Cornell Engineering Magazine

Summer 2017

EARTH SOURCE HEAT
CORNELL EYES ENGINEERING CHALLENGE TO HEAT ITS CAMPUS AND BEYOND

ESTABLISHING a PLANNED gift

SHOWS YOUR DEEPEST COMMITMENT TO THE CORNELL YOU KNOW AND LOVE.

To find out if naming Cornell University in your will, trust, as a beneficiary of a retirement plan or life insurance policy is right for you too, please contact the Office of Trusts, Estates, and Gift Planning.

What good will you do?

Professor Emeritus John "Jack" Muckstadt has been a presence at Cornell Engineering since 1974.

Each year, Jack's final lecture would end with some thoughts that transcended engineering. He noted that his students were about to graduate and commence their lives beyond Cornell: "Given your outstanding education, you will likely do well in life, but what good will you do? If you do not do good, you won't be happy."

A lifetime of engaging in philanthropy has brought happiness to Jack and his wife Linda. Recently, they decided to add Cornell Engineering to their estate plans. Their estate gift will support Cornell Engineering students so they can do well and do good for many years to come.

CONTACT:

GIFT_PLANNING@CORNELL.EDU
800-481-1865
ALUMNI.CORNELL.GIFTPLANS.ORG

CornellEngineering Magazine

CONTENTS

Summer 2017

FEATURES

DEPARTMENTS

ENGINEERINGNEWS

AguaClara opens its 14th Honduras plant, debuts micro system

AguaClara team leads Zoe Maisel '18, center, and Erica Marroquin '18, right, are pictured with Jorge Dueñas Carcamo of Agua Para el Pueblo, in Cuatro Comunidades, Honduras. The three were preparing to install AguaClara's first 1 liter-per-second system.

AguaClara was conceived more than a dozen years ago with the idea of providing clear, potable water to people in rural Honduras.

And with the opening in January of its 14th plant—AguaClara's biggest yet, in the town of Las Vegas—the project now serves more than 65,000 people in a country of more than 8 million, half of whom have limited access to clean water. Yet, due in part to what AguaClara program director Monroe Weber-Shirk calls the "economy of scale," providing clean water to residents in the country's smallest villages was simply not feasible.

That is, until now. AguaClara's latest innovation is a free-standing, 1 liter-per-second (1L/s) water treatment system, developed and tested last year in the program's Hollister Hall lab. During the annual two-week trip to Honduras by members of the AguaClara student team, the system was put on line in Cuatro Comunidades.

"This opens up all kinds of opportunities for us," Weber-Shirk, senior lecturer in civil and environmental engineering, said of the 1L/s technology. The system—employing the same principles of flocculation, sedimentation and filtration used in the larger plants—is housed in corrugated plastic and weighs less than 1,000 pounds. It can be built off-site, shipped on a pickup truck and installed.

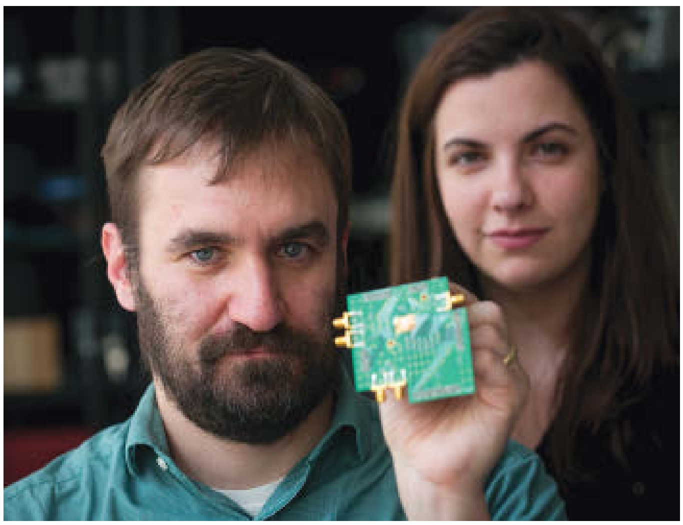
Cornell ranked among best in U.S. News grad school rankings

The 2018 *U.S. News & World Report* ranking of graduate schools is out, and Cornell has again landed in the top 10 for engineering programs.

At No. 4 in the nation, biological/agricultural engineering jumped two spots from last year's ranking. Other engineering categories ranked in the top 10 were: computer engineering, No. 7; industrial/manufacturing/systems engineering and mechanical engineering, both No. 8; materials engineering, No. 9; and civil engineering, No. 10. The fields are ranked by engineering school department heads.

Overall, Cornell's graduate engineering program ranked 13th among U.S. universities.

Engineers devise two-way radio on a single chip



Al Molnar, holding a test board with the two-way transceiver chip mounted in the center, is shown with graduate student Hazal Yüksel in Molnar's lab.

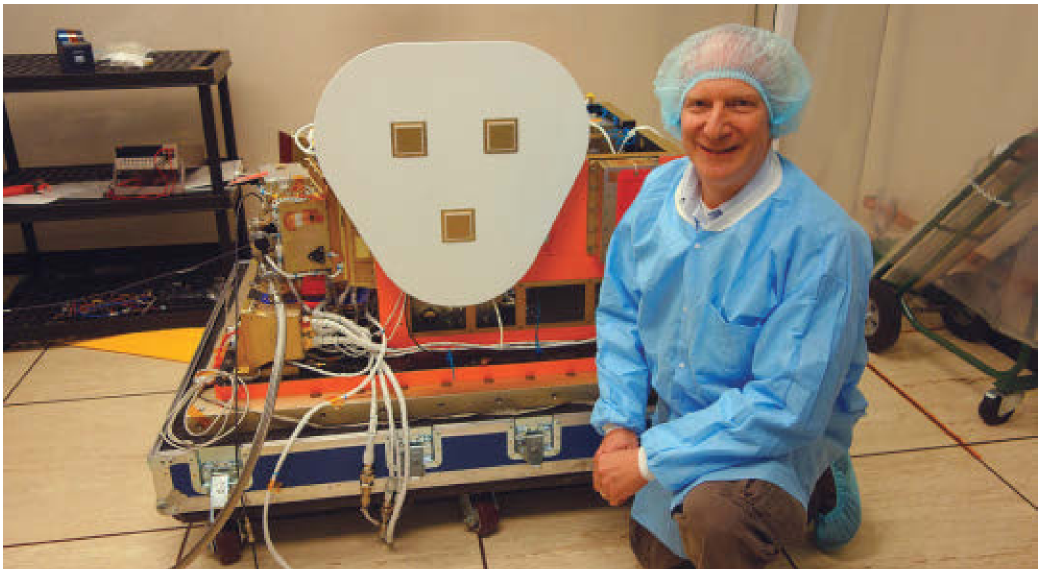
Two-way communication requires, of course, both send and receive capabilities. But putting them in the same device requires a filter between the send and receive circuits to provide signal isolation. From GPS to Bluetooth to Wi-Fi, each band requires a filter to stop the strong transmit signals from drowning out reception.

Alyosha Molnar, associate professor of electrical and computer engineering (ECE), and Alyssa Apsel, professor of ECE, have devised a method for both transmitting and receiving a radio signal on a single chip, which ultimately could help change the way wireless communication is done.

Their idea lies in the transmitter—actually a series of six subtransmitters all hooked into an artificial transmission line. Each sends its signal at regular intervals, and their individually weighted outputs are programmed so that they combine to produce a radio frequency signal in the forward direction, at the antenna port, while canceling out at the receive port. It's the theory behind noise-canceling headphones.

The Cornell group's subtransmitter concept will work over a range of frequencies – a positive for companies scrambling to buy new frequencies.

Experiment aboard space station studies 'space weather'



Steven Powell, research engineer in the department of electrical and computer engineering, is pictured with the Cornell GPS antenna array in a clean room at the NASA/Johnson Space Center in Houston, Texas.

To study conditions in the ionosphere, a band between 50 and 600 miles above the Earth, Steven Powell, research support specialist in electrical and computer engineering, and others have developed the FOTON (Fast Orbital TEC for Orbit and Navigation) GPS receiver. In February, the FOTON hitched a ride aboard the SpaceX Falcon 9 rocket to begin a long-term project at the International Space Station.

The project is called GROUP-C (GPS Radio Occultation and Ultraviolet Photometry-Colocated). Powell is the Cornell principal investigator for the project; another Cornell contributor includes David Hysell, professor of earth and atmospheric sciences.

The FOTON is a highly sensitive GPS receiver, designed to withstand the rigors of spaceflight while detecting subtle fluctuations in the signals from GPS satellites. "These fluctuations help us learn about the ionosphere in which the signals travel," said Powell.

GROUP-C's position onboard the ISS will allow it to study the ionosphere "at an edge-on perspective," Powell said, to measure variations in electron density. As they set, the radio signals travel through the ionosphere and are subtly delayed by the denser regions of the ionosphere. "From that, we obtain a vertical profile of the electron density," he added.

"The GROUP-C experiment duration will last up to two years," Powell said, "so the quantity of data and the potential for meaningful scientific discovery is huge."

CORNELL ENGINEERING MAGAZINE

ISSN 1081-3977
Volume 21, Number 2
Summer 2017

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

Dean
Lance Collins
Joseph Silbert Dean of Engineering

Associate Dean for Administration
Erin Mulrooney

Executive Editor
Dawn S. McWilliams
Director
Marketing and Communications

Editor
Syl Kacapyr
Marketing and Communications

Graphic Design
Robert Kurcoba
Graphic Designer
Marketing and Communications

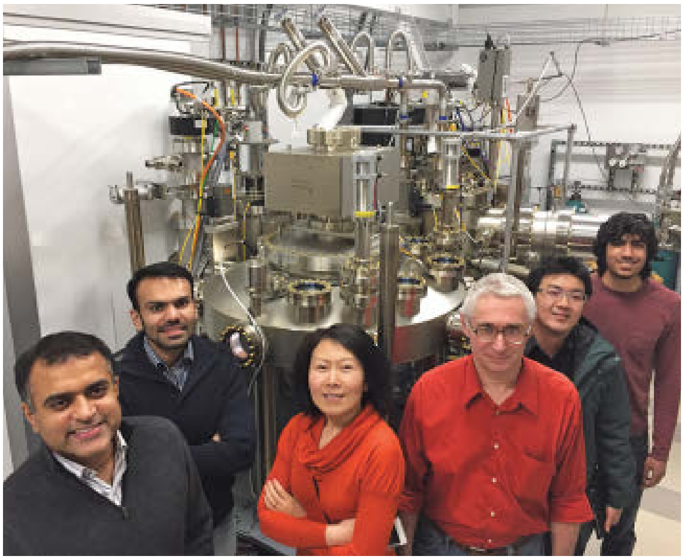
Printer
Cayuga Press

Photography
All photos by University Photography unless otherwise indicated

Editorial and Business Offices
252 Carpenter Hall
Ithaca, NY 14853-2201
phone 607 255-6095
fax 607 255-9606
e-mail cornell_engr_mag@cornell.edu

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

Group blazes path to efficient, eco-friendly deep-ultraviolet LED



Members of the Jena-Xing Research Group—Debdeep Jena, Moudud Islam, Huili (Grace) Xing, Vladimir Protasenko, Kevin Lee and Shyam Bharadwaj—are pictured in front of one of the molecular beam epitaxy systems used in their latest work.

The darkest form of ultraviolet light, known as UV-C, is unique because of its reputation as a killer of harmful organisms.

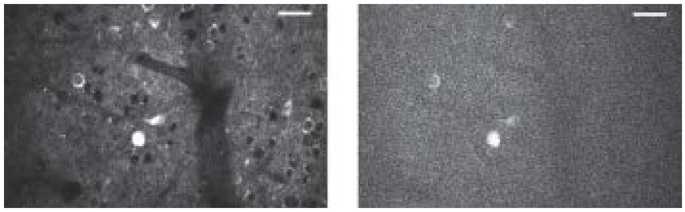
Currently, most deep-UV lamps are mercury-based. They pose a threat to the environment, and are bulky and inefficient. A Cornell research group led by Huili (Grace) Xing and Debdeep Jena, along with collaborators from the University of Notre Dame, has reported progress in creating a smaller, more earth-friendly alternative.

Using atomically controlled thin monolayers of gallium nitride (GaN) and aluminum nitride (AlN) as active regions, the group has shown the ability to produce deep-UV emission with a light-emitting diode (LED) between 232 and 270 nanometer wavelengths. Their 232-nanometer emission represents the shortest recorded wavelength using GaN as the light-emitting material.

Postdoctoral researcher SM (Moudud) Islam, the lead author, said: "UV-C light is very attractive because it can destroy the DNA of species that cause infectious diseases, which cause contamination of water and air."

Now that the group has proven its concept of enhanced deep-UV LED efficiency, its next task is packaging it in a device that could one day go on the market. Deep-UV LEDs are used in food preservation and counterfeit currency detection, among other things.

Group develops deep, noninvasive imaging of mouse brain



Measurement of signal-to-background ratio of three-photon (left) and two-photon (right) microscopy by imaging protein-labeled neurons 780 microns deep in a mouse brain.

Chris Xu, the Mong Family Foundation Director of Cornell Neurotech and professor of applied and engineering physics—together with Nozomi Nishimura, assistant professor of biomedical engineering, and a team of researchers—have reported clear, non-invasive imaging of activities of protein-labeled neurons in the subcortical region of the brain, beyond the limits of previous imaging technology.

Four years ago, Xu and his group reported proof-of-concept of three-photon microscopy (3PM), which can probe deeper into the brain than standard two-photon microscopy (2PM). In this work, Xu's group demonstrates 3PM operating at a wavelength of 1,300 nanometers using a new laser that was specifically developed for 3-photon imaging by a commercial company with Xu's guidance. The work recorded spontaneous activity from up to 150 neurons, labeled with a green fluorescent protein (GFP) based calcium sensor that makes the neuron glow bright green as it fires.

"We can see function; we can see how the mouse thinks," Xu said. "Neuroscientists could potentially connect the blinking neurons to the behavior exhibited at that instance by the mouse. What we are able to do is leave the brain intact and go all the way down [to the hippocampus] to see this. We were able to demonstrate this concept four years ago, but now we are saying that this is open for business, ready for neuroscience research."

On the Web

Cornell Engineering Magazine has a Website, with videos, Web extras, and the latest news. Come see what's happening and sign up for digital delivery.

www.engineering.cornell.edu/magazine

facebook.com/CornellEngineering

@CornellEng

www.youtube.com/CornellEng

http://bit.ly/1LukNq1

www.instagram.com/CornellEng

Mathematical models predict how we wait in line, traffic

From left, Jamol Pender, assistant professor of operations research and information engineering, Elizabeth Wesson, visiting assistant professor of mathematics, and Richard H. Rand, professor of mathematics and mechanical and aerospace engineering.

