the team each year. Fortunately, the advisers have remained the same, and we have maintained very good documentation to keep the project moving forward. I fully expect that ICE Cube will perform up to expectations, and we are excitedly looking forward to hearing our first signals from space!"

Jay Wrolstad is a freelance writer in Ithaca.

Terence Brauneis (above) slides the CubeSat into the test box prior to vibration testing and (below) works with engineer Judson Holl at the IMR Test Labs in Lansing, N.Y., to instrument the CubeSat (inside the test box) before vibration testing. Vibration testing is used to simulate the launch environment prior to launch.



At right: Norbert Huber '05 ECE (left), Lucy Cohan '05 ME, and Associate Professor Mark Campbell perform a final long distance communications test with one of the ICE Cube flight units. The test was set up at Ithaca College to transmit over several miles to the ground station at Cornell's Barton Hall, where data will be downloaded from the orbiting satellites. The skyline of Cornell campus, including McGraw Tower, can be seen in the background.

It's no surprise that Jeff Hawkins '79 EE, inventor of the PalmPilot, is passionate about mobile computing. But he's also

Crazy about Brains

by Beth Saulnier

JEFF Hawkins takes the podium at the New York Academy of Sciences, where dozens of extremely smart people have packed the house on a weeknight in early February to hear him speak about the fundamental nature of intelligence. He's come armed with some visual aids: a PowerPoint presentation, a blue cloth napkin—to depict the surface area of the neocortex—and a classic anatomical sculpture. "This looks like a brain model," he says, holding up the grapefruit-sized item with a smile, "but it's actually the best way of getting stopped by airport security." His audience offers a collective chuckle; clearly, Hawkins is no dry academic.

He isn't, in fact, an academic at all. The 1979 electrical engineering grad is an entrepreneur: inventor of the Palm Pilot, founder of Palm Computing and Handspring, and creator of the Treo line of smart phones. But Hawkins is much more than an engineer and businessman; he's what an earlier age might have called a gentleman scholar. Grown wealthy through his business ventures, the Silicon Valley phenom has chosen not to retire to some South Pacific island but to use his resources to study a subject that has fascinated him most of his life. As Hawkins himself puts it in the third paragraph of his recent book: "I am crazy about brains."

But though Hawkins may not have a Ph.D. in neuroscience, he's nobody's idea of a dilettante. He's been studying the subject for decades and has gained the respect of his be-robed peers. "I'm not a complete outsider," he says. "If you spoke to anyone who knows me, they would likely say I'm an expert in neuroscience. I'm not an academic in the sense that I don't make a career out of it—I don't apply for grants or worry about tenure—but my science is respected."

While his passion for all things neurobiological has been simmering since he was a teenager, it wasn't until a few years ago that Hawkins jumped into the deep end of the pool. In 2002, he founded the Redwood Neuroscience Institute (RNI) in Menlo Park, California, a research center where he and eight full-time scientists explore how the brain works. "It's the most important question facing humanity," he says. "Every other human endeavor is dependent on it. What does it mean to understand something? How do we do what we do? How come humans have taken over this planet? It's all because of the brain. I like to say it's the last great terrestrial frontier of science." Furthermore, he notes, it's a topic with powerful implications for every man, woman, and child. "Most of the big questions of science have to do with things that aren't very here-and-now," he says. "'How did the universe begin and how is it going to end? How do things work at the nano scale?' But everyone's got a brain. It's who we are."

Hawkins

PHOTO PROVIDED

Hawkins compares the effort to understand the fundamental nature of intelligence to another puzzle, one that transfixed great minds centuries ago: the truth about how the solar system is structured. "The smartest people in the world couldn't figure out what was going on up in the sky, and they were trying for decades." he says. "The answer wasn't very hard—but it *was* hard to figure out, because it wasn't intuitive. That's one of the characteristics of big unsolved problems in science."

As Hawkins himself happily admits, he is a man on a mission. He wants both scientists and laypeople to get excited about figuring out what's going on between their ears. "In an understated way, he's a compelling visionary," says Ramin Zabih, a Cornell computer science professor who has visited RNI. "You can see how he's succeeded in his commercial ventures. He has a gift for conveying enthusiasm about what he's interested in. He's a big-picture thinker." Or, as Nobel laureate James Watson said when he introduced Hawkins before a talk at The Juilliard School in February: "He has changed the lives of many people—and I have a feeling he's going to change the lives of many neuroscientists who don't yet think like him."

In an effort to spread the word about his theories, Hawkins has written *On Intelligence: How a New Understanding of the Brain Will Lead to the Creation of Truly Intelligent Machines*, published in October by Times Books. Co-authored with *New York Times* science writer Sandra Blakeslee (but written in the first person), the book offers a detailed account of Hawkins's take on how we learn. The reviews have been, well, fantastic. "I couldn't put it down," says Cornell president Jeffrey Lehman, a fan of Hawkins's work. "I was swept along from page to page. It's an important book, because it offers a theory of what the brain is about and a set of testable implications about that theory, and does it in a way that's really accessible."

Though *On Intelligence* does contain its share of technical jargon—in his talks, Hawkins good-naturedly warns non-scientists to take a deep breath before plunging into Chapter Six: "How the Cortex Works"—he intended it for a broad audience. He's especially interested in sparking a fire in young people, "students who haven't decided what they wanted to do in life." "It's an interdisciplinary book," he says. "I'm trying to create a movement in the sense that artificial intelligence and neural networks had movements. They had their day, where for a number of years there were thousands of people working in these fields—companies that got started, degree programs, and so on. I'm trying to do the same for the correct view of how brains work."

So what is Hawkins's theory? In a nutshell, it's all about memory and prediction, how we form memories and how we use those memories to predict the future. As Hawkins describes it, the human brain stores knowledge in a layered hierarchy: at the top is new information, while way at the bottom are tasks and facts that have become so well-learned as to be second nature. As humans learn, we're constantly taking in new information, comparing it to what we already know, and using that knowledge to predict the immediate future. "When you're learning to drive, the process of changing lanes requires all of your concentration, and you're intensely focused on what your hands and eyes are doing," says Lehman, recalling one of Hawkins's typical examples. "But when you've been driving for years, you can go for half an hour and suddenly realize you have no idea what

> **How the brain works is the most important question facing humanity. Every other human endeavor is dependent on it.**

you did—although you passed cars, changed lanes, and got off at an exit—because these very complex processes have been pushed down *below* the level where they're occupying all your conscious energy."

The power of prediction also plays an important role in Hawkins's premise: each time you take a step, he notes, you anticipate what a footfall will feel like. Similarly, as he demonstrated in the science academy talk, once you learn to clap your hands, you don't think about it anymore; your brain has learned expectations about what clapping entails. "I expected my hands would stop and not go through each other," he told the audience. "I expected they wouldn't turn into potatoes. They'd make a specific sound"—he clapped again to demonstrate—"and not squeal like a pig." But when something unexpected *does* happen—you're zipping along the highway, say, and a car suddenly cuts you off—your brain jumps back up to that top level of awareness and information gathering. "His core model, which depicts the brain as this wonderful recursive prediction machine that's constantly anticipating what information will come into it, fits in a very intuitive way with my own experience of both learning and teaching," says Lehman, a legal scholar. "It offers a picture of how an experience that we all know—having things that were once difficult become second nature—could actually map onto the physical structure of the brain."

Another basic tenet of Hawkins's theory is that the brain is not a static organ: it functions across time. In his book, he asks readers to imagine their homes, recalling various details. What does the front door look like? What items do you keep in your shower? "You might say these things are all part of the memory of your home," he writes. "But you can't think of them all at once. They are obviously related memories but there is no way you can bring to mind all of this detail at once. You have a thorough memory of your home; but to recall it you have to go through it in sequential segments, in much the same way as you experience it."

Because of this sequential nature, Hawkins often illustrates his theories by citing how people learn and recall music—hence the invitation to speak at Juilliard. "We store the memory of the music's intervals, not the actual notes," he told his audience, after humming a few bars of *Somewhere Over the Rainbow*. "Music can only exist in time." Hawkins himself is often immersed in music—not only as a longtime devotee, but also as the father of two teenage girls. "Why do we like music?" he muses, standing on the Juilliard stage in front of a huge set of organ pipes and a Steinway concert grand. "The brain likes to discover patterns in the world. It's pleasurable for us. And music is a pure pattern fix—it's like a drug for the brain."

Although Hawkins is interested in how the entire brain works, he has focused his energy on the neocortex—evolutionarily, the newest part of the brain, and the center of intelligence. Containing some 300 trillion synapses (the connections between neurons) the neocortex is a mass of scrunched-up, wavy matter that sits atop the evolutionarily ancient "old brain," which governs such fundamental things as blood pressure, hunger, sex, and emotion. If spread out, the neocortex would be two millimeters thick and about a foot and a half square—roughly the dimensions of Hawkins's trusty dinner napkin. "We have a very large neocortex," he says, "and a very sophisticated model of the world."

