SPRING
12

ENG
CORNELL ENGINEERING
MAGAZINE

DUST IN THE WIND

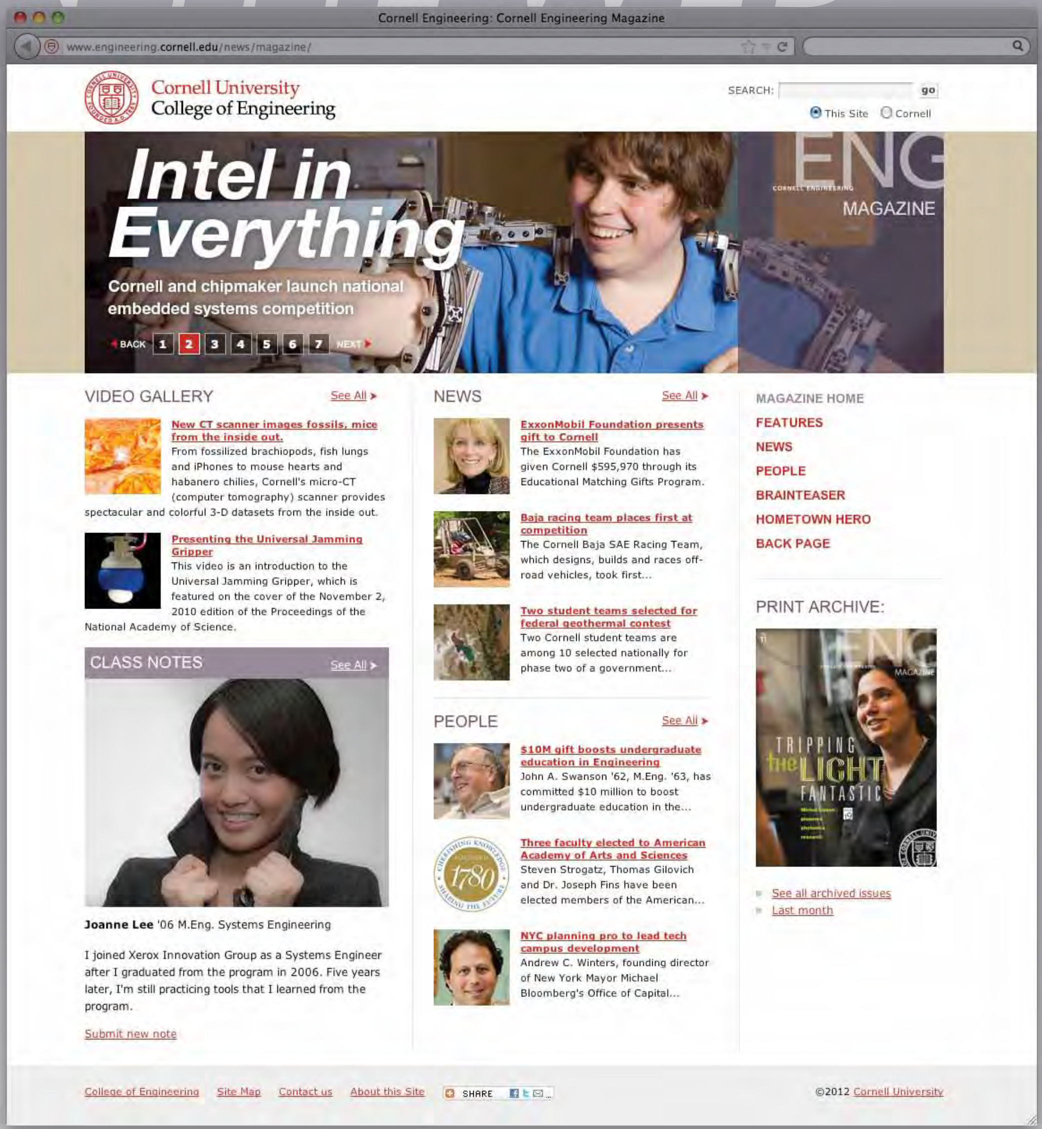
EAS Prof. Natalie Mahowald studies the complex impact of atmospheric aerosols on climate

PAGE 16

ENG
CORNELL ENGINEERING MAGAZINE

ON THE WEB

Cornell Engineering Magazine has a new Web site, with videos, Web extras, and the latest news. Come see what's happening in your old school or department, leave a Class Note to let your college friends know what you're up to, or sign up for digital delivery.



www.engineering.cornell.edu/magazine

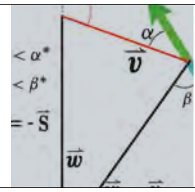
contents

DEPARTMENTS

CORNELL ENGINEERING MAGAZINE/SPRING 2012

2 NEWS

27 BRAINTEASER



28 PEOPLE

31 HOMETOWN HERO Matt Maxwell

Features

16 **Dust in the Wind:** EAS Prof. Natalie Mahowald studies the complex impact of atmospheric aerosols on climate.
By Lauren Cahoon

12 Life Achievements: Cornell at the frontier of biomolecular engineering from its very beginnings.
By Robert Emro

20 Intel in Everything: Cornell and chipmaker launch national embedded systems competition.
By Sherrie Negrea

24 Engineering Entrepreneurs: Three alumni entrepreneurs talk about going into business and the technical skills that helped them get there.
By Dan Tuohy

news

‘Game-changing’ tech campus goes to Cornell, Technion

CORNELL UNIVERSITY AND SKIDMORE, OWINGS, & MERRILL

CornellNYC Tech—Home of the Technion-Cornell Innovation Institute—is scheduled to break ground on New York City’s Roosevelt Island in early 2015. The first students will start in temporary off-site space in fall 2012.

The partnership with Technion-Israel Institute of Technology was announced the winner of a bid to build the groundbreaking new campus in New York City at a press conference Dec. 19.

New York City Mayor Michael Bloomberg said the “game-changing” project promises to spur economic growth, job creation, and high-tech entrepreneurship.

The announcement came just as Cornell announced a $350 million gift—later revealed to be from Chuck Feeney’s ’56 Atlantic Philanthropies—in support of the tech campus.

Congratulating the winners, Bloomberg invoked Cornell’s history as New York state’s land-grant university. With the promise of an 11-acre parcel on Roosevelt Island and $100 million in infrastructure improvements from the city, Bloomberg called the proposal a “new land grant” that will power economic growth.

“We believe this new land grant can help dreamers and entrepreneurs from around the world come to New York and help us become the world’s leading city for technological innovation,” Bloomberg said.

In the months since Cornell first announced its intention to win the bid, there was mounting evidence that it had support from many corners—a fact not unnoticed by the mayor and his staff. Deputy Mayor Bob Steel mused that of the approximately 50,000 New York area alumni, “most of them called me directly”; others sent him a book of 21,000 signatures petitioning for Cornell’s bid.

This groundswell was a large factor in Cornell’s success, noted Cornell Provost Kent Fuchs: “I think we were the only university that had unanimous support from the administration, faculty, staff, students, trustees, and alumni.”

Flanked by Cornell and Technion officials and by members of the New York City Economic Development Corp., politicians and Roosevelt Island representatives, Bloomberg waxed about why Cornell and Technion had emerged as the ideal choice for the plan.

The Cornell-Technion proposal, Bloomberg said, was the boldest and most ambitious, as it included an enrollment of 2,500 students, approximately 280 faculty and 2 million square feet of state-of-the-art classroom and research space. He talked about the dynamic partnership between Cornell and Technion. He praised Cornell’s established presence in New York City with its Weill Cornell Medical College, many academic and extension programs, and its active alumni base.

The campus is expected to generate $23 billion in economic activity over the next three decades, Bloomberg said, as well as $1.4 billion in tax revenue. Building it will create 20,000 construction jobs and 8,000 permanent jobs to operate it. These jobs, Bloomberg added, run the gamut from building staff to office workers—not just “people with Ph.D.s.”

The campus is also expected to generate nearly 600 spinoff companies over the projection period, which could create up to an additional 30,000 permanent jobs.

Finally, Bloomberg noted the aggressive schedule to which Cornell has pledged to get the campus up and running.

With “humility” and “gratitude,” President David Skorton described the win not as a “touchdown dance” for Cornell or Technion, but as a boon for New York City and a demonstration of the two institutions’ desire to serve the city’s high-tech future. With this “vote of confidence,” Skorton also pledged to work with K-12 schools, the CUNY and SUNY systems, and the city as a whole to make the partnership even more fruitful.

“This is not an exercise in exclusion or winning,” Skorton said, before wowing the crowd with a digital fly-through of the proposed campus rendering. “This is an exercise in inclusion and having all the ships rise in this fine city.”

Technion President Peretz Lavie spoke warmly of the partnership with Cornell and New York. “We are not going to have an extension of Cornell or Technion,” Lavie said. “We are going to have something new ... that will really energize this city.”

At a Feb. 3 open forum to answer questions, provide updates, and reiterate the transformative nature of the project for Cornell as a whole, Lance Collins, the Joseph Silbert Dean of Engineering, said Technion will bring additional expertise in entrepreneurship to the new venture.

“Their ability to take ideas and spin them out into working companies is legendary,” Collins said.

There’s work to be done at all levels, Fuchs told the forum, from acquiring academic accreditation, to hiring a principal designer and architect for the site, to structuring the entrepreneurship-oriented curricula, to hiring faculty and recruiting students—all while maintaining Cornell’s Ithaca campus and entering into key phases of the “Cornell Now” fundraising campaign.

The new campus is intended to be financially self-sufficient, Fuchs said. The $350 million gift from Atlantic Philanthropies will help the university immediately start recruiting and hiring new faculty to populate the campus. None of the Ithaca campus’s $2 billion operating budget is expected to be diverted to the new campus, Fuchs said (*continued on next page*)

A digital rendering of the proposed NYC tech campus on Roosevelt Island. If built today, the campus’s 150,000-square-foot core academic building would be the largest net-zero energy building in the eastern United States and among the top four largest such buildings in the United States.

CORNELL UNIVERSITY AND SKIDMORE, OWINGS, & MERRILL

Multiple spaces are connected and designed around facilitating idea creation. All public spaces are designed with the understanding that many of the most innovative ideas are a result of chance encounters.

The green roof system will capture and retain up to 80 percent of rainwater, provide insulation, sustain plant life and the natural habitat, and reduce cooling loads and the heat island effect.

CORNELL UNIVERSITY AND SKIDMORE, OWINGS, & MERRILL

Technion-Cornell Innovation Institute brings a number of initiatives to Roosevelt Island.

From creating the next generation of high-tech entrepreneurs to exemplifying the highest standards of sustainable building, the CornellNYC Tech—Home of the Technion-Cornell Innovation Institute will bring a number of transformative initiatives to Roosevelt Island.

Hubs: The campus will be organized initially around three interdisciplinary hubs — Connective Media, Healthier Life and the Built Environment — meant to encapsulate a wide range of disciplines and designed to evolve over time. The school will immediately offer master’s and doctoral degrees in such areas as computer science, electrical and computer engineering, and information science and engineering. After receiving required accreditation, the campus will offer Technion-Cornell dual Master of Applied Sciences degrees.

Green: The campus will be a living laboratory of green building and reduced energy use. Its main educational building, which will be LEED Platinum certified, is planned to be “net-zero energy”—harvesting as much energy from the site as it consumes. A solar array will generate 1.8 megawatts at daily peak. A four-acre geothermal well field will exceed any current geothermal heating system in the city.

Buildout: The completed campus will encompass 2 million square feet that includes housing for up to 2,500 students and approximately 280 faculty members by 2043.

CORRECTION:
In “Hola from Santander” in the Fall 2011 issue, our graphic designer drew inspiration from the flag of the Department of Santander in Colombia, rather than the flag of the city of Santander in, Spain, where the Universidad de Cantabria is located. We regret the error.

Santander, Columbia

Santander, Cantabria, Spain

ENG
CORNELL ENGINEERING MAGAZINE

ISSN 1081-3977
Volume 17, Number 2
Fall 2011

Cornell Engineering Magazine is published by the Cornell University College of Engineering

Dean
Lance Collins
Joseph Silbert Dean of Engineering

Executive Editor
Dawn S. McWilliams
Director
Engineering Marketing and Communications

Editor
Robert B. Emro
Assistant Director
Engineering Marketing and Communications

Art Director
Todd Edmonds
Creative Director/CEO
irondesign.com

Graphic Designer
Louis Johnson
Senior Designer
irondesign.com

Printer
Cayuga Press
Cortland, N.Y.

Photography
All photos by University Photography unless otherwise indicated

Editorial and Business Offices
247 Carpenter Hall
Ithaca, NY 14853-2201
phone 607 255-3981
fax 607 255-9606
e-mail cornell_engr_mag@cornell.edu

Visit *Cornell Engineering Magazine* online at www.engineering.cornell.edu/magazine

09/11 ML 40M 100196

Fuchs went on to predict that having the tech campus in New York City will create a symbiotic flow of people and ideas that will end up attracting people—and philanthropy—to Cornell in Ithaca, not just New York City.

"It elevates the visibility of Ithaca as a city and Tompkins County and all of this environment we love, and puts us on a worldwide stage that we've never had before as a community," Fuchs said. He noted, for example, the inaugural tech startup fair held in Ithaca Feb. 1; more than a thousand attended, probably due in large part to the tech campus bid.

Dan Huttenlocher, dean of computing and information science, who was later named vice provost and dean of CornellNYC Tech, said he and Collins are engaging with faculty members to commence academic planning for the new campus. As soon as accreditations and approvals are in place, students will start being admitted to specific degree programs, initially professional master's degrees in select fields that are core to the new campus.

Until approximately the end of March, the leadership team planned to "take a step back" and engage many people in the process of ironing out the details of bringing the campus from idea to reality, said Cathy Dove, associate dean of administration in the College of Engineering, who was later named vice president of CornellNYC Tech. Fuchs added that an email address—cornellnyc@cornell.edu—was being created through which people can ask questions or make suggestions about anything from aesthetics to programming.

The year 2012 will bring work on environmental reviews of the site, master planning and opening a satellite campus in leased space, which is to be occupied by current Ithaca-based students.

Fuchs shared some rough dates: Cornell expects to sign the official lease for the site in December 2013. January 2014 will see demolition of Goldwater Hospital, which currently occupies the future campus site. Phase I construction will commence in early 2015 and is scheduled to open in 2017.

—*Anne Ju*

Eighth student-designed water plant rises in Honduran town

Atima, HONDURAS—This spring, nearly every home in this modest Honduras hilltop town will have safe, clean drinking water, thanks to a water treatment plant principally designed by Cornell Engineering students.

The Atima plant, under construction, is the eighth project of AguaClara, Cornell's internationally recognized small-scale water treatment design team that has been working since 2005 in Honduras, where 60 percent to 70 percent of people do not have access to clean water. So far, AguaClara plants serve some 25,000 people.

Sixteen AguaClara team members, mostly undergraduate civil engineering students, visited the Atima construction site as part of an exhaustive two-week excursion Jan. 6-20 across Honduras with their leader, Monroe Weber-Shirk, senior lecturer in civil and environmental engineering. It was the seventh such adventure for AguaClara; the winter break trip is considered an integral part of the students' connection with their work and their ability to experience the political and social aspects of implementing water plants.

Students see so much of the computer software engineering they use for design that "it's interesting to see an actual physical process going on," said Tori Klug '14. "It's also really good we're forming relationships with everyone down here."