As New Jersey drivers approach the George Washington Bridge to enter New York City, a digital sign flashes overhead with estimates of the delays on the upper and lower levels of the bridge. Most drivers choose the level with the shortest predicted wait. But a few savvy drivers choose the other level, expecting that the digital signs are lagging and that conditions will change by the time they arrive at the bridge.

"Most people are waiting averse, so they tend to choose the shorter line—but occasionally, they'll choose the longer one," said Jamol Pender, assistant professor operations research and information engineering. "We really wanted to understand how delays in queue length or waiting time information affect the system dynamics, and so we developed a probabilistic way of calculating which line they will choose."

In collaboration with Richard Rand, professor of mechanical and aerospace engineering, Pender simulated probabilistic models that demonstrate that drivers obey digital signs that direct them toward less-congested routes. "As long as the discrepancy [between the digital sign and reality] is relatively minor, following the advice on the sign will continue to be the wisest decision," Pender said. "But once the discrepancy reaches a critical threshold—once the information lag is large enough—you get these oscillations in queues."

The team based its initial analysis on two-dimensional deterministic fluid models, which simulate how individuals tend to travel as a group from one destination to another. They found that, when individuals are given up-to-date information about queue lengths, the system evens itself out and no oscillations occur. Just the right number of individuals travel from a congested area to an open one until the next update advises those who have not yet migrated to stay put. But when individuals are given information with a significant lag, the system crumbles. As they flee the congested area in favor of the open one, individuals find it gradually becoming even more crowded than the first. When the information finally updates, the group rushes back in the other direction creating wild oscillations in the system.

Cornell engineers look to help arctic ships assess ice buildup

One of the main hazards of sailing in freezing temperatures is topside icing, in which water blown from the ocean freezes once it contacts a ship, potentially accumulating enough ice to put the vessel at risk of capsizing.

No tools have existed for ships to accurately monitor topside icing, but now Cornell engineers have demonstrated a novel method to do so using a combination of applied mathematics and computational mechanics.

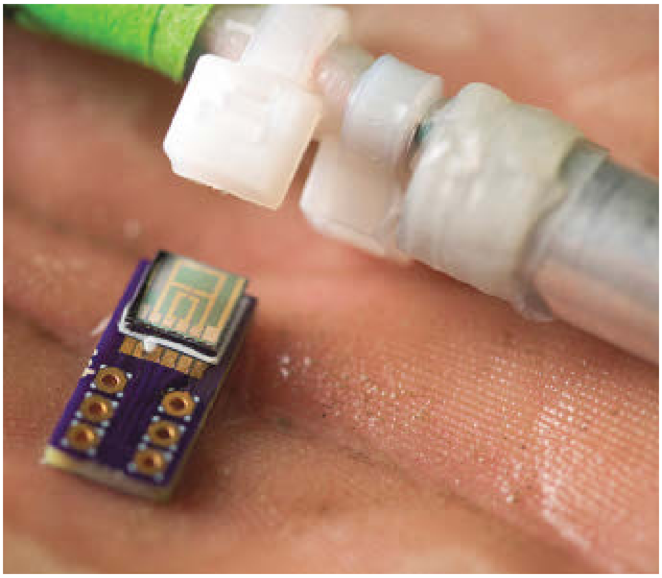
In topside icing, an effect is that the motion of the ship is changed due to the weight of the ice. "So we solve an inverse problem by using the inertial motion unit of the ship and a computer vision sensor that looks at the near wave field around the ship, and then use a model that turns that into an excitation," explained Chris Earls, professor of civil and environmental engineering. "So we have an excitation and a response to infer how much ice must be on the ship."

To demonstrate the inversion framework in the real world, Earls and his team applied it to the R/V Melville—a 279-foot Navy research vessel operated by the Scripps Institute of Oceanography prior to its retirement in 2015.

After validating the inversion framework at the model-scale, the team ran the framework on the full-scale ship, using the R/V Melville's onboard inertial motion unit. "Using telemetry, we were collecting data as the ship made some pretty severe maneuvers," said Earls. The full-scale results were more difficult to validate since the massive ship couldn't be lifted from the ocean and placed on a pendulum to measure the vessel's precise roll gyradius, "but it was within the expectations that we would have in our minds," Earls reported.

The team is now taking the successful proof of concept a step further by conducting new experiments using ships with more sophisticated equipment. "It's essentially a plug-and-play framework so you can put any seakeeping modeling tools into it," said Earls, who added that the new tests include applying topside icing to a scale-model ship.

Water sensor moves from basic research to promising business



Provided

Cornell-developed water sensor and probe that inserts into the stem or trunk of a plant.

A water sensor technology that began as basic research at Cornell is blooming into a business that fills a vital need for grape, nut, apple and other growers. The new sensor tells growers when their plants need irrigation with accurate, real-time readings at reasonable cost.

In mid-2016, Cornell engineers and horticulturalists who developed the sensor launched FloraPulse, a startup aimed at commercializing the sensor and using it to provide agricultural services. The first target markets are grape and nut growers in California's Central and Napa valleys.

"We're developing a service for growers to know exactly when, where and how much to irrigate," said Michael Santiago, Ph.D. '16, entrepreneurial lead for FloraPulse and a postdoctoral researcher in the lab of Abraham Stroock, the project's principal investigator.

In 2009, Stroock, director of the Robert Frederick Smith School of Chemical and Biomolecular Engineering, and Alan Lakso, professor emeritus of horticulture, began development of the sensor—a silicon chip with a tiny cavity that holds water. When the chip is embedded in a plant with drought stress, water leaves this cavity through a nanoporous membrane and the resulting tension is turned into an electrical signal.

"We're going to help make better wines, because there is a strong relationship between water pressure or the stress that we measure and the quality of red wine," Santiago said.

Students test Hyperloop pod at SpaceX competition

Provided

The OpenLoop pod on its way to Hyperloop Competition Weekend, Jan. 27-30, at the SpaceX headquarters.

Looking like a vehicle from the set of a sci-fi movie, an 18-foot-long pod engineered by a team that included Cornell students was put to the test during Hyperloop Competition Weekend, Jan. 27-30, at the SpaceX headquarters in Hawthorne, California.

Hyperloop is a high-speed transportation concept conceived by entrepreneur Elon Musk, CEO of SpaceX and Tesla, with the goal of sending a levitating passenger pod zipping through a near-vacuum tube at speeds of more than 700 mph.

More modest speeds were on display during the competition, in which 27 teams competed for a chance to test their fully functional prototype pods inside SpaceX's nearly mile-long vacuum tube. The tube is 6 feet in diameter and encases an aluminum track designed to guide the pods as they levitate using either magnetics or compressed air.

Among the teams was OpenLoop, a 60-member crew that included students from Cornell and five other universities. The team's pod uses scuba tanks to force compressed air downward, allowing it to float on a cushion of air above the track. Its air bearings, frame, suspension and controls are all hidden under a carbon-fiber shell.

The pod passed the competition's 100-point checklist and scored well in design, but experienced a malfunction during a preliminary trial inside a small test chamber. "SpaceX was basically giving half as much current as they needed to some of our valves, but outside of vacuum, our levitation was one of the best there. It has really low drag, and it's pretty smooth," explained Nick Parker '18, a computer science major who founded the team.

Due to unforeseen time constraints, only three pods were selected for a full test run inside the Hyperloop tube. While OpenLoop's pod was not among the three finalists, a second installment of the competition has been announced and a number of students are consulting with Parker to design a new Cornell-only pod.

New technique IDs micropollutants in New York waterways

Provided

Damian Helbling, left, and Amy Pochodylo, M.S. '14, examine samples of New York waterways in a search for previously undetected micropollutants.

Cornell engineers have developed a new technique to test for a wide range of micropollutants in lakes, rivers and other potable water sources that vastly outperforms conventional methods.

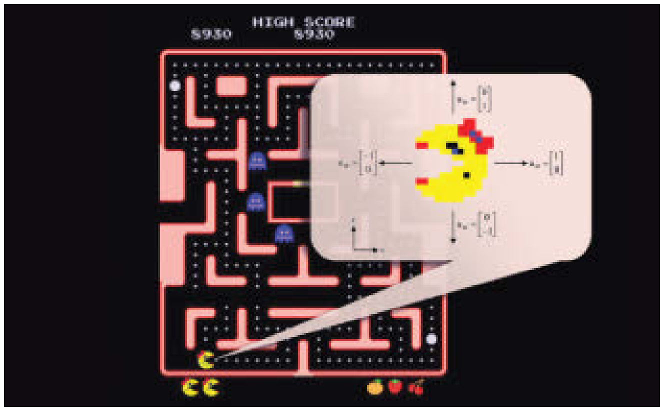
"Water quality monitoring is conventionally done by narrowly investigating one or a few contaminants at a time. We aimed to develop an analytical method that would be as broad as possible," said Damian Helbling, assistant professor of civil and environmental engineering.

The new technique—using high-resolution mass spectrometry—assessed 18 water samples collected from New York state waterways. A total of 112 so-called micropollutants were found in at least one of the samples—chemicals including pharmaceuticals, pesticides and personal care products. Helbling said that eight of the chemicals were found in every sample and dozens more were found in most samples.

Helbling refers to the approach as "suspect screening." The spectrometer analyzed the chemical composition of the water samples and the researchers compared the resulting data with a large list of 1,100 "suspect chemicals" by employing a nimble data-mining algorithm.

"It is no secret that the chemicals we use in our daily lives often find their way into our air and water. This work contributes to our understanding of the specific types of chemicals that influence our water resources," he said, noting that he believes this broad method will one day become routine in monitoring.

Engineers eat away at Ms. Pac-Man score with artificial player



Provided

A screen capture of the Ms. Pac-Man game showing control vector sign conventions used in a study led by Silvia Ferrari, professor of mechanical and aerospace engineering.

Using a novel approach for computing real-time game strategy, engineers have developed an artificial Ms. Pac-Man player that chomps the existing high score for computerized play.

The record score at the annual Ms. Pac-Man Screen Capture Competition stands at 36,280, but a trio of researchers led by Silvia Ferrari, professor of mechanical and aerospace engineering at Cornell, has produced a laboratory score of 43,720.

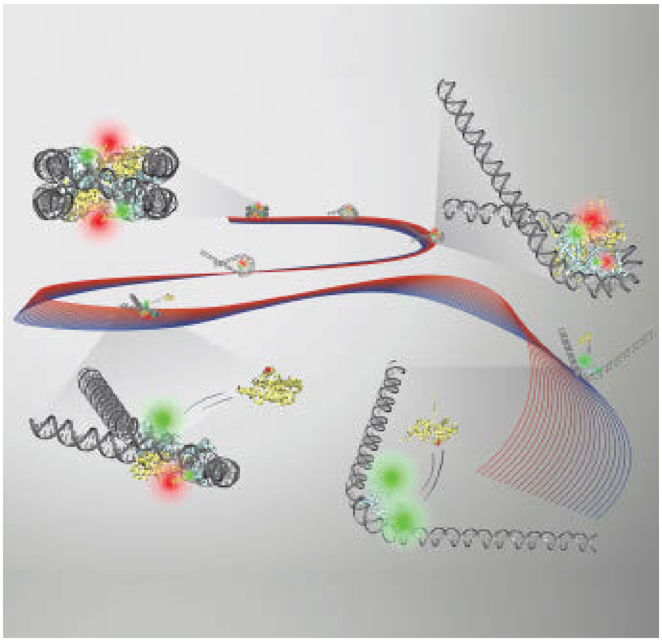
The score was achieved using a decision-tree approach in which the optimal moves for the artificial player are derived from a maze of geometry and dynamic equations that predict the movements of the ghosts with 94.6-percent accuracy. As the game progresses, the decision tree is updated in real-time.

"The novelty of our method is in how the decision tree is generated, combining both geometric elements of the maze with information-gathering objectives," said Ferrari, who noted that the information in this case is the fruit Ms. Pac-Man collects for bonus points. Her team is the first to mathematically model the game's components, whereas previous artificial players were developed with model-free methods.

Engineers take an interest in artificial players because they provide a benchmark challenge for developing new computational methods that can be applied to practical needs such as surveillance, search-and-rescue and mobile robotics.

While the Ms. Pac-Man Screen Capture Competition is now on indefinite hiatus, Ferrari said she may still revisit the project and improve the artificial player by adding a component that would allow it to autonomously learn from its mistakes as it plays more games.

Slo-mo unwrapping of nucleosomal DNA probes protein's role



Provided

Using X-rays to visualize DNA and fluorescence to monitor the histone proteins (yellow and cyan), Cornell researchers led by director of applied and engineering physics Lois Pollack found that the release of histone proteins is guided by unwrapping DNA.

A research group led by Lois Pollack, professor of applied and engineering physics, used a combination of X-ray and fluorescence-based approaches to study how the shapes and compositions of nucleosomes change after being destabilized.

The nucleosome core particle (NCP) consists of DNA wrapped around a core of eight histone proteins. Access to DNA is regulated through the unwrapping of the histone core, and an understanding of how this remodeling occurs can inform therapeutic strategies for many diseases, including cancer.

In the body, unwrapping of the DNA structure is triggered by proteins, but Pollack and her group used a salt solution. Earlier work by the group developed a new way to show that a high-concentration salt solution could make the DNA inside the nucleosome unwrap. This time around, the group used a salt solution that was about one-third less concentrated, slowing down the disassembly process and gaining new insights into how the DNA unwraps.

Using Forster resonance energy transfer (FRET), small-angle X-ray scattering and other methods, the group was able to get a clear picture of the DNA activity during unwrapping of the histone core. It was found that different DNA shapes were produced during the unwrapping process, most notably a "teardrop" shape that seemed to promote protein activity.

This finding suggests that the molecular transition is guided by this specific type of unwrapping. It's a step toward better understanding of DNA access during transcription, replication and repair.

Tailored organoid may help unravel immune response mystery

Ankur Singh, assistant professor of mechanical and aerospace engineering, and a team of researchers from the Meinig School of Biomedical Engineering and Weill Cornell Medicine have developed a modular immune organoid that can replicate the anatomical structures found within lymph nodes. The organoid mimics the early stages of a germinal center, where B cell differentiation and initiation of immunological responses take place during infection.

By manipulating the components of the organoid, the researchers are able to dictate the action of the immune-cell response and demonstrate, for the first time in a controlled manner, the role of the lymph node's environment in immune cell activation. And as opposed to two-dimensional models, the 3-D organoid enables much quicker and more plentiful replication of B cells, which are antibody-producing lymphocytes.

"This method presents the first lab-made 3-D immune tissue that allows you to change things found in immune organs once you get infected—the altered extracellular matrix, cell-cell interactions—and control the pace at which immune cell respond," Singh said.

"Up to now, we have not been able to study the earliest steps of malignant transformation of cells in the immune system," said Dr. Ari Melnick, professor of hematology/oncology at Weill Cornell Medicine. "Now we can design experiments that will give us unprecedented understanding of how these tumors form, which will in turn provide critical insights into how to treat these diseases."