Among the early readers of *On Intelligence* was Bob Constable, dean of the faculty of computing and information science at Cornell, who offered feedback during the writing process. Constable, who calls Hawkins "an incredibly smart guy," notes that just as he has a knack for starting companies, he was able to see that there was a gaping hole in the field of neuroscience—that no one was trying to present a complete model of how the brain works. "The more you get to know him, the more you realize he has an interesting way of looking at the world," Constable says of his friend. "He's very candid and funny. He's a disarming guy, an incredibly down-to-earth person. He sits there in his institute like everybody else, beavering away at the board, writing and thinking and talking."

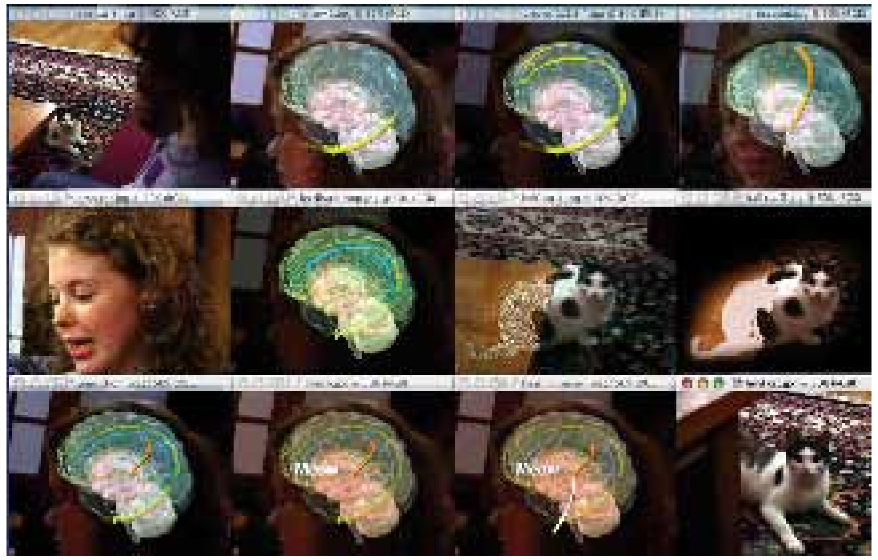
Cornell psychology professor David Field, an expert in computational neuroscience, spent an eight-month sabbatical in the Bay Area in 2003; his schedule included working one day a week with colleagues at RNI. (The institute is scheduled to relocate to the Berkeley campus this summer.) He describes Hawkins as having infectious enthusiasm and a no-nonsense approach. "You can see why his companies do well," Field says. "He works very hard, and he expects the people around him to work hard too. You can get lost in details, but Jeff was someone who always wanted a bigger picture."

Hawkins grew up on the North Shore of Long Island, in a family enamored of building things—boats in particular. Although he says he wasn't a "science kid," he was deeply curious and a voracious reader. At fifteen, he told his audience at the science academy, he drew up a list of four fundamental questions about the world. They went something like this:

1. Why does the universe exist?
2. Why does it have the laws that it does?
3. What is life and where did it come from?
4. What is intelligence?

In the interest of addressing Question Number Four, he did what he always did: went to the library and looked for a book on the subject. "As a teenager I had become accustomed to being able to find well-written books that explained almost any topic of interest," he writes in *On Intelligence*. "There were books on relativity theory, black holes, magic, and mathematics—whatever I was fascinated with at the moment. Yet my search for a satisfying brain book turned up empty. I came to realize that no one had any idea how the brain actually worked. There weren't even any bad or unproven theories; there simply were none."

The more you get to know him, the more you realize he has an interesting way of looking at the world. He's very candid and funny. He's a disarming guy, an incredibly down-to-earth person.



This representation shows how the human brain uses and interprets sensory input to predict what it can't see, in this case the portion of the cat hidden from view.

IMAGE PROVIDED

Fast-forward to September 1979 and the dawn of the microcomputer age. After graduating from Cornell, Hawkins had taken a job with Intel in Portland, Oregon. That month, *Scientific American* published a special issue dedicated to the brain—a volume that remains beloved among many neuroscientists of his generation. In addition to addressing such topics as brain organization, development, and chemistry, the issue included an essay by Francis Crick, James Watson's partner in discovering the double-helix structure of DNA. In the piece, entitled "Thinking About the Brain," Crick noted that despite all the accumulated knowledge about the organ, its workings remained a profound mystery. For Hawkins, Crick's piece was a "rallying call."

"He was like the boy pointing to the emperor with no clothes," Hawkins writes. "According to Crick, neuroscience was a lot of data without a theory. His exact words were, 'what is conspicuously lacking is a broad framework of ideas.' To me this was the British gentleman's way of saying, 'We don't have a clue how this thing works.' It was true then, and it's still true today."

While at Intel, Hawkins tried to convince his bosses that a greater understanding of the brain could lead to the development of better microprocessors; the company took a pass. After transferring to Intel's Boston campus to be near his future wife, Hawkins decided to apply to MIT's artificial intelligence lab, offering the same proposition. A.I. was all the rage—but its researchers were looking to surpass the human brain, not emulate it. Hawkins's application was rejected.

Hawkins eventually relocated to Northern California, where he went to work for GRiD Systems, designer of the first laptop computer. Still compelled to study the brain, he quit his job and enrolled as a full-time grad student in Berkeley's biophysics program. He studied there for two years in the mid-eighties, but left when his thesis proposal on neural pattern recognition was rejected—because there was no one on the faculty studying that topic, and therefore no one Hawkins could work under. (As Watson joked in his Juilliard introduction: "At Berkeley, he found out that his professors weren't that bright.") Hawkins returned to GRiD, becoming vice president for research and pioneering the GRiDPAD, the progenitor of the Palm Pilot. After licensing the technology, Hawkins founded Palm in January 1992.

Although Hawkins's brain research wasn't an active part of developing the Palm, it did play a role. In struggling to solve the problem of handwriting recognition—which so bedeviled Apple's failed Newton—it occurred to him that human beings are happy to learn new tools, such as touch-typing, as long as they work as expected. "It was about predictability, not writing style," he says. "If a tool is predictable then people will like it, even if you have to learn something new. But most people thought the idea of a new alphabet was really stupid." The result of Hawkins's stupid idea: Graffiti, the easy-to-master user interface that changed the way people manage their personal information.

In March, Hawkins announced his latest commercial venture: a company named Numenta, founded with longtime business partner Donna Dubinsky. Named after the Latin word for mind ("mentis"), the company will develop technology stemming from his neuroscience research. "It's very difficult to know what the exact applications are going to be because we are working on a fundamental technology, but I am confident it's going to be big business," he says. "It's like when they invented the microprocessor—no one anticipated the cell phone or the internet. I could try to tell you what it's going to be used for, but I'd probably get it wrong."

He does have a few example ideas, though. They include the possibility of a more accurate weather-prediction system, based on the concept that the planet's system of weather sensors add up to a "big eyeball." A computer that could process weather information like the brain processes visual input, he says, "would discover things like El Niño quicker than we would." Another potential use would be in analyzing genes—taking advantage of the brain's penchant for pattern recognition to sift through the genome and identify combinations that predict disease. In general, he says, his model of brain function holds promise for solving long-standing problems in computer vision, robotics, and artificial intelligence.

"He's just bubbling with ideas and plans," Constable says of Hawkins. "You know that when you meet him there's going to be some new thing he tells you with a great twinkle in his eye. *'What do you think of this? Isn't this cool?'* And you know that he'll have something remarkable to say—and that maybe he's going to create a whole new industry. So when you see that twinkle in his eye you think, 'Oh my God—what is he going to do *now*?'"

Beth Saulnier is a journalist and mystery author who lives in Manhattan. Her latest novel, an urban thriller called "See Isabelle Run," *came out in March 2005 under her married name, Elizabeth Bloom.*

Alyssa Apsel looks to photonics as the small solution for a big problem.

By Jerry Gabriel

FOR those of us who use computers to do uncomplicated things like check the weather or write research papers, the how of these machines remains elusive. Most people's understanding probably doesn't run much deeper than a rudimentary awareness that computers operate by means of binary code—0s and 1s operating as messages to the system to do this and not that. We might thank the '90s tech boom for even this scant knowledge; before the internet came along and rescued home computing, there may as well have been little sprites doing all of the work in there as far as we were concerned.

But understanding the binary is really just part of understanding computing. It's the interface with the real world that seems so difficult to get one's mind around: What is it that goes on inside these things that allows you to hit the delete key and have that action translated somehow into 0s and 1s, ultimately prompting the machine to carry out your wish? The answer to the question is circuits; they are the place where the analog "real" world (in the form of voltage) meets—and gets translated back and forth with—the digital cyber world.

And if you think of the effort to make computers—and devices that rely on computing, like calculators and iPods—smaller over the last half century as a race, then at the center of that race has been the integrated circuit. Making the body of a computer is after all not a difficult task; what was difficult was making a smaller computer that performed at least as well as the bigger one.

In 1965, Intel co-founder Gordon Moore predicted in a paper that the number of transistors per square inch on integrated circuits would double each year for the foreseeable future (as they had since the integrated circuit's invention in the late 1950s). The time frame of the prediction was a little off—it was more like 18 months—but the gist of the idea, known since as Moore's Law, has held steady, a bit of wisdom more valuable in the computer industry than any of Twain's best one-liners.

