College of Engineering
University of California, Berkeley
Fall 2016
Volume 10

Augmented Reality
Seeing is believing

New nukes
Leaner, greener energy

Q+A on homebrew opioids

BerkeleyENGINEER

DYNAMIC DUO

Engineering and Berkeley-Haas launch new Management, Entrepreneurship, & Technology undergrad program

Ambidextrous entrepreneurs

I believe the best way to prepare our students to create high-impact technologies and ventures is to teach them the skills to be career-long innovative thinkers.

Whether at an established corporation, or at a startup operating out of a dorm room, innovators share some traits: Innovators solve problems and invent things. They tirelessly look for ways to improve.

So, I think, in order to teach innovation, we must embrace it ourselves. That's why we have created a new academic program and formed a new partnership. It is with great enthusiasm that I'm looking forward to receiving the applications for the inaugural class of the Management, Entrepreneurship, & Technology (M.E.T.) program, which will launch next fall.

Working in collaboration with the Haas School of Business, we will give M.E.T. undergraduates a more comprehensive and holistic look at the way innovative thinking can lead to impact. They will be able to graduate with two degrees, one in business and one in engineering, in four years.

The new program adds to the college's already thriving innovation ecosystem. Our Sutardja Center for Entrepreneurship and Technology, Fung Institute for Engineering Leadership and Jacobs Institute for Design Innovation, along with many campus partners, are all working in concert to meet the growing demands of our students looking for a technically focused, yet multidisciplinary education.

Our goal is not to create better engineers, or better business leaders. Rather, our goal is to develop an integrated skillset and foster ambidextrous thinkers who are capable of designing, implementing and scaling solutions that will create value and solve some of the world's most pressing challenges.

Berkeley is exceptionally well-suited to build this new model for entrepreneurial education. As of this moment, we are one of only two institutions in the world offering this kind of program.

In that spirit, I'm looking forward to our continued collaboration with Berkeley-Haas and with our friends and partners in industry. We have already been receiving inquiries from companies — in all sectors — eager to work with our M.E.T. students.

As always, I welcome your thoughts and ideas.

—*S. Shankar Sastry*
DEAN AND ROY W. CARLSON PROFESSOR OF ENGINEERING
DIRECTOR, BLUM CENTER FOR DEVELOPING ECONOMIES

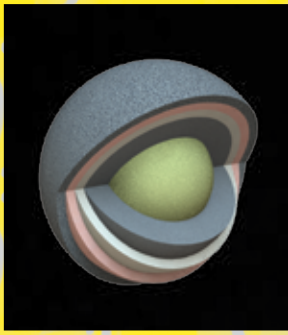
Berkeley is one of only two institutions in the world offering this kind of program.

Noah Berger

The Fung Institute for Engineering Leadership marked its five-year anniversary this fall by opening expanded offices at Shires Hall. Cutting the ribbon were (left to right) M.Eng. student Sneha Balan (Class of 2017), Chancellor Nicholas B. Dirks, Blue Goji co-founder and CEO Coleman Fung (B.S.'07 IEOR), Dean Shankar Sastry and Fung Institute faculty director Lee Fleming.

in this issue

BerkeleyENGINEER FALL 2016



MORE >

> COVER PHOTO: IMPRINT ENERGY CO-FOUNDERS **CHRISTINE HO** (B.S.'05, M.S.'07, PH.D.'10 MSE) AND **BROOKS KINCAID** (M.B.A.'11) REPRESENT THE BEST OF BERKELEY'S TOP-TIER PROGRAMS IN ENGINEERING AND BUSINESS, JUST LIKE THE NEW M.E.T. UNDERGRADUATE PROGRAM (SEE PAGE 12).

PHOTO BY **NOAH BERGER**

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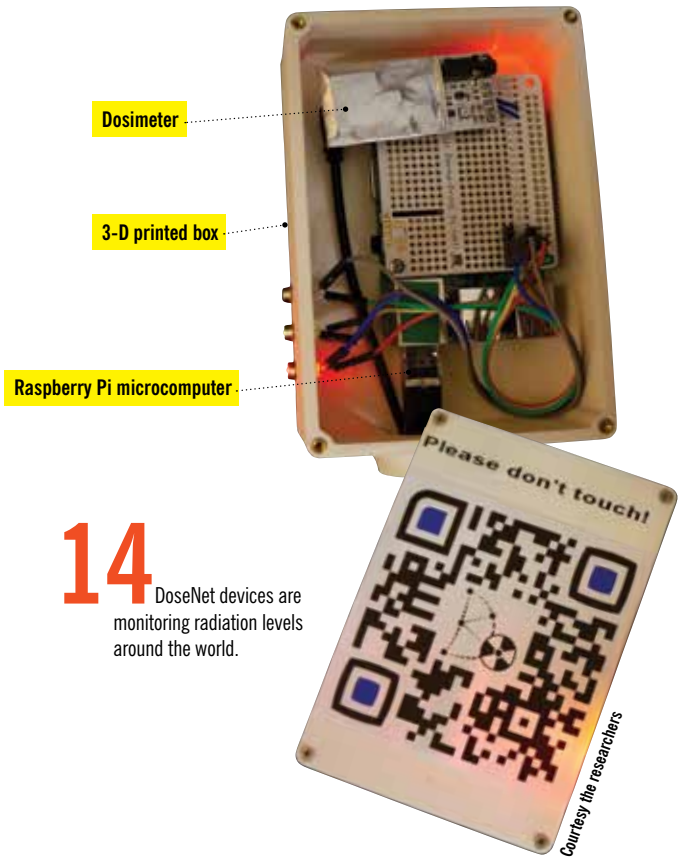


14 DoseNet devices are monitoring radiation levels around the world.

RADWATCH

Raising rad awareness

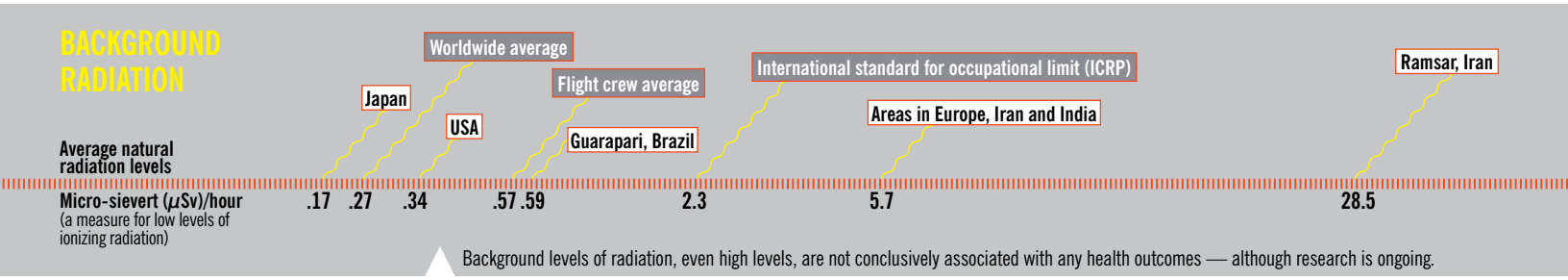
Working with high schools across the Bay Area and beyond, members of Berkeley RadWatch have launched a network of wall-mounted devices to measure naturally occurring background radiation. The project, called DoseNet, is a hands-on science education exercise. "Radiation is part of the world around us, and we are using it as a tool to work with students and teach them about science, engineering and programming," says nuclear engineering professor **Kai Vetter,** lead scientist for Berkeley RadWatch.

Berkeley RadWatch was set up to address fears that radiation from the 2011 tsunami-triggered Fukushima Daiichi Nuclear Power Plant accident could find its way to the U.S. West Coast. The RadWatch team has monitored air, fish, seaweed and other samples for several years, posting results online for maximum transparency. The team found traces of isotopes related to the disaster in the accident's immediate aftermath, but nothing since — and never enough to have health effects.

DoseNet sensors, which first went online in November 2015, were installed at Berkeley Lab and UC Berkeley, six San Francisco Bay Area schools, and Koriyama City Hall in Fukushima Prefecture, Japan. Koriyama was the network's first international site, about 45 miles from the Fukushima nuclear plant beyond the region's evacuation zone.

Vetter said plans to expand the network include more countries, so that the information exchange truly becomes global. "We want to establish this program as a social network, based on science and engineering, so that kids from around the world can communicate and collaborate on the varying natural background radiation levels in their local communities," he says.

WEB EXTRA > See the interactive map at **radwatch.berkeley.edu/dosenet.**



Background levels of radiation, even high levels, are not conclusively associated with any health outcomes — although research is ongoing.

TRANSIT

NOBEL (BIKE) PARKING: A new bike rack, recognizing Berkeley faculty contributions to the United Nations' Intergovernmental Panel on Climate Change (IPCC), which won the Nobel Peace Prize in 2007, sits to the left of a cluster of U-shaped bike racks outside the Free Speech Movement Café.

Thousands of scientists and officials from more than 100 countries collaborated on the prize-winning research that exposed the scale of global warming and sharpened the connection between warming and human activities. Berkeley contributors included **Daniel Kammen,** a professor of nuclear engineering and founding director of the Renewable and Appropriate Energy Laboratory, whose tongue-in-cheek comment at a 2013 panel discussion on climate change on campus planted the idea for an NL bike spot.

The bike rack is a light-hearted spin on a revered tradition. Berkeley Nobel Laureates get prime parking spots on campus — a prize coveted nearly as much as a Nobel. Berkeley now has 10 such parking spaces for cars. The decision to create NL bike parking "was also tied to broader efforts to provide enough bike parking in the right places for students, staff and faculty," says Lisa McNeilly, director of sustainability and energy.

CHOREOGRAPHY

Collision-free Cal Band

Last spring, **Tina Chow,** professor of civil and environmental engineering, was looking for a real-world problem for her 400 students to solve as a final project for E7, an introductory computer programming class for engineering undergraduates.