Abbreviated news clips appear courtesy of the *Cornell Chronicle* and were written by Tom Fleischman, Blaine Friedlander, Syl Kacapyr, Susan Kelley, Joshua Krisch and Krishna Ramanujan. Full versions of each news clip appear online at engineering.cornell.edu/news.

COLLABSPACE

MAKERS deserve their OWN SPACE ONLINE!

Cornell Engineering has launched CollabSpace, an online community where you can:

- Meet others people who share your interest in technology and creativity.
- Post details of projects you are working on and get feedback from the maker community.
- Learn skills from basic soldering to programming a Raspberry Pi.
- Gain access to advisors and mentors from among the ranks of Cornell Engineering's world-class professors, alumni and engineering students.

Follow your curiosity, share your strengths and gain new skills!

Visit COLLABSPACE.CORNELL.EDU

Questions? Email us at **COLLABSPACE@CORNELL.EDU**

CornellEngineering

UNDERGRADS DISCOVER THEIR RESEARCH PASSION IN THE LAB

By Chris Dawson

When Megan Hill '15 was a freshman at Cornell Engineering she dreamed that maybe someday before she graduated she would be able to get into the Cornell Nanoscale Science and Technology Facility (CNF) in Duffield Hall to do some research. "I came in thinking I wanted to be a Chem E, but then I took an intro to engineering class on nanoscience and after that I was like, 'I have to do that. I will do that before I leave here." In her mind, "before I leave here" meant probably sometime during her senior year.

It turns out, Hill didn't have to wait anywhere near that long. She took an introductory materials class and that led her to become a materials science major. Shortly after, she joined Associate Professor Mike Thompson's lab group and was doing research in the CNF as a sophomore.

While it may sound surprising that a 19-year-old student would have access to nanotechnology equipment that costs millions of dollars to build and operate, this sort of thing happens at Cornell Engineering fairly regularly. Many undergraduate engineering students choose Cornell for this very reason. In fact, almost half of the engineering undergraduates participate in some form of research before they graduate.

Mike Thompson, the materials science and engineering (MSE) faculty member who welcomed Hill into his lab, said "Megan Hill was just a natural for semiconductor processing. As a sophomore, her work fabricating microelectronic devices in the CNF was critical to our work on understanding alternative semiconductor materials." Thompson, who is always supportive of undergraduate researchers in his lab, added, "Inviting undergraduates into our research projects is definitely a win-win situation. Students gain real lab experiences with an opportunity to apply their course learning to current problems, and my lab gains incredibly enthusiastic and talented researchers."

These days, Hill is two years into a Ph.D. program in materials science and engineering at Northwestern University. She has continued to study nanomaterials in the group of Professor Lincoln Lauhon, focusing on characterizing strain and composition in semiconducting nanowires. Contacted recently by email, Hill confirmed the value of her undergraduate research at Cornell: "My invaluable experience in Professor Thompson's lab not only encouraged me to pursue a research career, but also gave me the skills necessary to excel in a top Ph.D. program."

Five minutes later, another email came in from Hill. "I forgot to mention: I was awarded a National Science Foundation (NSF) graduate research fellowship at the end

Carlie Mendoza '16, undergraduate student in biological science and materials science and engineering (MSE), works with graduate student Kai Ma in the lab.

of my senior year, which provides me three years of research funding. My undergraduate research was critical to NSF in the application process, as it showed my capability to succeed in graduate school."

What's In It For Me?

It makes sense that undergraduate engineering majors would want lab experience. A fair percentage of them go onto graduate studies or research positions within industry or government labs upon graduation. What better way to find out if research is something you want to pursue than by doing it?

Frank Wise, the Samuel B. Eckert Professor of Engineering in Cornell's School of Applied and Engineering Physics, agrees wholeheartedly on the value of undergraduates doing research. "In my opinion," said Wise, "it is critical for students to see the theoretical stuff they learn in classes put into action. I was lucky enough to work in a lab as an undergrad and it was a huge 'a-ha' moment. I would probably not be in research science today but for that experience."

When an undergraduate asks Wise about work in his lab, Wise and his Ph.D. students get together and brainstorm projects. They cannot simply say "yes" to each request since time and attention are resources in constant demand. But they sometimes see things that are the perfect scope for an undergraduate. Zachary Ziegler '17 took a quantum physics class with Wise in his junior year. "It was my favorite class at Cornell," said Ziegler, "and Professor Wise's research looked interesting, so I asked to join his group. After a little bit of back and forth we found a project that fit me well, so I joined the group."

Ziegler admits that he is actually doing several kinds of research when he works in Professor Wise's lab. He works with a new type of fiber laser that can reach the highest levels of performance in terms of output-pulse energy and quality while at the same time remaining competitive in both cost and stability. But in addition to the scientific research, Ziegler is also investigating his career options.

"I wanted to do research as an undergraduate mainly to learn what kind of things are out there in engineering physics, and what the state of the art looks like," said Ziegler. "While I've known that I enjoy STEM, I have always wanted to see what working in different fields is like, and the different kinds of problems one faces. Maybe I didn't know that was my motivation when I started doing research, but I think it's true. I will admit, some of my motivation is pretty selfish: I wanted to figure out what I would enjoy doing after I graduate."

University Support

Rather than calling Zeigler's motivation selfish, Lisa Schneider-Bentley would probably call it smart and reasonable. Schneider-Bentley is the director of Engineering Learning Initiatives (ELI) at Cornell. Part of her job is to administer the Undergraduate Research Program at Cornell Engineering. "There are tremendous benefits for engineering students doing research as undergraduates," said Schneider-Bentley. "It is a great opportunity to apply classroom learning to the broader field right away. It exposes students to the research process, and to the collaboration and mentoring relationships that are critical within a successful research group. Also, it helps them define their career paths."

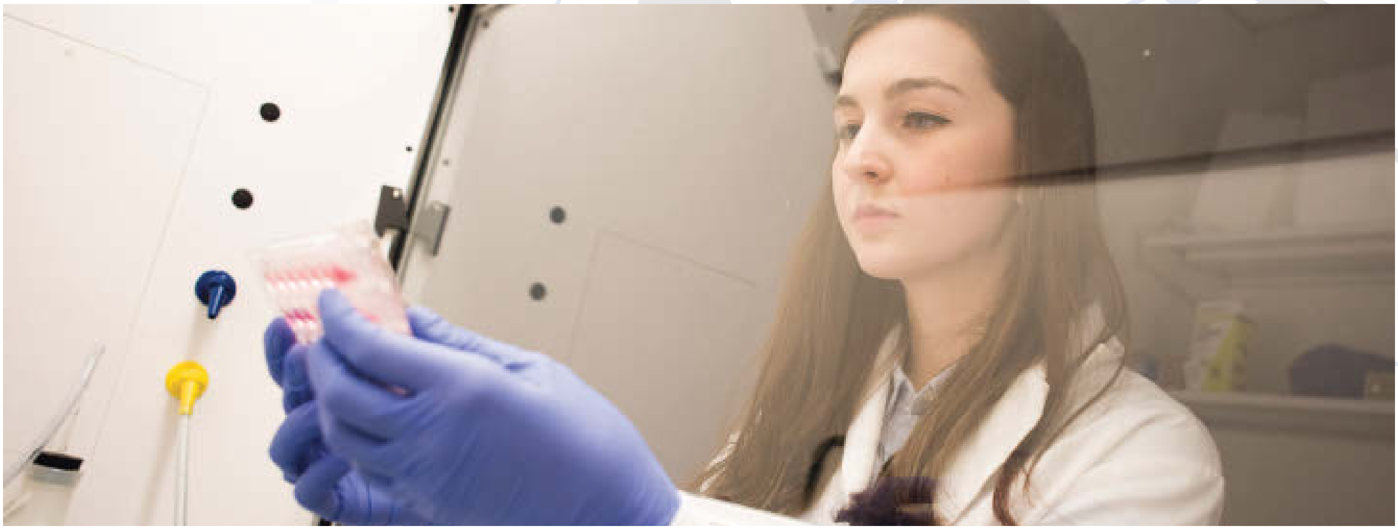
In addition to these benefits, engaging in undergraduate research can also lead to academic credits or pay. Once a student has secured a spot in a lab, they may be able to arrange with their faculty mentor to receive academic credit for their research effort.

Professors receive funding for their research projects from a variety of sources. These sources have varying rules on how those funds can be used. Some allow a professor to pay undergraduate researchers from their grants while some do not. This is where Schneider-Bentley's office can help. "Our undergraduate research grant program allows students to earn wages for their time spent engaging in research on a mentored project. This is especially helpful for those undergraduates who need to earn money toward school costs, enabling them to have a research experience rather than dedicating the time to some other on- or off-campus job," said Schneider-Bentley. "It also helps alleviate the costs for faculty members who include undergraduates in their research programs."

Schneider-Bentley says that in the current year, her office was able to fund roughly 60 percent of the engineering

"UNDERGRADUATES HAVE HELPED ME MOVE PROJECTS FORWARD FROM IDEA TO CONCRETE RESULTS THAT CAN THEN BE USED IN PROPOSALS AS WELL AS TO HELP COMPLETE RESEARCH PROJECTS AND CO-AUTHOR SCIENTIFIC PUBLICATIONS."

— Matthew Pritchard



Elizabeth Weiss '17 works in the lab of BME professor Claudia Fischbach-Teschl.

undergraduates who applied. "I have been in this position for 14 years," said Schneider-Bentley, "and in that time I have seen growing interest in undergraduate research from both students and faculty. We are working hard to expand and diversify our funding base to help support this interest."

Some money comes from the general pool of funds contributed by Cornell Engineering alumni, some comes from specific, directed alumni donations and some comes from corporate sponsorships. Air Products and Chemicals, Inc. and the Boeing Company are examples of corporate partners who have provided financial support for undergraduate research at Cornell Engineering in recent years.

Another consistent and valuable source of support over the years has been Jim Moore, a 1962 graduate of what was then the School of Electrical Engineering at Cornell. Undergraduate research "adds a whole new dimension to the academic experience that you can't get in the classroom," said Moore. "I had the opportunity to work with Professor Sam Linke one summer. I also worked several summers for Professor Ralph Bolgiano as a technician supporting his trans-horizon research. I gained a lot of practical knowledge and I got paid." Moore believes in the value of undergraduate research so passionately that he has been supporting the Undergraduate Research Program for almost 30 years.

Another means of support for undergraduate researchers is the Hunter R. Rawlings III Cornell Presidential Research Scholars Program (RCPRS). This program is not limited to engineering students. Rather, it supports a select group of undergraduate students from all of the colleges at Cornell. It provides each scholar with a generous research support account and other financial aid. Rawlings Scholars collaborate with a faculty mentor to design and carry out an individualized program of research.

Elizabeth Weiss '17, a biomedical engineering student, says that the Rawlings Program played a decisive part in her decision to come to Cornell. Weiss worked with Professor Julius Lucks, formerly with the Robert Frederick Smith School of Chemical and Biomolecular Engineering (CBE). Her project with Lucks focused on biomolecular engineering of RNA gene regulatory mechanisms. Before Weiss's junior year at Cornell, Professor Lucks took a new position at Northwestern. Weiss wanted to continue to do research that would help her grow as a scientist, so she sent a few emails to professors whose work she found interesting.

Weiss found a spot in the lab of Claudia Fischbach-Teschl, professor of biomedical engineering. The Fischbach Lab applies multidisciplinary strategies to gain a better qualitative and quantitative understanding of the microenvironmental conditions fundamental to the pathogenesis and therapy of cancer. Tapping into her previous experiences in other labs, Weiss was able to offer some real expertise in the design and implementation of a project looking at the difference in gene expression in bone cells under normal conditions and when tumor factors are present. "It feels good to make real contributions to the work of the lab," said Weiss.

Just Ask

Samantha Moruzzi '20 did not have a chance to do any sort of scientific research in high school. But it was something she was excited to pursue once she got to Cornell. "I was walking through ClubFest when I stopped at the table for the Cornell Undergraduate Research Board (CURB)," said Moruzzi, a science of earth systems student. "Pretty quickly, I was paired with a mentor who was a senior and she helped me figure out how to get started."

Moruzzi took it from there. She set up a meeting with Matthew Pritchard, associate professor of earth and atmospheric sciences, to ask about his research. That conversation led to an interview and the interview led to a research position in Pritchard's lab.

"I am looking at thermal anomalies at volcanoes in Central and South America as measured by orbiting remote sensing equipment," said Moruzzi. "In the end, we are trying to improve prediction capabilities when it comes to volcanic eruptions. I like it because it gives me hands-on experience, I get to see what I am learning in the classroom put into practice." Moruzzi's long term goal is to take what researchers are learning about other planets and moons in the solar system and use it to better understand geologic processes here on Earth. "I also know that I will apply to be a mentor through CURB to help other people find their own research path," says Moruzzi.

Pritchard has had 35 undergraduates work on various research projects over the years and says it is a very rewarding part of his job. "Undergraduates have helped me move projects forward from idea to concrete results that can then be used in proposals as well as to help complete research projects and co-author scientific publications," said Pritchard. "Undergraduates add enthusiasm that drives new experimental research projects, they have time available to finish ongoing or existing projects, and they are a force multiplier to help my graduate students and postdocs be successful in their own projects."

Another professor who has had many undergraduate researchers in his lab over the years is Uli Wiesner, the Spencer T. Olin Professor of Engineering in MSE. "Hands on experience is one of the best motivators for students," said Wiesner. "To be part of a research group and experience that research culture was an incredible experience for me and I would like to provide undergrads in my lab that same opportunity."

Wiesner also mentions an important benefit of having undergraduates in the lab: "My graduate students learn how to supervise a student themselves, which is an important experience for them to learn from. Working with an undergraduate may also allow them to work on a side project which otherwise would not be covered. It is a win-win."

Divya Srinivasan '18 is currently working in Wiesner's lab and she highly recommends the experience. "Sometimes I'm surprised at the work I do, and the opportunities I get through research," said the MSE student. "I had no exposure to research in high school. I tell a lot freshman here who are afraid or think that they may not have the necessary background that if they are interested they should just ask. It is never a bad thing to be in a room full of people smarter than you—that just creates an opportunity to learn so much more." Srinivasan's work in the Wiesner Lab has been funded through the Undergraduate Research Program and through the Rawlings Presidential Research Scholars Program.

Through her participation in the Rawlings Scholars Program she has attended the American Society for Engineering Education Conference and has presented posters on her research. "Going into it, my main goal was to learn how to do the things the Wiesner Lab does," said Srinivasan. "But I have also learned so much more about research and about the field."