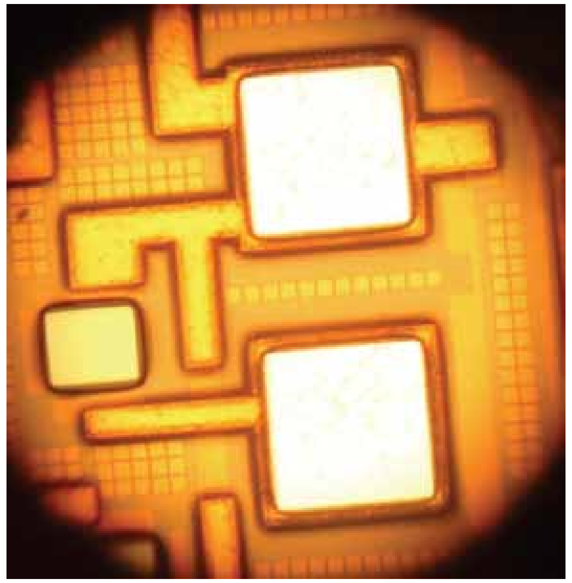
The industry's ability to scale, or shrink the number of transistors on an integrated circuit, has accounted for improvements in power, density, and performance like clockwork ever since. The problem is that the future that Moore was able to imagine in 1965 has nearly run its course. Scaling, in other words, is beginning to meet with material limits—and just about everyone agrees that this is true. In its 1999 "International Technology Roadmap for Semiconductors," the Semiconductor Industry Association itself predicted that by 2007, electrical fixes for chip-to-chip interconnect problems would be growing scarce.

Rajit Manohar, associate professor of electrical and computer engineering at Cornell, explains the nature of the dilemma thus: "There are a number of different physical mechanisms that together govern the behavior of devices used in a processor. Some are desirable, others not, because, for example, they cause a device to stop behaving like an ideal transistor. When devices are made very small, these less-than-ideal effects begin to dominate, making it difficult to design fast devices that have low power consumption."

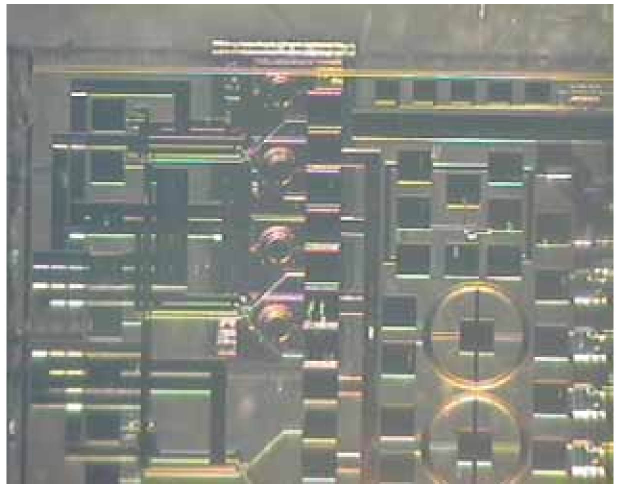
If we agree that our yearning for faster and smaller computers is going to continue over the next decade and

FRANK DIMEO

Reflecting the Future



The integrated photodetector shown here is used to convert light signals into electrical signals in a silicon-based optical receiver.



This receiver circuit, constructed on a sapphire substrate, is bonded to an array of photodetectors and, because sapphire is transparent, can be seen through the back side of the chip. Optical signals can be beamed through the substrate to speed movement of data across a single chip and from one chip to another.

beyond—and there seems no reason to think otherwise—then the computer industry is faced with a simple though thorny question: what next?

Alyssa Apsel, Clare Boothe Luce Assistant Professor of Electrical and Computer Engineering, believes she knows the answer to that question: a new paradigm.

Whether the actual limit is 35 nanometer scale or 15 or 10, Apsel argues, the limit for shrinking the integrated circuit is real and it calls for a different way of thinking. "We're going to have to look at a lot of approaches of doing processing in order to improve system performance," she says. A few such approaches already under examination include innovations in pipelining (the way a processor orders tasks) and optimizing a processor for a single application (as opposed to creating a machine, like our current computers, that can do a little of everything, though nothing spectacularly well).

At the chip level, says Apsel, "we're going to have to build integrated systems that combine approaches, that use things like nanotechnology, MEMS (micro-electro-mechanical systems), and other sensor devices.

"And," she adds, obviously leaving the best for last, "photonics."

Photonics is something that has been used most notably in telecommunications: fiber-optics is a word familiar to everyone's ears. Optics, because of the speed of light, are an excellent means of passing data over long distances very quickly (say, between continents). But over short distances like those on a chip, the thinking has gone, optics are no better than wire—in addition to being more expensive.

But Apsel and her lab group, which includes graduate students, undergrads, and one post-doc, have been investigating the truth of this wisdom. What they've found is that it might be possible to combine photonics with more conventional electronic approaches in order to design circuits capable of achieving a lower cost, higher performance machine.

"We began to ask what an optical signal was good for, rather than just speed," Apsel explains. "There's a lot of benefit to using an optical signal in a fiber when you want to transmit data from one point to another. We're looking at ways to make that system useful for a computer."

One of several possibilities that Apsel has been investigating is electrical isolation. Electrical isolation means that part of a system does not interact electrically with another part. Because of this, you can transmit data from one source to many nodes at higher speeds than you could achieve electrically. This is because each node no longer drains current directly from the source, as it would if they were electrically connected. With electrically isolated nodes, connecting more circuits or nodes to the "receive" side of the interconnect will not slow down the signal because in this method, the signal has a smaller effective load to drive.

"There are plenty of examples in circuit architectures where driving large loads is a problem that slows performance and costs energy," says Apsel. "With electrical isolation, a signal can be broadcasted to more destinations without degradation of the signal speed."

Some notable areas where electrical isolation might come in handy, says Apsel, are clock distribution and memories. Memories, for instance, have multiple cells connected to a single address line, all receiving the same signal. As memories increase in size, it takes longer and longer to access them because of the larger load that needs to be driven. Electrical isolation can speed up that access by connecting to all the cells at once with the ample drive.

Apsel speculates that in the next decade or two, we will be seeing these types of technology—if not this specific one—put in place in industry. "We'll see basic systems with higher performance pushed not by scaling, but by the integration of other technologies," she says. "You're going to see optics within a computer. I don't want to bet my life on it, but I'm pretty sure."

Graduate school trains you for much of what you end up doing as a professor, but it does not train you to run a lab. This aspect of the job, says Apsel—and particularly working with graduate students—has been a very pleasant surprise.

"It's a real collaboration," she says. "I find it the most interesting thing to see how others think, what kinds of ideas they generate, how they work creatively. A graduate student who is excited about a problem can very easily infuse me with their excitement."

In her own graduate school experience, at Johns Hopkins, she felt that she had a lot of freedom to take things in the directions she was interested in, which allowed her to get very excited about the work she was doing. This excitement, she says, goes a long way toward understanding.

"Graduate students don't need you very much actually, maybe just ten percent of the time," she says. "The value you add is by having a global context, being able to look at the world and see how things fit together and being able to come up with interesting new problems."

In describing the atmosphere of the Apsel lab, second year graduate student Zhongtao Fu stresses the importance of the collaborative, interdisciplinary atmosphere. At weekly meetings, the group members informally present their work to one another. The other members then respond, sometimes asking probing questions or seeking clarification. These discussions help to drive the discovery process for everyone. Each member, in a sense, is learning about the diverse areas that each of the other members wander into in the course of research. "When we don't know how to make a circuit meet a particular requirement," Fu says of working with Apsel, "we learn how to do it together."

When Apsel first embarked on her current research, she says she didn't know much about optics; her background was in more conventional circuit design. But she saw this deficiency as an opportunity to learn, an exciting challenge. The hallmark of her career so far has been her ability to see the system in its entirety and understand not just how the parts work together, but based on how those parts work, what could be improved upon.

Tania Khanna, an undergraduate in the lab, sums up the interconnectedness, the necessary interdisciplinary nature of this work: "There is no way you can design a useful product or idea if you know nothing about where it will fit into the grand scheme of things, though the way you view each part in this scheme is strongly affected by your area of study."

Apsel says that as a researcher, she's learned that there is more than one way to proceed—sometimes you might address an existing and well known problem, which is the way we tend to imagine engineers working. But sometimes you might go looking for a problem that no one else is trying to tackle. More often, in fact, she says it is the latter of the two that drives her research agenda.

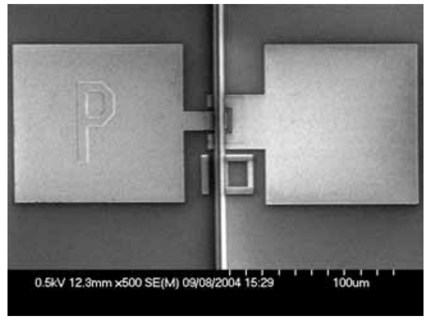
"Frequently," she says, "my job is not really looking at the problem and trying to come up with the solution; it's looking at the solution and coming up with problems. I've done that a lot."

The optics work is a good example of this. Apsel knew there were certain advantages to optics; the long-distance telecom applications made this abundantly clear. But she began asking what other kinds of applications weren't being used, if they were already being explored and, if not, if they were worth exploring.