AguaClara's longstanding partner is Agua Para el Pueblo (APP), a Honduran nonprofit organization that offers technical expertise and education to help municipalities implement water treatment systems.

This year's AguaClara team visited working plants, plants in process and future plant sites, such as one in early design phases in the town of San Nicolas.

A previous generation of AguaClara students invented an automated design tool that has greatly increased the efficiency with which students can generate basic designs for new plants. Improvements are constantly being made on the tool, and Weber-Shirk says it is a key reason why AguaClara plants can be scaled to fit individual communities.

On site, the students can deal with many unknowns, many of which cannot be solved from Ithaca.

"Every plant is different, and the terrain is always different," said Annie Newcomb '13.

ANNE JU/CORNELL CHRONICLE

AguaClara students visiting Honduras Jan. 6–20 toured existing water plants and helped improve others, including one in Marcala, where they installed a new inlet manifold. From left, AguaClara faculty leader Monroe Weber-Shirk; Jordanna Kendrot, M.Eng. '12; Breann Liebermann '14; and Patrick Farnham, M.Eng. '11.

In Honduras, the students also get to see the politics, fundraising and technical challenges that sometimes derail projects. But Weber-Shirk maintains AguaClara's plans for scalability, cost reduction and expansion are on the right track.

"Every one of the AguaClara facilities continues to provide safe drinking water," he said. "This is an amazing accomplishment in a world of failed development projects."

That AguaClara works so well is due to its partners on the ground. Antonio Elvir, APP's social and education coordinator for AguaClara projects, is the students' key liaison with Honduran communities.

Also, for the past several years, Sarah Long '09; Jeff Will '10, M.Eng. '11; Dan Smith '06 and others have moved to Honduras to work as AguaClara engineers, serving as advisers between APP and Cornell.

In Ithaca this semester, Klug and Newcomb are designing a more efficient, unified chemical dosing system for future plants to allow plant operators to be more precise in knowing how much chlorine to add to the water.

The system would build on AguaClara's innovative chemical dose controller, an automated tool that adds coagulant at a consistent rate, without the use of motors or electricity, as the water enters the plant.

And Jordanna Kendrot, M.Eng. '12, is working on improving the dose controller, which has proven tricky to get just right. Hopefully, an upgrade would allow completed plants to easily retrofit their equipment to more accurately and consistently apply coagulant.

—*Anne Ju*

Now you see it, now you didn't: Cloaking a moment in time

In movie magic, people and objects can appear or disappear or move from place to place in an instant. Just stop the camera, move things around and start it again. Now, Cornell researchers have demonstrated a similar "temporal cloak"—albeit on a very small scale—in the transport of information by a beam of light.

The trick is to create a gap in the beam of light, have the hidden event occur as the gap goes by and then stitch the beam back together. Alexander Gaeta, professor of applied and engineering physics, and colleagues report their work in the Jan. 5 issue of the journal *Nature*.

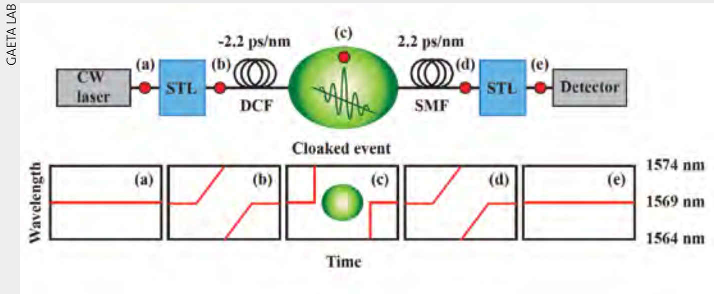
The researchers created what they call a time lens, which can manipulate and focus signals in time, analogous to the way a glass lens focuses light in space. They use a technique called four-wave mixing, in which two beams of light, a "signal" and a "pump," are sent together through an optical fiber. The two beams interact and change the wavelength of the signal. To begin creating a time gap, the researchers first bump the wavelength of the signal up, then by flipping the wavelength of the pump beam, bump it down.

The beam then passes through another, very long, stretch of optical fiber. Light passing through a transparent material is slowed down just a bit, and how much it is slowed varies with the wavelength. So the lower wavelength pulls ahead of the higher, leaving a gap, like the hare pulling ahead of the tortoise. During the gap the experimenters introduced a brief flash of light at a still higher wavelength that would cause a glitch in the beam coming out the other end.

Then the split beam passes through more optical fiber with a different composition, engineered to slow lower wavelengths more than higher. The higher wavelength signal now catches up with the lower, closing the gap. The hare is plodding through mud, but the tortoise is good at that and catches up. Finally, another four-wave mixer brings both parts back to the original wavelength, and the beam emerges with no trace that there ever was a gap, and no evidence of the intruding signal.

None of this will let you steal the crown jewels without anyone noticing. The gap created in the experiment was 15 picoseconds long, and might be increased up to 10 nanoseconds, Gaeta said. But the technique could have applications in fiber-optic data transmission and data processing, he added. For example, it might allow inserting an emergency signal without interrupting the main data stream, or multitasking operations in a photonic computer, where light beams on a chip replace wires.

The experiment was inspired, Gaeta said, by a theoretical proposal for a space-time cloak or "history editor" published by Martin McCall, professor of physics at Imperial College in London, in the *Journal of Optics* in November 2010.



GAETA LAB

A laser beam passes through a "split-time lens"—a specially designed waveguide that bumps up the wavelength for a while then suddenly bumps it down. The signal then passes through a filter that slows down the higher-wavelength part of the signal, creating a gap in which the cloaked event takes place. A second filter works in the opposite way from the first, letting the lower wavelength catch up, and a final split-time lens brings the beam back to the original wavelength, leaving no trace of what happened during the gap.

"But his method required an optical response from a material that does not exist," Gaeta said. "Now we've done it in one spatial dimension. Extending it to two [that is, hiding a moment in an entire scene] is not out of the realm of possibility. All advances have to start from somewhere."

The research was funded by the Defense Advanced Research Project Agency and by Cornell's Center for Nanoscale Systems, which is supported by the National Science Foundation and the New York State Division of Science, Technology and Innovation (NYSTAR).

—*Bill Steele*

Grad student Allessandro Farsi

Alexander Gaeta

PROVIDED

Time cloaking doesn't involve a DeLorean, just a kilometer of optical fiber coiled up on a lab table, supervised by postdoc Moti Fridman and research associate Yoshi Okawachi.

Biosensor may improve disease detection, water monitoring

A quick, inexpensive and highly sensitive test that identifies disease markers or other molecules in low-concentration solutions could be the result of a Cornell-developed nanomechanical biosensor, which could potentially help with early stage disease detection.

The biosensor, based on a photonic crystal nanowire array, was developed by Yuerui Lu, a graduate student in the lab of Amit Lal, professor of electrical and computer engineering. Their research was published online Dec. 6 in the journal *Nature Communications*.

The sensor's operation was confirmed in collaboration with Dan Luo, professor of biological and environmental engineering, and his graduate student Songming Peng.

The experimental device is a mechanical resonator 50 microns in diameter made of a thin silicon-silicon dioxide membrane with ordered, tightly packed vertical nanowires on top. The design achieves a high surface-to-volume ratio for biomolecule detection, which means it can detect molecules at very low—down to femtomolar—concentrations. The sensor could be useful, for example, for finding just a few molecules in a glass of water.

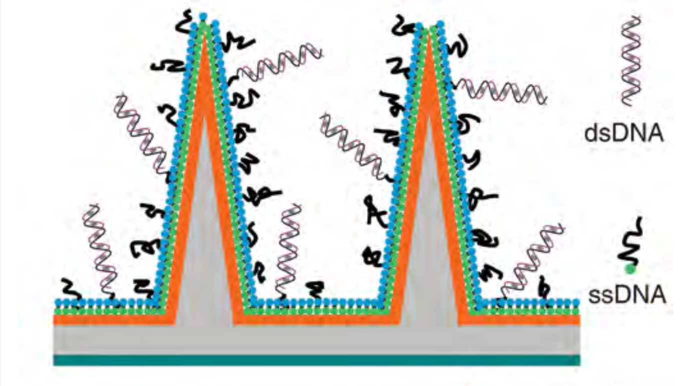
The sensor works by attaching single-stranded probe DNA molecules onto the nanowires. When those molecules come into contact with a target single-stranded DNA, the relevant molecules bind together, changing the mass detected by the device. The mass change causes a change in the resonance frequency of the device.

A laser beam is shined on the device, and the nanowires' innovative design allows for more than 90 percent absorption of the light, resulting in an efficient opto-thermo-mechanical excitation of the resonator. An optical readout of the resonance frequency change can be accomplished remotely, quickly and free of electrical wires, making the device convenient and inexpensive to make, the researchers said.

Lal said he imagines doctors could use such a device in clinical analysis, for example, in DNA testing. Typically today, DNA in drawn blood is compared against a standard sequence.

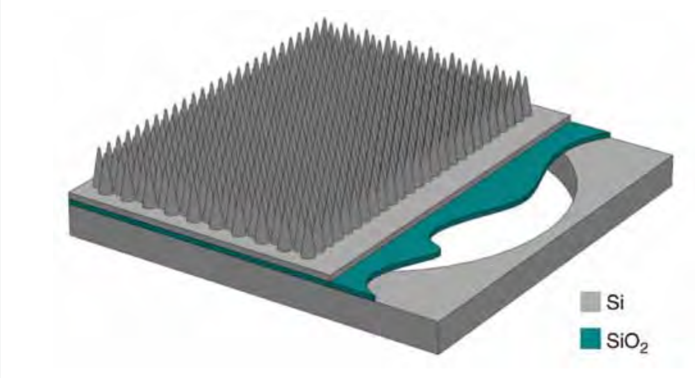
The new device could instead be coded with particular DNA sequences of relevance, and those specific molecules could be detected in early stages when concentrations are low.

"You could have a cartridge with an array of the membrane sensors, and you could quickly scan to see what DNA imperfection you might have," he said. "Today's tests take time and are expensive."



YUERUI LU

A drawing of how single-stranded DNA is immobilized and hybridized on the sensor.



YUERUI LU

A schematic drawing of the biosensor, which consists of ordered nanowires on top of a silicon-silicon dioxide membrane.

Such sensors could also be useful for environmental applications, such as water quality monitoring. The researchers hope to improve their device by making it sensitive to certain protein molecules, which are trickier because they do not bind as specifically as DNA molecules do.

The research was funded by the Defense Advanced Research Projects Agency Microsystems Technology Office.

—Anne Ju

Undergrad synthetic biology team takes a top prize at world championship

With today's most pressing problems ranging from the environment to health care, it's clear that life scientists and engineers need to work together. A Cornell undergraduate project team, only three years old but already winning international accolades, is getting in at the ground floor.

CU GEM (Cornell University Genetically Engineered Machines), a mostly undergraduate, highly interdisciplinary project team that started in 2008, achieved its highest honor yet at the iGEM 2011 World Championship Jamboree, Nov. 5-7.

Presenting their tested and working "Biofactory"—a series of microfluidic chips that use a biosynthetic pathway to produce a useful chemical—the students beat out 120 other teams to take the "Best Manufacturing Project" prize. CU GEM had previously won a gold medal at the iGEM Americas regional competition in October, catapulting them among 60 others to the worlds.

"At Cornell, our goal is to foster future leaders," said Xiling Shen, assistant professor of electrical and computer engineering and team adviser. "We are not trying to have research superhumans who can do it all, but to learn how to harness other people's expertise."

The nature of CU GEM's successful BioFactory project says it all. The goal of the project involved molecular biology, chemistry and chemical engineering—using a known biosynthetic pathway to convert tryptophan into prodeoxyviolacein, a useful precursor to some biopharmaceuticals. The device, an array of chips etched with microfluidic channels and lined with modified enzymes that act as a linear biochemical pathway, was made in the Cornell nanofabrication facility by electrical, mechanical engineering and materials science students.

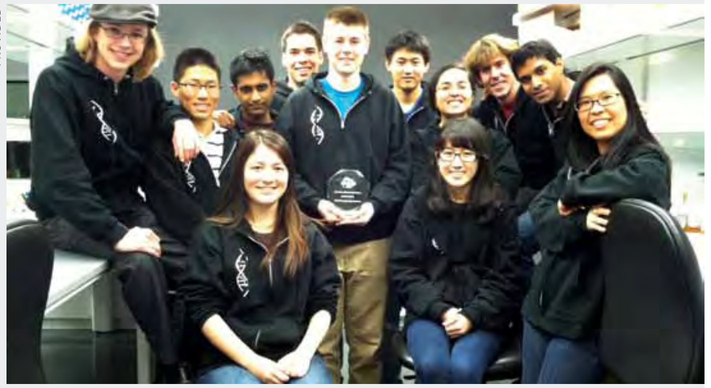
"We're interested in developing biopharmaceuticals inside of cells," said team leader Jim Mathew '14, a chemical engineering major. "But sometimes you have a lack of reactor control when working with cells, and it's hard to get a final chemical output."

CU GEM's microfluidic reactors are a scalable, cell-free method for producing complex biomolecules, which could reduce unwanted side reactions and ultimately lead to a lower-cost method of production, Mathew said.

Virtually every area of engineering, chemistry and biology were tapped in order to make the project successful—including mass spectrometry data to confirm their results.

"The judges said they were especially impressed with how we tied everything together," said Malinka Walaliyadde '12, senior undergraduate adviser.

PROVIDED



The 2011 CU GEM team with their world championship award.

The projects were scrutinized on technical details as well as ethical considerations. Teams were also judged by their commitment to outreach and helping public school students, for example, gain access to science. In its short duration, CU GEM has hosted outreach events at both the Ithaca Sciencenter and at Cornell's CURIE Academy, and has already sprouted an alumni network.

Shen also pointed out that Cornell's relatively young team beat out more established teams from other top institutions. They were one of the few who came with an entire working system, rather than staying on a conceptual level.

The team's interdisciplinary nature is evidenced through its growing list of sponsors: The College of Engineering, Department of Electrical and Computer Engineering, Weill Institute for Cell and Molecular Biology, Cornell Institute for Biotechnology and Life Sciences, and Cornell NanoScale Science and Technology Facility. They have also garnered corporate sponsorship from Corning Inc., New England Biolabs, Integrated DNA Technologies and Modo.

CU GEM is breaking into a relatively new field called synthetic biology, said Shen, who teaches the course Introduction to Systems and Synthetic Biology, which has doubled as a recruiting ground for CU GEM.

The team hopes to pique the interest of freshmen and sophomores especially. Their next information session will be Dec. 3, 3-4 p.m. in 120 Physical Sciences Building.

—Anne Ju

Device will quickly detect pathogens

Two Cornell professors will combine their inventions to develop a handheld pathogen detector that will give health care workers in the developing world speedy results to identify in the field such pathogens as tuberculosis, chlamydia, gonorrhea, and HIV.

Using synthetic DNA, Dan Luo, professor of biological and environmental engineering, has devised a method of "amplifying" very small samples of pathogen DNA, RNA, or proteins. Edwin Kan, professor of electrical and computer engineering, has designed a computer chip that quickly responds to the amplified samples targeted by Luo's method. They will combine these to make a handheld device, usable under harsh field conditions, that can report in about 30 minutes what would ordinarily require transporting samples to a laboratory and waiting days for results.

