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College of Engineering
University of California, Berkeley
Spring 2017
Volume 11

Startups on campus
7 steps from idea to impact

Meet the new meat
Lab-to-table protein

Robotic galagos
Learning to leap

Berkeley ENGINEER

SMART MOVES
California's next-gen infrastructure

Inventing a better future

The best minds. The hardest problems. A setting that sparks collaboration. These are the key ingredients in a new initiative we are launching, one with an audacious goal: to invent a better, more promising future for generations to come.

Nationally, we are confronted by challenges — an aging set of infrastructures, inefficient healthcare delivery, a changing labor market in the new "sharing economy." However, we have rapidly evolving technologies at hand to drive solutions to these problems, provided we take care to develop them responsibly.

In our early thinking, our "Institute for Inventing the Future" would enable us to pursue these questions. Such a hub would be more than a contemplative think tank. We would engage an interdisciplinary community of researchers, students and stakeholders in well-designed innovation and new venture creation, focusing on several high-impact domains:

- **The future of health:** Drawing on work in neural prostheses, customized therapies and other advances, we aim to realize the potential of personalized medicine as well as "Health@Home" — enabling wellness, healing and aging in place untethered from clinical settings.
- **The future of cognition:** Developments in virtual reality, augmented reality and body sensor networks are unveiling the "human intranet," heightening our experience of live performances and giving us the ability to tailor education to individual learning styles.
- **The future of work:** As robots come to coexist with humans in the workplace, how do we make them able collaborators? More broadly, as automation changes the workforce, how can we design new jobs that draw on human-machine interaction?
- **The future of mobility:** Where are ride-sharing services, self-driving cars and delivery drones taking us? How can we steer these disruptions in ways that reduce congestion and pollution and offer more ease of use?
- **The future of infrastructure:** The Internet of Things is transforming our physical infrastructures into "cyber-physical systems," embedded with sensing and computation. How can we inject these technologies into our communications, transportation, energy, water and other infrastructures while enhancing their resilience to attacks and protecting the privacy of the public?

In each of these domains, we recognize the unprecedented extent of technology's integration into our daily lives. Technology has always shaped how we live, and it is up to us to invent our future with holistic considerations of ethics, personal rights and social justice built in from the start. In this way, we will continue to uphold our core mission of educating leaders, creating knowledge and serving society.

As always, I welcome your thoughts and ideas.

An interdisciplinary community engaged in well-designed innovation and new venture creation.

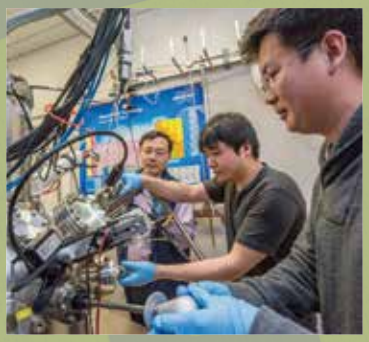
—*S. Shankar Sastry*
DEAN AND ROY W. CARLSON PROFESSOR OF ENGINEERING
DIRECTOR, BLUM CENTER FOR DEVELOPING ECONOMIES

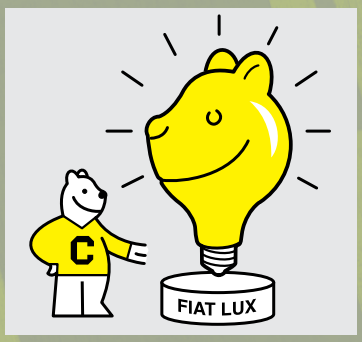
Dean Shankar Sastry introduces a faculty panel discussing California's next-generation infrastructure at a Dean's Society event this spring. Seated from left, David Sedlak and Susan Shaheen of CEE and Costas Spanos and Claire Tomlin of EECS.

Noah Berger

in this issue

Berkeley**ENGINEER SPRING** 2017





MORE >

> COVER PHOTO: EECS PROFESSOR **COSTAS SPANOS** RIDING HIS ELECTRIC BICYCLE IN DOWNTOWN BERKELEY.

PHOTO BY **NOAH BERGER**

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SUSTAINABILITY

Lab to table

Making a plant-based substitute to replace energy- and resource-intensive factory-farmed meat is among the latest challenges taken up by the Sutardja Center for Entrepreneurship and Technology (SCET). This semester, 45 students are studying the market dynamics of plant-based protein and trying to create vegetarian options that look, feel and taste like real meat but are more environmentally sustainable.