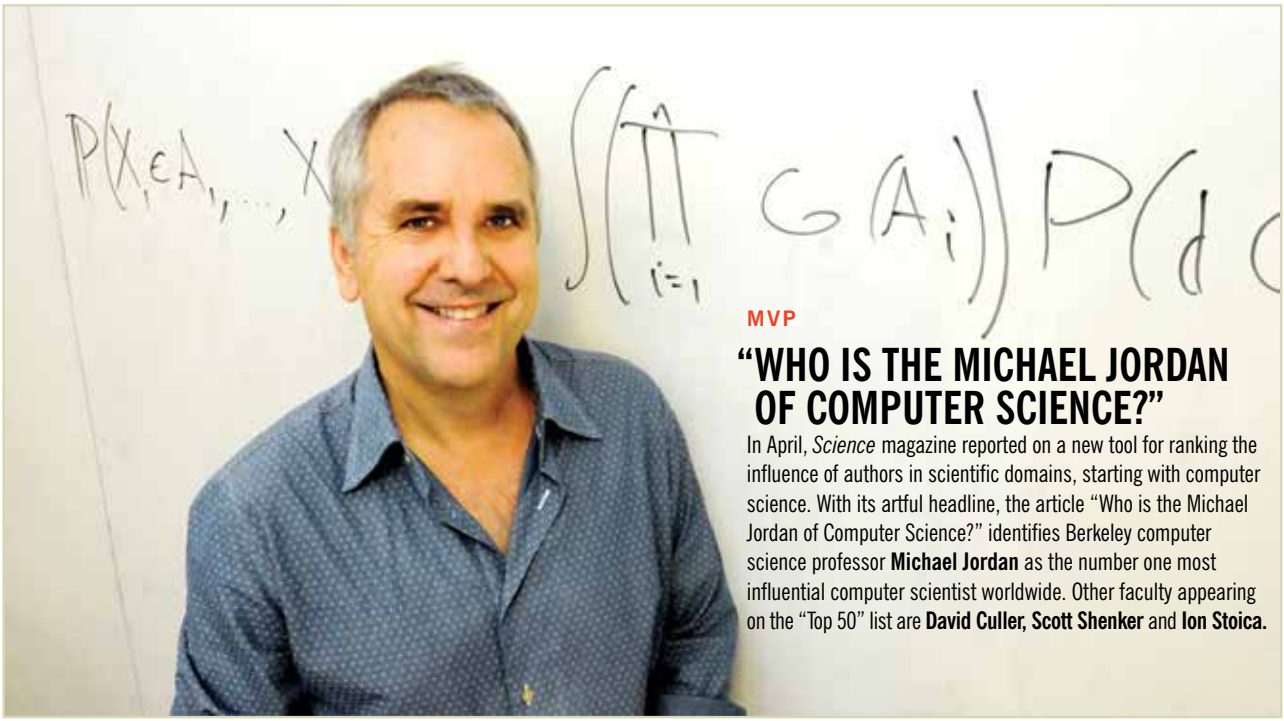
She found out the University of California Marching Band needed help developing a computer code to program transitions for their field routines — the band's search for a good algorithm kept coming up short, and crafting formations by hand takes hours. "We encouraged the students to brainstorm and watch videos of the band. We asked why a human can plan the transitions and why a computer couldn't," Chow says. "We didn't know what the solution would be when we assigned the project."

Jennifer Ding

Working in teams of twos and threes, several groups managed to develop efficient computational choreography. Some of the groups used the Hungarian algorithm, developed in the 1950s for economically assigning workers to tasks. "The elegance was in how they systematically went through the transitions and eliminated collisions," Chow says of the student projects. "They kept fixing the movements until there were zero collisions."

"We worried it was going to be too hard," Chow says. "But the band did have a real problem to solve." And the E7 students were able to solve it.

WEB EXTRA > See the Cal Band's algorithmic choreography at **engineering.berkeley.edu/magazine.**



Peg Skorpinski

MVP

"WHO IS THE MICHAEL JORDAN OF COMPUTER SCIENCE?"

In April, *Science* magazine reported on a new tool for ranking the influence of authors in scientific domains, starting with computer science. With its artful headline, the article "Who is the Michael Jordan of Computer Science?" identifies Berkeley computer science professor **Michael Jordan** as the number one most influential computer scientist worldwide. Other faculty appearing on the "Top 50" list are **David Culler, Scott Shenker** and **Ion Stoica.**

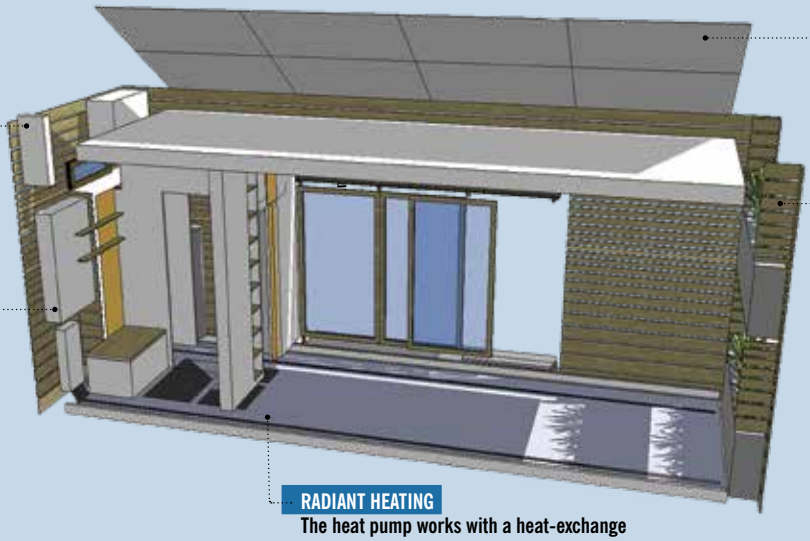
SUSTAINABILITY

Eco-friendly tiny house

Could you live in a house smaller than the average American kitchen? An interdisciplinary team of Berkeley students thinks so. The group took two years to design and build a 171-square-foot, off-grid, eco-friendly house for a statewide competition sponsored by the Sacramento Municipal Utility District. The students spent the first year puzzling over how to allocate space for a solar energy system, lithium-ion battery, greywater recycling and a heating system — while retaining enough space for two people to eat, sleep, bathe, cook and live comfortably throughout the year.

"We're balancing affordability with new technologies and making the house as energy-efficient as possible," says applied science and technology doctoral candidate **Kenny Gotlieb.** Other team members represent the Energy and Resources Group, business, architecture, urban studies, public policy and public health. Judges will evaluate the house on architecture, energy systems, sustainable materials use and how the house manages water and waste.

WEB EXTRA > Find out more about the competition at **smud.org.** For more on the Berkeley team, see **calthimby.org.**



WATER HEATING
A new eco-friendly and energy-efficient heat pump uses CO_2 instead of standard synthetic refrigerants, to raise water temperature.

ENERGY STORAGE
Using Tesla's new lightweight and compact "Powerwall" lithium-ion battery, the house can store 6.4 kWh of energy and provide 3.3 kW of power (depending on seasonal variability and power output of solar panels).

ENERGY PRODUCTION
Eight photovoltaic roof panels collect enough sunlight to generate between 5-12 kWh per day.

LIVING WALL
Water drained from the kitchen sink and shower flows through a "living wall" of plants and two feet of soil to remove organic contaminants before being filtered by activated carbon and disinfected by UV light. The processed greywater is then collected for bathing and non-potable reuse.

RADIANT HEATING
The heat pump works with a heat-exchange system to circulate water through the subfloor in a radiant heating system.

PROPERTIES

Materials database speeds innovation

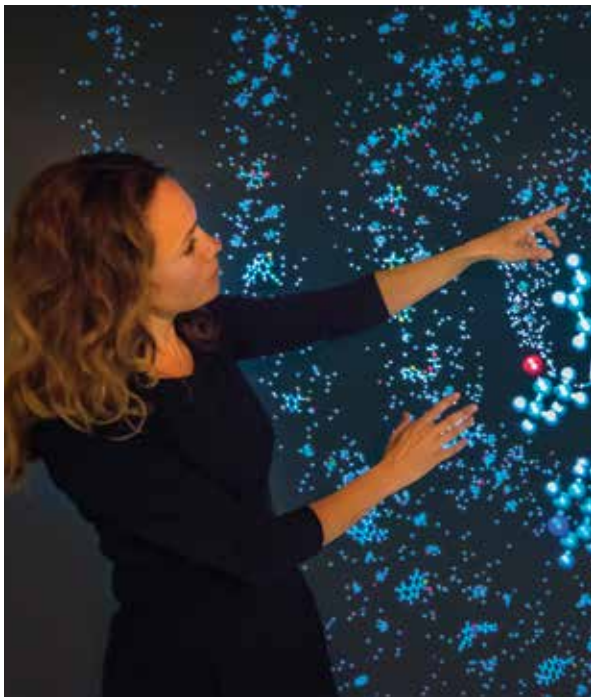
Kristin Persson, assistant professor of materials science and engineering, thinks a better database of materials will lead to breakthrough technologies that reshape how we live. "It's incredibly hard to find new materials, and even harder to bring them to market," she says. "It takes about 15 years for a successful material to move from lab testing to becoming commercially profitable."

To speed up this process, Persson and her colleagues launched the Materials Project, with funding from the Department of Energy and Berkeley Lab. The Materials Project uses high-throughput computational techniques to calculate properties for all known materials.

Persson can virtually "grow" new materials by using supercomputers to crunch thousands of quantum-mechanical calculations, arrange virtual atoms into crystal structures and analyze their physical and chemical properties. The data is then stored digitally and made freely accessible to the public.

"We have more than 20,000 registered users around the world, with 300 to 400 daily users," Persson says. "In the developing world, we're probably the only organized resource that scientists have for materials data. If you have Internet, you can use this resource."

WEB EXTRA > Learn more at **materialsproject.org.**



Q+A on homebrewed drugs with John Dueber

Morphine comes from *Papaver somniferum,* the opium poppy — but one day soon it might be grown in a lab. In 2015, bioengineering professor **John Dueber** and students engineered a yeast strain to convert glucose into reticuline, a key compound in the plant. Soon other researchers demonstrated subsequent steps toward developing thebaine, an opiate closely related to codeine and morphine, from yeast. The breakthrough holds both great promise and great risk, Dueber says.