The work will be supported by the Bill & Melinda Gates Foundation as part of the Grand Challenge program to develop "point-of-care diagnostics" for developing countries. The foundation has distributed $25 million to 12 teams, selected from more than 700 applicants. Various teams are working on different aspects of the technology, and eventually their work will be integrated to make a practical, low-cost testing kit, Luo said.

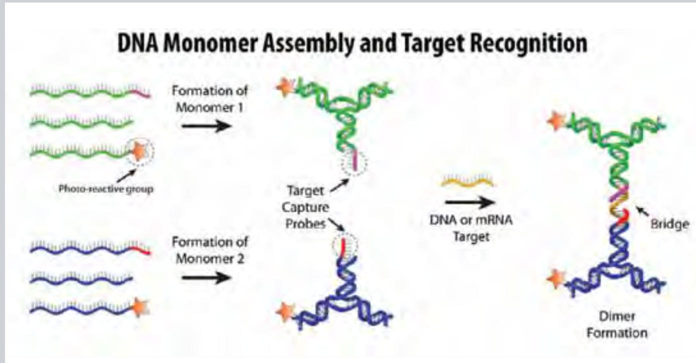
Luo's research group has found that DNA can be used like molecular-level Lego blocks. A single strand of DNA will lock onto another single strand that has a complementary genetic code. By synthesizing DNA strands that match over just part of their length, his team can assemble unusual shapes—in this case, a Y. Attached to the base of the Y is a DNA strand or antibody designed to lock onto a pathogen. Attached to one of the upper arms is a molecule that will polymerize—chain up with other similar molecules—when exposed to ultraviolet light.

When a pathogen is added to a solution of these Y-DNA molecules, the matching receptors on the stem of the Y will lock onto pathogen molecules, but only onto part of them; the mix will contain two different Y-structures, each tagged to lock onto a different part of the pathogen molecule. The result, when the targeted pathogen is present, is the formation of many double-Ys linked together by a pathogen molecule, each assembly carrying two molecules capable of polymerizing.

When the mixture is exposed to a portable ultraviolet light, the polymer molecules at the ends of each double-Y link to those on other double-Ys, forming long chains that clump up into larger masses. This polymerization won't happen, the researchers emphasize, unless a targeted pathogen is present to link two Ys together. A single Y with only one polymer molecule attached can only link to one other single Y, and no chain will form.

Kan's new chip measures both the mass and charge of molecules that fall on it. The large clumps of Y-DNA have a much larger mass and charge than single molecules, and trigger the detector. The chip uses the popular and inexpensive CMOS technology compatible with other common electronic devices. A detector might, for example, be controlled and powered by a mobile phone, Luo suggested.

All this can be combined with nanofluidics to make a robust battery-operated testing kit, the researchers said. After further development they plan to conduct tests simulating field conditions in the developing world. Along with surviving hot or cold weather, Luo said, "It has to work in dirty water."



To "amplify" a pathogen sample, two different Y-shaped DNA structures are used, each one designed to lock onto a different part of the target molecule. When two Y's are linked, polymer molecules attached to the ends of the double-Y can chain together to form a large, easily detected clump.

Structured English brings robots closer to everyday users

Move over, Jetsons. A humanoid robot named Mae is traipsing around Cornell's Autonomous Systems Lab, guided by plain-English instructions and sometimes even appearing to get frustrated.

Mae understands and executes English commands, thanks to algorithms and a software toolkit called Linear Temporal Logic Mission Planning (LTLMoP) being developed in the lab of Hadas Kress-Gazit, assistant professor of mechanical and aerospace engineering.

According to Kress-Gazit, the future of robotics is in the ability of robots to easily understand everyday users and to act reliably in different situations.

"The big picture is that we want to have anybody tell the robot what to do," explained Kress-Gazit, who studies how to create provably correct, high-level behaviors for robots. "You don't want to have a programmer who's been doing the job forever to have to write the code for every single behavior, as is currently done in the field. You want to take what someone said and automatically generate the code for the robot to successfully accomplish its task."

The LTLMoP toolkit combines logic, language and control algorithms. The group has demonstrated the algorithms by getting Mae, a 2-foot robot NAO humanoid made by Aldebaran Robotics, to simulate looking for missing items in a grocery store while also avoiding spills in the aisles. Depending on what she finds, the robot takes action based on the specifications that were given to her.

The "store" is located in the Rhodes Hall Autonomous Systems Lab. Mae knows how to react in certain situations—for example, if a "missing item" is encountered, she alerts a manager. If she sees a "spill," she'll avoid the area.

Traditionally, a controller for these relatively complex tasks requires specifically programming the robot to react in every conceivable state it may find itself in. This is the tedious and error-prone nature of robotics today, the researchers say. There's no guarantee that the code has accounted for every situation, and that it will work. There's also no guarantee the behavior is even possible.

For their work, the Cornell researchers are looking at how to provide explanations to the user when, for whatever reason, a task cannot be done. That kind of feedback from the robot does not exist in robotics today, Kress-Gazit says.

In LTLMoP, a high-level specification can be written in structured English. For example,


LINDSAY FRANCE/UNIVERSITY PHOTOGRAPHY

Mae demonstrates her understanding of structured-English commands during a demo in Rhodes Hall. Background from left, graduate students Vasu Raman, Jim Jing and Cameron Finucane stand with Hadas Kress-Gazit.

Mae is told to visit all the corners of the "store" and to look side to side while walking through the aisles. The commands can be written concisely because the robot understands breaking the store into "regions,"—and prepositional statements, such as "between" and conditional statements like "if … then."

"Instead of giving it a list of things to do in order, you give it a specification of the sort of behavior it should exhibit at all times," said graduate student Cameron Finucane, who works on the LTLMoP platform.

Kress-Gazit's research is supported by the National Science Foundation CAREER program and a Department of Defense Multidisciplinary University Research Initiative.
—*Anne Ju*


LINDSAY FRANCE/UNIVERSITY PHOTOGRAPHY

Hadas Kress-Gazit, assistant professor of mechanical and aerospace engineering.

NSF-funded project to test cloud computing for smart grid

A Cornell research team has received a four-year, $1.9 million grant from the National Science Foundation to develop a system for computation and information sharing when designing a "smart" electrical grid.

The team, led by principal investigator Lang Tong, the Irwin and Joan Jacobs Professor of Engineering, is exploring the computational aspects of how to manage the changing electrical grid, or so-called "smart grid," which is evolving due to a growing need to integrate renewable energy systems.

The team will study a cloud-computing architecture for scalable, consistent and secure operation of smart grids, and novel stochastic optimization techniques for future energy systems. Among their goals is to develop new software tools for cloud platforms.

The electric grid in the United States has evolved over a century from a series of small, independent, community-based systems to one of the largest and most complex cyber-physical systems in the world, according to the project team's proposal. The grid consists of thousands of generators and substations, linked by transmission and distribution networks. But these once-engineering marvels are being challenged by a worldwide effort to mitigate climate change by reducing carbon emissions, the proposal states.

"The fundamental question is, where should computation be done?" Tong said. "Locally, centrally, what are the types of information that need to be shared at different locations, can we make things consistent, and is cloud computing a viable platform for something like the smart grid?"

Cornell collaborators on the project are Bob Thomas, professor emeritus of electrical and computer engineering; Ken Birman, the N. Rama Rao Professor of Computer Science; and Tim Mount, professor of applied economics and management. The team also includes collaborators from the University of California-Berkeley and Georgia State University.
—*Anne Ju*

Graphene to propel mechanical device technology forward

Graphene is sort of a scientific rock star, with countless groups studying its amazing electrical properties and tensile strength and dreaming up applications ranging from flat-panel screens to elevators in space.

The single-layer carbon sheets' stellar qualities are only just being understood in all their capacities, say scientists at Cornell—and researchers can dream big (or rather, very small) when it comes to everything graphene can offer.

That's what scientists in the lab of Harold Craighead, the Charles W. Lake Professor of Engineering, say in an American Vacuum Society online review article, Sept. 9, about graphene's present and future. The article made the cover of the printed journal and quickly became one of its most-downloaded pieces.

"It's becoming clear that with modern fabrication techniques, you can imagine turning graphene into a technology," said Robert A. Barton, graduate student and lead author. "People often focus on the electronic applications of graphene, and they don't really think as much of its mechanical applications."

It's precisely this area where Cornell has produced some pioneering work. In particular the Craighead group, in collaboration with others including Jiwoong Park, assistant professor of chemistry and chemical biology, and Paul McEuen, the Goldwin Smith Professor of Physics, has used graphene in nanoelectromechanical systems (NEMS), analogous to an earlier generation's microelectromechanical systems (MEMS).

"We've moved beyond working with little exfoliated flakes and more with grown materials that can be incorporated and connected with electronics and other mechanics," Craighead said. "So the question is, can you make these reliably, uniformly and reproducibly?"

It was only a few years ago that scientists figured out how to make arrays of hundreds of thousands of graphene devices using a process called chemical vapor deposition. This involves growing the single-layer sheets of honeycomb-latticed carbon atoms on top of copper, then manipulating the graphene to make devices.

One of the Cornell researchers' devices is like a drum head—a piece of graphene, one atom thick, suspended over a hollow well. Although growth of graphene by chemical vapor deposition on copper was invented elsewhere, Cornell researchers were the first to figure out how to make mechanical resonators from the large-area material.

"Four years ago we were able to make about one, and that took several months," Barton said. Speeding up the fabrication process has greatly increased graphene's potential in devices.

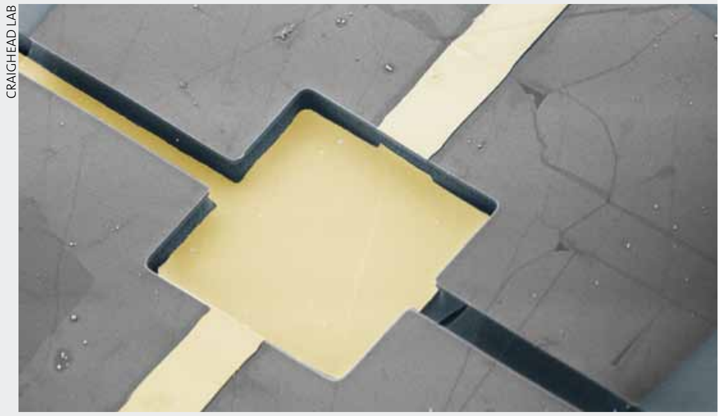
At Cornell, Barton and colleagues are working on making mass sensors out of graphene, which is atomically structured so it's sensitive to both mass and electric charge. What can result is that a bit of mass landing on a surface of suspended graphene will perturb the mechanical and electronic structure simultaneously, analogous to today's mass spectrometry but on a much smaller and more sensitive level, Barton explained.

The Cornell researchers are using optical interferometry to monitor the motion of a sheet of graphene. In this technique, the subtle device motions are read as variations in reflected light intensity, which are monitored by a fast photodiode connected to a spectrum analyzer. Another group at Cornell, led by McEuen, had earlier developed a way to "read out" carbon nanotubes, a technique that can also apply to graphene, Barton said.

The rapid progress of graphene makes its future very exciting, Craighead said.

"Graphene has gone from an oddity in a physics lab to something that can be practically incorporated into a variety of potential devices," he said. "The ability to fabricate things in these ways, to integrate them and to use them for different types of sensors, physical and chemical, is quite a step forward in a short time, and our group is one of the many that's contributed to this."

The authors' work is supported by the National Science Foundation.
—Anne Ju


CRAIGHEAD LAB

A false-color microscopy image of a 30-by-30 micron square of graphene covering a square trench to form a nanomechanical resonator. These devices, which are the thinnest possible microelectromechanical systems and are useful for sensing and signal processing, can now be batch-fabricated as a result of recent advances in graphene fabrication technology.

Campus researchers get a private cloud

Suppose you need just a little bit of computing power for a long time or a huge amount for a short period. Neither situation makes it worthwhile to buy and maintain your own server.

So the Cornell Center for Advanced Computing (CAC) has launched Red Cloud, an on-demand research computing service available by subscription.

Two Red Cloud services are available. The basic offering provides root access to virtual servers and virtual disks on Dell PowerEdge C servers with 50GB of storage. Red Cloud subscriptions provide fast access to data via 10Gb Ethernet in and out of the cloud at no additional charge.

The second offering, "Red Cloud with MATLAB," allows subscribers to run the MATLAB numerical computing environment and its graphical extension Simulink on a computer cluster. The Red Cloud environment for MATLAB includes NVIDIA graphics processing units for improved performance. Subscribers program applications on their desktops using their licensed copy of Parallel Computing Toolbox, then scale up to Red Cloud with MATLAB.

Red Cloud services are also available to researchers at other academic institutions. Industry can access Red Cloud through CAC's corporate program.

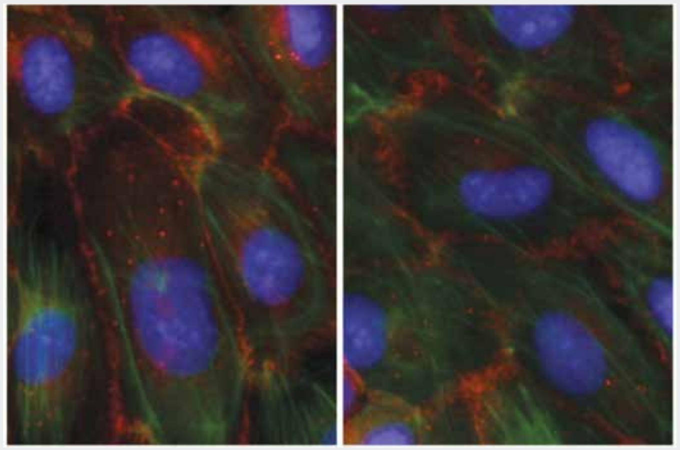
"Cloud computing has the potential to advance U.S. research discoveries and better prepare students for STEM careers by making computing, software and data resources more readily available at an economy of scale," said CAC Director David Lifka.

To learn more visit http://www.cac.cornell.edu/redcloud.
—*Bill Steele*

news

Study may lead to drug therapies to prevent atherosclerosis

JOHN HUYNH AND CYNTHIA REINHART-KING



Endothelial cells on biomaterial substrates, where the nuclei are blue, the actin cytoskeleton is green and the cell-cell junctions are red. On the left is a mimc of a younger vessel in which the cell-cell junctions are narrower, evidenced by crisper red lines. On the right is a mimic of an older, stiffer vessel where the cell-cell junctions are wider, evidenced by more jagged red lines.

As inevitable as the wrinkling of skin with age is the hardening of the blood vessels—a condition called atherosclerosis that is often blamed for heart disease.

New Cornell research offers a clue into the underlying causes of atherosclerosis in terms of how the cells that line the blood vessels, called endothelial cells, behave as the vessels stiffen with age. The researchers hope these insights could lead to more targeted drug therapies for the prevention of atherosclerosis.

"One of the things we wanted to do was understand how aging is linked to atherosclerosis, and how the mechanism of vessel stiffening plays into this link," said Cynthia Reinhart-King, assistant professor of biomedical engineering and lead author of the *Science Translational Medicine* study published online Dec. 7 and featured on the journal's cover that week.

The researchers showed that by changing the behavior of endothelial cells in the hardened vessel, without making the vessel any less stiff, they could reduce the effects of aging on vessel health. In other words, they could dull the vessels' inflammatory response to stiffening by, in essence, tricking the cells in the blood vessels into thinking the vessels were not stiff.