Factory-farmed meat accounts for about a quarter of global carbon emissions, according to the Good Food Institute, a nonprofit organization based in Washington, D.C. that is partnering with SCET on the course.

"Some of the students enrolled because they are convinced that this is urgently needed," says **Ricardo San Martin,** visiting SCET faculty member, course instructor and entrepreneur. "But all of them share a desire for impact — to be a force in the world."

The course is part of the center's Challenge Lab series and is formatted like an incubator: Teams design a product and pitch it to a panel of experts in hopes of winning prize money to form a company.

1 SOY Most commercially available plant-based meat alternatives start as soybeans.

2 REDUCTION Harvested soybeans undergo a chemical de-fattening process to isolate protein by removing soy oil.

3 POWDER Soy isolate is reduced to powder, like the kind commonly found in vegan protein shakes. Protein is a critical part of meat, but studying other components, such as fat and collagen, helps researchers reverse-engineer the flavor and texture of cooked meat.

4 TEXTURIZING Animal protein comes from muscle and is organized in straight lines. Plant protein, like soy, is erratically shaped. A mechanical extruder is used to make plant protein fibers behave more like animal protein — a crucial, difficult step that may vary from stock to stock.

5 CHEF The resulting plant-based meat product looks like manicured chicken strips. To best mimic meat, the flavor and texture should be artfully prepared.

COMMENTS

The fall 2016 Berkeley Engineer *story on "New nukes" elicited several comments about the future of nuclear energy and the direction of the advanced nuclear technologies. Edited excerpts follow.*

"This is hugely heartening news! I have tried repeatedly to encourage several professors at my alma mater to take up the cause of 'new nukes.'"
— **Kirk Gothier,** via Facebook

"…And, may I ask, why are there not more than 10 words here, by the author or the interviewees, about what they plan to do with the waste produced? Just keep burying it in underground facilities that are supposed to remain safe for the next 10,000+ years, designed by more experts in white coats on land scientifically stripped of history, politics and people? Send it off to poor countries? Buy carbon credits to offset nuclear power's 10,000+ year radiation problem?"
— **Name withheld,** Berkeley social science Ph.D. student, via Facebook

"While the article may not mention this aspect of nuclear science in as much detail as you may have wished, it is not an area that is being neglected — at Berkeley or in the nuclear science community at large. In fact, until his unfortunate passing earlier this year, nuclear engineering professor Joonhong Ahn was a distinguished leader in the field of radiological safety and waste management… Some of the advanced reactor types mentioned in the article find better ways to use more input fuel, producing waste that survives much shorter amounts of time — a few hundred years rather than tens of thousands. This is still a technical fix, I know, but I challenge you to find another carbon-neutral energy source with the base load power capacity of fossil fuels that is not in some way technical. If you want electricity, you'll need a scientific solution."
— **Mitch Negus,** Berkeley nuclear engineering Ph.D. student, via Facebook

"Please, both, all, keep up good work!"
— **Peter MacInerney,** via email

LEADERSHIP

Carol Christ named chancellor

After a unanimous vote by the regents in March, Carol Christ was confirmed as the 11th chancellor of UC Berkeley. In her own words, this is what the job means:

"Berkeley transformed me, as it has transformed so many of us, and it transformed my understanding of higher education. I had never been in a place of such intense intellectual vitality, with as great a sense of the consequence of its research. There seemed no field, of knowledge or endeavor, that someone on the faculty did not know profoundly — and indeed was not working to extend its understanding. And I had never been in a place so deeply committed to widening the doors to educational opportunity."