"The ability to easily synthesize powerful drugs from glucose through fermentation could be dangerous in the wrong hands. But this pathway also has the potential to lead to more effective, less addictive painkillers, as well as new miracle molecules for treating cancer, hypertension and more."

Noah Berger

At what point in your research did you begin to really think about the implications?

We started to think that we should contact policy experts when we reached the point where all but one step had been functionally expressed in yeast — albeit in pieces, not all together. We originally thought the field was probably 10 years away from being able to put all the pieces together to go from glucose to morphine. Then our project moved much faster than expected, and other labs made numerous advances as well, and it became apparent that we weren't looking at a decade, but as little as one year.

What remains to be done?

To date, researchers have only shown one strain converting glucose into thebaine, and then a separate strain that you can feed thebaine to and convert that to morphine, but it hasn't been shown where you put all of the enzymes into one single strain so that the strain converts glucose into morphine.

But really, the limitation is how much you are producing. The strain for converting glucose into thebaine makes 7 micrograms per liter — and a typical morphine pill is approximately 10 milligrams. So we have time to develop policies to balance encouraging valuable research while limiting the risks of illicit use.

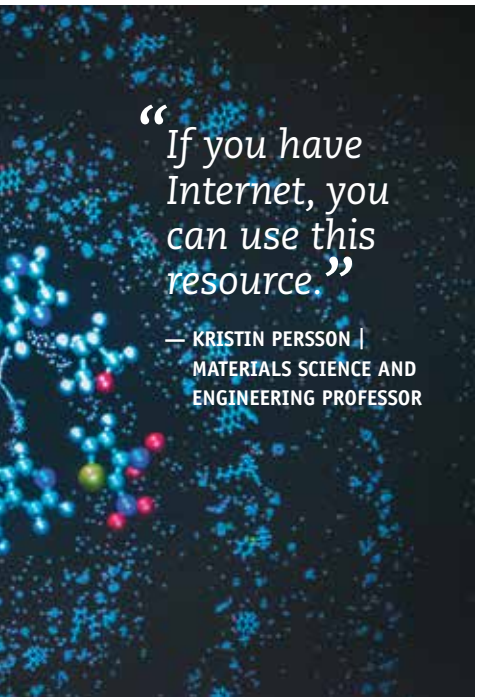
How significant is the risk inherent in this line of research?

There is a very real threat, I believe, with the potential for making a strain that can produce upwards of 10 milligrams per liter of morphine. Once such a strain is made, I think it's really important for that strain to be kept in a lab and not released outside the lab. Because from that point on, a homebrew scenario is feasible. Not that much expertise would be required to make a beer brew with physiologically relevant doses of morphine.

Where do you go from here in your pursuit of bioactive molecules?

First, finding genes from plants themselves that produce these interesting reactions, then implementing those genes to find as many of the 2,500 natural products as possible. Then, testing those for desirable activities, like antibiotic and anti-cancer activities. Synthetic biology also plays a role to further expand beyond those 2,500 natural products, by introducing enzymes that may not have been naturally expressed in the plants.

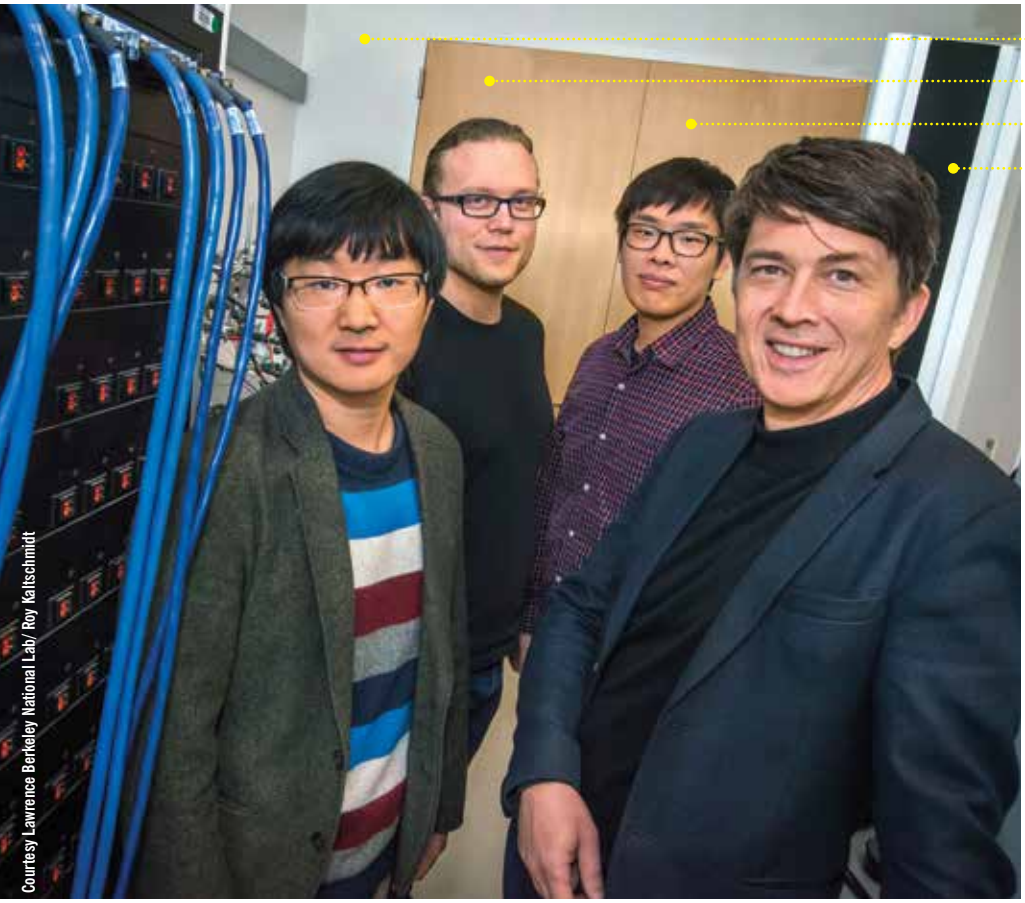
WEB EXTRA > Hear John Dueber explain his research at **go.nature.com/2epClZx.**



Courtesy Lawrence Berkeley National Lab/ Roy Kaltschmidt

William DeLoache

Yeast cells (left beaker) generate the beet pigment betaxanthin, which researchers use to identify key enzymes in the production of benzylisoquinoline alkaloids, the metabolites in the poppy plant that could lead to producing morphine, antibiotics and other pharmaceuticals.



Courtesy Lawrence Berkeley National Lab/ Roy Kaltschmidt

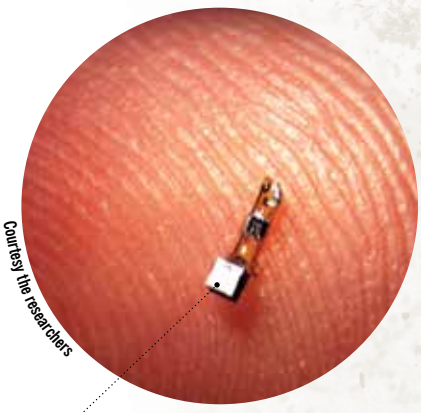
"YOU CAN TAKE AN ELECTRON OFF THE OXYGEN AND PUT IT BACK, WHICH IS FAIRLY RADICAL — THAT'S THE BIG IDEA FOR THIS CATHODE DESIGN."

— GERBRAND CEDER | MATERIALS SCIENCE AND ENGINEERING PROFESSOR

CHEMISTRY

Next-gen batteries

Anyone with a cell phone, laptop computer or electric vehicle can appreciate the benefit of a lithium battery that runs longer between charges. Now, a research team led by materials science and engineering professor **Gerbrand Ceder** has made a discovery that may lead to higher-energy, longer-lasting lithium batteries. Scientists had long speculated about the uncertain role that oxygen plays in lithium-rich cathodes. By studying the chemistry of lithium-rich cathodes, the researchers learned how oxygen oxidation creates extra capacity in the cathodes. Their findings not only explain observations about energy transfer from previous research, but also expand the options for cathode materials, which are currently limited to three transition metals — cobalt, nickel and manganese. With this discovery, scientists will now have the option of 15 to 20 different transition metals with substantially higher energy density than current cathode materials, allowing them to design the next generation of high-performing lithium batteries.



Courtesy the researchers

Micro-sensor implant measures 3 mm in length.

SENSORS

Neural dust

Berkeley engineers have created the first dust-sized sensor that can be implanted in the human body. The device, about the size of a large grain of sand, uses ultrasound — which can penetrate nearly anywhere in the body — to power and read out measurements. The sensor contains a piezoelectric crystal that converts ultrasound vibrations from outside the body into electricity to power a tiny, on-board transistor that is in contact with a nerve or muscle fiber. The sensor could monitor internal nerves, muscles or organs in real time, as well as stimulate nerves and muscles — possibly leading to new treatments for epilepsy, immune system disorders or inflammation. The technology may also lead to improved brain-machine interface technology and better brain control of prosthetics. Electrical engineering and computer sciences professors **Michel Maharbiz** and **Jose Carmena** are the study's main authors; graduate students **Dongjin Seo, Ryan Neely** and **Konlin Shen,** undergraduate **Utkarsh Singhal** and professors **Elad Alon** and **Jan Rabaey** co-authored the study.

SUSTAINABILITY

Green cities

By 2050, two-thirds of the world's population is projected to live in urban areas, which are major contributors to greenhouse gas emissions. However, according to nuclear engineering professor **Daniel Kammen** and postdoctoral fellow **Deborah Sunter** (M.S.'08, Ph.D.'13 ME), cities have great potential to become building blocks of sustainability. In their review in *Science*, the authors examined the use of renewable energy in urban areas to promote low-carbon, livable cities. They found that cities could transform from being resource drains to becoming "green generators" through advances in smart monitoring and management systems, and through the integration of energy efficiency, renewable power generation and storage and waste management into the urban fabric. They determined that a significant shift away from using personal vehicles would contribute dramatically to cleaner cities. Urban areas also need to develop environmental justice programs as part of the sustainable resource management process. By making more eco-friendly options accessible, particularly to low-income populations, cities can become more livable for all residents.