Atherosclerosis starts when excess cholesterol gets trapped underneath blood vessel walls, setting off an inflammatory response. The endothelial cells recruit white blood cells to the site to digest the cholesterol; both then get trapped in the area, forming plaques that clog the vessels.

A class of medications called statins (e.g., Lipitor and Crestor) work by changing how the liver metabolizes cholesterol and lowering the total amount of LDL cholesterol in the blood. The drugs are effective, Reinhart-King said, but they have side effects, and they seem to be most effective in patients who already have atherosclerosis and not as a preventative treatment.

"[But] if you just prevent the cholesterol from getting under the vessel wall to begin with, you stop the whole process," Reinhart-King said.

Her team focused on how cholesterol gets trapped. As the vessel stiffens, the endothelial cells tend to pull apart from each other, creating gaps through which cholesterol can leak and lead to plaque buildup. The researchers found that just by tuning the stiffness of the vessels, they could change how tightly bound the endothelial cells were to each other.

They did experiments by making "vessels" of varying stiffness out of a commonly used biomaterial. They tuned the stiffness of each biomaterial to exactly mimic the stiffness of vessels at various states of aging, and they seeded them with endothelial cells to measure their permeability.

The molecules that regulate the pulling apart of the cells, or their contractility, include Rho and Rho-associated kinase (ROCK). When the cultured hydrogels were treated with a drug called Y-27632 (which has not yet reached clinical trials) that inhibits ROCK, the gaps between the cells tended to close, which prevented more plaque buildup.

As it turns out, statins like Lipitor and Crestor, while FDA-approved to lower cholesterol, also appear to inhibit ROCK, and so might benefit high-risk patients as demonstrated in the Cornell experiments. The researchers also hope that their discoveries could lead to better therapies for preventing atherosclerosis by counteracting the effects of vessel stiffening before they do irreversible damage.

The paper's first author is graduate student John Huynh, and the collaboration included Michael King, associate professor of biomedical engineering; Chris Schaffer, associate professor of biomedical engineering; and research associate Nozomi Nishimura, former graduate student Kuldeepsinh Rana, former M.Eng. student John Peloquin, graduate student Joseph Califano and former postdoctoral associate Christine Montague.

The research was supported by the American Heart Association, American Federation for Aging Research, National Institutes of Health and L'Oreal USA Fellowship for Women in Science.

—Anne Ju

JumpStart funds faculty-business collaborations

This semester, four small businesses will receive up to $5,000 in matching funds from the Cornell Center for Materials Research JumpStart program to develop and improve their products through collaborations with university scientists. The ultimate goal of the program, funded by Empire State Development's Division of Science, Technology and Innovation, is revenue growth and job creation. Participating companies may provide part of their matching funds in material and employee time as well as cash.

Three Cornell Engineering faculty are involved in the Spring semester projects.

Intrinsiq Materials Co. in Rochester will collaborate with Chris Ober, the F.N. Bard Professor of Metallurgical Engineering, to investigate using copper nanoparticles in low-cost print processable conductive inks for the electronics industry.

Rapid Cure Technologies Inc. in Syracuse will collaborate with Emmanuel Giannelis, the Walter R. Read Professor of Engineering, to transform a unique nanoparticle technology into a light-curable primer coating for use on plastics that will reduce energy consumption and solvent emissions.

Thalle Industries Inc. of Briarcliff Manor will collaborate with Kenneth Hover, professor of civil and environmental engineering, to develop a manufactured sand blend yielding a workability desired by concrete producers and turning a waste product into a resource.

In addition, NOHMs Technology Inc. in Ithaca will collaborate with Héctor Abruña, the E.M. Chamot Professor of Chemistry and Chemical Biology, to study the efficiency and reliability of advanced electrode and electrolyte materials for next-generation lithium-ion batteries.

Since its inception, 47 companies have benefited from the program.

Optofluidics could change energy field, say engineers

CELLANA

A bioreactor with an open pond like this one, which uses photosynthesis to make fuels, could be improved with the use of optofluidic technologies.

The ability to manipulate light and fluids on a single chip, broadly called "optofluidics," has led to such technologies as liquid-crystal displays and liquid-filled optical fibers for fast data transfer. Optofluidics is now also on the cusp of improving such green technologies as solar-powered bioreactors, say Cornell researchers.

The biggest challenge, says Cornell's David Erickson, associate professor of mechanical and aerospace engineering, is how to upscale optofluidic chips, which are built at nanometer scales, to deliver enough energy to make a difference. These challenges and opportunities are detailed in a *Nature Photonics Review* article by Erickson and two colleagues, published online Sept. 11.

"Over the last five years or so, we have developed many new technologies to precisely deliver light and fluids and biology to the same place at the same time," Erickson said. "It's these new tools that we want to apply to the area of energy."

For example, photobioreactors are large-scale systems that use microorganisms such as algae or cyanobacteria, to convert light and carbon dioxide into hydrocarbon fuels. Photobioreactors employ photosynthesis for energy conversion, and Erickson envisions using an optofluidic chip to optimize how light and chemicals are distributed in the reactor.

In such systems as open-air ponds that harvest algae and collect sunlight, the light is scattered haphazardly, and the top layer gets more exposure. Optofluidic technologies, such as plasmonic nanoparticles or photonic waveguides, could more directly target the microorganisms and lead to greater energy output.

Similarly, the paper also describes how optofluidic devices could be used to improve photocatalytic systems, in which light energy splits water into the components hydrogen and oxygen, or converts carbon dioxide and water into hydrocarbon fuels. Other applications include optofluidic chips in solar collectors.

Erickson authored the review with Demetri Psaltis of Ecole Polytechnique Federal Lausanne, Switzerland, and David Sinton of the University of Toronto. His research is supported by the Academic Venture Fund of Cornell's Atkinson Center for a Sustainable Future and the National Science Foundation. Erickson is also a member of the Kavli Institute at Cornell for Nanoscale Science.

—Anne Ju

Diversity Programs honored by President Obama

From left, Trey Waller, Rick Allmendinger, Sara Xayarath Hernández and Jami Joyner receive the 2011 Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring Dec. 12 in the Eisenhower Executive Office Building in Washington, D.C.

President Barack Obama cited Cornell's Diversity Programs in Engineering among the four individuals and four other organizations to receive the 2011 Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring. The announcement was made Nov. 15.

The mentors received their awards at a White House ceremony Dec. 12. The award recipients received $25,000 from the National Science Foundation to advance their mentoring efforts.

"Through their commitment to education and innovation, these individuals and organizations are playing a crucial role in the development of our 21st century workforce. Our nation owes them a debt of gratitude for helping ensure that America remains the global leader in science and engineering for years to come," said Obama.

Upon hearing the White House announcement, Lance Collins, dean of the College of Engineering, said: "Diversity Programs in Engineering has been a leader on the campus at all levels since its inception in 2004. I am delighted to hear that we have been selected as among the best in the nation. It's an incredible honor.

"The work Diversity Programs in Engineering is doing to build and sustain the pipeline of outstanding women and underrepresented minority students will impact our profession for decades to come. I could not be more pleased with their success," he said.

Rick Allmendinger, associate dean for diversity, faculty development and mentoring for the College of Engineering, said: "Here at Cornell, we see diversity as an opportunity, not an obligation. We have to leverage an increasingly diverse pipeline of students if the university—and the country—is to remain competitive, and as engineers we firmly believe that a diverse population leads to better, more creative solutions to the problems we face. If we are successful at building diversity, it will pay dividends for Cornell."

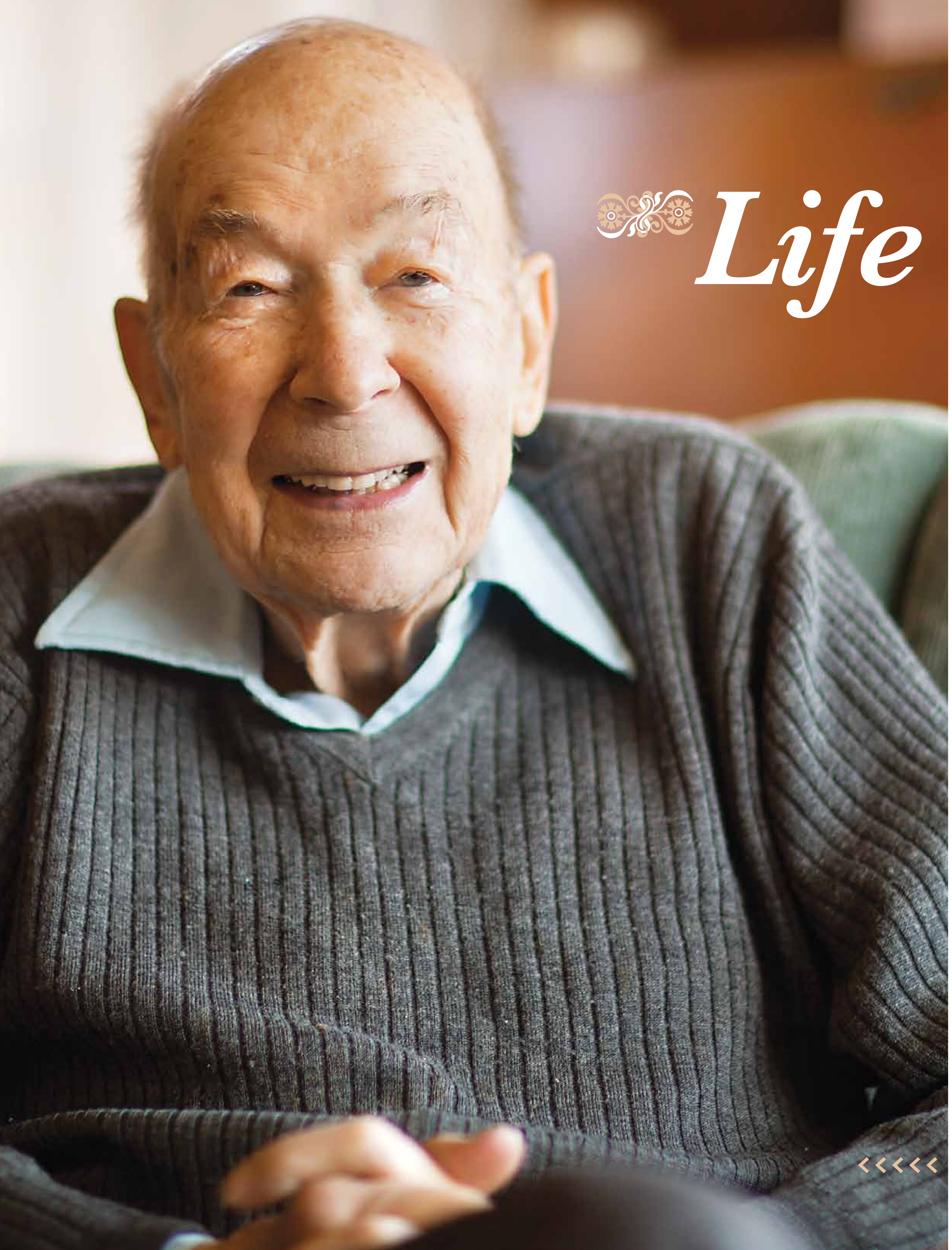
The Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring recognizes the crucial role that mentoring plays in the academic and personal development of students studying science and engineering—particularly those who belong to underrepresented groups in these fields. By offering their expertise and encouragement, mentors help prepare the next generation of scientists and engineers.

Sara Xayarath Hernández, director of Diversity Programs in Engineering, explains the importance of mentoring. "For science, technology, engineering and mathematics, engaging students from a diversity of backgrounds is a national imperative. At Cornell, we take that imperative seriously, and mentoring is an integral component of the solution."

Reinforcing diversity within the College of Engineering is a central priority at the undergraduate, graduate and faculty levels. The school strives to ensure that students of color, women and others historically underrepresented in engineering have the opportunity to realize their aspirations while also contributing their ideas, skills and talent.

Through various initiatives, Diversity Programs in Engineering is providing students with access to tiers of role models and mentors. High school students participating in engineering programs gain access to undergraduates and graduate student role models—a critical element to envisioning themselves as Cornell engineers. Said Hernandez: "Role models for our undergraduate and graduate students include other, more advanced students as well as faculty. Through our mentoring and other programs, we are helping our engineering students to define and fulfill their aspirations as well as to achieve success at Cornell and beyond."

—George Lowery



Life Achievements

CORNELL AT THE FRONTIER OF BIOMOLECULAR ENGINEERING FROM ITS VERY BEGINNINGS

By Robert Emro

WHEN EMERITUS PROFESSOR BOB FINN MATRICULATED AT CORNELL'S NEW SCHOOL of Chemical Engineering in 1937, developing a process for manufacturing a vitamin, drug, or enzyme usually involved finding its chemical structure and then figuring out how to synthesize it. But even then, the founding director of the school, F.H. "Dusty" Rhodes, had an inkling that there would be a growing role for engineers that knew some biology, and he let promising students, including Finn, substitute some microbiology courses for their chemical engineering requirements.

That background proved quite useful to Finn after he graduated in 1942 and went to work at Merck. The United States had recently entered World War II and the pharmaceutical company was part of an unprecedented collaboration between government, industry, and academia to quickly ramp up production of penicillin. The new drug, discovered by British researchers, had the potential to save millions of lives, but first it had to be mass-produced—from a mold grown in fermentation tanks.

It was the dawn of a new era in chemical engineering, one in which the production of biomolecules would increasingly be done by microorganisms, and later tissue cultures of living cells. "The world was turned upside down by antibiotics," says Finn. "It made true believers that there are some things that chemists cannot do. Living organisms can do it cheaper."

Finn was paired up with a microbiologist for the penicillin project. While his biology coursework at Cornell gave him a leg up on some of the other engineers, Merck still wouldn't let him near the fermentation tanks. "They knew we'd contaminate the whole doggone business," says Finn. "It was a touchy business in those days. It wasn't at all sure that anybody could so change the fermentation industry as to allow pure cultures of aerobic bacteria or molds or yeast."

Instead, Finn worked on purifying the "gunk" that was harvested from the tanks using liquid-liquid extraction. "You got this penicillin in a broth and you want a crystalline product in the end," he explains.

Merck was still working on the purification problem when Finn decided to enroll in graduate school at the University of Minnesota in 1946, where he minored in microbiology. "Most of us engineers at Merck realized that there were engineering problems in the fermentation," say Finn.

By the time Finn had his Ph.D., the Korean War had just ended and the U.S. economy was in recession, so he followed his professor who went to head the biology department at the University of Illinois. "I couldn't get a job in industry. I wanted to work; I wasn't planning to be a professor," says Finn. "I went down there and spent six years as assistant professor. And this is where I started teaching a course. We called it 'Biochemical Engineering.'"

At the time, Finn was one of just a handful of academic chemical engineers in the country doing this kind of work, but he soon had company. "Biotechnology was a brand new thing," he says. "All of a sudden we found out that, 'Hey,' these bugs could not only make penicillin and streptomycin, but they could make a whole lot of other products."

By 1955, Finn had investigated continuous fermentation techniques and was finishing up a critical review of aerations and agitation that was published in *Microbiological Reviews* when he got a call from Rhodes' successor, Chuck Winding.

Emeritus professor Bob Finn began his professional career at Cornell in 1955, marking the beginning of more than 50 years of continuous research in what would become known as biomolecular engineering.

> **The world was turned upside down by antibiotics. It made true believers that there are some things that chemists cannot do. Living organisms can do it cheaper.**
>
> BOB FINN

"He said to me, 'Would you like to come back to Cornell and be a teacher here?'" says Finn. "I accepted the job on the phone."