Brittany Hosea-Small

CAPITAL

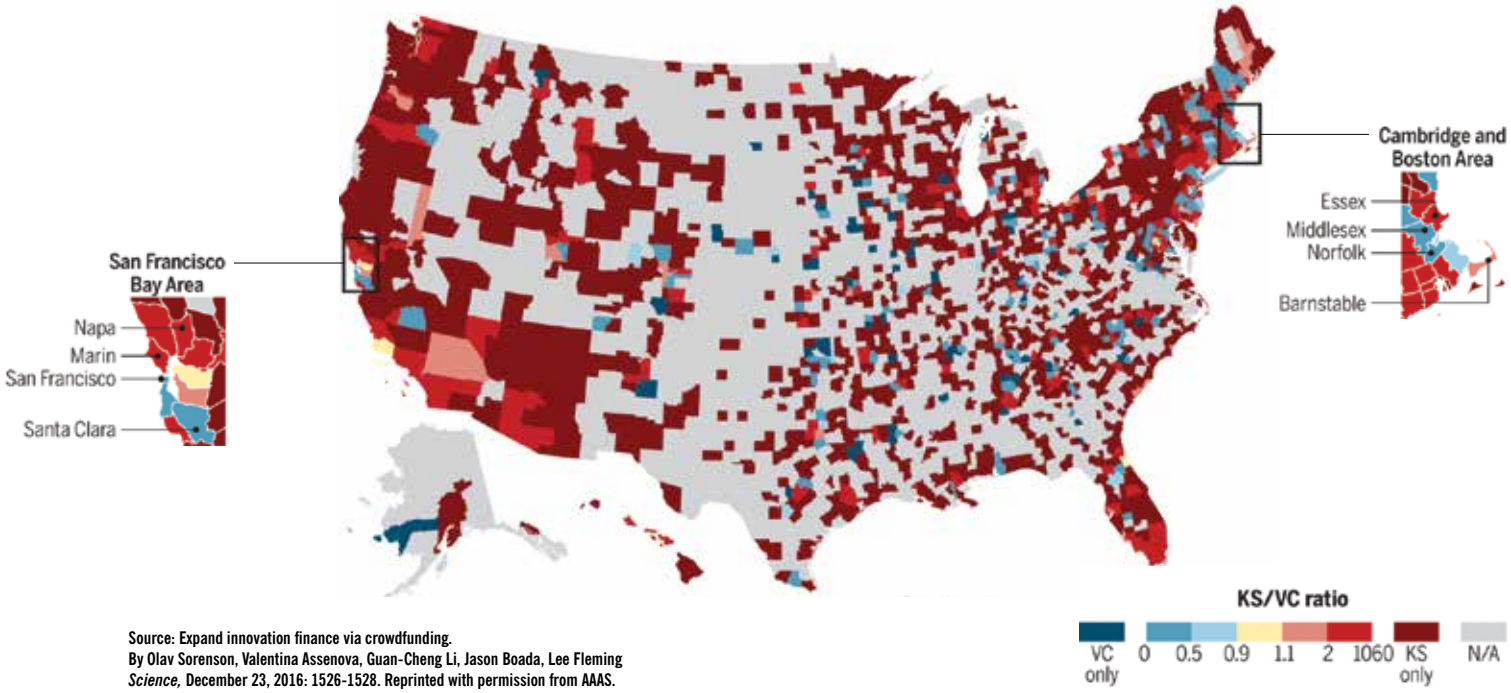
Crowdfunding disperses capital

Crowdfunding platforms, such as Kickstarter, have opened a funding spigot to startups in regions that have suffered from a venture capital drought, according to a new Berkeley study recently published in *Science*.

Historically, funding for innovation is concentrated in a small number of regions and is driven by venture capitalists. The study found that crowdfunding has expanded startup financing far beyond these traditional entrepreneurial bubbles.

"Most venture capital gets invested in Silicon Valley and Boston, and thus shortchanges the rest of the country for entrepreneurial financing," says **Lee Fleming,** one of the study's authors and faculty director of the Coleman Fung Institute for Engineering Leadership. "But crowdfunding has opened up funding to everyone else."

For the study, researchers analyzed data from 2009 to 2015 on successful Kickstarter campaigns and venture capital investments, identifying 55,005 Kickstarter projects in categories similar to the industries in which venture capitalists invested, and 17,493 venture capital investments in industries engaged in activities similar to those of Kickstarter campaigns. The researchers then used this dataset to map Kickstarter projects and venture capital investments by county and year.