"Being an academic is almost like being a comedian," she says with a grin. "You can't just sit there and grind out jokes, because they won't be funny. It has to be organic."

> Sometimes you might go looking for a problem that no one else is trying to tackle. More often, in fact, she says it is the latter of the two that drives her research agenda.

For Apsel, keeping the process "organic" seems to be connected to the combination of collaboration, imagination, and interdisciplinarity; together they provide perspective, and perspective is something Apsel values a great deal. She has a history of finding ways to get it. Her roommate at Swarthmore College, Sylvia Chong, herself an assistant professor of literature at the University of Virginia now, says that though Apsel knew she wanted to be in engineering early on, she was always straying outside her field—sometimes far outside—in her undergraduate coursework. She would take upper-level courses in subjects like history, and during her last two years of college, says Chong, Apsel acquired a strong interest in oil painting and studio art. Chong and many of their friends modeled for her.



A polyimide waveguide fabricated over a traveling wave photodetector enhances the efficiency with which light is converted into an electrical signal that can be used in circuits. This high-speed, high-sensitivity photodetector can be directly integrated with electronics on a single chip.

"I always thought it was unusual to have a scientist who was interested in the visual arts," says Chong. "Most scientists I knew who did anything artistic were musicians, maybe because music was more mathematical or precise than visual art."

But for Apsel, it was the precision she was getting away from. Painting, she says, was a way of balancing her mind, giving her a break from logical thinking, allowing her to look at the world in a different way.

"It's very hard to paint and stabilize a circuit at the same time," she says of the period. "It was almost like a way of forcing myself to do meditation. After several hours, my perspective would be shifted and I could leave the studio and either attack problems that had been stymieing me with a fresh approach or I could at least sleep well without obsessing about an equation.

"I sometimes feel," she adds, "that the way we study engineering encourages myopia, the way we have students be hyper-focused, only looking at one type of problem with one set of applications. I would urge young engineers not to fall into the trap of specializing too soon, of becoming pigeon-holed. Focus on fundamentals, on basic science. Don't spend a lot of time learning detailed protocols. The most interesting ideas I've seen have come out of breadth of ideas."

Jerry Gabriel lives in Ithaca and is a lecturer in Cornell's Engineering Communications Program.

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A House Undivided

Engineers and architects join forces to create a completely livable solar home.

By Melanie Bush

THIS year a Cornell group is proud to be a contender in the second Solar Decathlon, which challenges colleges and universities around the globe to research, design, and build a house that most spectacularly embodies the advantages of solar energy. In October, 18 teams will exhibit their finished houses in Washington, D.C., where they will construct a "solar village" on the National Mall, open to the public and judged on ten categories (hence "decathlon"). Although the exhibition stage gets the most attention, students have been intensely absorbed for the past two years with fundraising and planning, and the design and construction of their homes.

"We are on a quest for victory," says Tim Fu '04 ME, M.Eng. '05, the driving force behind Cornell's involvement. "As soon as I heard about it, I said, let's put in a proposal. I liked the idea of applying environmental activism to technology and to the real world. It's pretty clear that the U.S. expects to have energy problems, as the war in Iraq shows. Redirecting our long-term goals is what sparked my interest."

The Solar Decathlon is sponsored by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) and its National Renewable Energy Laboratory (NREL), as well as private organizations and corporations including the American Institute of Architects, the National Association of Home Builders, BP, and Home Depot. It is the hope of sponsors that today's students—tomorrow's engineers, architects, entrepreneurs, and homeowners—will incorporate energy efficiency and solar energy into their professional and personal lives. The contest also serves to raise public awareness of renewable energy and energy efficiency and to encourage the U.S. to move solar technologies more quickly into the marketplace.

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NREL's Cecile Warner led the team that designed the ten categories in the Decathlon competition: Architecture, Dwelling, Documentation, Communications, Comfort Zone, Appliances, Hot Water, Lighting, Energy Balance, and Getting Around. "Our biggest fear was that it wouldn't be interesting to the public—we were wrong about that!" (The first exhibition in 2002 hosted over 100,000 visitors.) The Department of Energy provides $5000 in seed money to each team, as well as an electric car (to fulfill the "Getting Around" requirement), a low-speed street-legal vehicle to be powered entirely by the solar electric system on each team's house. "They can get to Home Depot for supplies or up to Capitol Hill to visit their representatives. The point of the car [for the contest] is to show that solar energy has the potential to power every part of our lives, including the cars we drive."

Warner says the Decathlon can help shape the nation's energy future. "I think one of the important things the contest does is to create this really visible group of new practitioners in building energy, a steady population of passionate people who are being snapped up by the building industry."

The Cornell University Solar Decathlon (CUSD) team consists of more than 70 graduate and undergraduate decathletes from various academic backgrounds, primarily architecture, engineering, and business. Many of the students feel that CUSD represents a kind of proactive involvement that is more effective than political protest. Among the goals laid out in the team's mission statement are "to create a self-sustaining solar living system designed to exceed the expectations of the Solar Decathlon competition; to maximize our positive impact on humanity by encouraging sustainability in scientific, social, economic, and political contexts; and to educate industry, academia, legislators, and ourselves about sustainable living systems and strategies."

CUSD's subteams, each dedicated to different parts of the ten contests, seem fully capable of implementing these goals. The project is entirely student-run, with faculty involved only as advisers. "It's better this way," says Jesse Stolow '04, an applied economics and management major who led the CUSD business team in raising the estimated $300,000 needed to design, build, and transport the house to D.C. "The students have a much stronger involvement—we're making our own curriculum. We're setting our own standards. In the more traditional approach, a professor decides what you should learn; here, we're doing something that's never been done before."

Students from each discipline are building the house's systems, spending countless hours together asking questions and teaching one another. Each category of the competition is managed by team leaders, who ensure that work is proceeding smoothly. "With this level of commitment, giving academic credit for CUSD was a great idea," says Stolow. Engineering students are able to sign up for CUSD as a three-credit-per-semester elective in mechanical and aerospace engineering; architects took a Solar Decathlon design studio for six credits, with a two-credit follow-up class (the architectural design component of the project is now completed).

Nick Rajkovich, a visiting lecturer, is one of the current faculty advisers from the Department of Architecture. He feels that students are getting invaluable real-life experience with CUSD. "Other than the scale of the project, which is relatively small, it's like professional practice—resolving conflicts that come up in design, coordinating construction issues—all things you can talk about in classes but you can't really understand until you go through them. To my mind, this experience is much more intense than a regular architecture studio because here you actually get to *build* the project. I went to Cornell as an undergrad and I wish I'd gotten to do that."


Wanchee Pei '07 CE (left) and James Luk '07 ECE


Michelle Vigil '05 ME (left) and Rafael Dionello '05 ME

Zellman Warhaft, professor of mechanical and aerospace engineering, has been CUSD's engineering adviser since the beginning. "From my point of view it's been a lot of fun. Architecture and engineering are two very different disciplines; engineers are more involved in the mechanics of how things work, specifying the performance of different parts of a system, whereas architects tend to think more holistically, concerning themselves with how a project blends into the environment, say, or how it can be used at a later date. What CUSD is doing is making students on both sides appreciate each other as doing equally valid work. They're learning to accept different viewpoints within a complex design process, which is important because these interactions are necessary in the professional world, and people coming out of programs are generally not prepared for this."

"Integrating systems can be difficult," acknowledges Tim Fu, "and sometimes that presents personal problems, though that hasn't happened a lot. Steph and Ben [Stephanie Horowitz and Ben Uyeda, the Architecture team leaders] have become my best friends—we work together seamlessly. I think the hardest and the most rewarding part has been dealing with so many other people; in other words, developing real work skills. By now we've developed a common set of interests."

What about Cornell's famous rivalry between architects and engineers, best exemplified by Dragon Day? For the annual spring event, first-year architects construct a huge dragon to parade around campus while engineering students traditionally counterattack—spectacularly in 2002 when the tower crane on the Engineering Quad for Duffield Hall construction was used to fly a huge phoenix in the face of the approaching dragon. "It's clear there's still a culture of competition," say Fu, "but once people feel a sense of ownership for the project they tend to forget their previous notions."

"We've come to learn," says Stephanie Horowitz '05 Arch, "that each

Larissa Kaplan '05 Arch

Among the team's goals: To maximize our positive impact on humanity by encouraging sustainability in scientific, social, economic, and political contexts.

P. 22 and 23: CHARLES HARRINGTON

Josh Bonaventura-Sparagna '05 ECE (right) and Emile Chin-Dickey '05 Econ display the model of the house at the Sustainable Technology Showcase held in Ithaca in January.

NICOLA KOUNTOUPES/UP

discipline must really understand the requirements and constraints of the other disciplines. If I tell an engineer that he has five feet for a closet, but he needs six feet to fit an air handler or an electronic panel, we try to compromise in a way that produces something superior. CUSD is extremely different from any class I've ever taken—it's more like a part-time or sometimes a full-time job. I've known since high school that I want to work in sustainable design, so I feel that this is a bridge between my academic and professional careers."