GLOBAL WARMING

Concrete thinking

As the most widely used construction material in the world, concrete has a far-reaching environmental impact. It's composed primarily of cement, whose manufacture accounts for nearly 7 percent of global greenhouse gas emissions. But civil and environmental engineers have been developing methods to make concrete more sustainable, without compromising its strength. In a recent study, lead author **Sabbie Miller** and professors **Claudia Ostertag, Arpad Horvath** and **Paulo Monteiro** found the link between structural design and the environmental impact of concrete. Replacing cement with fly ash is known to reduce the environmental impact of concrete, but this delays its early strength development. However, the study showed that by specifying a higher design age — or longer curing time to reach desired compressive strength — these alternative mixtures can approximate the strength of traditional concrete with far fewer greenhouse gas emissions. By incorporating these and other findings from the study, the CO_2 emissions associated with concrete production in California could be reduced by 1.8 million metric tons per year.

BIOMEDICINE

Brand new glue

Despite many advances in fetal surgery over the past 35 years, rupture of the amniotic sac remains a constant risk from the lifesaving procedure. During this operation, an incision must be made in the membrane of the sac, which can leak amniotic fluid and result in premature delivery. But **Phillip Messersmith,** professor of bioengineering and materials science and engineering, hopes to make this procedure safer. Inspired by the underwater glues of the marine mussel, he is developing new adhesives to seal incisions made during fetal surgery. To anchor itself to rocks in the ocean, a mussel secretes proteins underwater that form tethers and a sticky, quick-setting glue; Messersmith has replicated the strength of this glue by using L-DOPA, an amino acid key to mussel adhesives. Next up: future generations of surgical adhesives, which he aims to strengthen with additional amino acids and metal ions, similar to those found in a mussel's glue.

Courtesy the researchers

"Novel materials are needed to seal fetal membranes after surgical intervention."

— PHILLIP MESSERSMITH | BIOENGINEER AND MATERIALS SCIENTIST

HOW DO I FIND OUT MORE?

Find links to source articles, news details and expanded coverage at **engineering.berkeley.edu/magazine.**

SEEING

IS BELIEVING

Leveling up with augmented reality

STORY BY DANIEL MCGLYNN • PHOTOS BY NOAH BERGER

When I was a kid, I would set off traversing orienteering courses through the hardwood forests of my native New England. The goal was to find a flag somewhere far off a trail using a topographic map and compass. It's a very interactive process: I was constantly positioning the map, readjusting headings and trying to find discernible landmarks.

Sometimes I would end up lost; other times, with my bearing right on, I felt like a successful explorer, emerging from the untrammeled wilderness. It was a straightforward lesson about how using technology, albeit simple, changed the way I considered what was right in front of me.

I haven't thought about orienteering in a long time. These days, my wayfinding needs are typically satisfied by opening Google Maps on my phone. But recently, as I sat down with electrical engineering and computer sciences (EECS) major Daniel Pok and computer science major Isabel Zhang, the co-founders of a relatively new student organization called VR@Berkeley, my mind wandered back to my experiences with maps and compasses.

We talked about how virtual reality (VR) and augmented reality (AR) — once relegated to movie screens and sci-fi novels — are poised to revolutionize computing. Forty years ago, we saw AR's potential in the opening scene of the "Star Wars" epic, when Luke Skywalker responds to a hologram of a distressed Princess Leia.

Today, if the recent Pokémon Go craze (where players blend the fictional world of Pokémon with real-world environments) is any indication, AR has arrived.

Through a combination of hardware and software, AR and VR convert computing from a flat, two-dimensional screen to an immersive, interactive, three-dimensional experience. AR users wear a headset, but retain some visibility. Software is constantly mapping a user's surroundings with efficient localization functions and then simultaneously overlying digital images and interfaces in appropriate places in the real physical surroundings.

VR is a different experience: users wear an eye-covering headset, which serves as a wearable screen with embedded motion sensors — a fully synthetic digital experience that is completely divorced from actual physical surroundings.

Pokémon Go isn't quite AR because it uses a phone screen instead of a headset, so it's not completely immersive. The game does, however, give a glimpse of where the technology is heading.

So far, commercially available VR applications include gaming and entertainment. While a few limited AR products are available now, Silicon Valley-based consulting firm Digi-Capital predicts that the field will explode in market value, reaching $150 billion by 2020. Potential applications range from telemedicine to more intuitive control for robots on factory floors.

For Zhang, the technology is already life-changing. She was carrying heavy biology-related course loads with aspirations of pursuing a career in medicine when Pok introduced her to VR. "I got interested in VR and then took an intro computer science course. After that, I decided to switch to computer science," Zhang says. "So it's definitely changed my life." Now she's creating immersive animated short films. "Watching a film in VR can create so much more emotion and evoke a lot more out of a wide variety of people. Being able to contribute to that is exciting."

The VR club started with a handful of members in early 2015, and has since grown to 200 members from across campus working on a range of projects, including an augmented 3-D virus model that pops off the page of a biology textbook and the use of virtual reality to play the Campanile's carillon.

"The idea is that VR is the ultimate medium," Pok says. "When you get there, you can shape the world however you want."

Pok, Zhang and fellow members of Berkeley's VR club are advised by Allen Yang, executive director of the Center for Augmented Cognition (CAC), headquartered in Cory Hall. Yang is working at a new frontier, one where the topography of the physical world is being reconfigured by digital tools.

Yang came to Berkeley as an EECS postdoctoral researcher in 2006. After a stint in industry as employee number one at Atheer Labs, the maker of headsets that enable interactive computing, he returned to campus to lead CAC, along with faculty director Shankar Sastry, also dean of the college. The center opened this spring, after the college identified the need to integrate emerging research on virtual and augmented reality, including human-computer and human-robot interactions.

"We realized we need two things," Yang says about the center's founding. "We need resources for researchers and students to be able to conduct projects or research in this area, and we need to have a community that can circle around this topic."

Unlike many other university-based research areas, where commercial products follow theoretical research,

in the case of augmented reality, Yang says, companies are moving faster than academia. "Industry has provided us a lot of significant problems to solve," he says.

FUTURE HISTORY

While the technology might be crackling with a sense of newness, Berkeley researchers have been laying the foundation for augmented reality's theoretical and computational framework for more than a decade.

In 2005, Berkeley's Teleimmersion Lab, led by EECS professor Ruzena Bajcsy, began collaborating with researchers from the University of Illinois Urbana-Champaign to build virtual teleportation systems, first through virtual choreography and dance. "We were looking to immerse people in virtual environments and see how they could collaborate remotely," says Gregorij Kurillo, a research engineer in the lab. "A lot of our work was using computer vision to image and capture people in real time, send the data over the net and render the data in a virtual environment to allow some kind of interaction."

In 2007, Berkeley engineers collaborated with Stanford researchers, creating virtual Tai Chi classes. "We showed that when you immerse people in a virtual environment with an instructor, they learn movements faster and are able to more accurately replicate what the teacher is showing," Kurillo says. By 2009, the lab moved more toward interacting with data via a virtual geology platform with UC Davis and on virtual archaeology with UC Merced.

In 2010, Microsoft released its Kinect camera, which captures full-body 3-D images and is designed for the gaming community. Berkeley researchers saw a potential for other applications and began a partnership with physicians at UC Davis Medical Center to study how to use AR and VR technologies to improve telemedicine.

Recently, I met with Yang at the Center for Augmented Cognition on the third floor of Cory Hall to try to better understand what augmented reality looks like. After a couple of rounds of questions, he suggests I try the different headsets to see for myself. He retreats to his office for a minute, to retrieve a Microsoft HoloLens headset.

He returns, and it's time to augment my reality. He turns on the HoloLens and gives me a quick tutorial, which consists of demonstrating a pinching motion to use as a mouse function. The rest is pretty intuitive; after I put the device on my head, it tracks my gaze and gestures.

A detective game starts to unfold in this new world, which is not completely digital, but transformed just enough that I forget that I'm wearing odd headgear and moving in somewhat exaggerated gestures (swiping and pointing and pinching) in the middle of a public space. Real walls now contain maps, information and game menus. Elements are added to my surroundings — a garbage can containing clues appears next to a real chair, for instance.

I have only just put on the headset, but already I'm "advancing the story," as Yang calls it, with relative ease. Immediately the potential for AR to become a better and more intuitive way for humans to interact with machines becomes clear.

THE AR/VR FIELD IS PREDICTED TO EXPLODE IN MARKET VALUE, REACHING $150 BILLION BY 2020.
SOURCE: DIGI-CAPITAL

ISABEL ZHANG | VR@Berkeley co-founder

A NEW MAP

Yang and his team obtained HoloLens gear only a few months earlier, after being selected as one of five research groups sponsored by Microsoft. The Berkeley team proposed investigating using the HoloLens as an interface to control drones.

"We submitted a proposal together with DJI, the maker of one of the most popular drones, to lower the bar for everyday people to be able to control a drone through a new kind of interface, because existing controllers are very difficult to learn," Yang says.

Like teleimmersion, studying the control systems undergirding drone flight has a history on campus. "The Berkeley Robotics Lab with Shankar Sastry, Claire Tomlin and others has conducted pioneering work in drone safety, drone control and unmanned drone maneuvering," Yang says, "a very solid foundation for this kind of work."

Now, a team of graduate students at the CAC is developing more intuitive interfaces for piloting drones and other robots that rely on high levels of human direction and control. "What we want is to reimagine the modality of training or working, especially with aerial drones," Yang says. "Instead of just a master-client relationship, we want to make it more interactive."

Oladapo Afolabi, an EECS Ph.D. student working on the HoloLens research project, explains one potential application for more advanced drone interactions. "The idea is that a remote user would have control over a group of robots, specifically quadcopters, like in a search-and-rescue scenario," he says. "If the quadcopters are in a remote location, separated from the team, then the operator would be able to visualize what the drones see using an AR headset, and get a better understanding of what's going on inside an unsafe environment. They can also set waypoints or coordinates where they want more robots to visit."