Finn's return marked the beginning of more than 50 years of continuous research at Cornell in what, with the discovery of DNA, would become known as biomolecular engineering. One area Finn explored was measuring the cell damage caused by aeration. "We made it more quantitative to characterize the shear damage that was caused by various types of impellers," he says. "That still is more of an art than a science. It's so complex."

Finn also branched off into waste treatment, especially chemical waste, developing a patented process for treating wastes low in nitrogen with bacteria that fix nitrogen from the atmosphere. "My process has been used in Belgium for this. It's used to treat certain types of food waste, even from the wine industry," he says. "You can discharge the whole thing; you don't have any sludge. It's a highly aerobic process for special waste."

On the hunt for useful microbes, Finn sampled soil all over campus. "We found some bacteria out here in Wee Stinky Creek by Barnes Hall," he recalls. "They would grow on methanol—wood alcohol—that's kinda poisonous to most things. They couldn't grow on anything else."

Finn wondered where these bacteria were finding methanol in dirt and thought of pectin, found in the skin of many fruits. It turned out that the bacteria made an enzyme that could release methanol from pectin methyl esterase. Finn found that these methanol bacteria made an interesting polymer, similar to xanthan gum, the product of another bacteria. Marketed commercially as Kelzan since 1968, the gum is used to thicken everything from salad dressing to concrete. Large quantities are used to fortify the drilling mud used to push the last recoverable oil from wells. Finn figured his biopolymer could be used the same way.

"You could have a fermentation out on the oil field and make your own stuff right on site and pump it down in. We're talking a lot of gallons," he says. "This would be a cheap way—because it wouldn't be so contaminated if all you added was mineral salts and methanol as your fermentation medium."

Cornell took out a patent and nearly licensed the technology but the deal fell through. While not all of his research was commercially successful—an earlier effort to scale up electrophoresis as a method of separation revealed that it could not work on Earth where gravity gives rise to natural convection currents—Finn's work continues to have relevance.

"He thought of a lot of problems and did a lot of things before they were ever really popular in the field. Twenty years later people came back and saw they were important," says Michael Shuler, who joined the School in 1974. "He was one of the first people that did work on shear sensitive cells in bioreactors. He did it with protozoa but it became extremely important when people wanted to use mammalian cells in culture. Bob's was the only prior work that anybody could look at."

Shuler, now the James M. and Marsha McCormick Chair of Biomedical Engineering and Samuel B. Eckert Professor of Chemical Engineering, came at a time when Finn—20 years into his career at Cornell—was starting to dabble in what he calls the "new kind" of biotechnology that followed the unraveling of DNA. Now instead of hunting for useful microbes, he could alter them to produce compounds more effectively, or even make completely new products. "He was one of the first ones that did what we call metabolic engineering," said Shuler. "Bob was a real pioneer in that area as well."

Shuler followed another new path, growing not independent microorganisms but plant cell tissues capable of producing useful biochemicals. Two of his students, Chris Prince Ph.D. '91 and Bobby Bringi '91 ChemE, formed Phyton Biotech to commercialize a process to produce Taxol, an important cancer drug that was first extracted from the bark of the Pacific Yew tree. "It was very scarce, so we developed a process that is based on using yew cells in culture and that process is used commercially by Bristol-Myers Squibb to make all its Taxol," says Shuler, who advised the company. "That was the first large-scale commercial process based on plant cell culture and it really came from the work and ideas that we developed here."

Shuler also collaborated with researchers at the Boyce Thompson Institute for Plant Research on using insect cell cultures to make therapeutic recombinant proteins. "There is a cell line which became very, very popular and was used extensively by a lot of people called the High-Five cell line," he says. "One of the things that's good about Cornell is you have such a diversity of people working on a wide variety of different topics, it's possible for someone in engineering to interact with people that have real expertise with other systems. The graduate field system kind of promotes that."

Over time, Shuler's interest turned toward biomedical engineering, such as treating brain tumors, investigating cancer metastasis through blood cells, and using the techniques of nanofabrication to build scaffolds for tissue engineering. "We've invented a body-on-a-chip which is to try to predict the response of the body to new drugs or combinations of drugs or potentially to chemicals which might be toxic," he says.

But the distinctions between biochemical, bioprocess, and biomedical engineering have blurred, says Shuler, in part because many of the same techniques are used. "If I'm interested in tissue engineering, I can use it in the context of making a chemical, testing how the body is going to respond to the chemical, or to potentially make replacement parts for the body. So it's a spectrum," he says. "The term biomolecular engineering really

Professor Michael Shuler followed another new path, growing not independent microorganisms but plant cell tissues capable of producing useful biochemicals.

says that what we're interested in is understanding the biology at the cellular and molecular level and then using that in terms of processes, typically involving chemical change, and those could be ones that have medical implications, or impacts on bioprocesses to make something like pharmaceuticals, or it could have an impact on things like waste water treatment."

As scientists fill in the picture of how molecules interact to perform the functions of life, engineers are manipulating them more rationally and effectively. For Associate Professor Matt DeLisa, cells are filled with useful molecular machines all with millions of moving parts known as proteins. By swapping in parts from other organisms, he is working to engineer supercharged cells that can produce treatments for Alzheimer's, cancer, and autoimmune diseases. "One of the most important types of therapeutic proteins that we have an eye toward making are glycoproteins," he says. "A glycoprotein, just like a regular protein, is made of amino acids but it's then further modified with complex sugar structures. These sugars are attached to many proteins and this attachment turns out to be very important in terms of drug development."

By inserting human genes into *E. coli*, DeLisa can give this simple organism the machinery to attach different sugars to proteins, giving them specific biological actions. He has co-founded Glycobia, Inc. to commercialize the process. "We bring in the entire protein machinery for sugar biosynthesis and attachment and give *E. coli* the ability to perform glycosylation, something it does not normally do," he says. "It's a very bottom-up engineering approach that is made possible by a deep understanding of the underlying biological mechanism."

Such a mechanistic understanding of biomolecules raises the prospect of computational models that can not only show how to make a protein that might not exist in nature, but also predict

> **As scientists fill in the picture of how molecules interact to perform the functions of life, engineers are manipulating them more rationally and effectively.**

its effect. Assistant Professor Jeffrey Varner is already developing such tools to rationally reprogram cell machinery. "Our ability to make accurate predictions is still in its infancy," says Shuler. "In 40 years we'll be able to make much more accurate predictions."

It may one day even be possible to tailor make entire microorganisms from scratch. "That's not an impossibility and in fact in some sense is probably closer than many people realize," says Shuler. "The idea in both of these cases is to have a human-designed organism fulfill a predetermined task as efficiently and effectively as possible."

Creating such artificial life forms presents a host of technical challenges, not to mention philosophical questions, so most chemical engineers will continue to work with modified cells for the foreseeable future. What biomolecules they will create is anyone's guess. "There are still all sorts of things to be learned. It's hard to imagine what the next use of living organisms will be," says Finn. "So, you know, we're just getting started." CEM

ISTOCK.COM

DUST IN THE WIND

EAS Prof. Natalie Mahowald studies the complex impact of atmospheric aerosols on climate

By Lauren Cahoon

Natalie Mahowald studies how dust—both man-made and natural—affects the planet's ecosystems and climate, revealing multilayered feedback systems that, despite their broad-ranging effects, have largely been ignored.

Natalie Mahowald studies the complex climate impacts of dust, here driven by a sand storm toward Merzouga in Morocco's Chebbi Desert.

We all know dust can be a pain; it makes you sneeze, collects under your bed, and then there's the way it can mess with geological climate change patterns and models. Didn't know about that last one? You're not alone. "Even people in the scientific community overlook it," says Natalie Mahowald, an associate professor in Cornell Engineering's Earth and Atmospheric Sciences department. She studies how dust—both man-made and natural—affects the planet's ecosystems and climate, revealing multilayered feedback systems that, despite their broad-ranging effects, have largely been ignored.

Climatic Consequences

Carbon dioxide is the primary culprit when it comes to climate change, but, thanks to Mahowald and her collaborator's, dust and aerosols are beginning to get attention. In fact, Mahowald will serve as a lead author on the next edition of the International Panel on Climate Change (IPCC) report. She will work with 250 other experts in Working Group I, which assesses the physical, scientific aspects of the climate system and climate change. Mahowald will write the introduction and contribute to chapters on paleoclimate and the impacts of clouds and aerosols—a topic that didn't get much play in the last report.

"That was one of the big uncertainties that came from the 4th assessment report," says Pauline Midgley, head of the technical support unit for IPCC Working Group I. For this iteration, Midgley noted, there was a "large enough nucleus of work" for an entire chapter to be dedicated to clouds and aerosols.

Dust's role in climate change is "really complicated," Mahowald says. In fact, one of its most significant effects on the climate is actually a cooling one. Dust affects the "radiative budget," or the ratio of incoming solar radiation to the radiation that is reflected from the earth. CO2, for example, traps only outgoing radiation—thus the term "greenhouse effect." Dust, however, can alter the heat that both enters and leaves the planet's atmosphere. "Dust acts like a greenhouse gas," says Mahowald, "but it reflects solar energy too. We think that in the net, it actually cools."

The climate turned cooler by 0.1 degrees Celsius—a seemingly small change, but a significant one. More important, Mahowald says, is that many scientists don't understand that the change was due to dust. "It's important to understand what's going on," she says. "Even people in the scientific community are ignoring mineral dust, especially when looking at what's happened in the past."

Natalie Mahowald works with earth and atmospheric sciences postdoctoral researcher Daniel Ward in Bradfield Hall.

A dramatic example of this effect is illustrated in global climate data from the 1950s to the 1980s, a period in which North Africa experienced massive droughts, turning once-lush regions into parched desert. With deserts came the dust, so much that by 1980, there was four times as much dust pouring into the atmosphere as there was in the '50s. The climate turned cooler by 0.1 degrees Celsius—a seemingly small change, but a significant one. More important, Mahowald says, is that many scientists don't understand that the change was due to dust. "It's important to understand what's going on," she says. "Even people in the scientific community are ignoring mineral dust, especially when looking at what's happened in the past."

While a cooling effect sounds like a good thing when it comes to droughts, Mahowald and her colleagues argue that the '80's drought was partly due to the dust. As the tiny particles reflect back heat and cool the air, the air sinks, preventing precipitation (warm, rising air is the kind that breeds rain clouds) and exacerbating the drought. It's subtle phenomena like this that drive Mahowald to increase awareness and understanding of desert dust's effects on climate change.

In an effort to do this, Mahowald and her collaborators have compiled a series of data sets that aggregate dust-relevant information—including data from satellites, wind observations, deposition data, as well as paleoarchives such as ice cores and marine, terrestrial, and lake sediments. This information is combined to create climate models that simulate atmospheric dust's effect on the climate for every year between 1870 and 2000. Those datasets, and similar datasets for paleoclimate time periods (e.g., last glacial maximum), are "available to anyone who wants to use them," Mahowald says. As a result, the model data have become the gold standard of dust data for climate researchers worldwide. "That's our claim to fame," says Mahowald. A key finding from this wealth of data is a stunning one; the amount of atmospheric dust has doubled over the 20th century.

Mahowald clearly enjoys being a teacher as well. She raves about a climate change class that she co-taught at Cornell with a philosophy professor, and is looking forward to teaching classes on climate change and how it impacts humans. " Teaching is really hard, a whole lot of work," she says, "but students make you think so much more creatively."

"Whenever I'm meeting with Natalie to discuss research, she will often come up with entirely new ideas and directions for science," says Daniel Ward, a postdoc in Mahowald's lab. "This makes her a scientist that many people want to collaborate with … she shifts people's viewpoints."

Effects on Ecosystems

Part of Mahowald's view-shifting work has looked at how dust's effects can go beyond the atmosphere and affect other ecosystems, such as the oceans. Mahowald first began to unravel this connection more than a decade ago while working as an assistant professor at the University of California Santa Barbara's Bren School of Environmental Science and Management. There, she collaborated with oceanographers such as Dave Siegel, now director of the Earth Research Institute at U.C.S.B. He recalls Mahowald's novel perspective toward the relationship between dust and the living planet. "So much of our planning on how aerosols work has been on their roles in [the atmosphere]," says Siegel. "And what Natalie did was to say, wait a minute, there are ecosystem-based systems…that are playing a role."

Siegel says that her ability to think outside the box has earned Mahowald significant recognition within the scientific community. "She is one of the most productive young scientists in this area," says Siegel. "The work that she does is the best in the field."

Siegel says that her ability to think outside the box has earned Mahowald significant recognition within the scientific community. "She is one of the most productive young scientists in this area," says Siegel. "The work that she does is the best in the field."

Mahowald estimates that this cooling effect is enabling the land and the ocean to take up an extra one to 50 ppm of CO_2. As humans reduce aerosols for health reasons, they will also reduce the cooling and carbon uptake these aerosols indirectly provide.

As Mahowald and her colleagues found, when desert dust lands in the ocean, it deposits key nutrients and minerals, such as iron. The iron is consumed by phytoplankton, the base of the ocean food chain. A higher abundance of iron yields greater blooms of phytoplankton, which then pull more CO_2 out of the air as they photosynthesize, a phenomenon known as a biological pump. This effect, which reduces CO_2, adds yet another complicated layer to dust's impact on the climate. Adding to the complexity is the fact that man-made aerosols given off by pollution can chemically react with desert dust, making the iron more soluble, thus increasing the amount that enters the ocean. "We showed that humans have probably doubled the amount of soluble iron going into the oceans," says Mahowald. Overall, she says that the iron deposition from desert dust since 1870 has resulted in the uptake of roughly 4 parts per million (ppm) of CO_2.

Mahowald has also studied how aerosols affect terrestrial ecosystems. Desert dust can carry phosphorus, a limiting nutrient for many tropical forests. "These forests use all the phosphorus they can," says Mahowald. Thus, she says any that comes via mineral dust is eagerly absorbed. As it turns out, "North Africa is probably fertilizing the Amazon, and Asian dust is fertilizing Hawaii."

Even anthropogenic aerosols, typically viewed as having a negative impact on the environment, have a more nuanced role. These man-made pollutants can often carry nitrogen—another necessary nutrient for plant growth, a fact that has led to more interdisciplinary collaboration between Mahowald and other scientists. At Cornell, Mahowald has collaborated with Christine Goodale, a forest ecosystem ecologist in the Department of Ecology and Evolutionary Biology. "She's greatly expanded the opportunities for me and my lab group," Goodale says of Mahowald. While Goodale's group typically looks at how nitrogen affects one particular section of land, Mahowald and her group have helped put that phenomenon into a larger, more comprehensive context. "She's provided a door opening for people who work on plot scale to look at things on the global scale," Goodale adds. "She's amazingly collaborative and productive—I was at a conference last week and three colleagues and I were just saying how we wish we could be more like her," she adds with a laugh.

As with ocean ecosystems, the overall effect of aerosols on forest ecosystems seems to also create a cooling effect on the climate, thanks to nutrient-rich aerosols that enhance plant growth and CO_2 uptake.

Mahowald has summed up the myriad climate effects of aerosols, both natural and man-made, in a paper published this last November in *Science*, with a cautioning message: reducing aerosols, which has long been an environmental goal due to public health reasons, could exacerbate warming global temperatures. Mahowald estimates that this cooling effect is enabling the land and the ocean to take up an extra one to 50 ppm of CO_2. As humans reduce aerosols for health reasons, they will also reduce the cooling and carbon uptake these aerosols indirectly provide.