The need to transport the house 400 miles from Ithaca to Washington, D.C., has added a design requirement usually only present in manufactured or modular homes (the CUSD house more closely resembles the latter). The house is being built directly on a chassis, which will be trucked down the highway by a transporter, then jacked up and set down on the Mall. "The need for transportation had a pretty extreme effect on the design," says Horowitz, "because we needed to strip it down to road-size limits of 14 feet wide and 40 feet long. Once we get to the Mall we only have three or four days to assemble the house, and it was just not in our vocabulary to do that without the chassis." Other teams are doing more of the construction right at the Mall and one team—from Madrid—will be shipping their house across the Atlantic.

"All in all we decreased the interior space—what we call the heated footprint—to 650 feet out of the allowed 800 feet, which also allows us more flexibility in designing other elements," Horowitz continues. "For example, we're raising the outside landscape to the two-foot-high finished floor of the house. So, in some ways, we are going beyond the demands of the competition while in others we are very constrained by them."

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For Tim Fu, the head engineer, the solar electric system was the hardest part to design. "Photovoltaic electricity is a new field; the other major systems—mechanical and plumbing—are not. We had to design the lighting, wiring, and control panels to meet building codes, and since we don't have that skill set, we've had to consult people in industry."

Fu continues, "We had to understand, for example, electrical components, division of circuits, where you can place outlets. This was also probably the most fun part, talking to so many people who wanted to help. A local engineer, Ian Shapiro of Taitem Engineering in Ithaca, was very helpful. We're also talking with PDC [Cornell's own department of Planning, Design and Construction] about reviewing our drawings and helping with construction. The best part of the project will be actually building the house."

The HVAC (Heating, Ventilation and Air Conditioning) team, which designed the house's other two major systems—mechanical and plumbing—is led by biological engineering major Jordan Goldman '04, M.Eng. '05. "Our primary goal was to make these systems as energy efficient as possible while keeping them economically feasible for the consumer," Goldman says. "We've incorporated an ultra-efficient air source heat pump with a variable-speed air handler and a custom-designed energy recovery ventilator. These three pieces in conjunction will satisfy the heating and cooling needs of the house while meeting the highest indoor air quality standards. We've also designed a gray water tank, which will collect water from the shower, washing machine, and bathroom sink for reuse as irrigation water for the landscape. "

"Also important is our design's versatility," adds Jesse Stolow. "Our house can integrate itself into any solar environment, from sunny Los Angeles to cloudy Ithaca, because the panels can be positioned at any angle and the cladding can be made of almost any material—wood, aluminum, crushed cans. These things go beyond the contest requirements, but we think that presenting it as completely livable makes it more valuable."

The team also hopes their house will find a permanent home after the competition. "We met with President Lehman last week to discuss our options," says Fu. "Maybe it can be visiting faculty housing or an exhibit, so Cornell and the public can appreciate our legacy.

"A completely livable solar home is absolutely feasible right now," he continues. "It's just a matter of consumer acceptance. There's a large capital cost, around $20 to $30K to set up the solar array and the control devices to optimize the system, but the government offers up to a 75 percent rebate on the solar panels—a lot of people are just not educated about that. I think it's going to go mainstream in the next five years; a lot of big firms, like GE, are now constructing solar panels."

NREL's Warner also feels hopeful about the future of solar power in America. "The National Association of Homebuilders just did a study of the long-term potential of solar homes in the U.S.," she says, "and they predict that with incentives in place, solar will have a 20 percent market share by 2025. That's just new starts, so that represents a lot of housing. We're very excited that industry has solar on its screen—if it wasn't going to be lucrative, they wouldn't be interested."

There is no reliable estimate of how many solar houses exist in the U.S. today; the Solar Energy Industries Association says the closest gauge is the number of solar panels purchased. In this the U.S. lags far behind other industrialized countries: Its demand for panels has remained about level since 1996 while other nations' consumption has skyrocketed. Government incentives have stimulated solar panel sales elsewhere, Warner said, but what is important is to keep an eye on the future. "All you have to do is look at Japan, where there are 55,000 solar houses being built per year, or at Europe, with 20,000. These countries have long-range energy planning."

CHARLES HARRINGTON

Although the CUSD team has made consumer affordability a goal determining all of their choices, a project of this magnitude could not have been tackled by the group without monetary and material sponsors. "As soon as I heard about the project," says Jesse Stolow, "being a business student, I thought: They're going to have to raise money. That was a challenge, thinking, how am I going to raise $300,000?" The business team implemented a coordinated marketing effort including a website, brochures, and press releases, to stimulate public giving, and Stolow estimates they have so far raised over $150,000 in monetary and material help. "We started fundraising in spring '04. The subteams brought us lists of companies they wanted materials from; we did a direct campaign to businesses and got a great response. GE, for example, has agreed to donate all of the photovoltaic panels, plus a couple of the large kitchen appliances, an astronomical cash value. A lot of the money came from alums."

CUSD is already giving back to the local community. The Outreach team, headed by Melissa Wrolstad '06 ME, has spent the past year developing programs with local partner schools in Ithaca, encouraging teachers to make sustainable energy a permanent part of their curricula. In Spring '04, the Outreach team helped students at Dewitt Middle School build small solar houses, made a three-day presentation on passive and active solar concepts to sixth-grade science students at Boynton Middle School, and led a class on solar energy at Enfield Elementary. "The science teachers are so excited," said Wrolstad. "They can't wait to have us back."

Next semester, Outreach hopes to arrange field trips for kids to tour the completed house.

"We don't just want to win this competition; we want to have an impact on the whole world," says Stolow. "Every aspect of our design is centered on the idea that this house can be used in everyday life. We'd like to win because that will prove what we're doing is right, but deep down we know we're right anyway."

Melanie Bush is a freelance writer living in Ithaca.

Boomtown in Duffield

Annual showcase fills the atrium with an array of computing projects.

This was the first year BOOM exhibitors enjoyed one central location—the contiguous Swanson, Winter Garden, and Baum atria of Duffield Hall. In previous years, the exhibits were spread throughout several floors in Upson Hall.

Hundreds of enthusiastic students filled the Duffield Hall atria March 9 with glossy posters and computer presentations for BOOM (Bits On Our Minds) 2005, an annual fair that showcases Cornell's best student computing projects to the community.

BOOM 2005 boasted more than 50 projects with the common theme of computing. In between the expected projects on databases, programming, and robotics, a few displays demonstrated how computing could be applied in fields as diverse as biology, psychology, economics, and even the arts.

The Genetic MusicComposer—a Java-based creation of two students from the College of Arts and Sciences, Yash Parghi '06 and Andrew Dailey '06—brings together computer science and music by intelligently composing short tunes. Using a genetic algorithm, the program generates random tunes and scores them based on such criteria as harmony and rhythm. In the next stage, the most promising tunes are selected and recombined to make better tunes. This process is repeated until a worthy tune emerges. "Our program will not produce anything approaching a masterpiece anytime soon, but our approach is very open-ended and has great potential," said Parghi.

While its tunes might not be ready for the concert halls, Genetic MusicComposer was a perfect fit at BOOM. The program created new tunes within seconds and played them through speakers. To have an objective feedback for their work, the team set up a web page with five MIDI samples and asked participants to rate them on humanness and pleasantness. "The survey response varies. Some would say they couldn't believe the tunes were generated by a computer. Others, especially the musically trained, were disappointed at the music quality," said Parghi.

Daniel Cohen's project on solid freeform fabrication of tissue implants was an interdisciplinary effort combining computing and medicine. Cohen, a master's degree student in biomedical engineering, and his adviser, Hod Lipson, assistant professor of mechanical and aerospace engineering, made gantry robots that deposit cell-seeded gels layer by layer, following a pattern from computer-aided design drawings. When incubated under growth conditions, the cells consume the gel and form a structure made of living tissue.

"We can make these tissues in impressive geometries. Compared to the conventional fabrication methods using scaffolding, our technique is very efficient and quick," explained Cohen. He also noted that their technique enables them to create tissues consisting of multiple types of materials. "Our eventual goal is to provide inexpensive implants that are specific to the needs of a patient," he said.

This year was the ninth time that BOOM was held, but it was the first time the event was held in Duffield Hall. The spacious atria provided the perfect venue for all the student projects to be displayed in one central location. In previous years, the event spanned several floors in Upson Hall.

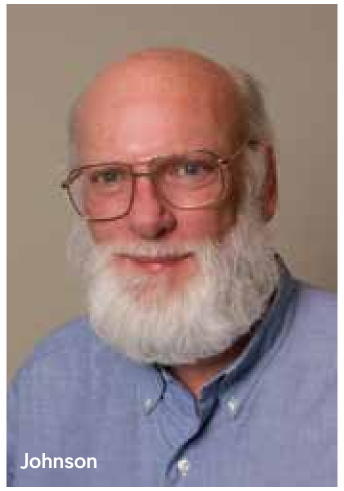
The BOOM 2005 web site at http://www.cis.cornell.edu/boom contains links for all the exhibits. The event was organized by the faculty of Computer and Information Science and sponsored by Bloomberg and Credit Suisse First Boston.