The idea of improving communication between humans and devices operating with artificial intelligence is crucial to advancing robotic technology. "All of these virtual reality and augmented reality headsets are giving you that door that lets a machine talk to you and lets you see things in your surroundings as a machine would see them," says Vicenç Rubies Royo, an EECS Ph.D. student who is also collaborating on the HoloLens project. "What you have right now are tools like joysticks and screens to send and receive information, but with augmented reality, the real 3-D environment becomes the interface, so you get and send information that is way more expressive."

In all, eight faculty members are currently affiliated with CAC. Beyond engineering, other researchers are examining how to use these new tools to create and consume information across multiple disciplines, including autonomous vehicle navigation, content creation and new media.

In a lot of ways, Berkeley researchers are trying to build the tools, maps and compasses to make our world more immersive. After all, Yang says, "In the future, a parallel digital world will exist side-by-side with the physical world." And we'll all need to know how to navigate there. BE

Envisioning a whole new reality

Not yet a year old, the Center for Augmented Cognition (CAC) was established to advance the new frontier of augmented and virtual reality. Allen Yang, the center's executive director (pictured above), is joined by other engineering faculty including Ruzena Bajcsy, Francesco Borrelli, Lee Fleming, Ren Ng, Claire Tomlin and CAC faculty director and college dean Shankar Sastry. Also on the team are multimedia journalist Richard Koci Hernandez, assistant professor at the Graduate School of Journalism, and Oculus co-founder Jack McCauley (B.S.'86 EECS), now Innovator-in-Residence at the Jacobs Institute for Design Innovation.

Among the center's first projects, CAC researchers have launched ISAACS — the Immersive Semi-autonomous Aerial Command System — that will use an augmented reality headset to make a more intuitive drone interface.

WEB EXTRA > See more about the Center for Augmented Cognition at **augcog.berkeley.edu.**

Dynamic duo

Engineering and Berkeley-Haas launch Management, Entrepreneurship, & Technology double-degree undergraduate program

In the expanding universe of tech enterprises, there's a growing need for real-world leaders who possess both a skillset in management and commerce and a deep knowledge of technology. Until now, tech innovators and entrepreneurs have usually come from one school or another — either business or engineering. But starting in the fall of 2017, Berkeley will welcome a new breed: students who can graduate with both specialties and two bachelor's degrees in just four years.

"Our industry partners tell us they face a significant gap in their search for talent," says Shankar Sastry, dean of Berkeley Engineering. "Those with technical backgrounds need the expertise to bring a great idea to market, while those with business backgrounds must have a stronger grasp of the technologies that drive innovation."

A fast track for future tech leaders

In response, the college has joined forces with the Haas School of Business to offer the Management, Entrepreneurship, & Technology (M.E.T.) program for students who aspire to create new companies or become innovative leaders within existing ones. The program will launch with two tracks: either business and electrical engineering and computer sciences, or business and industrial engineering and operations research. The new program admits freshmen to Berkeley-Haas for the first time; up until now, all students entered Haas in their junior year.

The curriculum will offer a selection of liberal arts, business and engineering courses led by stellar faculty and will also include hands-on design and industry internships. M.E.T. is the latest addition to the college's robust innovation ecosystem, which includes the Fung Institute for Engineering Leadership, Jacobs Institute for Design Innovation, Sutardja Center for Entrepreneurship and Technology and incubators and accelerators like SkyDeck and the CITRIS Foundry.

The perfect combination of talent and location

The M.E.T. program offers students the chance to study in two top-tier schools: *U.S. News & World Report* currently ranks Berkeley-Haas as number two and Berkeley Engineering as number three in the country. In addition, both schools enjoy strong connections with Silicon Valley and other global hubs of innovation, a geographical advantage that will continue to enrich the new program.

"We're launching this new degree smack-dab in the center of the Bay Area, a major driver of world technology," says Berkeley-Haas Dean Rich Lyons. "No other program can offer that kind of advantage."

WEB EXTRA > For details and application information, see **met.berkeley.edu.**

TEXT BY KIRSTEN MICKELWAIT, PHOTOS BY NOAH BERGER

TRIPLE THREAT

#1 Public university
UC BERKELEY

#2 Business school
Berkeley-Haas

#3 Engineering school
Berkeley Engineering

Source: *U.S. News & World Report*

"A PROGRAM THAT FOR THE FUTURE

Imprint Energy co-founders Christine Ho (B.S.'05, M.S.'07, Ph.D.'10 MSE) and Brooks Kincaid (M.B.A.'11) represent the best of Berkeley's top-tier programs in engineering and business, just like the new M.E.T. undergraduate program.

Imprint Energy: Supercharged collaboration

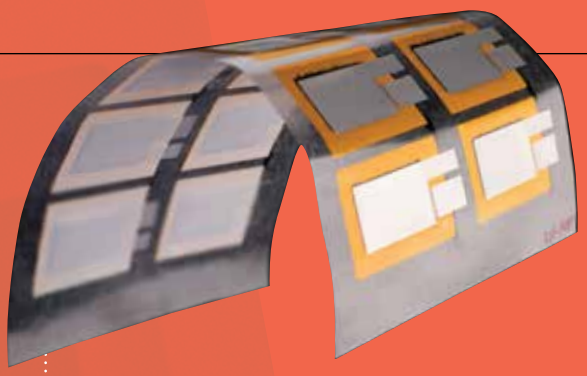
Christine Ho knows better than most how powerful a partnership between the College of Engineering and the Haas School of Business can be. As a graduate student she recognized that battery performance was constraining the design and application of portable electronic devices. So she invented a new battery chemistry and process to simultaneously fabricate and place batteries onto wireless sensors just one centimeter square. In addition to powering the tiniest smart devices, this technology will potentially enhance a range of energy applications, including medical devices, wearables and always-connected Internet of Things gadgets.

In 2010, Ho enrolled in a Berkeley-Haas "Cleantech to Market" course, which matched promising inventors with business, law and public policy students. One partner turned out to be a former high-school classmate, Brooks Kincaid. The two decided to enter Ho's battery in a Berkeley Venture Lab competition sponsored by what's now the Sutardja Center for Entrepreneurship and Technology. They won the competition and officially launched Imprint Energy in 2011.

"When we first met, it felt like Brooks and I came from different worlds," Ho says. "His business background and acumen were in sharp contrast to my technical training. Our work together forced us to learn each other's languages and articulate to each other in a more understandable way. We became more confident and proficient at communicating both scientific and business concepts, which was critical as we gathered momentum to start Imprint Energy."

Today, Imprint Energy is revolutionizing battery technology from its Alameda facility, where 12 employees manufacture and distribute products utilizing its trademarked zinc-based rechargeable battery technology called ZincPoly.

"So much of what I do sits at the intersection of business and science, and I would have greatly benefited from the training and exposure of an M.E.T. degree," says Ho. "I learned a lot about business and entrepreneurship from working with Brooks, but having a formal program that provides both sets of skills will be incredibly powerful for the future of innovation."



A BETTER BATTERY: Imprint Energy's trademarked ZincPoly system uses a series of electrochemical inks and an easily scalable, print-based manufacturing process to create a thin and flexible battery that opens the door to new product design opportunities.

Size The width of just two human hairs, the ultra-thin, solid-state printable batteries are safe, long-lasting, flexible, disposable and easy to manufacture.

Scaling In comparison with other battery fabrication processes, this printing technique is fast, scalable and wastes little material.

Materials Ho "painted" layers of zinc electrode, polymer electrolyte and metal oxide electrode on a precise spot on the substrate. Within a few hours, the material "sandwich" is ready for use as a built-in zinc polymer battery.

Impact Imprint Energy's technology can power thin, flexible displays, such as smart labels and e-readers. Industrial-size printers could also churn out large battery sheets for storing solar energy.

PROVIDES BOTH SETS OF SKILLS WILL BE INCREDIBLY POWERFUL OF INNOVATION." — CHRISTINE HO | MATERIALS SCIENTIST AND CO-FOUNDER, IMPRINT ENERGY

New nukes

The race is on to develop technologies that will make possible new nuclear reactor designs and safer fuels

STORY BY DANIEL MCGLYNN

Early this year, Rachel Slaybaugh attended a campus mixer on technological innovation. When she introduced herself as a professor of nuclear engineering, other attendees would pause and ask for clarification. She remembers, "People were like, 'Wait. What? You're from where?'"

'"I don't know if you've noticed," she would reply, "but the nuclear industry is a little behind in terms of innovation."

The nuclear energy sector is often perceived as a last-century industry. But that is changing. A growing market of venture-backed startups signals that we are on the verge of a nuclear do-over.

Despite a turbulent history, the allure of nuclear energy — electricity production on a massive scale with minimal emissions — remains attractive. Its low emission rate is why the United Nations International Panel on Climate Change recommends doubling the world's nuclear capacity by 2050.

Nuclear energy as an effective strategy to combat climate change, along with the fascinating physics of nuclear fission, is what drew Slaybaugh to the field in the first place. "I keep going back to the numbers for safety and impacts," she says. "Even without considering climate change, just look at the public health impact of air pollution. I just can't come to any answer that isn't nuclear."

Yet the bulk of the 100 nuclear reactors currently operating in the U.S., which continue to produce about 20 percent of the nation's energy, are reaching retirement age, and energy market forces don't always favor nuclear.

In June, California's Pacific Gas and Electric utility announced plans to shutter its long-controversial Diablo Canyon reactor within a decade. The reason cited was not environmental issues or safety concerns, but economic: the aging reactor can't compete price-wise with other energy sources. "It's ironic that as environmental groups switch to pro-nuclear or at least neutral on nuclear, existing nuclear plants are closing — not because of increased public backlash, but because of distortions in the electricity market," Slaybaugh says.

"I'm very pro-renewables, but production tax credits are paid to some resources that don't emit air pollution and not others," she continues. "That doesn't make a lot of sense."

Many realize that for nuclear energy production to have a future, the entire industry needs an overhaul — including how regulatory structures and energy markets are constructed, as well as how nuclear reactors are designed, financed and built. The need for industry-wide modernization is clear even in highly partisan Washington, D.C., where lawmakers from both sides of the aisle are largely in agreement that the nuclear sector — one of the most heavily regulated industries in the world — needs to be more accommodating to new ventures.