"I'm thinking about the uncertainties," says Mahowald. "Right now 50 percent of CO_2 that humans are emitting is being taken up by land and ocean, which is unlikely to continue. That's a huge negative feedback on the climate system and we poorly understand it. If we cut aerosols, that's going to impact the carbon cycle—it will make things tougher."

PHOTO BY JACQUES DESCLOITRES, MODIS LAND RAPID RESPONSE TEAM, NASA/GSFC

As it turns out, "North Africa is probably fertilizing the Amazon, and Asian dust is fertilizing Hawaii," says Mahowald.

Intel in Everything

Cornell and chipmaker launch national embedded systems competition

By Sherrie Negrea

Jim Kehoe '12 ME poses wearing team-made humanoid RockBand robot controlling harness.

YOU ARE ABOUT TO LEAVE YOUR OFFICE FOR HOME. With a couple last keystrokes on your computer, you turn up the thermostat inside your house and turn on the oven. Driving home, you pass through an "intelligent" intersection where the traffic light automatically changes as it senses your car approaching. It begins to rain, and without your noticing it, your car reacts by adjusting the power to your wheels.

Embedded systems make it all happen. Devices containing microprocessors that monitor information and react to it are already prevalent in our lives: it's what makes your smart phone "smart," and it's what allows more and more consumer electronics to communicate with other devices. The rapid growth of such devices is creating an "Internet of Things" expected to include more than 15 billion devices within the next four years.

With an eye toward this technology's growing importance, Intel Corporation and Cornell's Systems Engineering Program are launching a new competition that will challenge college students across the country to invent the next generation of embedded systems.

May 4–5, the Cornell Cup USA Presented by Intel finals are slated to kick off at Walt Disney World's Contemporary Resort in Lake Buena Vista, Fla., with 24 teams from 19 American colleges and universities competing. Equipped with donated Intel Atom boards, Tektronix test equipment, MathWorks software, and $2,500 in development and travel funds, the teams will present a wide array of inventions: solar-powered unmanned aircraft, belts that allow the visually impaired to detect obstacles, home energy control systems, and robots that pick up stray tennis balls.

The top three entries will be awarded prizes of $10,000, $5,000, and $2,500.

The competition grew out of the success of an Intel Cup embedded technology competition in China—which now includes over 26,000 students—and one started more recently in India. The company that introduced the world's first microprocessor asked Cornell systems engineering lecturer David Schneider M.S. '06 ME, Ph.D. '07, how he would create a U.S. competition. Schneider was given just a month to craft his proposal. Intel approved it last spring and work began on a competition that would give a new generation of innovators the chance to showcase their own "world's first."

The rapid growth of such devices is creating an "Internet of Things" expected to include more than 15 billion devices within the next four years.

"We know and we've seen through the participants that these hands-on projects give students a very rich learning environment," says Kimberly Sills, Intel university relations manager. "They get to do everything they've been working on in their classes. They get to test it and put it together and see if it works."

Schneider says one of the aspects that makes this competition unique is its attention to what he calls professional design: defining the challenge you're trying to solve, how your solution meets that challenge's needs, and how to measure how well your solution has met its goals. Add in a bit of risk management and planning, some objective decision justification, and attention to communicating your ideas effectively, and you have many of the skills that are targeted by this competition, but that industry says are often lacking in college graduates from even the nation's top colleges.

"So we wanted to try to provide this very exciting and very empowering experience that would bring these skills to the forefront." Schneider says, "And at the same time, allow the students to express their creativity."

"From an engineering and educational perspective, they've broken ground in this competition on the types of things that students can do," says Professor Linda Nozick, director of Cornell's Systems Engineering Program. "This one I believe is unique because of the flexibility on the kinds of entries and allowing a lot of creativity on the part of students."

The competition is open to any invention using an embedded system. Teams can consist of three to five undergraduate or master's degree students. By October, teams from schools

“We know and we’ve seen through the participants that these hands-on projects give students a very rich learning environment. They get to do everything they’ve been working on in their classes. They get to test it and put it together and see if it works.”

KIMBERLY SILLS, INTEL’S UNIVERSITY RELATIONS MANAGER.

Makhlook Singh ’12 ECE, M.Eng. ’13 Systems, demonstrates to Intel CTO Justin Rattner the plug’n’play modularity of the ModBot’s electronics system.

including the University of California at Berkeley, MIT, and Purdue had submitted a diverse range of ideas. The finalists’ concepts can now be found at www.systemseng.cornell.edu/intel.

Besides Intel, the competition has attracted support from other companies, including Tektronix, a Beaverton, Ore.-based company that makes testing and measuring equipment, and MathWorks, a Natick, Mass.-based company that develops mathematical computing software. As the competition approaches, Cornell expects other companies to also become sponsors. “If what happened with the Intel China Cup is any example, we expect that this new competition will bring in sponsors of all sorts,” says Abby Westervelt, Cornell Engineering’s director of Corporate and Foundation Relations.

Having Cornell create and develop the competition presented a quandary to Schneider. If Cornell sponsored a team and won the competition in its inaugural year, participants might question the fairness of the competition. So Schneider decided that his robotics lab of more than 30 students would instead showcase two innovative robotic systems they have developed with the additional assistance of electrical and computer engineering senior lecturer Bruce Land and mechanical and aerospace engineering assistant professor Brandon Hencey.

The ripple effect of this work can already be seen in other Cornell projects like Cornell University Sustainable Design (CUSD). David Schneider shows Justin Rattner potential renderings of the CUSD SRF building.

“It’s one thing to win the competition—that’s great and exciting,” Schneider says. “But in a lot of ways, that’s kind of a flash in a pan. Getting to construct the competition and continue to bring it to life and grow it, I would say is an even higher honor.”

The Cornell robotics team’s first showcase project is a modular robotic platform developed for other schools to use as the basis of their own embedded systems projects. As a modular system, the 12-inch-by-12-inch silver and gray robot’s wheels, motors, sensors, and even supporting software have all been designed to be replaced, added to, or otherwise modified via well-documented “plug’n’play” interfaces. Schneider says this flexibility is empowering. “It will aid students in learning the basics while providing a robust framework to build their own unique aspects,” he said, estimating that at least half of the competing teams’ entries would have benefited from this modular platform, and he hopes that future entries will be even more amazing as a result of it.

Part of the Cornell project team stands proudly displaying their latest ModBot and RockBand playing guitars.

“It’s a really powerful experience in terms of just managing the product. We’re giving the plans up to other teams and this needs to be as cost effective as possible. So it’s given the students on this team a great perspective on how to keep costs in mind and overall just how to execute a successful engineering project. It’s really an experience on a scale that you just don’t get in the undergraduate curriculum.”

JIM KEHOE ’12 ME

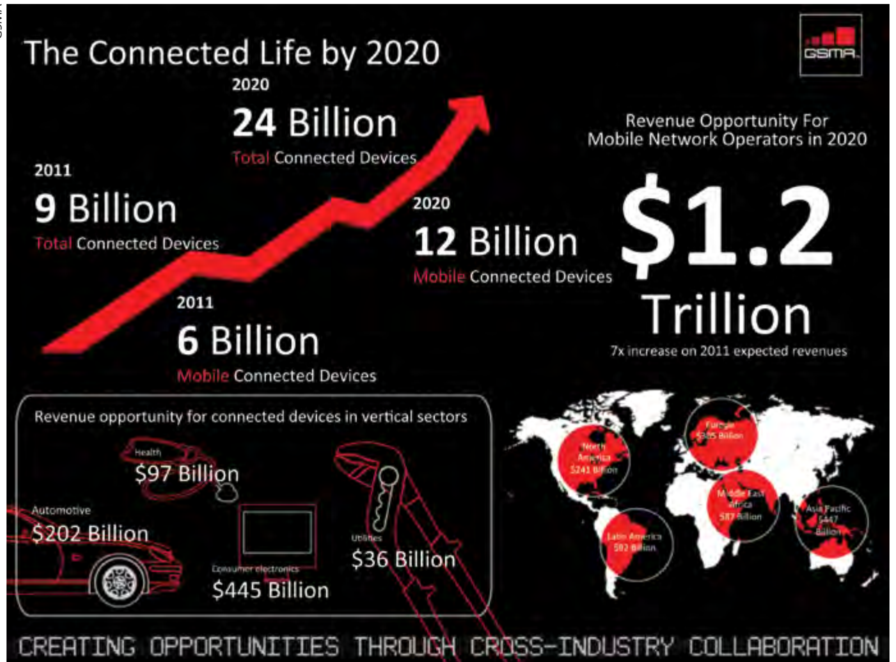
“The fact that we’re delivering a complete starter system for other teams is really important,” says Jim Kehoe ’12 ME, a mechanical engineering team leader for the robot. “To create just the core system in a robotic platform takes a lot of time and effort. And to be able to have the time to create additional functionality on top of that, most teams wouldn’t be able to fully accomplish that over the course of just one year, which is the time frame for the competition.”

Besides the modular platform, the Cornell team has another project to exhibit at the competition at Disney World: a three-member robotic rock band. With a guitar, drum, and bass, the human-size robots, running on an Intel Atom board, will perform RockBand and Guitar Hero video game songs on an XBox as background music to welcome each speaker on stage. “Just like Saturday Night Live has a band, this is our band for the competition,” Schneider says.

Beyond learning how to create an embedded technology project, the students say preparing for the competition has given them valuable skills that will help them in the job market. “Working with a team that has 11 people in our subgroup and 30 people overall, you really have to learn just how to do project management and work in groups and teams and learn how to motivate people,” says Chad Meis M.Eng. ’12 EE, an electrical engineering team leader. “I think it’s pushed all of us in a lot of different ways, not necessarily just engineering.”

As an undergraduate engineering student at Cornell, Kehoe says design was not a focus of the curriculum, since most of the courses are based on textbooks, problem sets, and exams. Yet while working on the modular platform, Kehoe also helped with a range of tasks, including monitoring the budget, working with vendors, and controlling costs, all while justifying the team’s decisions to better help them obtain their technical goals.

GSMA



Industry expects 24 billion connected smart devices by 2020. Intel partners with Cornell Systems Engineering to inspire students to harness the power of this “Internet of Things.”

“It’s a really powerful experience in terms of just managing the product,” Kehoe says. “We’re giving the plans up to other teams and this needs to be as cost effective as possible. So it’s given the students on this team a great perspective on how to keep costs in mind and overall just how to execute a successful engineering project. It’s really an experience on a scale that you just don’t get in the undergraduate curriculum.” CEM

engineering entrepreneurs

By Dan Tuohy

Three alumni entrepreneurs talk about going into business and the technical skills that helped them get there.

Steve Haas had an ear for music and a nose for business. He knew what he wanted to do during his years at Cornell University. Gavin McKay applied his expertise in a more traditional milieu before he had a professional epiphany and pursued a less conventional, more personal path. Cheryl Yeoh was working in New York when practical experience met opportunity and she went her own way. ¶ Once wedded, their personal drive and their formative educations transformed them into entrepreneurs. They are in different fields today, but they have much in common: They love a challenge. They love making a difference. And they love solving stubborn problems.

Steve Haas '89 ME
Founder and President, SH Acoustics

PROVIDED

"Basically what we look at is the quality of sound in a space, but also controlling the sound so that it's not noisy or that sound doesn't get from one space to another and interfere with any kind of functionality."

His great-grandfather was a mason who worked on some of Europe's finest concert halls. His grandfather was a concert pianist and violinist who played in numerous orchestras, including the Cleveland Orchestra. His uncles were engineers, including one who would regularly quiz him as a kid on the three laws of thermodynamics. So destiny would find him early in life, and propel him as a versatile and industry-leading acoustical designer.

The elevator pitch. "I could say it very simply: We make spaces sound good. But there's more to it than that. Basically what we look at is the quality of sound in a space, but also controlling the sound so that it's not noisy or that sound doesn't get from one space to another and interfere with any kind of functionality."

Steve Haas has dedicated his life to making concert halls, museum spaces, home theaters, and private residences sound better. He has designed hundreds of acoustic spaces.

He has played a major role in the acoustic and audio designs for a wide variety of prestigious facilities, including the U.S. Holocaust Museum and the Newseum, both in Washington, D.C., and Carnegie Hall's Zankel Hall in New York City.

It can be unsung work, and Haas is fine with that.

"I often tell people that when I do my job well, nobody notices."

Haas works with architects and engineers, and other project members, to make sure that whatever solution is implemented works from a functional and technical standpoint, as well as from an aesthetic standpoint.

Haas and his team also work in audio system design to make sure the way that sound is delivered is appropriate. They are often involved with a project early on, and can be among the last on site to tweak and calibrate systems.

Annenberg Theater – Newseum, Washington D.C.

SH Acoustics has a proprietary "Concertino" system, which changes the acoustics of a place electronically. It is not a sound system, but more of an enhancement system, Haas explains.

"If you bring a musician, a cellist, or a pianist into a small place and you play naturally, it's not going to sound like much. It's going to sound like a small room. But by integrating our technology and our system in this space we can actually turn it into a virtual Carnegie Hall."

The Newseum remains one of his signature projects. It was handed to him only two months after he launched his firm in 2003–after 14 years of working for a major consultancy. Completed in 2008, the Newseum may be the biggest project he may ever work on, and most complicated, given the size and number of technological exhibits.

"It was a challenging project but everything turned out incredibly well."

Haas, a pianist, saxophonist, and electronic musician, does not often play professional gigs; but he does play in connection with his work. It's very handy, he notes, to be able to sit down at a grand piano in a private studio to demonstrate the acoustics of an environment.

Haas has challenged himself since his days at Cornell Engineering.

There was not a lot opportunity to study sound at the time, so with the help of Professor Al George, he made his own. He basically created his own curriculum. His senior thesis was designing a recording studio for Cornell's Music Department.

"It helped really introduce me to the industry and I never looked back from there," he said. "I did not want to transfer out of Cornell to look for an acoustic engineering program. I really loved all that Cornell brought me and the opportunities to graduate from there, so I basically made my own path, so to speak, and it worked out. I certainly will be forever grateful because it has led to a very rewarding career."

Gavin McKay '99 OR
Owner/Manager Fusion Cross-Training

PROVIDED

It courses through his fitness company, Fusion Cross-Training: Heart. Muscle. Mind. "It's the core of everything we do."

One friend went to Sonoma to become a winemaker. Another went to a start-up. Another became a Bain investment strategist. And Gavin McKay proceeded to work in consulting and marketing.

So there he was, in New York, a young man in love with the idea of getting ahead, when he realized his job was not stirring his creative energies. He applied to business school, having felt the pull of climbing the corporate ladder, and on a trip to California he got a taste of working for a start-up.

B-school would have to wait. His creative energies were firing, and he set out traveling the world. The farther abroad he went, the closer he came to purpose and meaningful living. "Getting so lost that you are kind of coming back to your core," McKay describes it.

He made his way back home with a singular focus, an understanding that synergy has interplay in every single thing of import. It courses through his fitness company, Fusion Cross-Training: Heart. Muscle. Mind. "It's the core of everything we do," he said.

The exhilaration that comes with sense of place and purpose is one thing. Getting to launch is another. McKay still marvels at the challenge he took head-on.

"I'll never forget how hard it was. The first piece was just getting a bank to give me a loan."