Another Cornell undergraduate who has found a meaningful research project simply by asking is Ivy Suiwen Wu '17. Wu took a class on stochastic modeling with Andreea Minca, assistant professor of operations research and information engineering (ORIE), and at the end of the semester, Wu and three other students asked for Minca's help finding a project they could tackle that would have real impact in the world. Minca had the team join her on an interdisciplinary project with Human Ecology Professor Rana Zadeh of the Cornell Health Designs Innovations Lab. "Undergraduates have the technical skills to approach difficult problems," said Minca. "They also have the courage. They are not afraid of the challenge. They can leverage their knowledge and solve real problems."

Wu, along with ORIE undergrads Jane Lee, Dae Won Kim and So Yeon Yoon, worked to optimize the floorplan of hospital intensive care units (ICUs). Nurses in ICUs have many routine tasks that are dictated by workplace and medicine safety rules. Depending on the physical layout of the unit, some of these rules can result in nurses making multiple trips to and from the same room simply to accomplish a task as basic as delivering morning meds. Wu and her team believe there has to be a better way. "Our project aims to find a way to optimize the floor plan of a nursing unit to minimize the walking distance traveled by a nurse during a typical workday and to maximize the quality of patient care," said Wu.

Stwart Pena '16 and Oliver Lake '17 conducted research with CBE Professor Paul Steen in the summer of 2014. Both received funding through the Cornell Engineering Undergraduate Research Program.

Wu and her group were able to design a simulator to model the way a typical nurse's work flows in an acute care unit. Using the simulator, they are able to see how work flow interacts with the environment. They are now writing a paper describing their findings. Their hope is that healthcare architects will use their simulator and their ideas to design the ICUs of the future.

Learning By Doing

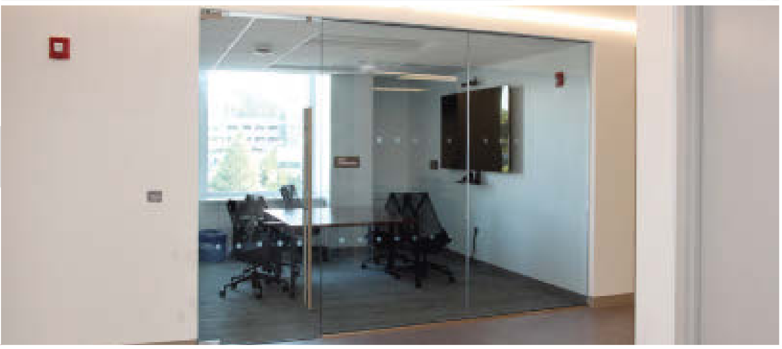
The best way to learn what research scientists do is by doing it. Engineering students benefit, professors benefit, graduate students and postdocs benefit. Just as importantly, society benefits from the innovations that come out of these labs and from the development of the next generation of skilled researchers. In the same way that medieval guilds brought people into the field of glass-blowing or carpentry or metalwork, research labs at Cornell Engineering are taking in and training undergraduates who often go on to academic, government or industrial research positions of their own.

Students see the relevance of classroom learning right away, they see how the research process works in their particular field, they learn more about their own possible career paths and they often develop valuable mentor-mentee relationships with professors and graduate students. Professors gain enthusiastic lab members and create focused projects that move their labs' efforts forward. Grad students and postdocs get experience managing other people. And the generational march of scientific research continues forward.

“TRUST WE HAVE LAID THE FOUNDATION OF AN UNIVERSITY—AN INSTITUTION WHERE ANY PERSON CAN FIND INSTRUCTION IN ANY STUDY.”

— Ezra Cornell

UPSON HALL



Keeping Ezra’s vision alive.

Upson Hall has been completely recreated—top to bottom and walls to wires. Show what Cornell Engineering means to you. Consider a gift to support the Sibley School’s new home for the 21st century.

What will your gift support?

The new Upson Hall has a state-of-the-art suite of robotics labs, an entire floor devoted to the wildly successful student project teams, seven collaboration spaces designed to encourage the cross-pollination of ideas, specialized hybrid research areas, and many features designed to enhance the visual façade and greatly increase the energy efficiency of the building.

CONTACT:

Debra Hurley, Major Gifts Officer, Cornell Engineering

dlh242@cornell.edu • 607-255-1789

PROGRAM TRANSFORMS ENGINEERS FROM LEARNERS TO LEADERS

BY SYL KACAPYR

When Jerica Huang '18 first set foot on Cornell's campus, she was by most standards a typical engineering student: a computer science major with an affinity for math, a bit reserved, passing her time by studying and competing in hackathons. But on the inside dwelled another persona.

So when less than a year later she found herself competing in the 2015 Miss New Jersey USA Ambassador Pageant, an event she describes as the most nerve-wracking thing she's ever done, it was clear there had been a revelation in her life.

That revelation was the Cornell Engineering Leadership Program, an initiative launched in 2012 to provide a number of opportunities for students to tap their inner strengths while also building new leadership skills. With only two full-time staff members, the program has grown to reach 80 percent of all Cornell Engineering students today.

"There's just a real hunger for this kind of education," said Erica Dawson Ph.D. '04, the Nancy and Bob Selander Director of the program. "So many of our students are involved in project teams and leadership opportunities. The other thing I think there's a hunger for is impact. They're very multifaceted and they want to do big things. They're asking themselves, 'how can I be this person that can have a huge impact on the world?'"

Huang had asked herself that very question after coding opened her eyes to the potential computer science has to make a tangible impact on people's lives. Through the course of one of the leadership program's offerings, Huang realized that she needed to challenge herself to have more of a voice, and that's when she guardedly entered the pageant. To her surprise, she won.

"Pageantry became my platform to advocate for the causes I care deeply about, such as ending the stigma surrounding mental illnesses and promoting Girls Who Code," said Huang, referring to the non-profit organization that encourages young women interested in computer science. Huang has since continued competing in pageants and switched her major to information science, systems and technology—a move she says will help her best prepare for a leadership role in her career.

Jerica Huang '18

"She's gotten so much out of this program and given so much back," said Dawson. "She just really blows me away." Dawson has been impressed with many of her students' new-found personal and professional skills—skills that are now considered essential assets for today's working engineers expected to manage projects, lead working groups, teach students, inform policy or start their own company. Through the Leadership Program, students prepare for those professional responsibilities by embracing them as undergraduates.

MODERN SKILLS FOR MODERN ENGINEERS

The Cornell Engineering Leadership Program has roots in the business world, where leadership is a trait that has long been valued and students are generally offered a number of courses, programs and opportunities to learn those skills in a classroom environment.

Lance Collins, the Joseph Silbert Dean of Engineering, saw the need for providing those same opportunities to engineering students after overseeing several student project teams during his tenure as director of the Sibley School of Mechanical and Aerospace Engineering. "I was often amazed at the quality of leadership that the students were able to show, but on occasion, there were times when some of the teams had some difficulties and it occurred to me that it would be great for us to have a more structured way of teaching the students about leadership."

So naturally Collins turned to someone with experience in business education. Dawson had previously been an assistant professor of management and organizations at Yale University and at the Rady School of Management in San Diego. When she arrived at Cornell, financial support from alumnus Charles S. Brown Jr. '72, '73 M.Eng. and an anonymous donor helped launch the leadership program. Dawson's first order of business was to establish programming that catered to the needs of engineers, a group she was not familiar with at the time, but quickly came to understand.

"I don't think different models of leadership fundamentally apply to different fields. So you can take a model of leadership and it applies to engineers just as well as anybody else," said Dawson. "But the big difference is how engineers learn. So you can't just take an M.B.A. program and plop it in the College of Engineering and have it be successful."

Dawson is currently writing an academic report that highlights her findings regarding how engineers learn. "I reject the stereotype that engineers are like introverted nerds and that they don't have any people skills. That's just not true. What we do know is they've self-selected into a field that is very oriented toward problem solving that rejects ambiguity. They like clear right or wrong answers. And they don't get a lot of training, or previously didn't, on personal and professional skills. So by the time you see professional engineers, they can appear introverted, but that's just because they haven't had that kind of training," said Dawson.

Professional skills can be misconstrued in both engineering and business, according to Robert Selander '72, former CEO of MasterCard. Selander has given $6 million to blossom the Cornell Engineering Leadership Program from its beginning stages to its next evolution, endowing an associate director position that Dawson says will allow new offerings and opportunities for students. Selander says a lack of communication skills can sometimes be associated with a lack of competency, even though that isn't the case. "Early in my career I had the chance to work in several countries. I recall visiting branches in Brazil and realizing that judging the capabilities and insights of individuals based on their English language skills—I was still struggling with their native Portuguese—could lead to bad calls on relative capabilities and potential," said Selander.

"Some people do come with a set of skills that's a little more oriented toward leadership, but a lot of it is you're just being rewarded for being outgoing and confident," said Dawson. "And it looks like in the end some people have it and some people don't. If we go on that model, we're missing all of the students who maybe don't fit the stereotype of a leader. These are the quieter students, the people who wouldn't consider themselves leaders. That's who I'm here to serve."

BUILDING A PROGRAM

In its first five years, the Cornell Engineering Leadership Program has grown to include a number of courses, a certificate program, individualized consulting and has fused itself into a number of existing courses.

Dawson has built the program around what she calls the four pillars of leadership—knowledge, experience, insight, courage—all while maintaining a hands-on, problem-solving curriculum that engineers have a propensity for.

"It's a chance for personal reflection and development grounded in values and ethics, and at the other end is: here are the skills of a manager, here's how you run a meeting, how you manage a project," explained Dawson, highlighting the importance of introspect and tangible skills in leadership training. "We cover both of those things and I think that is what makes us unique here at Cornell."

Students are exposed to the program early, with faculty inviting Dawson into freshman advising seminars to discuss the importance of teamwork—something that is universally recognized as an essential aspect of engineering. The encounter also gives Dawson the opportunity to share other offerings, such as the Engineering Leadership Certificate Program. The highly selective, one-year program for undergraduates requires two courses that cover competencies in self management, teamwork, leadership and professional skills.

The certificate program also requires students to work in small groups to design and implement a project related to their interests. In 2016, a group created a network between Cornell and the greater Ithaca community by organizing, recruiting and transporting students to volunteer at the Ithaca Children's Garden and the Jenkins Center for Hope and Recovery. "In the case of our project, we had to get other people on board with us. And so that's one aspect of leadership: you have to be passionate about what you're doing in order to be able to inspire others to follow you. And I think that's one thing we developed through this project," said Esther Chen '18, a

Students participate in a team exercise during a retreat hosted by the Engineering Leadership Program.

Erica Dawson, director of the Engineering Leadership Program, instructs a group of students.

biomedical engineering major and a member of the group that created the volunteer network.

Another group engineered solar-powered composters and worked with a local high school to install them on school grounds. The group included an educational component that helped the high school students revitalize existing composting efforts. Like other groups in the certificate program, the students who built the composters were required to raise the necessary funds on their own. But Dawson says support from the Selanders now allows her to offer seed funding when student groups are able to develop a budget and justification for it.

Graduates of the program earn a designation on their transcript recognizing demonstrated excellence in engineering leadership. Some of those graduates return to the program as mentors, working peer-to-peer with the program's new students.

Dawson teaches a third course outside of the certificate program that focuses on women in the workplace. Although the course is offered by the SC Johnson College of Business, typically about a third of the enrollees are engineering students. It's geared toward both male and female students, and explores the challenges of managing gender diversity and best practices for attracting and leveraging female talent.

"It's really any field where you have a male majority. For women, there's going to be those hurdles. And that's also true for underrepresented minorities," said Dawson, who adds that her office works with the office of Diversity Programs in Engineering to develop and update the curriculum. "We're trying to work more with them on what it is to be underrepresented in your group. So if I'm the solo, fill in the blank, African American or woman in my group, how are other people likely to see me and interact with me, and what can I do about that?"

COLLABORATIVE TEACHING

Dawson concedes that few students are able to squeeze additional courses into their packed class schedules, so she has expanded the reach of her program by finding courses where students are already working in teams and integrating leadership skills into those experiences. Dawson calls the effort "collaborative teaching," and it's another attribute that makes Cornell unique among engineering leadership programs.

One of those courses is ECE 3400 Electrical and Computer Engineering Practice and Design, in which students work in teams throughout the semester to design and build a system. Last year the course concluded with a competition in which robots built by the undergraduate teams had to autonomously navigate and map labyrinths in the shortest amount of time.

"We're working with professors to make some small adjustments to the way those teams are run so students can get a lot more out of that experience," said Dawson. That includes selecting team members using a novel software—developed at Cornell by Kathy Dimiduk '79, director of the James McCormick Family Teaching Excellence Institute—that's designed to form healthy, well-functioning teams based on social science research. "So the software knows not to isolate women or unrepresented minorities, for instance. It looks at a number of different metrics and based on social science, it forms a team that will have the highest chance for success," added Dawson.

In the case of ECE 3400, Dawson's office also gave guest lectures on team skills and encouraged the student teams to craft and sign group contracts with team goals and ground rules. Charles Seyler, a professor of electrical and computer engineering who taught the course when the Leadership Program first intervened, says the team performances were much more uniform than in pervious years, with the gap between the best and worst performing teams diminished.

Higher participation rates in the course's final presentations were also observed and end-of-semester questionnaires submitted by the students revealed positive interactions between team members. "From my direct experience as a professor in a course that benefited from the Engineering Leadership Program as well my observations of results from other components of the program, I'm a very enthusiastic supporter," said Seyler. "The program has great value for our students. Teamwork and leadership skills are essential to being a productive engineer in today's workplace."

Despite the reach of the program, Dawson says her office still isn't able to meet the demand for leadership training. In the case of the certificate program, her office turns away three students for everyone one that it accepts. But as the program continues to grow, so too will opportunities for students.

"We're trying to have as big of an impact as possible with a small staff," Dawson said, noting that her office recently hired its second full-time employee, Rob Parker, the Nancy and Bob Selander Associate Director. The program is already having a larger impact because of Parker, who is designing leadership software of his own while also working one-on-one with student project teams, providing coaching and customized consulting.

As she discussed her vision for the program's future, a smile grew on Dawson's face and she uttered the words one might expect to hear from a true leader: "I have big dreams."

EARTH SOURCE HEAT

CORNELL EYES ENGINEERING CHALLENGE TO HEAT ITS CAMPUS AND BEYOND

By Syl Kacapyr

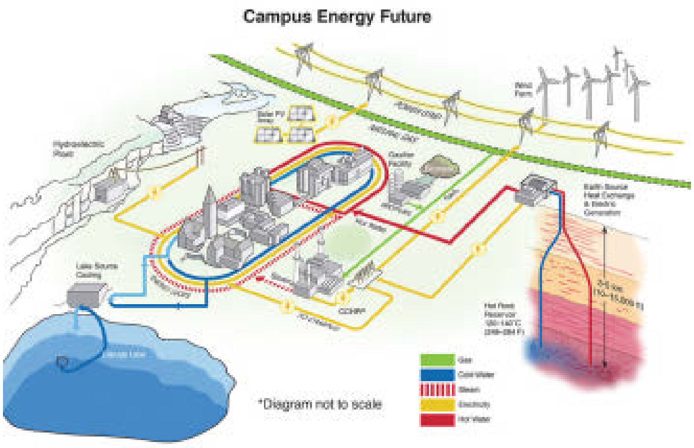


Diagram illustrating current and future energy sources employed on Cornell's campus, including the proposed Earth Source Heat system.