Likewise, training a new nuclear workforce will also need an overhaul. That's why, with a sense of urgency and favorable political tailwinds, Slaybaugh launched a nuclear innovation bootcamp. Held in August, the two-week bootcamp hosted 25 university students from around the world and encouraged them to envision what "new nuclear" would look like. Slaybaugh collaborated with Third Way, a D.C.-based centrist think tank working on nuclear energy-related issues, along with the Nuclear Innovation Alliance industrial consortium, to develop the curriculum for the two-week course.

"One of the reasons it makes sense to have this bootcamp at Berkeley," says Todd Allen, a nuclear energy expert and senior visiting fellow at Third Way, "is because there is a culture of innovation. One of the Department of Energy's first incubators, Cyclotron Road, is located at the Berkeley Lab. The Bay Area has all of the pieces that could support something like this."

THE ATOMIC AGE

The golden age of nuclear began immediately following World War II, when the federal government started pouring research and development money into commercial nuclear reactor designs.

In 1951, in a concrete building nestled in the sagebrush scrub plains of eastern Idaho, scientists working at the National Reactor Testing Station (now part of the Idaho National Laboratory) flipped the switch on the first reactor designed to convert heat derived from splitting uranium atoms into electricity. During its first flickers of life, the reactor lit up four 200-watt lightbulbs, kicking off a decade of pioneering research and engineering — followed by four decades of controversy and catastrophic technological failures.

By the late 1950s, the first large-scale commercial nuclear reactors came online across the country. In 1960, the Atomic Energy Commission estimated that the nation would be powered by thousands of nuclear reactors by the year 2000.

"Back in the day, the philosophy was that commercial deployment had to be done as quickly as possible," says Per Peterson, nuclear engineering professor and the college's executive associate dean. "We became competent in building and operating water-cooled reactors for submarines. And then we got locked into that one kind of technology."

Despite early developments using other reactor designs and fuel configurations,

the industry settled on that single design — water-cooled reactors, also known as light-water reactors — as a universal standard. The time and money involved in the nuclear regulatory permitting process made deviating from the accepted design prohibitively expensive.

Light-water reactors produce electricity by creating steam to spin a turbine. The solid fuel, usually uranium arranged in rods that need replacing roughly every four years, is cooled by pressurized water. An accident at a light-water reactor can release radioactive materials as fine particles. With high pressure steam, these particles can leak from a reactor building, as in the high-profile accidents at Chernobyl and Fukushima.

"The consequence space for severe accidents is pretty substantial with this type of reactor," Peterson says. "Therefore, it took a lot of effort to develop extremely reliable active systems to provide cooling, low leakage and high-pressure containment structures, which make these reactors more expensive. So they were built bigger and bigger to achieve economies of scale."

"In the end, that didn't seem to work too well," he says.

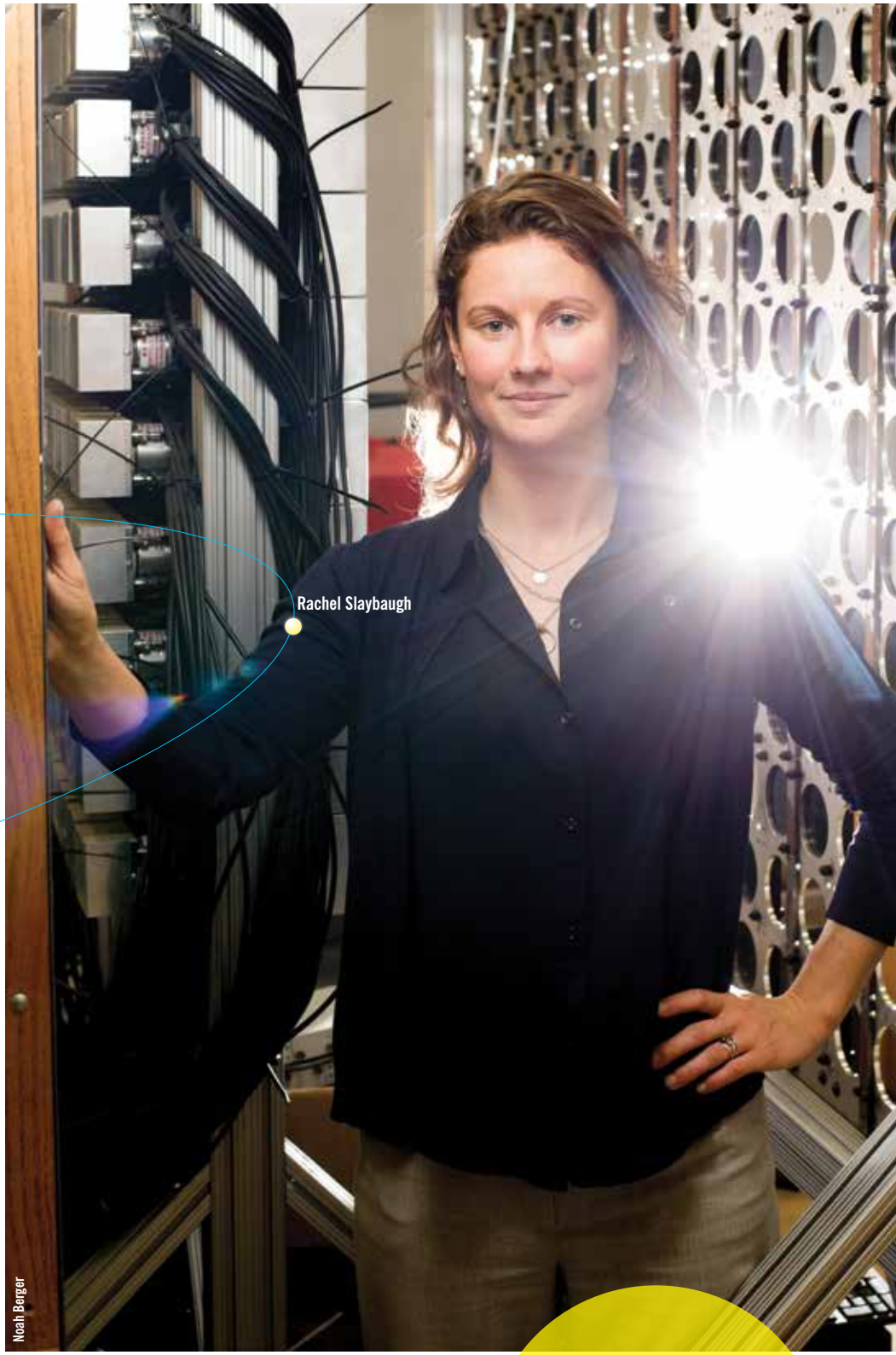
In 1979, a reactor at Three Mile Island in Pennsylvania had a partial meltdown because of valve failure and human operator error, resulting in the evacuation of 140,000 people. Following the accident, anti-nuclear sentiments became a foundation of the country's budding environmental movement, raising questions about the safety of nuclear facilities and what to do with the growing pile of spent nuclear fuel rods.

Over the next 30 years, the vision from nuclear's early days — of thousands of reactors pumping out emissions-free energy — was tempered by economics and politics.

A DESIGN PROBLEM

Despite the grim outlook for growth, Slaybaugh became curious about a career in nuclear engineering as an undergraduate at Penn State in the early 2000s. She was initially interested in physics when she happened to get a work-study assignment at the university's research reactor.

In graduate school at the University of Wisconsin, she began studying the Boltzmann Transport Equation — "a single equation that describes where all of the neutrons are in a nuclear system," Slaybaugh explains. "Anything in a nuclear system starts with where all of the neutrons are, so it lets you figure out everything else."



Noah Berger

Working with the equation can be challenging, so Slaybaugh developed expertise in creating algorithms and software to solve the equation faster and more efficiently, which ultimately can be applied to designing and modeling new nuclear technologies.

"Truly predictive modeling will end up making it a lot more feasible, affordable

"I just can't come to any answer that isn't nuclear."

– Rachel Slaybaugh, assistant professor of nuclear engineering

Peg Skorpinski

Research team next to the Compact Integral Effects Test facility they built to study models of molten salt effectiveness.

> "There is the potential for rapid innovation to occur, and we can make major changes in nuclear technology."
>
> – Per Peterson, professor of nuclear engineering

and practical to ask questions about what's going to happen in new reactor design scenarios," Slaybaugh says. "I also have this serious concern about best practices and quality: You want to make sure that the codes you are using in nuclear systems work."

"Fundamentally," Slaybaugh says, "I make the tools that other people use to do analysis. So I get really excited about making better hammers so that other people can make better houses." Slaybaugh, recently appointed by the Secretary of Energy to the Nuclear Energy Advisory Committee, also works with the Gateway for Accelerated Innovation in Nuclear (GAIN), a group organized by the Department of Energy to provide guidance on technical, regulatory and financial issues facing this emerging "advanced nuclear" industry.

Advanced nuclear is the umbrella term used to describe novel research on smaller reactor designs that incorporate alternative nuclear fuels and cooling systems. Some advanced designs reuse existing nuclear waste as fuel; or use fuel that does not require enrichment, which reduces security concerns associated with nuclear energy.

"The big thing is that the government is making national lab resources available to private companies in a way that it wasn't before," Slaybaugh says. "If you are a nuclear startup, you can only go so far before you need to do testing, and you are not going to build a nuclear test facility, because that is hard and expensive. But now you could partner with a national lab to use their experimental resources. I've been talking about how to set up a pathway from universities for this kind of research."

Over the past year, Third Way, a supporter of Slaybaugh's nuclear innovation bootcamp, published a number of reports and white papers defining the advanced nuclear industry. They found 48 projects and startup companies working on advanced nuclear energy technologies, worth over $1.3 billion, all over the U.S. and Canada.

One of those projects is led by Per Peterson's research group at Berkeley. Following his Ph.D. research in mechanical engineering at Berkeley, Peterson began designing passive safety systems for light-water reactors, with an eye toward replacing and greatly simplifying the active safety systems the industry had originally adopted.

"Back in 2002," he says, "the U.S. launched an international effort on advanced nuclear technologies called Generation IV. This got us thinking about what we wanted to see in advanced nuclear technologies, beyond just passive safety."