Source: Expand innovation finance via crowdfunding.
By Olav Sorenson, Valentina Assenova, Guan-Cheng Li, Jason Boada, Lee Fleming
***Science,* December 23, 2016: 1526-1528. Reprinted with permission from AAAS.**

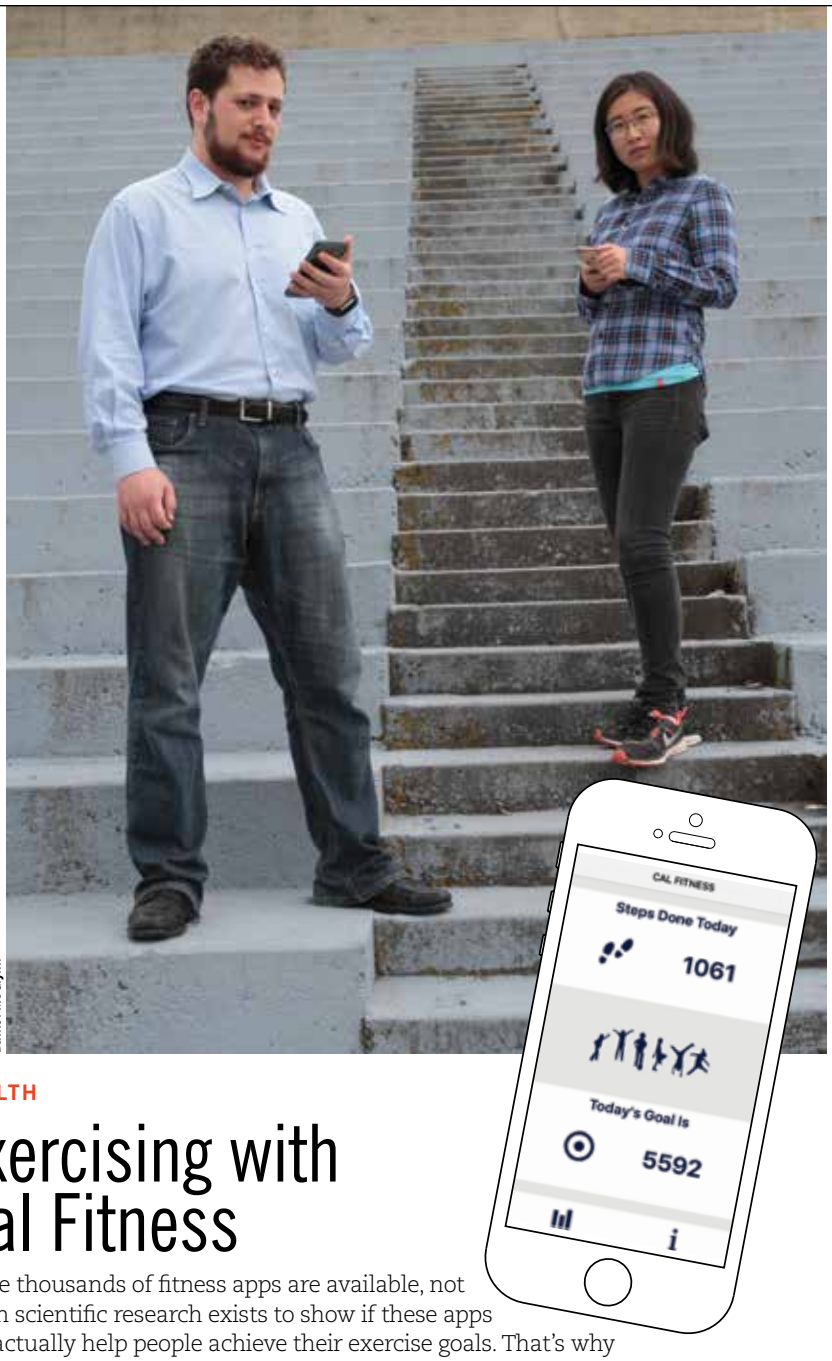
INDUSTRY

Boosting robotics in manufacturing

In January, the Department of Defense announced a new $253 million Advanced Robotics Manufacturing (ARM) Innovation Hub, with Berkeley Engineering as a key partner.

The ARM consortium, headquartered in Pittsburgh with academic and industrial partners in 31 states, is organizing domestic capabilities in robotics technology to amplify U.S. manufacturing. The Berkeley team, led by professor of mechanical engineering **Tarek Zohdi,** brings strengths in advanced manufacturing, computational mechanics, robotics and control to the consortium's research and technology innovation agenda.

"U.S. industries stand to make the greatest gains by understanding and adopting the latest tools and processes in robotically enabled systems," says Zohdi. "We want to develop the laboratory and computational tools that allow manufacturers to produce superior products, even the most complex, at lower operational costs."