When asking Cornell alumni about some of their more infamous memories, a likely answer is the arduous winter trek up Libe Slope. Not wanting to arrive late to class, students can be seen climbing the small, but steep, hill with the determination of early 19th century explorers attempting to reach the North Pole.

But unlike those rugged explorers who first navigated the arctic, students enjoy a much more reasonable winter and can quickly find warmth inside the confines of a classroom. Ensuring the luxury of warmth throughout Cornell's 745-acre campus comes at a cost, as it does for any resident of a seasonal climate. The university's annual energy bill is approximately $42 million, a large fraction of which pays for heating-related expenses. The heat expended by campus leaves behind an annual footprint of roughly 110,000 metric tons of carbon dioxide.

Recognizing that business as usual would continue to bear these costs, former university President David Skorton committed Cornell to becoming a carbon neutral campus. In 2009 he launched the Climate Action Plan, which evolved through the years to ultimately proclaim the ambitious goal of making the Ithaca campus carbon neutral by 2035.

Since that time, Cornell has decommissioned its coal-powered boilers, constructed several solar farms, committed to purchase wind power and met most of its cooling needs using renewable cold water from the depths of Cayuga Lake. This, combined with energy conservation efforts, has reduced Cornell's carbon emissions by more than 30 percent. But to become carbon neutral, it's become clear that Cornell must find a powerful, yet cheap and renewable source of heat for its campus. So what does an institution full of engineers, scientists and thought leaders do when a practical solution to a challenge doesn't exist? It creates it.

In September, the university announced a project called Earth Source Heat. The idea behind the project is to tap the earth's vast heat reservoir using an enhanced-geothermal system. Unlike traditional geothermal systems, Earth Source Heat would be best optimized by reaching hot basement rock—metamorphic or igneous rock that is 200- to 300-degrees Fahrenheit—sitting up to 5 kilometers below campus. To reach that depth, extract the clean, renewable heat and then distribute it throughout the campus would require a feat of engineering that has yet to be achieved in the U.S. It would require breaking the rules to challenge conventional thought about how and where such geothermal systems can be deployed.

The stakes are high. If successful, Cornell would all but eliminate the use of fossil-fuels to heat its campus. But the ultimate goal is much larger than that. Success would mean demonstrating a new energy solution that could be adopted by other communities in the U.S. and beyond.

GEOTHERMAL TODAY

To understand the technical and economic challenges of engineering the geothermal system envisioned by Cornell, one must also understand why there has been little precedent.

Facilities leaders at Cornell first began conceiving of Earth Source Heat, or at least how the university might take advantage of geothermal energy at a large scale, nearly a decade ago following the 2007 release of the landmark report "The Future of Geothermal Energy." The report, chaired by Jeff Tester, director of the Cornell Energy Institute who was an MIT faculty member at the time, was a comprehensive assessment of the potential for geothermal energy to become a major energy source for the U.S.

A major finding of the report is that geothermal energy has the potential to add about 10 gigawatts of commercial electric-generating capacity to the U.S., representing about 1 percent of the country's overall capacity today. That's if the energy is generated from traditional hydrothermal systems that require the presence of fluid, heat and permeable rock. But if enhanced-geothermal systems were used to extract heat from harder-to-reach basement rock, the U.S. could gain over 100 gigawatts of

> **"WHAT PEOPLE DON'T THINK ABOUT IS BY DOING NOTHING, YOU'RE NOT MAKING A DECISION TO DO NOTHING. YOU'RE MAKING A DECISION TO DO THE STATUS QUO."**
>
> **—Todd Cowen**

Phase 1

Depiction of Earth Source Heat Phase 1, which includes community engagement, system design, seismic data gathering and other preparatory research.

capacity within 50 years, representing an astounding 10 percent of the country's electric capacity. Unlike hydrothermal systems, enhanced-geothermal systems don't require naturally-occurring water and rock permeability because those elements can be engineered, geographically broadening where geothermal energy can be deployed.

The report garnered interest from energy leaders and policy makers. Geothermal technology companies like AltaRock Energy began to sprout. At the same time, countries like Australia were already beginning to implement enhanced-geothermal systems. "So it was really a period of international enlightenment for this. Even Google and other companies like Kleiner Perkins were putting money into research," said Tester, who is also the Croll Professor of Sustainable Energy Systems in the Robert F. Smith School of Chemical and Biomolecular Engineering.

But U.S. enthusiasm for the renewable energy source soon began to wane. There wasn't any one place to cast blame, according to Tester. Relatively cheap fossil fuels, competing renewable technologies and an economic recession, among other diversions, quelled interest in geothermal research and development despite the implications for energy security and the environment.

Today, a small handful of enhanced-geothermal systems exist in the U.S., all of which are found in western states where geological conditions are more favorable and basement rock is easier to access. Those systems are serving mostly as experimental, demonstration projects that focus on using the earth's heat to produce electricity, as opposed to "direct-use heat," in which it's applied directly for use in a heating system.

"We should have much more of a national sense of urgency of doing this. The issues of climate change are becoming so apparent now that we've got to get started in a serious way," said Tester, who was motivated to come to Cornell, in part, by the opportunity to develop a geothermal district energy system for campus.

Tester, along with his students and faculty colleagues, has continued to publish work highlighting the potential of geothermal energy through a series of reports examining direct-use heating. A recent study authored by Koenraad Beckers '16 Ph.D., a former student of Tester's who now works for the National Renewable Energy Laboratory, demonstrates a new model for quantifying the technical and economic direct-use potential for the U.S. Tester says the research represents an interesting shift in geothermal interest, away from the inherent limitations of electricity production. "To really make enhanced geothermal work economically, particularly with the low-cost, affordable fuels we have now like natural gas, we're going to have to look at ways in which we can use geothermal heat directly," he said.

ENVISIONING THE SYSTEM

The challenge of harvesting heat submerged deep within the earth and transporting it to more than 250 buildings on campus is exacerbated by the fact that no existing geothermal systems address Cornell's precise geological circumstance and heating goals. But faculty and facilities engineers do have a conceptual vision of Earth Source Heat.

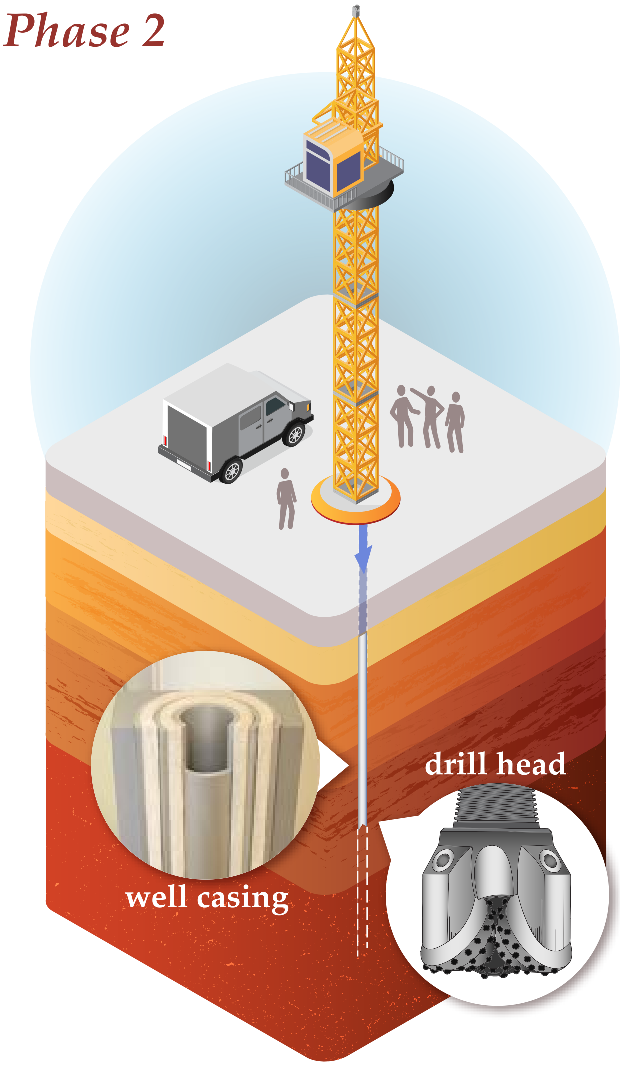
To reach the underground hot rock and extract heat, a pair of wells would be drilled. Each well would have a sufficient diameter to accommodate 40 to 80 liters per second of water flow, leaving enough room for thick concrete casing and metal piping. Until more is determined about the rock formations below Cornell, it's not known exactly how deep the wells would need to be. Reaching the desired temperature range would likely require delving 3 to 5 kilometers, or 1.9 to 3.1 miles, below the surface.

Water would flow down the first well into a deep reservoir, circulating through a network of pores and crevasses within hot reservoir rock and absorbing a portion of its thermal energy. The water would then be pumped back to the surface through the second well.

Once at the surface, the heated water would enter a heat exchanger—essentially two chambers separated by a thin layer of steel—that transfers heat from the geothermal fluid to water contained in a second, closed-loop system that would distribute the supply of heat to a network of campus buildings. A facility would safely house the wells, heat exchangers and most other visible components of the system.

The single well pair would only be capable of heating a section of campus, so approximately four to six well pairs would be required to heat the entire campus. A formal siting hasn't been conducted, but criteria for the location of each well pair includes distance from private land and adjacency to the designated area of campus it would serve.

Earth Source Heat resembles Cornell's existing system in that a centralized source of heat supplies the entire campus. The current system relies on the university's Combined Heat and Power Plant, where natural gas powers two large combustion turbines that produce the campus's electricity supply. Waste heat from the turbines is collected by steam generators and the steam is distributed throughout campus. "Steam is not a modern and efficient way to distribute heat in a district energy



Depiction of Earth Source Heat Phase 2, which includes digging a 3-to-5-kilometer-deep test well safely enclosed in thick concrete and metal piping.

system," said Robert Bland '74, M.S. '80, M.B.A. '96, associate vice president for energy and sustainability in Cornell's division of Infrastructure, Properties and Planning. "About 20 percent of energy is lost to the ground, even through a well maintained and insulated system."

Water used in the Earth Source Heat system would maintain more of that energy. The desired temperature engineers hope to reach underground is at least 200-degrees Fahrenheit, although research will reveal the full range of temperatures attainable under campus, and at what depths they occur, so that a cost-benefit analysis can be done to determine the best temperature to use in the system.

The cost of converting the current distribution system into one compatible with Earth Source Heat is estimated at $200 million, but the existing pipe routes and potentially some of the power plant could be utilized. "The real advantage is the buildings are already set up for an external source of heat," said Bland, adding that most buildings would only require modifications as opposed to complete revamps.

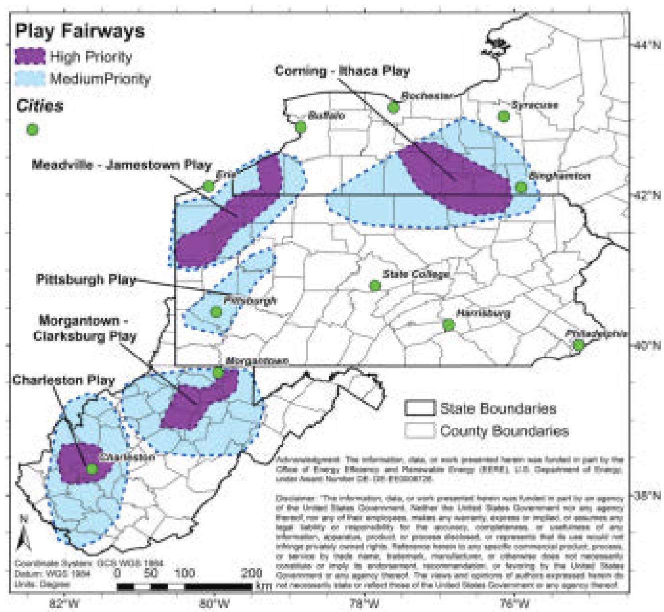
ENERGY SOURCES

An exciting vision for Earth Source Heat is its cascading uses, according to Bland, meaning the heated water produced by the system could deliver financial and environmental benefits beyond heated buildings. "So the idea is it comes out of the ground, heats buildings, then flows at a lower temperature to heat a greenhouse or heat-dry biomass," said Bland.

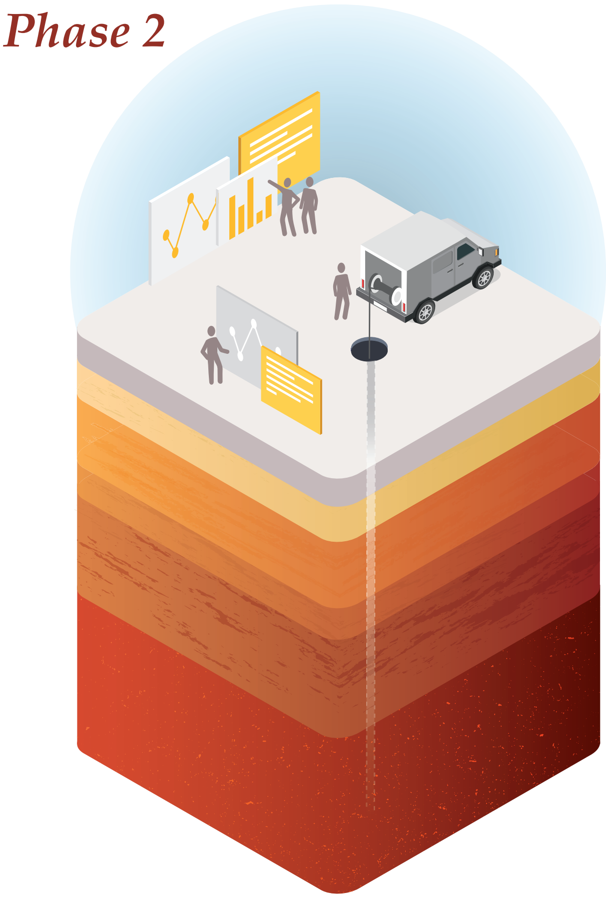
The prospect of being able to dry biomass materials such as willow and switch grass plays into one of the recommendations for the Earth Source Heat system, which is to supplement it with a biomass gasification facility. The biomass facility would serve as an additional heat source during winter cold snaps when the increased demand for heat can't be fully satisfied by the geothermal system. Bland says heating the entire campus with biomass isn't feasible, but for managing peak load on the system, "it's a cheaper alternative to building a relatively expensive well pair that would just be used for a few days a year."