Those experiences led Peterson to conceptualize entirely new designs. "Now the majority of my research relates to advanced reactors cooled by molten fluoride salts, which have undergone major advances since molten salts were first studied for reactor applications starting in the late 1950s," he says.

Molten-salt reactors are cooled by fluoride salts that liquefy and remain stable at high temperatures. They do not need to be pressurized like light-water reactors do, reducing the probability of large-scale accidents.

"Molten salts are fantastic heat-transfer fluids; they have enormous volumetric heat capacity, which means they are remarkably compact. This puts you in a position to design reactor vessels to have limited service life, to be replaced multiple times during a life of a plant," Peterson says. "As soon as you focus on limited service life, you are in a very different space in terms of innovation and upgrading old components."

Named to the Department of Energy's Blue-Ribbon Commission on America's Nuclear Future in 2010, Peterson also contributes to the national discussion about new nuclear regulatory standards. "Here we are just 10 years after NASA launched its Commercial Orbital Transport Services program to fund startup companies like SpaceX, and massive change has occurred with the idea that private-sector startup companies can be significantly more nimble and still work in areas requiring high levels of technical sophistication."

Drawing inspiration from successes from other heavily regulated industries, Peterson says, is what keeps him optimistic. "There is the potential for rapid innovation to occur, and we can make major changes in nuclear technology. This is what we need to be working on this coming decade." BE

WEB EXTRA > See bootcamp video at **www.youtube.com/BerkeleyEngineering.**

2010+

Cierra Atkinson (M.S.'12 CEE) was named a fellow by the Knowles Science Teaching Foundation, a program designed specifically for early-career, high school mathematics and science teachers. She earned a Master of Arts in education from Stanford University in 2016. Before transitioning to the teaching profession, Atkinson worked as a staff geotechnical engineer at Engeo, Inc. She begins her first year of teaching this fall at Del Mar High School in San Jose, California.

Peter Bailis (Ph.D.'15 EECS) was named as one of *Forbes'* "30 Under 30" in Enterprise Technology for his work on large-scale data management. A recipient of a National Science Foundation Graduate Research Fellowship, he became the youngest-ever tenure-track assistant professor at Stanford's computer science department this fall.

Patrick Goodwill (Ph.D.'10 BioE) and bioengineering professor **Steven Conolly** lead a startup called Magnetic Insight. They plan on installing their first magnetic particle imaging scanner at the Stanford School of Medicine, where researchers will explore using MPI to solve challenges in cell therapy and vascular imaging. The company has also recently secured an oversubscribed seed funding round of $3 million.

Kory Hedman (Ph.D.'10 IEOR) has won the Outstanding Young Engineer Award from the IEEE Power and Energy Society. He is currently an assistant professor in the School of Electrical, Computer and Energy Engineering at Arizona State University, where he was recently promoted to tenure.

Moneer Helu (M.S.'09, Ph.D.'13 ME) was recognized by the Society of Manufacturing Engineers on their list, "30 Under 30: Future Leaders of Manufacturing." The former associate director of Berkeley's Laboratory for Manufacturing and Sustainability, he now works at the National Institute of Standards and Technology. His research at Berkeley focused on developing data-driven tools and analytics to assess the performance and productivity of machining systems.

Daniel Kawano (Ph.D.'11 ME) was awarded the Outstanding New Mechanics Educator Award by the Mechanics Division of the American Society for Engineering Education in June. An assistant professor of mechanical engineering at Rose-Hulman Institute of Technology in Indiana, Kawano is also a coauthor of the forthcoming textbook *Engineering Mechanics: Dynamics,* with ME professor emeritus **Benson Tongue.**

Chung-Wei Lin (Ph.D.'15 EECS), along with EECS professor **Alberto Sangiovanni-Vincentelli,** has received the 2016 ACM Transactions on Design Automation of Electronic Systems Best Paper Award. Titled "Security-Aware Design Methodology and Optimization for Automotive Systems," the paper was written in collaboration with researchers from UC Riverside and supported by the TerraSwarm Research Center.

Nicole Michenfelder-Schauser (B.S.'15 MSE) has been named a winner of the Hertz Foundation Fellowship, the most competitive Ph.D. fellowship program in science and engineering in the United States. She is one of 12 recipients from over 800 applicants across the fields of science, engineering and mathematics. This fall, she begins her Ph.D. studies in materials science at UC Santa Barbara.

Jack Reilly (Ph.D.'14 CEE) received the Council of University Transportation Center's Milton Pikarsky Memorial Award in Science and Technology for his dissertation on new methods for coordinated, predictive and decentralized freeway traffic control to help connect related corridors and increase traffic flow. Now at Google, he is part of the Ground Truth team at Google Maps, which leverages the company's vast resources to develop the underlying map data that powers location-aware products like navigation and traffic.

Olivier Siegelaar (B.S.'13 ME) rowed for the Dutch national team in the 2016 Olympics. Siegelaar has

Jalel Sager (Ph.D.'13 ERG, left) and **Jonathan Lee** (B.S.'13 EECS) co-founded New Sun Road, a technology company committed to implementing solutions to climate change and global energy poverty and to providing electricity to communities, health clinics and education centers in remote and challenging environments. The company currently has on-the-ground operations in East Africa and Vietnam, and is growing its team while scaling up microgrid projects in Uganda.

"Entrepreneurs need affordable lighting for security and extended business hours, refrigeration for food preservation and adding value to consumer goods, computers for entertainment and information services and machinery ranging from hair clippers and blenders to construction and power tools," the founders say on their website at **newsunroad.com.**

PHOTO ADRIEL OLMOS

SEND YOUR CLASS NOTES to **berkeleyengineer@berkeley.edu,** or mail to:
Berkeley Engineer, UC Berkeley College of Engineering, 312 McLaughlin Hall #1704, Berkeley, CA 94720-1704.

2 professors among the "7 over 70"

It turns out that good ideas don't stop at age 35. That never really was the case that the *MIT Technology Review's* annual 35 innovators under 35 was trying to make. Nonetheless, the magazine took the step this year to acknowledge innovators who are continuing to have sustained impacts in their field well after most of their colleagues have decided to retire.

A companion to *Tech Review*'s annual 35 Innovators Under 35 list features 7 innovators older than 70, including electrical engineering and computer sciences (EECS) professor **Ruzena Bajcsy** and professor emeritus **Michael Stonebraker,** now at MIT.

Being 70 is so last decade for roboticist Ruzena Bajcsy (read more about Bajcsy's work on page 10.) Before coming to Berkeley, where she is a director emerita of the Center for Information Technology Research in the Interest of Society (CITRIS), Bajcsy was a professor of electrical engineering at the University of Pennsylvania. She also led the Engineering Directorate of the National Science Foundation. Currently, her work focuses on artificial intelligence, computational biology and biosystems. Last year, she worked on research about how technology — specifically the Microsoft Kinect — can be used to improve the quality of life for elderly adults with muscular dystrophy.

Stonebraker is a computer scientist known for database research. Through a combination of academic work and a number of commercial ventures, he has heavily influenced popular understanding of relationship databases. He was a professor at Berkeley for 29 years and is currently an adjunct faculty member at MIT. Stonebraker has won numerous awards for his work, including a 1997 induction into the National Academy of Engineering and a 2014 ACM Turing Award.

PHOTOS COURTESY MIT TECHNOLOGY REVIEW

also rowed in the 2008 and 2012 Summer Olympic Games for his native Netherlands. While at Berkeley, Siegelaar rowed for the Bears and competed in world championship-caliber events. Over the summer, Siegelaar was named the recipient of a Pac-12 postgraduate scholarship. He has plans to pursue an M.B.A. at Oxford University.

Augusto Tentori (Ph.D.'15 BioE), now a researcher at MIT, was one of 21 scholars granted postdoctoral fellowships this year by the Ford Foundation.

2000+

Scott Aaronson (Ph.D.'04 EECS), associate professor at MIT (soon UT Austin) and an authority on quantum computation, "Answers Every Ridiculously Big Question (John Horgan) Throws at Him" in an interview for *Scientific American.* In the article, he riffs on simulated universes, the Singularity, unified theories, P/NP, the mind-body problem, free will, why there's something rather than nothing and more.

Dino Di Carlo (B.S.'02, Ph.D.'06 BioE) has been named the 2016 Outstanding Young Investigator by the Materials Research Society. He is currently a professor in UCLA's bioengineering department. His award-winning research on microstructured materials for cell analysis and regeneration was presented at the 2016 MRS Spring Meeting at UCLA.

Sumit Gulwani (Ph.D.'05 CS) is leading an effort to bring the power of computer code to those who are unable to write it themselves. His research was featured in a *Financial Times* article, which described how his team at Microsoft developed Flash Fill for Excel, which uses programming by example to automatically fill in outputs without entering a formula.

Tasha Kamegai-Karadi (B.S.'09 CEE) received a New Faces of Engineering Award from DiscoverE, the largest nonprofit promoting the engineering industry. After graduating, she earned her master's degree in environmental engineering and science from Stanford. Now she works as a groundwater expert at Geosyntec Consultants, remediating contaminated groundwater and soil and protecting occupants with field investigations to assess vapor intrusion. In honor of her mother, she also advocates for women's mental health in engineering, and has lectured on the subject at the Society of Women Engineers' largest conference.

Tejas Narechania (B.S.'05 EECS, B.A.'05 Political Science) has joined the faculty of Berkeley's School of Law as an assistant professor. He will teach courses on property, intellectual property and telecommunications regulation. Prior to joining the law school, he served as a law clerk to Associate Justice Stephen G. Breyer of the United States Supreme Court.

1990+

Susan Hubbard (Ph.D.'98 CEE), a geophysicist and Berkeley Lab's associate director for earth and environmental sciences, will head up a three-year Department of Energy initiative to quantify how mountainous watershed floods, drought, fire and early snowmelt affect the downstream delivery of water, nutrients, carbon and metals.

Jason Mikami (B.S.'98 EECS, B.A.'92 East Asian Languages) is now the vice president of engineering and operations at Bitcasa, a cloud technology provider. He also helps operate the family winery, Mikami Vineyards, whose 2013 Zinfandel was recently awarded 90 points by *Wine Enthusiast.* The wine also won a Double Gold Medal at the 2016 *San Francisco Chronicle* Wine Competition.