—Alex Kwan
Cornell News Service

SHARING THE PASSION

Engineering faculty members garnered two of the three 2004 Stephen H. Weiss Presidential Fellowships for effective, inspiring, and distinguished teaching of undergraduate students. They are T. Michael Duncan, associate professor, School of Chemical and Biomolecular Engineering, and C. Richard Johnson Jr., professor, School of Electrical and Computer Engineering. The third winner was Peter J. Katzenstein, the Walter S. Carpenter Jr. Professor of International Studies, Department of Government.

PHOTOS P. 26–27 CHARLES HARRINGTON; PHOTO T. MICHAEL DUNCAN COURTESY OF T. MICHAEL DUNCAN



Johnson

Duncan

The awards—$5,000 for five years for each faculty member—are named for Stephen H. Weiss '57, emeritus chair of the Cornell Board of Trustees, who endowed the program. They recognize excellence in teaching, advising, and outstanding efforts toward instructional improvement and development.

"Most Cornell professors have a burning need to contribute something of lasting significance to their disciplines and a concomitant desire to share their intellectual passions with students," said Cornell President Jeffrey Lehman. "I am delighted that, because of Steve Weiss's vision and generosity, we have the opportunity each year to honor some of Cornell's most inspiring and effective undergraduate teachers as Weiss Presidential Fellows." The faculty members were honored at an awards dinner in March.

Duncan, who joined the Cornell faculty in 1990 and has been the associate director of his school for the last ten years, is known for his keen interest in keeping material fresh and relevant to students while ensuring that it is grounded in scientific fundamentals of chemistry, physics, and math. For example, he devises demonstrations, exercises, and competitions for first-year engineering students to help them learn engineering design and creative problem solving. He is the recipient of numerous teaching awards and has been named a Merrill Presidential Scholar Mentor six times.

Johnson, who began teaching at Cornell in 1981, has earned a reputation as a professor who not only serves as a leader in electrical and computer engineering but also as a mentor who gets involved with undergraduates and changes their lives for the better. He is considered a demanding, involved, and thorough teacher who challenges his students with significant design projects and who brings his research experience into the classroom. Johnson is the recipient of numerous teaching awards, including selection as the 1983 C. Holmes MacDonald Outstanding Teacher, a national award from the electrical engineering honorary society Eta Kappa Nu.

The Stephen H. Weiss Presidential Fellowships were established in 1992 by the Cornell Board of Trustees in recognition of the importance of undergraduate teaching.

—Susan S. Lang
Cornell News Service

Shen Yuan Huang '06, Melisssa Wrolstad '06, and Amy Orlansky '06 make adjustments to a robot during the competition.

THOSE A-MAZING ROBOTS

A course called "mechatronics," teaches mechanical engineering students the basics of using electronics and programming to operate mechanical devices.

It's a simple task, really: Program a robot to find its way through a maze. An electrical and computer engineering student could probably do it on a Saturday afternoon. But it's not a mainstream study for mechanical engineering students, so Ephrahim Garcia, associate professor of mechanical and aerospace engineering, has created a course called "mechatronics," which teaches mechanical engineering students the basics of using electronics and programming to operate mechanical devices. Next year the course will be required for all students in mechanical engineering.

The final project in the course is to build and program small robots to find their way through a maze of simulated rocks strewn across a 12-foot-square course painted orange to suggest the landscape of

Mars. The final test was held as a competition in the atrium of Duffield Hall on Dec. 3. About 115 students, working in teams of two or three, participated. A sizeable crowd, mostly other engineering students, gathered to watch the competition, cheering when a robot seemed to be heading for the finish box and groaning whenever one went in the wrong direction.

As with any engineering project, students found themselves making last-minute adjustments, dashing back to the lab, or tinkering with their robots on the floor of the atrium.

The robots, about six inches square, use infrared proximity sensors or tactile "feelers" or both. The control unit is a commercial Basic Stamp chip. An overhead camera provides a simulated GPS signal, telling the robots where they are in relation to the start and finish of the maze.

The basic maze-running algorithm is something like "Go toward the finish until you sense an obstacle, then back up, turn a little and go again." But variations make all the difference. Garcia's requirement was that a robot finish in five minutes or less, but the robot built by the winning team of Gabe Newell, Jackie Romero, and Frank Keller, all seniors, managed a phenomenal 25 seconds. Their secret: confidence. While most robots moved in short spurts, stopping frequently to check for obstacles, theirs charged ahead until it sensed something, then made a full 90-degree turn and took off again.

—Bill Steele
Cornell News Service

TEACHABLE MOMENT

If there ever were a teachable moment when it comes to tsunamis, physics, and fault lines, that moment happened in December. And Cornell graduate student Evan Variano made

Evan Variano, a graduate student in civil and environmental engineering, demonstrates a portable tsunami teaching device he helped build to an earth science class at Dryden High School Jan. 13. As part of his fellowship with the Cornell Scientific Inquiry Partnerships program, Variano put together a lesson on the physics of tsunamis, drawing on his studies of turbulence, that he shared with area high school classes.

sure it was not lost.

In the wake of the devastating Asian tsunami, he took a lesson plan he developed—and a portable teaching device—to high schools in the Ithaca and Rochester areas during January to answer students' questions about the physics of tsunamis, the technology required to detect the killer waves, and the economics and sociology of developing early warning systems.

"I'm trying to cover whatever the students are curious about," said Variano, a graduate student in Cornell's School of Civil and Environmental Engineering. His mentor is tsunami expert Philip Liu, professor of civil and environmental engineering, who led a fact-gathering delegation of American scientists from the National Science Foundation's Tsunami Research Group and the U.S. Geological Survey into wave-ravaged Sri Lanka.

Variano, whose specialty is turbulence, is a fellow in the Cornell Scientific Inquiry Partnerships (CSIP) program. The fellowship is a National Science Foundation-supported program that gives 10 Cornell graduate students free tuition and a stipend in exchange for about 15 hours a week teaching in area public schools.

He is teaching high school students studying earth science, environmental science, and biology how underwater earthquakes trigger the destructive waves. The teaching device, which Variano built with the help of Cornell technicians Paul Charles and Tim Brock, is a tube that allows students to experiment to see how a tsunami develops differently depending on what type of shoreline it hits.

"The wave drives through the deep ocean at 500 miles per hour, and without losing energy it builds up to 30 feet tall as it approaches shallower water and the shore," explained Variano. "When it hits the coastline, it's the turbulence—the mixing—that hits from all sides and holds people underneath the water. This causes most of the death and destruction."

Variano also makes a point of discussing more than the science of waves and earthquakes with the high school students, because, he said, "Science doesn't happen in a vacuum." Observed Karen Taylor, an earth science teacher at Dryden High School, where Variano visited in January: "Many eyebrows were raised when Evan shared with them the cost of an early tsunami detection system in the Indian Ocean [about $20 million] versus the amount of relief money donated worldwide [$3 billion to $4 billion] versus the amount of money the United States has spent on the war in Iraq [more than $20 billion]. Evan did a great job of clearing up some misconceptions the students had, and they learned quite a bit about wave formation and why the tsunami behaved as it did."

Variano visited a half dozen schools by the end of January, to discuss both the science of tsunamis and the socioeconomic problems resulting from the disaster.

TOP: KEVIN STEARNS/UP; BOTTOM: CHARLES HARRINGTON

—Susan S. Lang
Cornell News Service

KEEPER OF THE FLAME

Kevin Kornegay, Cornell associate professor of electrical and computer engineering, has been named the Janice Lumpkin Educator of the Year by the National Society of Black Engineers (NSBE). The award is one of 15 annual Golden Torch Awards given by the NSBE for those in the profession who have achieved excellence in their chosen disciplines. The award was recognized during NSBE's 31st Annual National Convention and Career Fair in Boston in March.

The Golden Torch, which symbolizes the "everlasting burning desire to succeed and affect positive change in the quality of life for all people," is the premier award and recognition program for African-American technical professionals. The Educator of the Year award recognizes a faculty member with demonstrated commitment to advancing education in engineering, science, and mathematics. This is the second year in a row the award has been given to Kornegay.

Kornegay is director of the Cornell Broadband Communications Research Laboratory, where research focuses on the design of integrated circuits that operate at radio and millimeter wave frequencies for broadband wired, wireless, and optical communications systems, such as high-speed wireless local area networks. He previously has been named one of the "50 Most Important Blacks in Research Science for 2004," has received the Cornell Provost's 2004 Award for Distinguished Scholarship, and was named Black Engineer of the Year in 2001. He joined the Cornell faculty in 1998.

—Cornell News Service

A LITTLE HELP HERE

Thanks to some fancy number crunching by two Cornell operations research faculty members and a graduate student, the number of undergraduate students facing three finals in a 24-hour period this May will fall by roughly 85 percent from what the average was over the previous three spring terms.

Likewise, the number of students facing three exams in the same day will drop by about 75 percent and those having back-to-back exams should fall by about 65 percent of what they were over the past three springs.

"Kudos to Professors Bob Bland and David Shmoys in operations research and grad student Dmitriy Levchenkov for pulling this off," said Charles Walcott, the dean of the faculty. He said that he'd received many complaints around finals time in the past from unhappy students who faced three exams in one day or back-to-back finals with just 30 minutes between them. "Students often had to ask their professors to give them make-ups because of back-to-back exams," Walcott said. "That required a lot of negotiations, especially for professors of large classes."