The idea of adding not one, but two new sustainable energy sources to Cornell's repertoire is exciting for many, but especially for Bland, who has dedicated much of his 30-year career at Cornell to keeping the university at the forefront of energy sustainability. After graduating from Cornell with a chemical engineering degree, Bland worked in the energy industry before returning to Cornell to research alternative fuels, specifically waste cellulosic ethanol biofuels. He has since brought his passion for energy and the environment to the division of Infrastructure, Properties and Planning, where he's been instrumental in bringing renewable energy sources to Cornell, including the Lake Source Cooling system that inspired Earth Source Heat.

Lake Source Cooling pumps water from the depths of Cayuga Lake—where temperatures remain around 40-degrees Fahrenheit year-round—to a heat-exchange facility that then pumps cold water to campus, where it cools buildings and lab equipment. The system went online in 2000, replacing the university's less efficient refrigeration-based water chillers and reducing campus electricity use by more than 10 percent. In its 17 years of operation, Lake Source Cooling has flawlessly



Map highlighting the Appalachian Basin's most favorable "play fairways," or areas most attractive for an Earth-Source-Heat-type system, according to a 2016 Cornell study.



Depiction of Earth Source Heat Phase 2, which includes gathering data from the test well to gain a better understanding of the geology below the well site.

worked to reduce Cornell's carbon footprint while also serving as an award-winning model of innovative energy technology.

Bland hopes the same radical ingenuity that produced Lake Source Cooling can also make Earth Source Heat a reality. "I really believe we have a climate crisis and I'm personally motivated and passionate about creating a carbon neutral campus," said Bland. "It's great that Cornell can do this not only to reduce our own emissions, but also to demonstrate to the world a new use for this technology."

WHAT LIES BELOW

The precise design of the Earth Source Heat system is contingent upon the geology that lies beneath Cornell, particularly how deep, how hot and how permeable the rock formations are. "We don't quite know what we're going to find when we drill down 3, 4, 5 kilometers. We have earth scientists, geophysicists and a variety of people involved in studying what that is going to look like," said Todd Cowen, a professor of civil and environmental engineering, the Kathy Dwyer Marble and Curt Marble Faculty Director for Energy at Cornell's David R. Atkinson Center for a Sustainable Future, and a member of the Earth Source Heat Executive Steering Team.

There are early clues as to what those scientists will find thanks to a 2016 Cornell study that analyzed the subsurface rock properties of a large portion of the Appalachian Basin. Faculty and graduate students from three different Cornell Engineering departments rigorously pored through data generated by the fossil fuel industry, examining nearly 40,000 drilling locations throughout much of New York, Pennsylvania and West Virginia. Informed by oil- and gas-well logs, the scientists were able to map which regions were most likely favorable for direct- use geothermal energy.

From the perspective of Cornell's Earth Source Heat plans, the most important factor analyzed by the researchers was natural reservoir quality. "We were looking for rocks that had natural pore space. You want rocks that have holes in which hot water can be stored. You also want those pores to be interconnected by flow paths," said Teresa Jordan, the J. Preston Levis Professor of Engineering and principal investigator for the study. These reservoirs can include anything from sedimentary rock layers that have permeable zones to basement rock in which water would more likely flow along fractures or old fault zones.

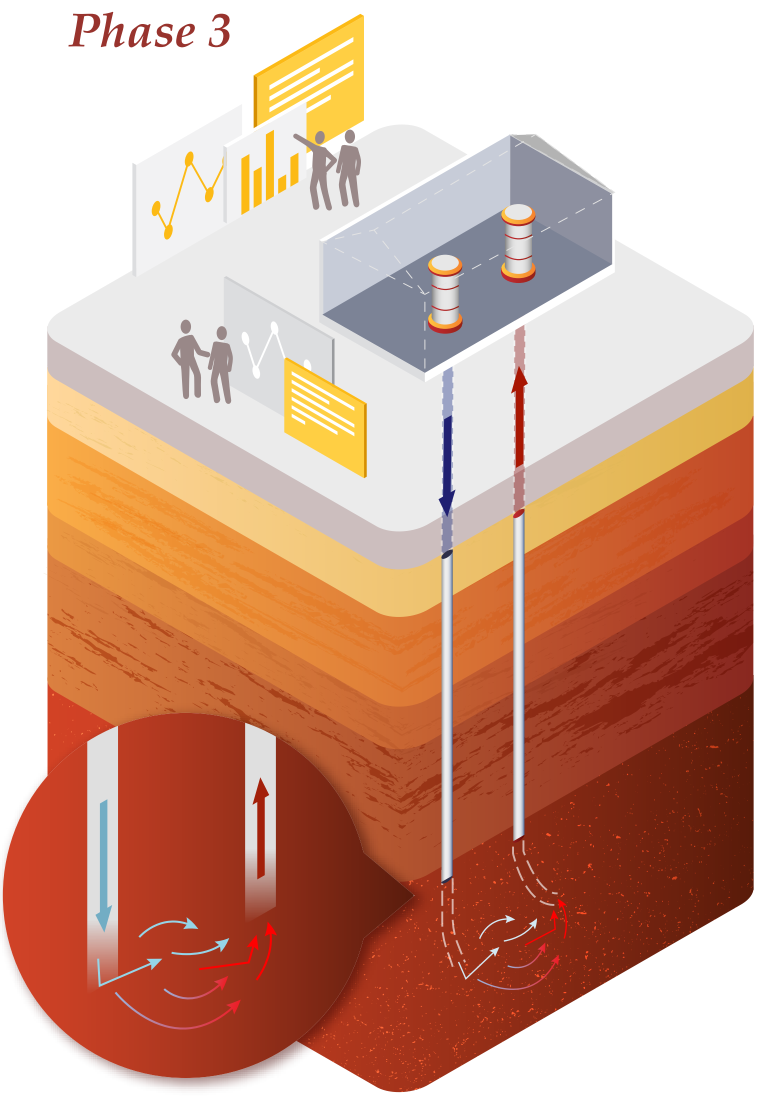
Such permeability needs to be well tuned in a geothermal system: it should allow water to move slowly enough to absorb the earth's heat, yet fast enough to be pumped to the surface. The larger the reservoir, the larger the water flow and amount of heat that can be delivered.

"The Appalachian Basin has a small set of locations where we think natural flow will suffice for a Cornell-type system," said Jordan, noting that the Elmira-Corning region of New York provides attractive conditions. "Gas fields there are proven to be able to flow at high rates. Gas isn't the same as geothermal fluid, but if you're in a good position to flow the gas, the odds are improved that you're in a good position to flow the water as well," added Jordan.

Sitting directly between Elmira and other locations where fossil fuel companies discovered favorable rock types is Cornell. But it's still unknown if the Ithaca area shares the same reservoir quality because those companies never explored it, leaving the research team with little data to analyze.

"It's entirely plausible that sitting right under campus could be the rocks with the pore spaces that are just as good as the ones in Corning. Maybe there are horizons in the rock at around 2.6 kilometers below us which would be happy to deliver water to us if we started pumping," said Jordan, noting that such a dream scenario could allow Cornell to move forward with the Earth Source Heat project without the challenge of artificially engineering suitable permeability conditions.

Katie Keranen, assistant professor of earth and atmospheric sciences, right, works with students to bury a seismometer on campus as part of preparatory research for Earth Source Heat.



Depiction of Earth Source Heat Phase 3, which includes drilling a second well to form an operating pair, creating a demonstration project that could heat a section of campus. After exiting the first well, water circulates through a network of pores and crevasses within hot reservoir rock, absorbing a portion of its thermal energy before a pump forces the water into the second well and back to the surface.

A CLOSER LOOK

A first step toward gathering better geological data for the Ithaca area began in 2015 when—supported by an Atkinson Center Academic Venture Fund—Cornell engineers buried 15 seismometers across the campus to measure seismic activity over the course of a year.

Data from the Intraplate Tectonics Monitoring Project—led by Larry Brown, the Sidney Kaufman Professor in Geophysics, and Katie Keranen, assistant professor of earth and atmospheric sciences—is still being analyzed, but will eventually shape the engineering behind Earth Source Heat by helping to determine the subsurface conditions that will affect design options. Those conditions include rock permeability, response to water being pumped through, and how that water flow could be artificially enhanced.

Early analysis of the data has revealed spikes in activity, but according to Brown, it's unclear if those spikes are related to earthquakes. "One spike looks like we picked up airplanes landing at the airport, for example. We also expect to detect some of the blasting going on relative to the area salt mines."

The sensitivity of the equipment is key because the ability to detect small earthquakes that aren't felt by people on the surface could indicate that the area has an active fault, something that would, under certain conditions, respond poorly to a geothermal system circulating water underground. But so far there's no reason to believe that's the case, especially given Ithaca's lack of earthquake history. Still, more analysis needs to be conducted.

Aside from background seismicity, the project recorded global earthquakes that were detected locally. "That data will tell us something about how the ground here responds to earthquake waves. We may get very different responses if we're sitting on a thick layer of glacial deposits versus sitting closer to bedrock," said Brown.

These data are also important because they could give researchers a better idea of where quality reservoirs or rock layers prime for geothermal are located below campus. This would allow engineers to choose locations to conduct more sophisticated experiments such as active seismic surveys, in which vibroseis trucks send vibrations into the ground, resulting in an acoustic, three-dimensional views of exactly what lies below.

All of the data being gathered by the research team are being made public through a website that, once launched, will also share real-time seismic data for the Ithaca area. In the meantime, Brown invites the public to view the analog seismograph station located in Cornell's Snee Hall.

"This is a great opportunity to let the community in on what we're studying and to help them understand the distinction between induced seismic activity that is dangerous and induced seismic activity which is actually just signals that help us to avoid earthquakes," said Brown, referring to seismic surveys. Once Earth Source Heat moves into the installation phase, small tremors may also occur during the well-drilling process. Scientists can use this seismic data in the same way, including to track how fluid is flowing through the subsurface. "Think of it like receiving an X-ray," said Brown, analogizing seismic imaging to how a doctor would image bones in the human body.

BUILDING A TEAM

Understanding the geology below Cornell's campus and then engineering a system based on those findings will be challenging, "but the reality is we have people that are building businesses on these technologies already. The technical challenges are surmountable," said Cowen. "The greatest challenge we're going to face is really one of the traditional challenges we always see in energy transformations, and that is engaging our community, listening to and addressing their concerns, and working with them to develop a way forward."

In October, the university released a report titled "Options for Achieving a Carbon Neutral Campus by 2035: Analysis of Solutions." In it, Cornell's Senior Leaders Climate Action Group stressed the importance of pursuing energy solutions in partnership with local, national and international entities. This includes local community members, Cornell alumni, private businesses, foundations and government partners interested in helping to move Earth Source Heat and other sustainability initiatives forward.

"Our aim is to not only work toward carbon neutrality on campus, but to pioneer new technologies that communities large and small can implement," said Lance Collins, the Joseph Silbert Dean of Cornell Engineering and co-chair of the action group. "Everyone should have a stake in this because we're all facing the same need for new energy solutions."

Cornell faculty, staff and students are especially called upon to help move the university's Climate Action Plan forward. While Earth Source Heat and other renewable-energy projects are highlighted as key recommendations for achieving carbon neutrality, the report also lauds a multi-level approach that includes reducing the overall demand for energy on campus.

"Over the past decade, our Ithaca campus has grown by more than 2 million square feet, but energy consumption has actually decreased thanks to improving building-energy efficiency and the Energy Conservation Initiative driven by ingenuity and engagement from faculty, staff and students who share the urgency to make a difference on campus," said Provost Michael Kotlikoff while discussing the report with the *Cornell Chronicle*. Other programs such as Think Big, Live Green and Campus Climate Literacy Engagement are noted in the report as having produced significant energy savings.

University leaders have hosted open community forums to discuss the report and the Earth Source Heat project. More are being planned as Cornell continues to share the risks and rewards of its Climate Action Plan, including the costs associated with becoming carbon neutral. While pursuing Earth Source Heat, wind-water-solar projects and a biomass facility could reduce Cornell's annual operating costs by as much as $19 million, according to the report, capital costs could reach $700 million.

Cowen believes that must be weighed against the cost of doing nothing. "We have a challenge as we face transitions, where we look and say, 'I don't want a wind farm because that affects my viewshed. Or I'm worried about what that does,'" said Cowen. "What people don't think about is by doing nothing, you're not making a decision to do nothing. You're making a decision to do the status quo."

NEXT STEPS

While much of Cornell's Climate Action Plan has already been set in motion, its key component—Earth Source Heat—is far from shovel ready. Research to determine exactly what the geology under Ithaca's East Hill looks like will continue along with other experiments to determine the feasibility of engineering a safe and economical enhanced-geothermal system.

"The very first phase is really a preparatory phase to do the permitting, siting, to figure out where we would place this and to do the community outreach," said Collins. "We need to make sure that the community is supportive and that the permits are going to be able to come forward." Collins says the first phase will also examine system design at a baseline level.

Within the next two years, Cornell hopes to move into phase two with the installation of a single test well that will provide the best understanding yet of the ground beneath campus and what a full-scale system might require. "But at the moment, the funding doesn't exist. So we're in the process of trying to build the fund to initiate," Collins added. "It's going to be like that peg solution, where each time you get one thing to happen, it allows you to reach a little bit higher on the next one." If the test well produces viable results, a third phase would seek to install an adjacent well and heat-exchange facility, creating a small-scale demonstration project that could heat multiple buildings within a section of campus. It's expected to take about six years to complete all three phases and if successful, a full-scale project could then be implemented over the next 10 years.

"IT'S REALLY UNIQUE AND THERE ARE FEW PLACES IN THE WORLD THAT CAN PULL ALL OF THAT OFF, AND SO IT MAKES ME VERY PROUD TO SEE WHAT WE'RE GOING TO BE ABLE TO DO HERE AT CORNELL."

—Lance Collins

"It's the seamless connection between students, faculty and the facilities people that can actually implement what we learn from the experiments and from the research that we're doing into a full-scale demonstration," said Collins, describing the university as a "living laboratory" that often employs a research-to-application model. "It's really unique and there are few places in the world that can pull all of that off, and so it makes me very proud to see what we're going to be able to do here at Cornell."

The path to Earth Source Heat is a long, steep hill to climb—one that makes a snow-covered Libe Slope seem not as daunting. But Libe Slope does provide some foresight. At its peak is the Arts Quad where a statue stands of the university's founder, Ezra Cornell—an engineer himself who once envisioned how a technology might one day change the world.