The young entrepreneur eventually found a bank that was specializing in small lending. "The other hard part: just maintaining faith in yourself."

His business was a different kind of fitness center—and he knew it would take time to build his brand.

Fusion Cross-Training has 12 employees at two locations: Philadelphia and Laurel, N.J. Heading into 2012, he was working on establishing two additional locations and becoming a franchise.

McKay is dedicated to group and personal training. Engagement is his key to success. There is coaching, counseling, and nutritional programming. His HMM Cross-Training (Heart. Muscle. Mind) features 30 minutes of cardio, 30 minutes of strength training, and then 15 minutes of yoga and stretching.

"We push people to do things in a smarter way, in a more efficient way, but in a harder way."

His studio includes a cardio arena with treadmills, bikes, and rowing machines, and a separate area for the muscle and mind training.

"We kind of take you on a journey every time," he said.

As he plans growth in 2012, he is putting himself through paces he first took at Cornell.

"I took 'Entrepreneurship for Engineers'," he said, recalling learning to approach everything in a structured way, to assess and evaluate.

"It was the best course I ever took. It was exactly what you need. Above and beyond the best course I ever took."

McKay is an entrepreneur, but an engineer at heart. That is ... Heart. Muscle. Mind.

Cheryl Yeoh '05 OR, M.Eng. '07 CE
CEO and Co-founder, CityPockets

PROVIDED

"The story there is to really put yourself out there, never give up, and don't let anybody discourage you from realizing your passions."

Cheryl Yeoh is always on the lookout for a great deal.

At one point in 2010 she had signed up for eight different daily deal websites and purchased close to 40 vouchers, everything from restaurant deals to spa treatments. So many that this highly organized person started to lose track of them.

So she created a tab on her food blog where she could list her growing number of deals. Friends quickly noticed and touted the value of a place to organize and track daily deals.

"That made me think," she recalls in a light-bulb moment, "'Hey, there should be a product for this."

So the hands-on, practical user emerged as visionary: CityPockets, a "digital wallet" and secondary marketplace for online deals and discounts, was born.

"I like to say that I created the product to solve my own problem and it happened to work for a lot of other people."

Before launching CityPockets, Yeoh was a management consultant for KPMG and Opera Solutions—with a focus in strategy, marketing, and operations. It wasn't what she thought it'd be, especially during the economic downturn. She wanted to make a real impact in the world and launching a tech company seemed like a good way to do that.

The research, design, and development of a prototype came next. She and CityPockets co-founder Jhony Fung '05 CS, then a senior developer at IBM Technology, logged many hours investigating the idea and crafting a user-friendly interface. After two months, they launched the beta version. A couple hundred friends joined, and it took off.

CityPockets tracks a user's daily deals, sending reminders to use them before they expire. It currently supports more than 40 deal sites, including Groupon, LivingSocial, BuyWithMe, and restaurant.com.

Yeoh estimates 40 percent of CityPockets traffic comes from word of mouth. "That's when you know you have a product that fills a need in the market," she says.

In a logical extension of its service, CityPockets launched a secondary marketplace in April 2010 to help users sell vouchers they can no longer use. A quarter of users now profit from reselling vouchers, but at its core, CityPockets remains a digital wallet, according to Yeoh. "We're the best organizer out there and that's why people come to our site," she said.

"People are putting money down for a daily deal—pre-paying for a service with an expiration date—and they need a helping hand to manage this new form of currency," she said. "If you don't use it in a given time you're throwing your money away and nobody wants that."

Yeoh has enjoyed watching her first Internet start-up take off. She continues to study the market as well as field user feedback. Heading into 2012, Yeoh estimated there were about 400 daily deal sites—with CityPockets established as the go-to organizer. The company has found plenty of investors who agree, raising $770,000 in seed funding.

In a way, Yeoh has returned to her business roots. She launched her first business when she was 8, manufacturing and selling a traditional game to school friends in her native Malaysia. She kept at it, even when she encountered obstacles from school administrators.

"The story there," she said, "is to really put yourself out there, never give up, and don't let anybody discourage you from realizing your passions." CEM

WEB EXTRA

PROVIDED

Marshall Cox '03 MS, M.Eng. '04 launched not one, but two ventures. Radiator Labs is developing a low-cost, easily installed radiator retrofit that can equalize temperatures across apartments in a building and Chromation company uses new, low-cost nanotechnology to measure the color content of light.

Read more online at www.engineering.cornell.edu/magazine.

brainteaser

The Geometry of Sailing

PROVIDED

Professor Andy Ruina, Mechanical and Aerospace Engineering

Geometry puzzle

You are given $w > 0$, $0 < \alpha^* < \pi/2$ and $0 < \beta^* < \pi/2$. The unit vector $\hat{\jmath}$ points along the y axes and $\vec{w} = -w\,\hat{\jmath}$. Find the biggest $v = |\vec{v}|$ for a given θ, where θ is the angle between $\hat{\jmath}$ and $\vec{v}$. But first you need to pick vectors $\vec{\mathrm{S}}$ and $\vec{\mathrm{K}}$ to be anything you like with the provisos that: 1) $|\alpha| \leq \alpha^*$, where α is the angle between $\vec{\mathrm{K}}$ and $-\vec{v}$, 2) $|\beta| \leq \beta^*$, where β is the angle between $\vec{\mathrm{S}}$ and $\vec{\omega} - \vec{v}$, and 3) $\vec{\mathrm{K}} + \vec{\mathrm{S}} = \vec{\mathbf{0}}$.

1. What is the range of values of θ for which you can find some $\vec{\mathrm{K}}$ and $\vec{\mathrm{S}}$ so you can find $v > 0$?
2. What is the biggest possible value of v and in what direction θ is it?
3. If you draw all possible $\vec{v}$ vectors with the tail of the vectors at the origin, what is the shape of the boundary of the region that encloses all possible tips of the arrows?

Sailing interpretation

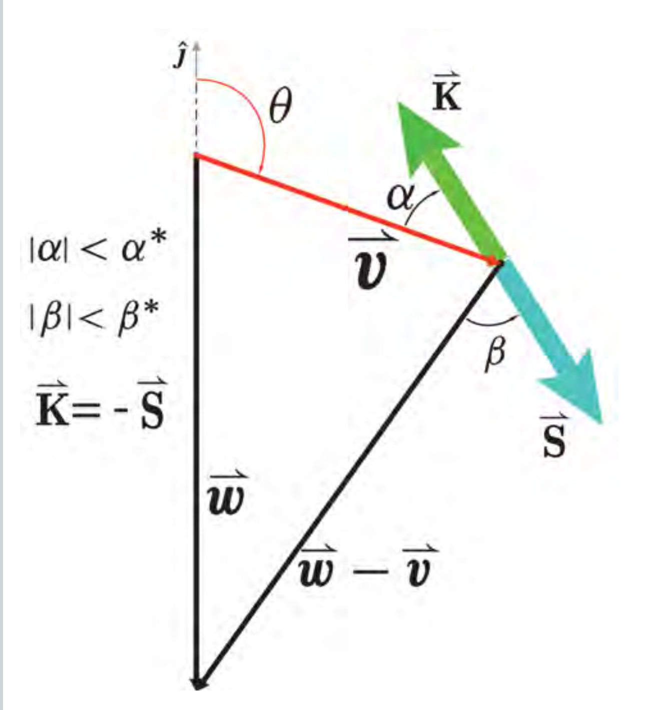
The wind speed is w, going South. The boat velocity is $\vec{v}$ making angle θ from North. The force of the water on the keel is $\vec{\mathrm{K}}$ and has to make less than an angle of α^* with the motion of the water relative to the boat ($\tan\alpha^*$ = the best lift-to-drag ratio of the hull). The force of the air on the sail is $\vec{\mathrm{S}}$ and has to make less than an angle of β^* with the velocity of the wind relative to the boat ($\tan\beta^*$ = the best lift-to-drag ratio of the sail). The net force on the boat must be zero. The shapes of the keel and sail determine α^* and β^* and the sizes of $\vec{\mathrm{K}}$ and $\vec{\mathrm{S}}$ can be adjusted by changing the size of the boat and sail. Assuming given shapes for the keel and sail:

1. What directions can a sailboat sail?
2. What is the fastest a sailboat can go and in what direction is that?
3. What is the set of all possible speeds and directions for a sailboat?

Hints

a) Try a special case first, like $w = 10$, $\alpha^* = \pi/4$; **b)** the answer to Question 2 depends on whether $\alpha^* + \beta^* <$ or $> \pi/2$; **c)** it may help to use the angles $\hat{\alpha} \equiv \pi/2 - \alpha^*$ and $\hat{\beta} \equiv \pi/2 - \beta^*$; **d)** the best boats have α^* and β^* as close to $\pi/2$ as possible; and **e)** the set of answers is called X's theorem, where X is a mildly famous person.

Please give concise answers in terms of w, α^* *or* $\hat{\alpha}$, and β^* or $\hat{\beta}$.



You are given α^*, β^* and $\vec{w}$. You pick $\vec{\mathrm{K}}$ and $\vec{\mathrm{S}}$ any way you want, but following the given restrictions. For given θ what is the biggest possible $\vec{v}$?

Solve this to win Cornell Engineering gear

We will draw three winners from correct entries submitted by July 1. They will receive a Garland gift pen, a stainless steel water bottle, or a Cornell Engineering car decal. Congratulations to Jerold Green '80 EE, Jeffrey Hart '95 EE, and Yakov Shkolnikov '99 EP for correctly solving the fall brainteaser! You can see the solution, and submit your answer, at www.engineering.cornell.edu/brainteaser.

people

Christine Shoemaker

NAE Electees

Christine Shoemaker, Cornell's Joseph P. Ripley Professor of Engineering, has been elected to the National Academy of Engineering, among the highest professional distinctions for an engineer.

Shoemaker, a professor in the School of Civil and Environmental Engineering (CEE), was cited "for development of decision-making optimization algorithms for environmental and water resources problems."

Her research focuses on cost-effective, robust solutions for environmental problems by using optimization, modeling, and statistical analyses. This includes development of general purpose, numerically efficient nonlinear and global optimization algorithms utilizing high-performance computing and applications to data from complex, nonlinear environmental systems.

Shoemaker's research is interdisciplinary; she has supervised Ph.D. students from a number of fields including operations research and information engineering and applied mathematics, as well as students in CEE.

With NSF funding from various directorates, her projects are often collaborative and include physical and biological groundwater remediation, pesticide management, ecology, climate modeling, carbon sequestration, and surface water pollutant transport in large watersheds.

Shoemaker is a distinguished member of the American Society of Civil Engineering (ASCE). She has been elected a fellow in the American Geophysical Union, ASCE and INFORMS (Institute for Operations Research and Management Science). She also won a Humboldt Research Prize from Germany.

She initiated and led a nine-year multidisciplinary international project, sponsored by the Scientific Committee on Problems of the Environment and the United Nations Environment Program, that brought information and workshops about groundwater contamination to developing countries at a time (1987–96) when those regions were doing little to prevent contamination from industrial chemicals. Such contamination is often irreversible or extremely expensive to remove because it is in groundwater, so prevention is the best strategy.

Shoemaker, who joined the faculty in 1972, was the first woman faculty member in the College of Engineering to be awarded tenure. In 1985 she was the first woman to be an engineering department chair at Cornell. She received a national award from the Society of Women Engineers in 1991 for her scholarship and efforts to encourage women engineers during years when there were few women students or faculty members in engineering.

Membership in the National Academy of Engineering honors those who have made outstanding contributions to "engineering research, practice or education, including, where appropriate, significant contributions to the engineering literature," and to the "pioneering of new and developing fields of technology, making major advancements in traditional fields of engineering, or developing/implementing innovative approaches to engineering education."

Also elected to the NAE this year were Mark Adamiak '75 EE, M.Eng. '76, director of advanced technologies, GE Digital Energy Multilin, "for contributions to power system protection, control, monitoring and communications"; and Amit Singhal, M.S. '95 CS, Ph.D. '97, Google fellow, Google Inc., "for contributions to information retrieval and search."

—Anne Ju

Flying High

Two Cornell faculty members—**Gregory Fuchs** and **A. Kevin Tang**—are among this year's 48 winners of the Air Force Young Investigator Research Program.

Gregory Fuchs

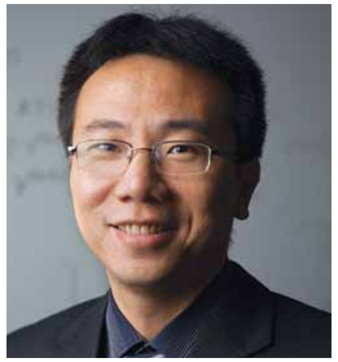
The program, administered by the Air Force Office of Scientific Research, is open to U.S. scientists and engineers who have received a Ph.D. or equivalent in the last five years and have shown "exceptional ability and promise for conducting basic research." The objective of the program is to "foster creative basic research in science and engineering; enhance early career development of outstanding young investigators; and increase opportunities for the young investigator to recognize the Air Force mission and related challenges in science and engineering."

Fuchs, assistant professor of applied and engineering physics, has been awarded $375,000 over three years to support his research into optical methods of probing magnetization with nanoscale spatial resolution and picosecond time resolution. He plans to use these techniques to study the dynamics of magnetic oscillators and memory.

Tang, assistant professor of electrical and computer engineering, has been awarded $375,000 over three years to conduct a research project to help monitor such large-scale networks as the Internet and power grids to avoid possible system failure and to optimize performance. The scale and complexity of such systems raise the need to quickly infer and monitor component characteristics from a relatively small number of indirect aggregate measurements. Tang's project aims at providing fundamental understanding and constructing algorithms for such measurements.

This year the Air Force received 220 proposals in such areas as aerospace, chemical, and materials sciences; physics and electronics; and mathematics, information, and life sciences.

—Susan Lang



A. Kevin Tang

Concerto King

Pianist **Eric Tan** '14 CS won the eighth annual Cornell Concerto Competition, held Dec. 11 in Barnes Hall Auditorium. Tan performed the first movement of Beethoven's Piano Concerto No. 4 in G major, accompanied by Tiffany Tsay '13.

Tan, a computer science major in the College of Engineering, studies piano with associate professor of music Xak Bjerken and is a member of CU Winds. A native of Toronto, he has won top prizes at music festivals and competitions at the national, provincial, and local levels.

Sixteen student musicians, with student and faculty accompanists, participated earlier in the day in preliminary rounds of the 2011 competition. Judges chose five students to compete in the final round.

As the winner, Tan performed a concerto as a featured soloist with the Cornell Symphony Orchestra, March 10.

The other finalists were soprano Marybeth Keiser '13, an exchange student from the Manhattan School of Music, studying music in the College of Arts and Sciences; and violinists Elaine Higashi '12, a biological engineering major in the College of Engineering; Jonathan Park '14, a psychology major in the College of Arts and Sciences; and Moriah Son '14, an environmental engineering major in the College of Agriculture and Life Sciences.

—Daniel Aloi

NASA Chief

Mason Peck, associate professor of mechanical and aerospace engineering, has been named

Eric Tan

NASA's chief technologist, effective January 2012. Peck will serve as the agency's principal adviser and advocate on matters of technology policy and programs.

Peck leads several Cornell spacecraft research programs including CUSat, an in-orbit inspection system consisting of a pair of twin satellites designed and built at Cornell. CUSat is scheduled to launch in 2013 on a Falcon 9 rocket through the U.S. Air Force Research Laboratory's University Nanosatellite Program.