Walcott's predecessor, J. Robert Cooke, professor of biological and environmental engineering, formed a task force in 2002 to address scheduling issues and turned to Bland and Shmoys, knowing that their field of operations research engineering specializes in developing more efficient ways of handling data and processes.

CHARLES HARRINGTON

Thanks to (from left) David Shmoys, Bob Bland, Dmitriy Levchenkov, and Cindy Sedlacek, undergraduates are much less likely to face three finals in 24 hours.

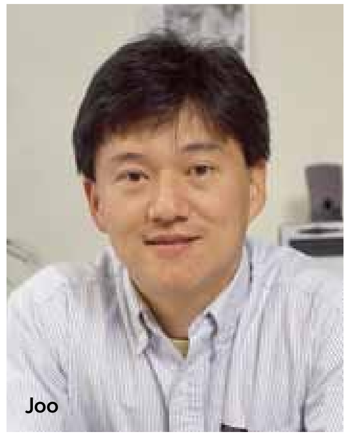
Cindy Sedlacek, an expert on the university's student data, played a crucial role by extracting and analyzing the historical and current data into a form suitable for the optimization methods. "Without her tireless efforts, there is no way this project would ever have even started," said Shmoys.

Under the new schedule, which was constructed by optimization techniques commonly used in a wide variety of business and government settings, only 51 students who pre-registered for their courses will have three exams in a 24-hour period. That's down from 341 students that would have had three exams in one day under the old method of scheduling finals.

—Susan S. Lang
Cornell News Service

AN EARLY START

Two Cornell faculty members are among this year's recipients of National Science Foundation (NSF) Career Awards. The Faculty Early Career Devel-



opment Program offers NSF's most prestigious award for new faculty members. The program recognizes and supports the early career development activities of those teacher-scholars who are considered most likely to become the academic leaders of the 21st century.

Matthew DeLisa and Yong Joo, both assistant professors of chemical and biomolecular engineering, each will receive five-year grants of about $500,000.

DeLisa, who earned a Ph.D. in 2000 at the University of Maryland, joined the Cornell faculty in 2003. His research focuses on the molecular engineering of biological systems in which protein machines play an important role. Specifically, he aims to blend protein engineering principles with the tools of genetics and molecular biology to better understand how complex protein machines perform their given tasks.

In the project funded by the NSF award, DeLisa will develop techniques to analyze and engineer a model complex protein machine, namely the bacterial twin-arginine translocation (Tat) machinery. By exploiting the twin-arginine translocation system for protein expression that transports folded proteins across the E. coli membrane, he hopes to shed light on a poorly understood biological mechanism that could lead to the expression of commercially important proteins, the identification of correctly folded protein sequences, and the creation of novel biotechnology-based drugs.

Joo, who received a a Ph.D. in 1993 from Stanford University, joined the Cornell faculty in July 2001. His research focuses on the integration of continuum analysis with molecular details in polymeric materials processing, specifically the microstructural rheology and processing of complex fluids, the formation of nanofibers via electrospinning, and the occurrence of purely elastic instabilities in polymer flows.

In the project funded by the NSF award, Joo will investigate nanofiber formation directly from polymer melts, offering a novel solvent-free approach. The proposed melt electrospinning process can overcome some of current barriers for commercializing conventional nanofiber technology. The award will also provide research experiences for middle and high school teachers and urban high school students as well as Cornell undergraduate students. Short courses on research ethics and modules on fiber science also will be developed for grades K–12.

—Susan S. Lang
Cornell News Service

SIMULATION PIONEER

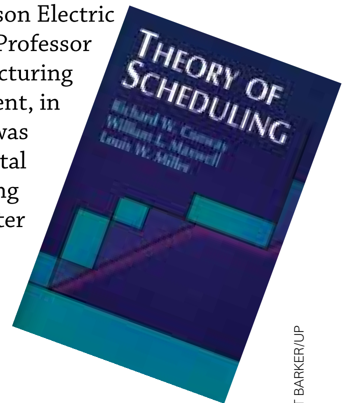
Dick Conway, a founder of Cornell's computer science department and chaired professor emeritus at the Johnson Graduate School of Management, has been honored by *Management Science* for his early, seminal research in computer simulation. The pre-eminent journal in its field, *Management Science* is published by the Institute for Operations Research and the Management Sciences (INFORMS).

The journal's editor-in-chief, Wallace Hopp, the Breed University Professor at Northwestern University, described Conway's findings as "visionary" and said that they "established the research agenda for the simulation field for decades."

Computer simulation seeks to model such problems as inefficiency in a manufacturing facility's supply chain, study what's not working well, and come up with a systematic way to improve the operation, said Hopp. "In the '60s, Dick identified what problems simulation had to solve. He laid them out neatly. People in the field followed his road map for decades."

An article in the July 2004 issue of *Management Science* by Barry Nelson, a professor at Northwestern University, noted that a 1959 paper co-authored by Conway (with Cornell researchers William Maxwell and B.M. Johnson) and a second paper authored by Conway alone in 1963 "described a number of simulation problems that continue to occupy researchers to this day." The article, which was written as part of a series marking the journal's 50th anniversary this year, traced the impact of the two papers on the work of other researchers, notably the authors of eight award-winning papers published in *Management Science*.

Conway, B.M.E. '54, Ph.D. '58, began his academic career as a faculty member in operations research and industrial engineering at Cornell. He helped found the computer science department in 1965 and was acting chair in 1978–79 and 1983–84. In 1966–68, he was director of Cornell Computer Services, a precursor to Cornell Information Technologies (CIT). Conway left the College of Engineering to join the faculty of the Johnson School in 1984, becoming the first Emerson Electric Company Professor of Manufacturing Management, in 1989. He was instrumental in launching the Semester in Manufacturing, a course that was the model for other immersion courses at the Johnson School. He became emeritus in 1999 but continued to teach in the school's executive MBA program.



Conway's 1967 book was co-authored with ORIE colleague William Maxwell and Louis Miller of the RAND Corporation and included computer simulation among a range of techniques for resolving scheduling problems. It was named among the 25 books most influential to the development of operations research.

TOP: KEVIN STEARNS; BELOW: ROBERT BARKER/UP

Conway was elected to the National Academy of Engineering 1992 for his contributions.

—Linda Myers
Cornell News Service

TOP: FRANK DIMEO; BOTTOM: WWW.JON REIS.COM

COLORING SOUND

A melody of staccato piano notes sings out from the speakers of Victor K. Wong's desktop computer. But it is not a melody made by Bach, or Liberace, or even Alicia Keys. It is the melody of color.

Wong, a Cornell University graduate student from Hong Kong who lost his sight in a road accident at age seven, is helping to develop innovative software that translates color into sound.

He helped develop the software in the School of Electrical and Computer Engineering (ECE) with undergraduate engineering student Ankur Moitra and research associate James Ferwerda from the Program of Computer Graphics.

The inspiration for using image-to-sound software came in early 2004 when Wong realized his problems in reading color-scaled weather maps of Earth's upper atmosphere—a task that is a necessary part of his doctoral work in Professor Mike Kelley's ECE research group.

As a scientist, Wong needs to know more than just the general shape of an image. He needs to explore minute fluctuations and discern the numerical values of the pixels so that he can create mathematical models that match the image. "Color is an extra dimension," explains Wong.

At first, the team tried everything from having Kelley verbally describe the maps to Wong to attempting to print the maps in Braille. When none of those methods provided the detail and resolution Wong needed, he and Ferwerda began investigating software.

Moitra later became their project programmer. Over the summer of 2004, he wrote a Java computer code that could translate images into sound, and in August he unveiled a rudimentary software program capable of converting pixels of various colors into piano notes of various tones.

Wong test-drove the software by exploring a color photograph of a parrot. He used a rectangular Wacom tablet and stylus—a computer input device used as an alternative to the mouse—which gives an absolute reference to the computer screen, with the bottom left-hand corner of the tablet always corresponding to the bottom left-hand corner of the screen.

As Wong guided the stylus about the tablet, piano notes began to sing out. The full range of keys on a piano was employed, allowing color resolution in 88 gradations, ranging from blue for the lowest notes to red for the highest.

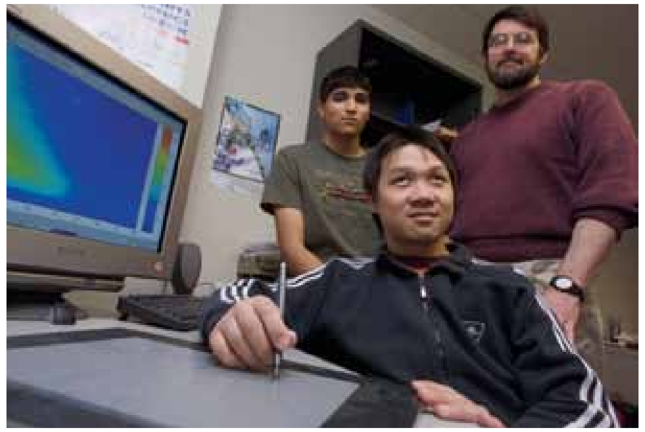
Wong, Moitra, and Ferwerda are still working to develop software that can effectively pick out the important boundaries in an image so that it can be printed.