Cornell Engineering Dean Lance Collins, middle, talks with Todd Cowen, professor of civil and environmental engineering, and Irene Weiser, a town council member from Caroline, N.Y., at a March 28 public meeting that addressed Earth Source Heat and Cornell's goals for carbon neutrality.

by Geoffrey Giller

INSIGHT

Institute for Nutritional Sciences, Global Health, and Technology

DESIGNING DIAGNOSTIC TOOLS FOR THE DEVELOPING WORLD

In the Star Trek franchise, the go-to diagnostic tool for doctors is the tricorder. This futuristic device can rapidly diagnose a variety of medical conditions without so much as the need for a blood sample.

The tricorder does not, of course, exist in the real world. But science fiction has a strange way of both predicting real scientific advances and of spurring innovation. In fact, there's an X Prize competition to design a tricorder that can detect anemia, pneumonia and urinary tract infections, among multiple other conditions.

While David Erickson, a professor at the Sibley School of Mechanical and Aerospace Engineering, and Saurabh Mehta, an associate professor of global health, epidemiology and nutrition at Cornell's College of Human Ecology, aren't striving to win that prize, they are also building something that can quickly and efficiently reveal medically-relevant data. The NutriPhone, with just a small finger-prick of blood, can reliably detect levels of vitamins A and B12 in the bloodstream, and the device may soon have the ability to diagnose vitamin D and iron deficiencies.

Mehta and Erickson teamed up about five years ago when they realized that most medical technological advances "usually widen the health gap between the poor and the rich," says Mehta. This is true both in the United States and internationally, he says, resulting in a disparity: if you can afford it, you get access to better, fancier equipment; if you can't, then you usually end up with sub-par or outdated technology. Their collaborative work led them to form the Institute for Nutritional Sciences, Global Health, and Technology—or INSiGHT—last year. What they want to find out is, says Mehta: "Can we apply advances in modern technology to solve problems that can bridge these health divides?"

INSiGHT also has several other public health endeavors under development, including a tool similar to the NutriPhone that could quickly diagnose diseases including dengue and malaria. "The idea behind INSiGHT," says Erickson, "is that it's a center by which we can bring together people interested in global health and nutrition... with engineers who have both the skills and the interest to solve those problems."

Erickson and Mehta want to take advantage of the ubiquity and familiarity of smartphones. Erickson envisions someone

Former students Li Jiang, front left, and Dakota O'Dell, front, examine a web page in the new laboratory space for VitaScan, as the director of the McGovern Center Lou Walcer, back left, looks on with Saurabh Mehta, associate professor of global health, epidemiology and nutrition, and David Erickson, professor of mechanical and aerospace engineering.

A field staff member measures the arm circumference of a child in India as part of a research project led by Saurabh Mehta, associate professor of global health, epidemiology and nutrition.

switching seamlessly from their Facebook app to their vitamin D app. “People are extremely comfortable in the smartphone ecosystem,” says Erickson. He and his colleagues hope to take advantage of that comfort to maximize use of the NutriPhone.

Currently, there are working NutriPhone prototypes being produced by a company, VitaScan, which is run by Li Jiang Ph.D. ‘14 and Dakota O’Dell Ph.D. ‘16, former students of Erickson’s (Erickson and Mehta are both founding members and on the board of directors of VitaScan). The company is currently housed at the McGovern Center at Cornell, an incubator for biotechnology companies, and recently received a nearly $75,000 grant from the non-profit FuzeHub. The grant will be used to develop a manufacturing and packaging process in preparation for commercialization of the device.

“THE IDEA BEHIND INSIGHT, IS THAT IT’S A CENTER BY WHICH WE CAN BRING TOGETHER PEOPLE INTERESTED IN GLOBAL HEALTH AND NUTRITION… WITH ENGINEERS WHO HAVE BOTH THE SKILLS AND THE INTEREST TO SOLVE THOSE PROBLEMS.”

— David Erickson

The prototype—now dubbed the VitaScan in preparation for its entry into the commercial market—is a small white box with a slot in the front. This is where the small blood sample, absorbed onto a test strip, would be inserted. The test strip works by first filtering out blood cells, letting the micronutrient-containing plasma pass to the next stage. The vitamin or mineral in question—let’s take iron, stored as ferritin in the body, as an example—first binds with specific antibodies, which are also part of the test strip. Those antibodies are also attached to gold nanoparticles. The combined ferritin-antibody-gold complex then flows across one of two lines. The first is a line of antibodies that also bind to ferritin. Gold nanoparticles show up as pink, so the darker pink this first line is, the higher the concentration of ferritin in the sample. The second test line binds to all remaining antibodies that didn’t bind to ferritin. If there are a lot of these unbound antibodies left over after passing the first test line, then this second line would be relatively dark compared to the first line, meaning that iron concentrations are low. If, however, the person has good iron levels, there will be relatively few antibodies left unattached to ferritin, and this second line will be lighter compared with the first one.

“THERE IS A LOT OF INTERDISCIPLINARY WORK THAT HAPPENS AT CORNELL. WE WANT TO GET ALL THE BRIGHT MINDS AT CORNELL UNDER AN UMBRELLA AND PROVIDE THE SPARK.”

— Saurabh Mehta

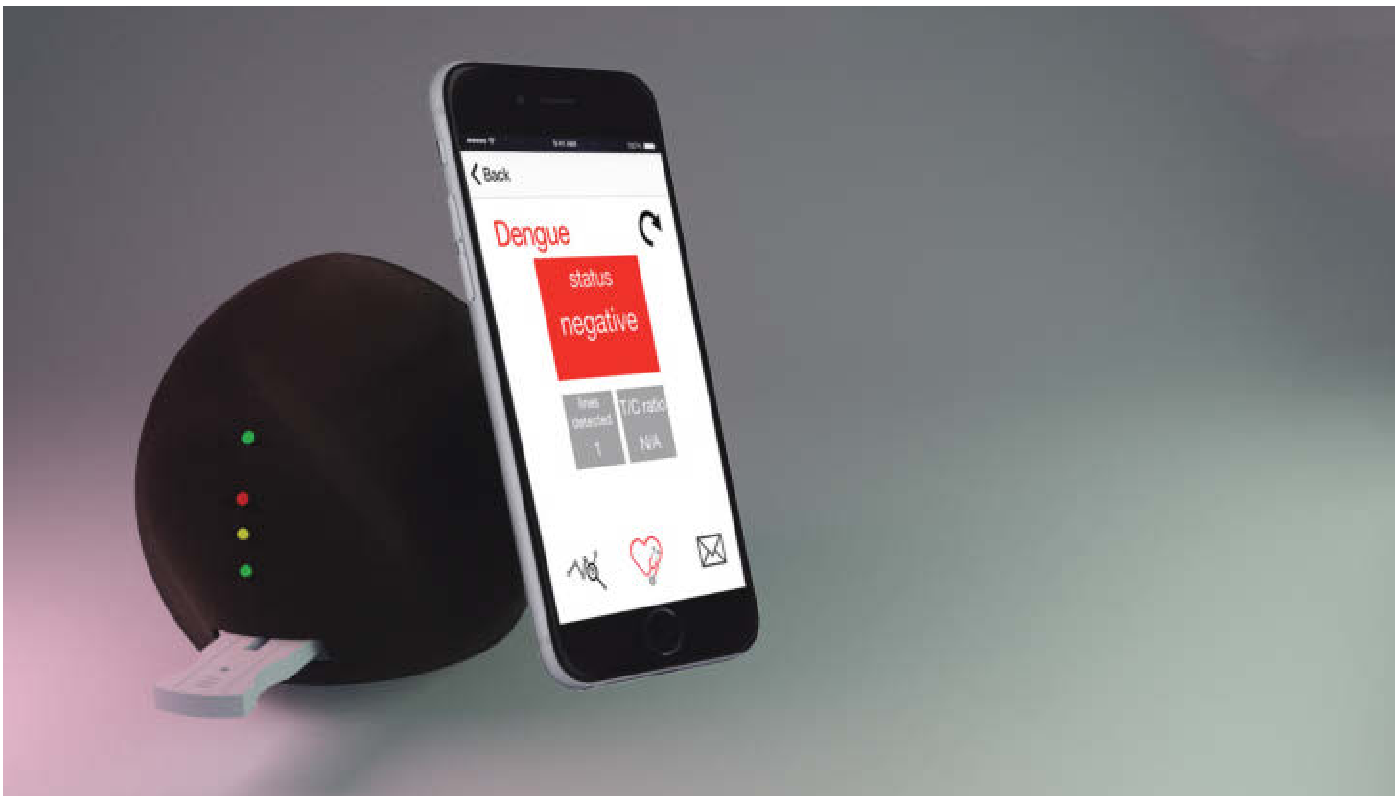
This type of lateral flow test strip is not new, but there have been challenges in using them to get the kind of exact, quantitative results necessary for measuring micronutrients whose normal range may be measured in mere picograms per milliliter, as is the case for vitamin B12. And there are other challenges as well: despite their grouping as “vitamins,” each different letter and sometimes number (A, B6, B12, C, D, etc.) actually represents an entirely different compound, each of which needs its own techniques for sample processing and quantification.

Sasank Vemulapati, a Ph.D. student in Erickson’s lab, is working on an especially tricky one: vitamin D. Not only is it fat-soluble (most of the others are water-soluble), but in the bloodstream, it’s not alone. Rather, it’s bound to a large protein that helps it travel around, says Vemulapati. “It’s a huge molecule that sort of envelops vitamin D,” he says. The bond between vitamin D and the large protein has to be unlocked before the vitamin D levels can actually be measured. “A big part of my struggle was finding the right sort of reagents that would work in a short amount of time,” he says. They also would have to work in small amounts so as not to dilute the sample. Eventually, he hit on a combination of organic solvents and low pH buffers last year and he’s been working to perfect the process since then. The first small trial in Ithaca was not very successful, Vemulapati says, but by round two they had ironed out some of the wrinkles.

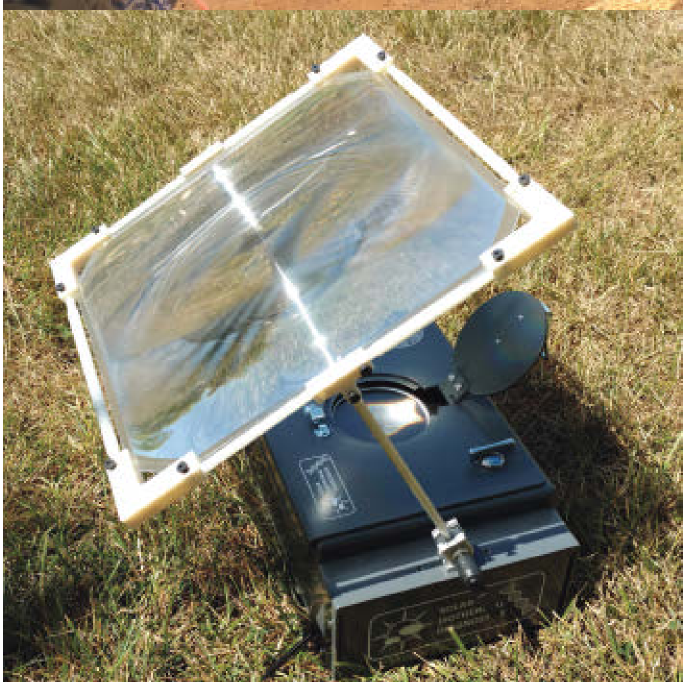
They decided to compare their test strips with the gold standard: tandem mass spectrometry. This kind of testing takes over a day to complete, involving multiple trained experts, and is incredibly expensive—the exact opposite of what those at INSiGHT are trying to achieve. They teamed up with Professor Marie Caudilla’s nutritional sciences lab on campus to run the tests. “The results from the NutriPhone, when compared to the results from mass spectrometry, were remarkably accurate,” Mehta says. It was “a pretty big revelation,” adds Vemulapati.

Cheap, quick and easy vitamin D testing may benefit a large number of Americans. By some estimates, 40 percent of people in the U.S. are vitamin D deficient. The micronutrient is important for calcium absorption, helping prevent osteoporosis in older adults. It also has several other roles in cell growth and immune function. And a recent study suggests that vitamin D may help prevent respiratory tract infections.

While the NutriPhone is closest to full implementation, INSiGHT has several other projects on the docket. The FeverPhone, built on a similar platform to that of the NutriPhone, aims to be able to diagnose six different diseases



A rendering of an early prototype of the FeverPhone.



Ryan Snodgrass, a Ph.D. student in the Erickson Lab, left, demonstrates a Kaposi's sarcoma detection system at the Infectious Disease Institute in Kampala, Uganda.

"IT REALLY MAKES A CRITICAL DIFFERENCE FOR THE PHYSICIAN OR THE HEALTHCARE PROVIDER TO KNOW, EARLY ON, WHAT THIS IS SO THAT THEY CAN TAILOR THE MEDICATION."

—Saurabh Mehta

in the field: dengue, malaria, chikungunya, typhoid fever, leptospirosis and Chagas' disease. These febrile diseases are some of the most common worldwide, but they don't always attract the most funding dollars. And they're especially common in parts of the world with limited access to hospitals and diagnostic labs. One problem, says Mehta, is that if you have a fever and you're in a certain part of the world, "often the diagnosis is presumptive. So if you were in Latin America, for example, and somebody presented with fever, then the easy thing would be, 'Let's assume it's dengue.'" In East Africa, however, the assumption would be malaria; in India, it might be typhoid. But these assumptions aren't always correct, leading to incorrect and ineffective treatments. Mehta says he and Erickson wanted to pick diseases that are not only common, but for which "it really makes a critical difference for the physician or the healthcare provider to know, early on, what this is so that they can tailor the medication." Last year, Erickson and Mehta received a grant from the National Institutes of Health for $2.3 million to continue working on and developing the FeverPhone.

Outside of the FeverPhone, Erickson is also working on another interdisciplinary project—this one with researchers at Weill Cornell Medicine—on a system to quickly diagnose Kaposi's sarcoma, a type of cancer often associated with HIV infections, and which is extremely common in sub-Saharan Africa. The solar-powered device can detect the cancer in about half an hour. The National Institutes of Health awarded the project a $1 million grant last year to support that device's development.

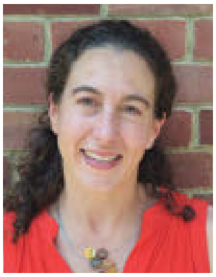
Mehta says that being at Cornell is a big reason why the collaborations that underpin INSiGHT's projects are successful. Compared with institutions where Mehta worked before coming to Cornell, Mehta says, the collaborations here just happen organically. "I'm a big believer," adds Erickson, in these sorts of collaborations, which are "the way a lot of real-world problems are solved."

"There is a lot of interdisciplinary work that happens at Cornell," Mehta says, including radical collaborations like that between him and Erickson. Down the line, he hopes that INSiGHT will foster more such partnerships. "We want to get all the bright minds at Cornell under an umbrella and provide the spark."