Peck also is principal investigator of the Violet satellite experiment, also a Cornell-built system that will provide an orbiting test bed for investigating better commercial Earth-imaging satellites. Violet carries an ultraviolet spectrometer that will be used as a precursor to understanding exoplanet atmospheres.

In his NASA role, Peck will help communicate how NASA technologies benefit space missions and the day-to-day lives of Americans. The office coordinates, tracks, and integrates technology investments across the agency and works to infuse innovative discoveries into future missions.

In addition, Peck will lead NASA technology transfer and technology commercialization efforts, facilitate internal creativity and innovation, and work directly with other government agencies, the commercial aerospace community, and academia.

Peck will serve in the position through an intergovernmental personnel agreement with Cornell, where he will continue as a faculty member.

At Cornell, Peck's work focuses on spacecraft dynamics, control and mission architectures. His research includes microscale flight dynamics, gyroscopic robotics, and magnetically controlled spacecraft, most of which

Mason Peck

have been demonstrated on NASA microgravity flights.

He has worked with NASA as an engineer on a variety of technology programs, including the Tracking and Data Relay Satellite System and Geostationary Operational Environmental Satellites. The NASA Institute for Advanced Concepts sponsored his academic research in modular spacecraft architectures and propellant-less propulsion, and the International Space Station currently hosts his research group's flight experiment in microchip-sized spacecraft.

As an engineer and consultant in the aerospace industry, he has worked with organizations including Boeing, Honeywell, Northrop Grumman, Goodrich, and Lockheed Martin. He has authored 82 academic articles and holds 17 patents in the United States and European Union.

Peck earned a doctorate in aerospace engineering from the University of California–Los Angeles as a Howard Hughes Fellow and a master's degree in English literature from the University of Chicago.

—Anne Ju

SWE Success

Cornell's chapter of the **Society of Women Engineers** (SWE) has been recognized as a top collegiate section by the national organization whose mission is to empower women to succeed and advance in engineering fields.

At the SWE annual conference, held Oct. 12–15 in Chicago, Cornell SWE took home a Gold Award for Outstanding Collegiate Section. The award is the highest honor to be bestowed on a collegiate section.

Collegiate awards are determined by such activities as effectiveness of communications among chapter members, the chapter website, member recruitment activities, and regional and national participation.

In addition, two Cornell SWE alumnae were recognized with top awards for professional membership.

Allison Goodman '99 received the Distinguished New Engineer Award "for creative and effective team leadership in her career and in her contributions to SWE and the community." She received her bachelor's degree in electrical and computer engineering from Cornell, and is now senior systems engineer and validation program manager in the Non-Volatile Memory Solutions Group at Intel Corp. Goodman serves on the Cornell SWE advisory board and is also former president of Cornell SWE.

Stephanie Shanley '93 received the Emerging Leader Award for "strong personal leadership that balances environmental stewardship, professional accomplishments and dedication to community." Shanley received her bachelor's degree in civil and environmental engineering from Cornell, and is now senior environmental engineer in the environmental, health, and safety department at Intel Corp.

—Anne Ju

Geothermal Achiever

Jefferson W. Tester, the Croll Professor of Sustainable Energy Systems in the School of Chemical and Biomolecular Engineering, director of the Cornell Energy Institute and associate director for energy in the Atkinson Center for a Sustainable Future, was honored with the Geothermal Special Achievement Award from the Geothermal Resources Council Oct. 26 in San Diego.

Tester was cited for his "outstanding contributions to the development of geothermal

Jefferson W. Tester

resources" over more than three decades. His most noteworthy contributions are pioneering work on many aspects of enhanced/engineered geothermal systems, including thermal energy conversion and utilization, tracer methods for characterizing reservoir thermal hydraulic behavior, and geothermal systems analysis.

Tester began his career in geothermal technology as a member of the Los Alamos Hot Dry Rock project in the 1970s and 1980s and as a professor of chemical engineering at the Massachusetts Institute of Technology in the 1990s, and he continues his initiatives in advanced drilling methods and geothermal resource assessment and applications for combined heat and power. He chaired the 18-member international panel that evaluated the long-term geothermal potential of the United States and, in 2006, produced a major report, "The Future of Geothermal Energy."

From 2009 to 2011, Tester served as the U.S. representative for geothermal energy to the Intergovernmental Panel on Climate Change working group evaluating the global potential of renewable energy. He was a member of the 1997 Energy R&D Panel of President Clinton's Committee of Advisers on Science and Technology.

Tester has published extensively in the energy field, co-authoring more than 210 research papers and 10 books, including two monographs on geothermal energy technology and a popular energy textbook, *Sustainable Energy—Choosing Among Options*.


Rajesh Bhaskaran


Jonathan Butcher


Salman Avestimehr


David Erickson

Frontiersmen

Cornell faculty members **Rajesh Bhaskaran** and **Jonathan Butcher** were among 65 researchers selected to take part in the National Academy of Engineering's third Frontiers of Engineering Education (FOEE) symposium, Nov. 13–16.

The conference, held in Irvine, Calif., invites early-career faculty members who are "developing and implementing innovative educational approaches" in their engineering disciplines to share ideas, learn from research and best practice in education, and leave with a charter to bring about improvement in their home institutions.

Bhaskaran, senior lecturer in mechanical and aerospace engineering, is interested in integration of modern computer-based simulation technology into the mechanical and aerospace engineering curriculum. His efforts are directed not only at providing students with a solid foundation in the use of simulation technology but also at enhancing the learning experience through this technology.

Butcher, assistant professor of biomedical engineering, conducts a research program on understanding the roles of mechanical forces in shaping cardiovascular morphogenesis and adult disease with an emphasis on heart valves. His long-term objectives include discovery of novel disease paradigms and regenerative strategies.

The attendees were nominated by fellow engineers or deans and chosen from a highly competitive pool of applicants.

This year's program will focus on teaching leading-edge engineering knowledge, project-based learning, active and self-directed learning, and assessment of student learning and education innovation.

—Anne Ju

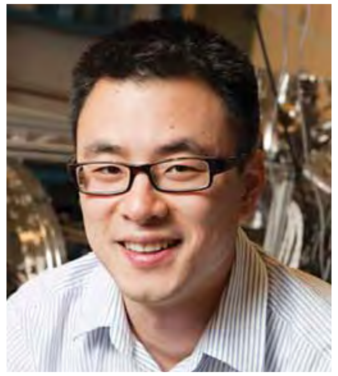
President's Men

Cornell engineers **Salman Avestimehr**, **David Erickson**, and **John C. March** are recipients of this year's Presidential Early Career Awards for Scientists and Engineers (PECASE)—the highest honor bestowed by the U.S. government on early-career science and engineering professionals.

Annually, 16 federal departments and agencies unite to nominate the scientists, of which there are 94 this year, who show "the greatest promise for assuring America's pre-eminence in science and engineering and contributing to the awarding agencies' missions."

Avestimehr, assistant professor of electrical and computer engineering, was awarded through the National Science Foundation for his work in complex wireless information networks. As society becomes more and more mobile, Avestimehr says, it is critical to find novel ways to significantly enhance wireless network capacity in order to enable the future mobile world. Avestimehr is proposing new approximation techniques to tackle longstanding problems in wireless network information theory whose solutions are expected to reveal principles for designing large-scale distributed wireless networks of the future. In particular, he is targeting fundamental problems in multi-hop communication networks, distributed networks with local network views at the nodes, and


John C. March


Kyle Shen

wireless networks with rapidly changing topologies.

Erickson, associate professor of mechanical and aerospace engineering, was awarded through the Department of Energy for his work in directed assembly of hybrid nanostructures. His research deals with self-assembling nanomaterials with optical and energy conversion properties, and he has recently demonstrated how electromagnetic fields in nanophotonic devices are strong enough to physically manipulate biological and non-biological materials that are just a few nanometers in size. He proposes studies that aim to elucidate the underlying physics behind this new assembly process. Specifically, he uses optically resonant "nanotweezers" and kinetic models to determine conditions under which stable nanoparticle manipulation can take place. Efforts will extend to such complex materials systems as gold nanoparticles, quantum dots, and carbon nanotubes.

March, assistant professor of biological and environmental engineering, was awarded through the Department of Health and Human Services to support his research into human intestinal bacteria. He proposes examining the use of these bacteria, called commensal bacteria, for the controlled expression of an insulin-stimulating peptide in the intestinal epithelial cell space, which could mediate a glucose regulatory mechanism through reprogramming of intestinal stem cells. March hopes these results will translate to orally dosed treatments for type 1 diabetes that cost just pennies a day, to potentially mediate the long-term effects of the disease.

Kyle Shen, assistant professor of physics, also received a PECASE through the Department of Defense to advance his work on new superconductors in artificially engineered quantum electronic materials.

The PECASE awards, established by President Bill Clinton in 1996, are coordinated by the Office of Science and Technology Policy within the Executive Office of the President. Awardees are selected for their pursuit of innovative research at the frontiers of science and technology and their commitment to community service as demonstrated through scientific leadership, public education, or community outreach.

Dynamic Modeler

From football to ambulance deployment, Matt Maxwell Ph.D. '11 OR predicts the future.

When you call for an ambulance, you want it ASAP. But how can an ambulance company ensure the fastest possible response time when previous calls have sent ambulances all over town?


Matt Maxwell Ph.D. '11 OR

This is the question Matt Maxwell Ph.D. '11 OR answered in his thesis. "As the day progresses, and ambulances are called out, that creates holes in coverage," he explains, "so you want to move them around dynamically so they can serve calls rapidly."

Maxwell used approximate dynamic programming to improve a simulation-based algorithm developed by a previous student. "I was able to boil it down to a very simple algorithm so you don't need a lot of additional complexity to run it," says Maxwell. "I was able to speed up running the simulations by up to 100 times faster."

With that speed, Maxwell could run many weeks' worth of simulations, giving him the data he needed to fine-tune the algorithm, cutting response times by a small, but significant amount. "These performance increases are a big deal for ambulance companies," says Maxwell. "If they can take one ambulance and crew off the road, they can save about a million dollars a year."

Maxwell has co-authored several papers on the work with his advisers Professor Shane Henderson and Associate Professor Huseyin Topaloglu. One was a finalist for best paper at the 2009 Winter Simulation Conference. And he says he has two more in the works.

No ambulance company has yet to implement Maxwell's work, but there has been some interest, and fire and police redeployment present similar problems.

Maxwell's skill with algorithms caught the attention of Andrew Daines '10, an undergrad philosophy major and *Cornell Daily Sun* columnist Maxwell knew from church. Daines and Emily Cohn '10, a communications major and *Sun* editor, were working on a social app, but they needed help.

Daines came up with the idea at a New York Yankees game in June of 2009. By the eighth inning, the score was heavily lopsided in the Washington National's favor and he wondered how to keep fans interested in the game. When he looked around, he saw that many were on their smart phones checking stats and scores. If fans could use them to compete with their friends at predicting the outcome of the next play, he thought, they would remain engaged no matter how bad the blowout.

Daines sought out Maxwell and PrePlay Sports was born. "He needed someone to come up with a probability-based scoring algorithm," says Maxwell. "That's how I got involved. And because of my computer science background, I also got involved in some of the server-side programming."

Because real-time stats on past plays were more readily available from the NFL, the young entrepreneurs switched their focus to football. Maxwell devised an algorithm that, given a team's current field position and score, could estimate the probability of outcomes, like an incomplete pass, a hold, or a run over 5 yards. It wasn't so different from ambulance deployment, according to Maxwell.

"In both situations you come up with a fundamental model of what you think can describe it, but then you have to make it fit," he says. "You can look through previous history and not find an exact match, but maybe something a lot similar. The key here is to group similar outcomes to get a good estimate. So you have to define what is similar and what is the right amount of data."

With some startup capital from family and friends, PrePlay Sports hired a development firm to create a prototype. It was greeted enthusiastically by investors and the company raised enough money to create a beta version. After launching in the fall of 2010, the free app was ranked number one on Apple's list of hot sports apps.

Today the company employs around 10 people in New York and Paris. It has raised $2 million in venture capital and boasts of users in the hundreds of thousands. During the 2011 season, they made about 600,000 guesses and the average number of guesses per weekend hovered around 60,000. Subway sponsored the PrePlay 2012 Playoffs contest, in which users competed for prizes including a 32" flat screen TV, Apple TVs, and gift certificates to Dick's Sporting Goods.

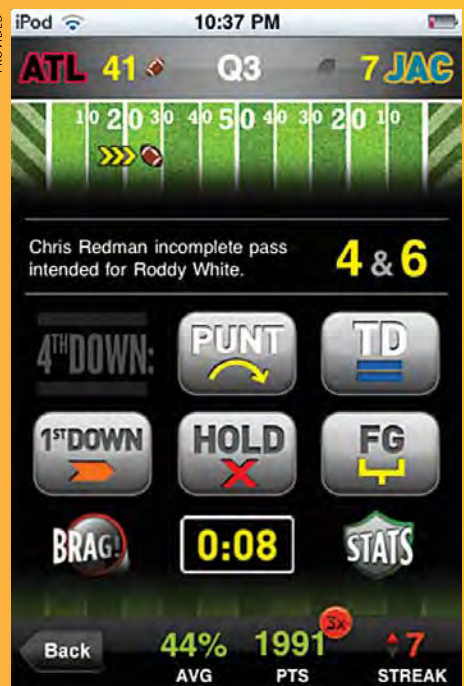
The company also has expansion plans. "Our company has attracted interest from sports and entertainment companies and we are currently building technology for them," says Maxwell.

But for now, PrePlay Sports remains a sideline for Maxwell, whose day job is at the SAS Institute, the North Carolina-based business analytics services and software company, working on a revenue management product for hotels.

Maxwell still finds time to play the app, though he says he's not the best at predicting plays. "I think the most fun part of it is actually holding it in my hand and watching the game and saying 'Hey, that number is there because of something I did,' and that's a pretty neat experience," he says.

— Robert Emro

PROVIDED



The PrePlay app lets users compete with their friends at predicting the outcome of NFL plays.

Space Weather

A NASA-funded collaborative research team led by Steven Powell, Cornell senior engineer in electrical and computer engineering, launched a sounding rocket Feb. 18 from Alaska's Poker Flat Research Range to collect data straight from the heart of the aurora borealis.

The project — the Magnetosphere-Ionosphere Coupling in the Alfven resonator (MICA) mission — involves 60 scientists, engineers, technicians and graduate students from several institutions and NASA. From Cornell they include Powell, principal investigator for the mission; David Hysell, co-investigator and professor of earth and atmospheric sciences; Robert Miceli and Brady O'Hanlon, graduate students in the fields of electrical and computer engineering; and Mark Psiaki, professor of mechanical and aerospace engineering. One of the scientists' main goals is to investigate the effects of space weather on GPS satellites.

The project, in its third and final year, was initiated by the late Paul Kintner, Cornell professor of electrical and computer engineering, who served as the mission's principal investigator during its proposal and early development phases.

PHOTO: CASEY THOMPSON

Cornell University
College of Engineering
Cornell Engineering Magazine
B1 Carpenter Hall
Ithaca, NY 14853-2201

Non-Profit Org.
US POSTAGE
PAID
Cornell University

INTEL IN EVERYTHING

Industry expects 24 billion connected smart devices by 2020.

Intel partners with Cornell Systems Engineering to inspire students to harness the power of this "Internet of Things."

PAGE 20