Dawn Tilbury (M.S.'92, Ph.D.'94 EECS), professor of mechanical engineering and associate dean of research at the University of Michigan College of Engineering, has won the 2016 Gold Award from the Engineering Society of Detroit's Affiliate Council, their most prestigious distinction. Tilbury joined the UM faculty in 1995; her research interests include distributed control of mechanical systems with network communication, logic control of manufacturing systems, reliability of ground robotics and dynamic systems modeling of physiological systems. She was elected an IEEE fellow in 2008 and an ASME fellow in 2012.

1980+

Dimitri Bevc (M.S.'89 Engineering Geoscience) was named the Fall 2015 Distinguished Lecturer by the Society of Exploration Geophysicists.

Ho Gardner Bowerman Hegyi Vinyals Gao Levine

7 Berkeley engineers among top 35 innovators under 35

Five alumni — among seven engineers in all from the college — were named the Top Innovators Under 35 of 2016 by *MIT Technology Review.*

The alumni are: materials scientist **Christine Ho** (B.S.'05, M.S.'07, Ph.D.'10 MSE) of Imprint Energy (see page 13); bioengineers **Kelly Gardner** (Ph.D.'13 BioE) of Zephyrus Biosciences and Dot Laboratories CEO **Heather Bowerman** (B.S.'06 BioE); and two electrical engineering and computer sciences (EECS) alumni, **Alex Hegyi** (M.S.'12, Ph.D.'13 CS), now at Xerox's PARC, and **Oriol Vinyals** (Ph.D.'13 EECS), now at Google DeepMind. **Wei Gao,** a postdoctoral researcher in the lab of professor **Ali Javey,** and newly arrived assistant EECS professor **Sergey Levine,** former postdoc with EECS professor **Pieter Abbeel**, also graced the list.

This year's honorees were featured in the September/October edition of the *MIT Technology Review* as well as online, and were honored in person at the EmTech MIT fall conference in Cambridge, Massachusetts.

PHOTOS COURTESY MIT TECHNOLOGY REVIEW

His lecture, "Full-waveform inversion: challenges, opportunities and impact," was delivered at 26 locations throughout North America (including Berkeley), South America and Europe.

Rudolph Bonaparte (M.S.'78, Ph.D.'82 CE) received the 2016 Outstanding Projects and Leaders Lifetime Achievement Award in Design from the American Society of Civil Engineers. The president and CEO of Geosyntec Consultants, he is a member of the National Academy of Engineering and serves as board chair for Berkeley Engineering's CEE Academy of Distinguished Alumni.

Joon Sik Lee (Ph.D.'85 ME) was appointed deputy prime minister for social affairs by South Korean President Park Geunhye. After graduate work in heat transfer, he joined the faculty at Seoul National University, where he later served as executive vice president and provost. He recently spent his sabbatical at the Laser Thermal Laboratory at Berkeley's Department of Mechanical Engineering.

Rhonda Righter (B.S.'82, Ph.D.'86 IEOR), professor and former chair of the IEOR department, was named program co-chair for the European Conference on Queueing Theory, where scientists and technicians can promote research and exchange ideas, theory and applications.

1970+

Donald T. Hawkins (B.S.'64 Chemistry, M.S.'66, Ph.D.'70 MSE), editor at Information Today, Inc., in Medford, NJ, has co-edited his second book, *Public Knowledge: Access and*

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YOUR CLASS NOTE (please print legibly):

Benefits, with the late Miriam Drake, former dean of libraries at Georgia Institute of Technology.

Jorg Imberger (Ph.D.'70 CEE) is credited with founding the field of environmental fluid mechanics — specifically, for applying fundamental fluid mechanics principles to environmental flows. He is best known for pioneering work in physical limnology — transforming the field with state-of-the-art measurement tools and computation.

James Roberts (B.S.'79, M.S.'80 CEE) has risen through the ranks over the years at Granite Construction Company, a national civil construction firm based in Watsonville, CA, and became president and CEO in 2010.

Ronald W. Yeung (Ph.D.'73 ME), inaugural faculty holder of the American Bureau of Shipping Endowed Chair in Ocean Engineering and professor of hydromechanics and ocean engineering, received the Lifetime Achievement Award from the Ocean, Offshore and Arctic Engineering Division at their annual conference in June. In his acceptance speech, Yeung acknowledged the efforts of his many collaborators and students during his 34 years on the Berkeley faculty.

1960+

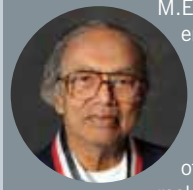
Jean Paul Jacob (M.S.'65, Ph.D.'66 EECS) was honored with a medal of the Rio Branco Order, one of the highest honors of the Brazilian Government, in part for his work with the college as faculty-in-residence in the electrical engineering and computer sciences department and as special advisor to the Center for Information Technology Research in the Interest of Society (CITRIS). The medal was bestowed by Eduardo Prisco Ramos, consul general of Brazil in San Francisco, in July. Jacob's research interests have covered software engineering, artificial intelligence, multimedia, personal digital assistants and decision-support systems. He is considered a worldwide expert on informatics for the 21st century.

Ron Laurie (B.S.'64 IEOR) went to law school and became a patent attorney and intellectual property strategist at several large law firms. After 35 years as a lawyer, he started an investment banking firm to advise technology companies and institutional investors in acquiring, divesting and investing in IP assets and in sourcing and executing corporate transactions in which IP plays a significant role.

Farewell

This year the college lost four professors who were also alumni.

Joonhong Ahn (Ph.D.'88 NE), professor of nuclear engineering and former nuclear engineering department vice chair, died in June at the age of 58. He was also a faculty member of Japanese Studies at the Institute of East Asian Studies and a geologist at Berkeley Lab. His research encompassed the entire nuclear fuel cycle, and he played a key role in the engineering ethics program. He was a leading expert on nuclear power in Asia, and after the 2011 Fukushima nuclear accident, he shifted his focus to the intersection of science, technology and society.



Chittor V. Ramamoorthy (M.S.'51, M.Eng.'53 ME), EECS professor emeritus, died in March at the age of 89. A native of Burma, he received his Ph.D. at Harvard in 1964. His research enhanced the dependability of safety-critical distributed real-time embedded systems, including an automated system in the late 1960s that uncovered programming errors in the U.S. Army's Safeguard Missile Defense System. The system evolved into tools used to test NASA's Space Shuttle System in 1971. He is widely recognized as one of the early creators of the discipline of software engineering.

Kal Sastry (Ph.D.'70 MSE), materials science and engineering professor emeritus, died in July at the age of 74. Raised in India, he was known for his contributions in mining research, particularly iron ore processing. According to professor emeritus Douglas Fuerstenau, his doctoral thesis supervisor, Sastry was a worldwide expert in his field and was responsible for creative ideas in conglomerating fine particles. He joined the faculty in 1975 and retired in 2000. After retirement, he continued to teach in The Berkeley Experience, a campus freshman and sophomore seminar.

Robert Wiegel (B.S.'43, M.S.'49 ME), a coastal engineering pioneer and professor of civil engineering for 27 years, died in July at the age of 93. He served as assistant dean of the college from 1963 to 1972 and as acting dean from 1972 to 1973. He received the Berkeley Citation in 1987 and was inducted into the CEE Academy of Distinguished Alumni in 2012. His research included pioneering work in applying the scientific principles of oceanography to civil engineering problems.

Murray Kuperman (B.S.'59 Metallurgy) died in August 2015 at the age of 78. After serving in the Navy, he worked on the Polaris missile at Lockheed and also worked as a quality engineer for United Technologies on the Titan III and Scout rocket engines. In 1979, he began a career at United Airlines, retiring as a staff engineer working on composite repair and de-icing.

Jacques Pankove (B.S.'44, M.S.'48 EE), an early pioneer of LED technology, died in July at age 93. Born in Ukraine, Pankove and his family immigrated first to Turkey, and then to France, until the Nazi invasion prompted a move to Oakland in 1942. During World War II, he served in the U.S. Army Signal Corps in the Philippines. After Berkeley, he earned his Ph.D. in physics from the University of Paris. His scientific pursuit of LEDs started at the RCA Lab in Princeton, New Jersey, where he spent most of his scientific career. He returned to Berkeley in 1968 as a visiting McKay Lecturer and authored the seminal textbook *Optical Processes in Semiconductors* (1972). Upon retirement from RCA in 1985, he joined the faculty at the University of Colorado.

Eay ("Jack") Watanabe (B.S.'50 Eng. Physics) died in May at age 90. Originally from Washington, his family was interned at the Tule Lake Relocation Center near the California-Oregon border during World War II. While there, Watanabe learned calculus from a Berkeley graduate student and was the star pitcher for his Block 54 baseball team. During the Korean War, he served in the U.S. Army as an electronics technician. He later worked on the first satellite that transmitted live television and on unmanned spacecrafts that landed on the moon, paving the way for the Apollo space program. During his 31 years at Hughes Aircraft, he worked on space and defense projects including Intelsat I (Early Bird) and Surveyor.

William Prince Smith, Class of 2017

A lasting legacy

After serving as an aviation electronics technician in the United States Marine Corps for nine years, William Prince Smith is now studying electrical engineering and computer sciences at Berkeley Engineering, thanks in part to the Stanley and Madalyn Hutchison Scholarship.

"I'm very grateful for the scholarship," he says. "It's definitely helping me a lot financially and allowing me to be able to focus just on school and on what's important."

Stanley and Madalyn Hutchison

Stanley Hutchison (B.S. '51 Petroleum Engineering), who served with distinction as an Army pilot during World War II, had himself benefitted from financial aid when he studied at Berkeley. His education launched his successful career at Standard Oil - Chevron, where he had more than 75 successful patents and over 130 published technical papers.

Stanley and Madalyn believed in the power of education to transform lives. The scholarship honors their strong work ethic and many accomplishments, and leaves an important legacy: funding exceptional Berkeley Engineering undergraduates, allowing them, to every possible extent, to graduate debt-free.

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