"It is also important that there is no time delay between notes," says Moitra. "That is something we need to improve. Otherwise the image will become shifted and distorted in Victor's mind."

One of the major issues facing the project is funding. "The initial work was done on a shoestring as a side project to grants Kelley and I have received," says Ferwerda, who is preparing a proposal to the National Science Foundation to extend this work and explore other ideas for making images and other technical content accessible to blind scientists and engineers.

Says Wong: "Tackling complex color images is only one problem out of many that blind scientists are facing. But I think this is a pretty important idea."

—Thomas Oberst
Cornell News Service



Engineering graduate student Victor Kai-Chu Wong uses software he helped develop with undergraduate Ankur Moitra, left, and research associate James Ferwerda, right, that translates colors into sounds. The image-to-sound software enables Wong to continue his research into space weather. He is shown working with a space weather map that represents atmospheric density in different colors.

Research Hall of Fame

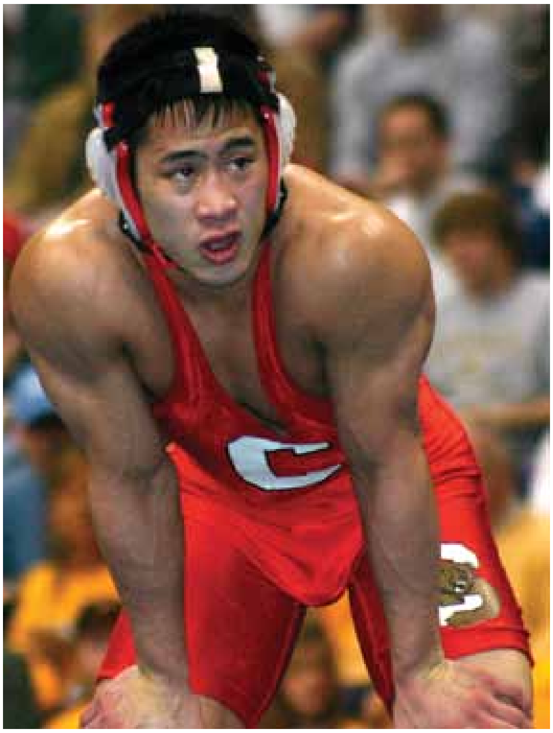
Cornell President Jeffrey Lehman applauds Dale Corson, president emeritus and former dean of engineering, as Corson watches while his portrait is unveiled last fall in Clark Hall. The Cornell Center for Materials Research (CCMR), the nationally renowned interdisciplinary research group, is creating the beginnings of a hall of fame in the first-floor offices of Clark Hall. Last summer the center installed a portrait of its first director, Robert Sproull. On Dec. 1, it honored Corson, its second "hall of famer." As a professor of physics, Corson first proposed such a center in the late 1950s and, with his colleagues, helped shepherd it when it opened for business as the Cornell Materials Science Center in July 1960 under the aegis of the Defense Department's Advanced Research Projects Agency. The National Science Foundation took over the funding in 1972, using the renamed CCMR as a flagship center for what has become a national network of 28 materials research centers at major U.S. universities.

Never Satisfied

The most successful wrestler in Ivy League history is already looking for his next challenge: Beijing 2008.

Honestly, Travis Lee can't remember the last time he was taken down in a wrestling match. It might have been in preseason this year, but he's not sure, and even the question sounds foreign to him. That's how he good he is. Notching his 135th career victory in February, Lee became the most successful wrestler in Cornell history. Eight matches later, winning the national championship for the second time in three years, Lee became the most successful wrestler in Ivy League history.

"It's a great feeling, being up on that podium," says Lee, a senior majoring in biological and environmental engineering, relaxing at home on his first spring break in years. "And it's a relief too, to know that the season is finally over, because there's been a lot of pressure."



Much of that pressure comes from Lee, whose motto is "never be satisfied," and even after his second championship, it's hard for him to admit more than, "I'm happy, happy with my college career, but no, I'm not satisfied." Still, some of that pressure has come from outside, and as he's tried to balance Division I wrestling with Cornell Engineering, he's missed his share of classes and learned that some professors are more forgiving than others.

For most of his four years at Cornell, Lee has spent 15 to 20 hours a week on wrestling, with one workout in the morning and another in the afternoon. But even when he's not working out, he's thinking about wrestling, replaying matches in his head, watching videotapes to improve his technique, visualizing his next contest, and training his body to drop weight—usually about 10 pounds, shed over four days—before the next meet.

Growing up in Hawaii as the youngest of three boys, Travis started wrestling as soon as he could chase his brothers around the house. "Obviously, my parents weren't too happy about us always getting into fights," he says, "but I think it helped me become a competitor." By 5 years old, Travis was channeling his aggression into judo, and by 12, he was good enough to become a junior national champion, but still too small to beat his brothers. So in eighth grade, he started wrestling competitively and hasn't stopped.

Drawn to Cornell by the dream of training with head coach Rob Koll, Lee arrived in town without a single piece of warm clothing. He braved that first mild winter, compiling a 33-9 record as a freshman, then topped it as a sophomore with a perfect 34-0, upsetting the favorite to win the NCAA championship at 125 pounds. For Lee, the surprise wasn't that he'd won, but how quickly he'd done it. "I always thought I would become a national champion," says Lee, "but I never expected to do it my second year."

Moving up to 133 pounds as a junior, Lee took a hard loss in the NCAA quarterfinals, but hasn't been surprised since. At his normal weight of 143, he's tight as a spring, speaking softly but radiating confidence. He's not sure if engineering has made him a better wrestler, but he knows wrestling has made him a better engineer.

"The hard work and determination that we take from wrestling allows us to pursue pretty much anything in life," says Lee. "We've been through so many hard workouts, and the coaches keep testing us to see how far we can go, pushing us to our limits. Being able to stay focused, to show that kind of determination, that persistence, is what helps push me through all the engineering work."

With the nationals behind him, Lee plans to concentrate on academics again and expects to stay at Cornell until he finishes his M.Eng. degree in May 2006. The extra year will give him a chance to keep working out with the team, retool his technique to fit the rules of amateur competition, and wrestle at his first international tournaments.

After that, the future is much less clear. He's enjoyed his major, especially the coursework in fluid mechanics and an internship last summer at Kionix, which he calls his "first full-blown research experience, finally getting to see where all this biology and chemistry come into play." But the dream of competing at the 2008 Olympics is much clearer than any sense of what he might do with his engineering degree. "Now that I don't have to worry about practice every day, life will be a lot less stressful," he says. "Going into the finals, I knew this was my last chance for another title. So winning meant a lot, but I always think I can do more. That's my mindset, and helps push me to the next level.

"I'm not sure where my interests are going to fall," he says, "but right now, I can focus on finishing school."

—Kenny Berkowitz

DANIELLE HOBEIKA

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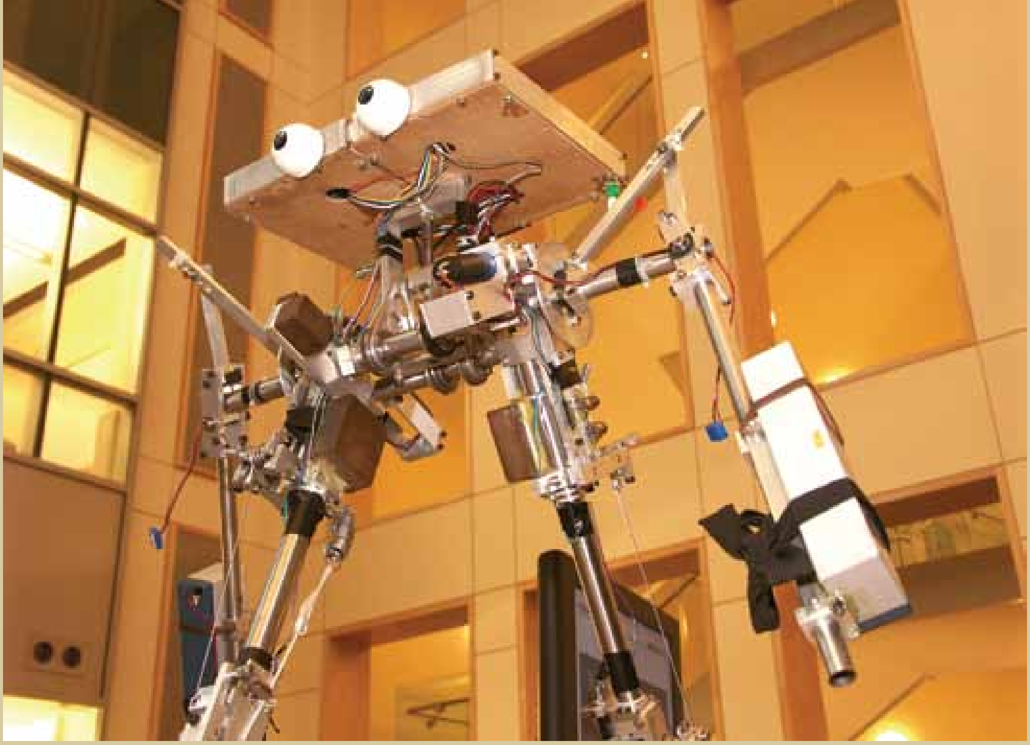

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