PEOPLE


Ludmilla Aristilde


Kavita Bala


Ilana Brito


Betta Fisher


Shane Henderson

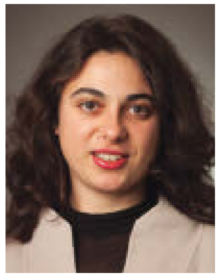

Guy Hoffman

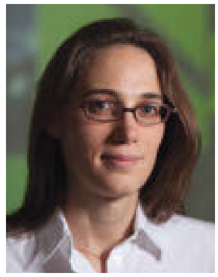

Lena Kourkoutis


Guillaume Lambert

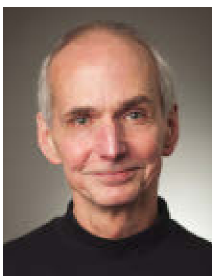

Manfred Lindau


Natalie Mahowald

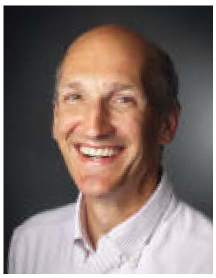

Andreea Minca

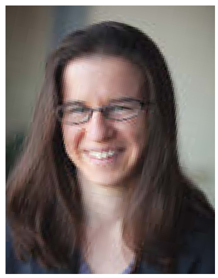

Perrine Pepiot


Martha Pollack

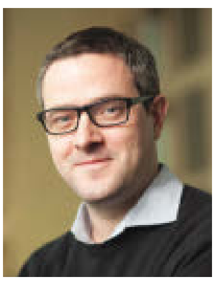

James Renegar


Robbert van Renesse


Darrell Schlom

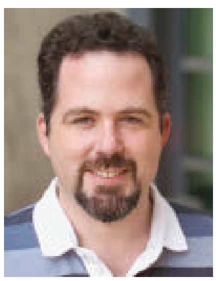

Meredith Silberstein


Ankur Singh


Christoph Studer


Eva Tardos


Hakim Weatherspoon


Walker White


Fengqi You


Roseanna Zia

SCHOOL AND DEPARTMENT ABBREVIATIONS

AEP – Applied and Engineering Physics
BEE – Biological and Environmental Engineering
BME – Biomedical Engineering
CBE – Chemical and Biomolecular Engineering
CEE – Civil and Environmental Engineering
CS – Computer Science
EAS – Earth and Atmospheric Sciences
MSE – Materials Science and Engineering
MAE – Mechanical and Aerospace Engineering
ORIE – Operations Research and Information Engineering

Ludmilla Aristilde, assistant professor (BEE), has received a CAREER Award from the National Science Foundation. The funding will be used to study mechanisms underlying the trapping of organic matter, including contaminants and biomolecules within environmental matrices. Aristilde has also been given a Professeurs Invites (Invited Professor) position in France where she'll spend one month this summer in the city of Grenoble and then travel the country throughout the year to give lectures.

Kavita Bala, professor (CS), and GrokStyle, a company she co-founded with Sean Bell Ph.D. '16, were selected to CB Insights' 2017 AI 100, a ranking of the 100 most promising private artificial intelligence companies in the world.

Ilana Brito, the Mong Family Sesquicentennial Faculty Fellow and assistant professor (BME), has received an Alfred P. Sloan Foundation fellowship, which supports early career faculty members' original research and broad-based education related to science, technology and economic performance. She uses systems biology approaches to study the transmission of bacterial and genetic components of the human microbiome.

Betta Fisher, associate professor (MAE), received the Outstanding Teacher Award from the St. Lawrence Section of the American Society of Engineering Education. The award was presented at the section's meeting and conference, April 21-22 in Buffalo.

Shane Henderson, professor (ORIE), has been named editor-in-chief of the journal *Stochastic Systems*, the flagship journal of the INFORMS Applied Probability Society.

Guy Hoffman, the Mills Family Faculty Fellow and assistant professor (MAE), is currently displaying his robot 'Kip' in the Hello, Robot exhibition at the Vitra Design Museum in Germany. The exhibition examines the robotics boom and how it's changing lives.

Lena Kourkoutis, the Rebecca Q. and James C. Morgan Sesquicentennial Faculty Fellow and assistant professor (AEP), has received a CAREER Award from the National Science Foundation. The funding will be used to develop and apply novel electron microscopy techniques that allow liquid-solid and soft-hard interfaces to be studied at the nanometer to atomic scale.

Guillaume Lambert, the Gordon Lankton Sesquicentennial Faculty Fellow (AEP), has received an Alfred P. Sloan Foundation fellowship, which supports early career faculty members' original research and broad-based education related to science, technology and economic performance. Among his ongoing research projects is the study of the survival strategies used by bacteria in response to toxic environments.

Manfred Lindau, professor (AEP), was given emeritus status.

Natalie Mahowald, professor (EAS), has been selected as the Atkinson Center for a Sustainable Future's new faculty director of environment. Three faculty directors lead the center's programs in energy, environment and economic development. Mahowald has also been selected by the United Nations' Intergovernmental Panel on Climate Change as a lead author on the "Special Report on Global Warming of 1.5 degrees Celsius."

Andreea Minca, Andrew Schultz '36 Ph.D. '41 Sesquicentennial Fellow (ORIE), has received a CAREER Award from the National Science Foundation. The funding will be used to develop a comprehensive framework for the design of and optimal resource allocation in star-shaped stochastic networks with a central control node.

Perrine Pepiot, assistant professor (MAE), has received a CAREER Award from the National Science Foundation for her proposed research project "Enabling fuel design and optimization: a comprehensive approach to capture multi-component chemistry effects in large-scale combustion simulations of complex fuels."

PEOPLE

Mark Psiaki, professor emeritus (MAE), has been promoted to fellow of the American Institute of Aeronautics and Astronautics. He is recognized for distinguished contributions to theory and practice of estimation and data fusion for satellite attitude and orbit determination as well as GPS signal processing.

James Renegar, professor (ORIE), was named a fellow of the Society for Industrial and Applied Mathematics for his fundamental work on continuous optimization and the interface between algorithms, numerical analysis and algebra. He'll be formally recognized during the organization's annual meeting, July 10-14 in Pittsburgh.

Robbert van Renesse (CS), has been named a full-time research professor. He is the first faculty within the college to receive the title. Renesse is a member of the Systems and Networking Group and is interested in distributed systems, particularly in their fault tolerance and scalability aspects.

Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry (MSE), has been elected a member of the National Academy of Engineering, among the highest professional distinctions accorded to an engineer. The organization notes his contributions to molecular-beam epitaxy "Materials-by-Design" of complex oxides impacting the integration of high dielectric oxides in semiconductor devices.

Meredith Silberstein, assistant professor (MAE), has received a CAREER Award from the National Science Foundation for her proposed research project "Building a Mechanistic Understanding of Mechanochemically Adaptive Polymers."

Ankur Singh, assistant professor (MAE), was selected to receive the 2017 Young Investigator Award from the Society For Biomaterials. The award recognizes those who demonstrate outstanding achievements in the field of biomaterials research within 10 years of receiving their degree. The award was presented during the society's annual meeting in April.

Christoph Studer, assistant professor (ECE), has received a CAREER Award from the National Science Foundation. The funding will be used for research related to hardware-accelerated Bayesian inference in order to bridge the ever-growing gap between theory and practice using a holistic approach that spans the circuit design, algorithm and theory levels.

Eva Tardos, the Jacob Gould Schurman Professor (CS), has been named the recipient of the 2017 EATCS Award—the lifetime achievement award given annually by the European Association for Theoretical Computer Science to acknowledge extensive and widely recognized contributions to theoretical computer science over a life-long scientific career.

Hakim Weatherspoon, associate professor (CS), has received a University of Washington Computer Science and Engineering Alumni Achievement Award in recognition of his impact in the academic arena. He'll be presented with the award during the university's June graduation ceremony.

Walker White, senior lecturer (CS), has been named the Stephen H. Weiss Provost's Teaching Fellow for excellence in teaching undergraduate students. White directs the Game Design Initiative and is responsible for the undergraduate minor in game design, comprising several classes spread across multiple departments.

Fengqi You, the Roxanne E. and Michael J. Zak Professor (CBE), has received a $500K CAREER grant from the National Science Foundation. You will use the grant over the next five years to incorporate sustainability principles systematically into the design and optimization of process systems. He has also been appointed as a consulting editor of *AIChE Journal*, the flagship journal of the American Institute of Chemical Engineers, and to the editorial board of the journal *ACS Sustainable Chemistry and Engineering*, a leading journal published by the American Chemical Society.

Roseanna Zia, assistant professor and Rebecca Q. Morgan Sesquicentennial Faculty Fellow (CBE), was awarded a Director of Research Early Career Grant from the Office of Naval Research (ONR). The competitive grant recognizes the best of the ONR Young Investigator Program award recipients. Zia was also highlighted by the *Journal of Rheology* for having one of the most read studies in 2016, "Delayed yield in colloidal gels: Creep, flow and re-entrant solid regimes."

Cornell Engineering Magazine has a website, 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

facebook.com/CornellEngineering

@CornellEng

www.youtube.com/CornellEng

http://bit.ly/1LukNq1

www.instagram.com/CornellEng

ALUMNI PROFILE

ROBERT SCHARF '77

AFTER WHIRLWIND CAREER, ENTREPRENEUR RETURNS TO ADVISE STUDENTS, FACULTY

During his whirlwind career as an engineer, Robert Scharf '77 has seen it all. A mechanical engineer turned marketing director, he would eventually start his own company, survive about a dozen buyouts, crash with the dot com bubble, resurrect to become an executive vice president, only to decide it was time to move on to another adventure. If you're looking for some advice, pay a visit to Scharf because he has been there, done that.

Scharf's passion for engineering began when he was a child growing up outside of Philadelphia. His father, who owned a small business designing machinery, would travel into the city to conduct patent research, which often gave Scharf time to explore the latest science and technology exhibits at The Franklin Institute.

Robert Scharf '77, center, meets with engineering students during a visit to campus.

Arriving at Cornell as a mechanical and aerospace engineering student was somewhat of a revelation for Scharf. "This was so different than the way my father does it," he remembers thinking to himself. "And there are so many different things to do than just the gears and the wheels and the pulleys he was designing."

Scharf's first job after graduating in 1977 was with General Motors, but his natural curiosity would quickly find him pursuing other endeavors. "I was a terrible designer, but someone thought I had some talent at explaining things to engineers," said Scharf, who used his skill for writing technical literature to become marketing director for Thomas & Betts, a product design company.

As marketing director, Scharf grew frustrated watching the company's fiber optics product line continue to lose money so, in 1995, he and another employee offered to buy the line of products so they could manage it themselves. It was Scharf's first entrepreneurial venture, but as an experienced engineer in his 40s, his confidence in becoming self-employed translated into success. His company was eventually sold to engineering giant ABB.

Scharf admits that some of his professional moves had been risky, but he understood the value of knowing when to break the rules to create new career paths. "There were many times I thought this doesn't fit within the rules. It doesn't mean this is wrong, it just means the rules don't fit me. Clearly there were situations where the rules were developed in a historical environment where the input and outputs were completely different and just didn't apply to today," said Scharf.

After several name changes and acquisitions, the company Scharf founded grew into Stratos Lightwave, a publicly traded company valued at $21 per share. That was in June of 2000. By July, shares of the stock jumped to $66. "At that point we had a $3 billion valuation. Mind you, this is a company I started with a friend and borrowed against our credit cards to start," exclaimed Scharf.

But like many other technology companies at the time, Stratos Lightwave was riding a bubble that was about to pop. By November, the stock was below $10. Eventually the stock crumbled to below $1 per share. It was an experience Scharf describes as "an amazing rollercoaster," that included one last hill to climb.

Scharf remembers taking a phone call from the CEO of Stratos Lightwave, who told him "You're moving to Chicago and you're going to become executive vice president. Now you're on the board of directors and you're going to fix this $10-million-a-month problem." Scharf accepted the job and proceeded to downsize the company's payroll until its monthly losses were manageable.

At that point he took another phone call, this time from his former business partner who invited Scharf to start a new company with him. And so Scharf took another risk and quit his executive-vice-president position to begin a new company "with no venture capital, with nothing. Not even a really firm idea of what we were going to do," recalled Scharf. "I was so unhappy with what I was doing at Stratos, I kept saying to myself 'well, nothing I do as an entrepreneur could make me as unhappy as I am now,'" he added.

Scharf and his partner started Protokraft in 2002 and developed a new way of packaging components to improve their reliability in aerospace applications. Not even two months after founding the company, Redstone Arsenal, a U.S. Army post, came knocking on the door. "It turns out we had stumbled upon one of the largest upgrade projects in the U.S. military arsenal," Scharf said. "So instantly we were getting million-dollar orders and we had no equipment and no employees. We had nothing but a really good idea."

Despite the lack of preparation, the early business dealings were a success. Scharf would eventually sell the company to Moog, Inc., and retire with 12 patents in his pocket.

"The one thing I would say about entrepreneurship is, for me, this was a good fit because I always felt frustrated when I couldn't express my desire to fix some problem in the world that I saw, but the people I worked for didn't share my view or understand it the way I did," said Scharf. "Becoming an entrepreneur was my way of pursuing that idea to fix something or solve a problem."

Now, Scharf is helping the next generation of entrepreneurs find their own path. In October, he committed to becoming an "entrepreneur in residence" at Cornell. He now splits his time between Florida and New York, spending one week each month on campus where he holds open office hours and advises students from programs like eHub, eLab and the Commercialization Fellows. He also works with faculty to encourage collaborative efforts with industry, which he says can provide intricate details of real-world problems and new strategies for faculty research projects.

Another chunk of Scharf's time as entrepreneur in residence is dedicated to developing a new technology translation program with Emmanuel Giannelis, associate dean for research and graduate education at Cornell Engineering. "One thing that's not well structured at research universities is building prototypes. Typically, when the National Science Foundation funds research, they don't fund you to the point where you can build a working model that you can take around to commercialize," said Scharf, who is providing seed funding so the program can offer students grants to fund prototypes.

"We're very fortunate to have Bob on campus," said Giannelis. "He brings a lifetime of experience that's invaluable to our students and faculty, and that knowledge has been critical as the college continues to develop new entrepreneurship programs."

Scharf views his volunteer position at Cornell as a fitting way to spend his early retirement days. He had always felt a gravitational attraction to come back to the Ivy League institution, a place he can now call home again after departing 40 years ago. "What a nice place," he stated upon his return. "Why did I ever leave here?"

Robert Scharf '77, left, shakes hands with Amit Lal, professor of electrical and computer engineering. Lal's professorship is endowed with support from Scharf.

CornellEngineering

Cornell Engineering Magazine
252 Carpenter Hall
Ithaca, NY 14853-2201

INSIGHT

DESIGNING DIAGNOSTIC TOOLS FOR THE DEVELOPING WORLD

26