Daniel McGlynn

HEALTH

Exercising with Cal Fitness

While thousands of fitness apps are available, not much scientific research exists to show if these apps can actually help people achieve their exercise goals. That's why industrial engineering and operations research Ph.D. students **Yonatan Mintz** and **Mo Zhou** (pictured above), working with professor **Anil Aswani,** built a mobile health application and enrolled Berkeley staff and students as subjects in an on-campus study.

"No one has really looked at how these different features can motivate people to exercise more," Zhou says. "We want to look at this problem on the scientific spectrum to see if they really work."

In collaboration with clinical researchers at UCSF, the Berkeley team designed a series of investigations to see if a mobile phone-based app called Cal Fitness — or more importantly, the algorithms powering the app — can help people better tailor their exercise load and fitness outcomes.

"The crux of the algorithm," Mintz says, "is to figure out how you behave every day and then customize your activity goals to your personal data."

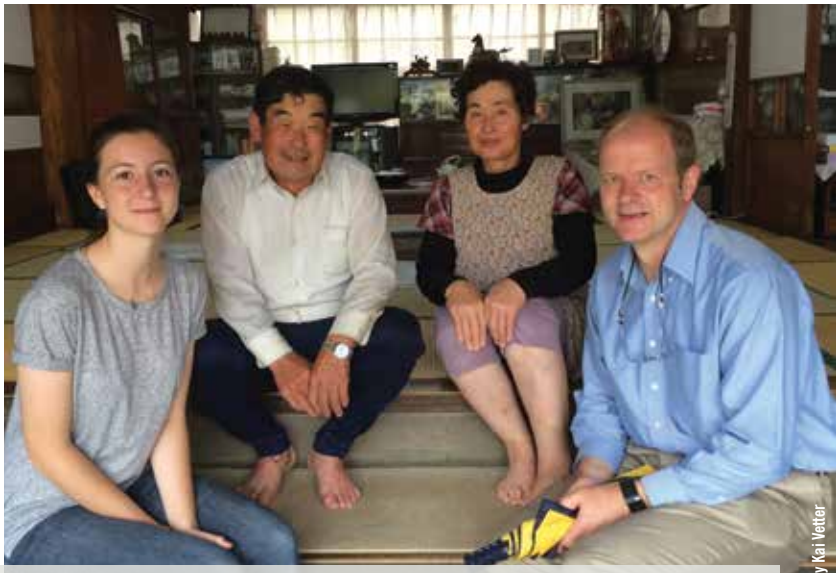
The first of three studies launched last fall with 65 participants, investigating whether or not setting dynamic goals increases daily steps. For upcoming trials, the team will study the role of personalized notifications in helping inspire people to take action and get active.

"We want to capture all of the nuances of what would make you want to exercise more," Mintz says, "versus not exercise at all."

Q+A on resilient communities

Kai Vetter, professor of nuclear engineering and director of Berkeley Lab's applied nuclear physics program, is a frequent visitor to the Fukushima Prefecture, the site of one of the world's worst nuclear accidents — he's been to Japan 15 times in the past four years alone. On March 11, 2011, three reactors at the Fukushima Daiichi nuclear power plant melted down, following a cooling failure caused by a tsunami that damaged the plant's safety systems.

In response to what he's seen, Vetter created a Berkeley Lab-based organization in 2015 called the Institute for Resilient Communities, which is designed to help authorities better communicate critical scientific information following disasters.



Courtesy Kai Vetter

Kai Vetter and his daughter, Sophia, visit the Moto family in Kawauchi Village in September 2015. The village was partially evacuated after the Fukushima accident, but the family decided to stay because they were informed that the radiation level in their home was minimal.

How does better communication help during disasters?

Communication about technical topics, like radioactive contamination, enables community leaders and the general public to make informed decisions. For example, health effects resulting from the psychological impacts of disasters are absolutely measurable. After Fukushima, estimates indicate 2,000 fatalities from the indirect health effects of dealing with the uncertainty and stress of losing homes and fear of radiation exposure.

With better communication about sensitive topics, such as radioactive contamination, it is possible to develop better risk assessments to reduce impacts on residents. Our goal is to help communities understand what happened to them and what will happen to them in the future. One way we do that is to use state-of-the-art technologies to show them the data on contamination levels.

What's the Institute for Resilient Communities' role in this?

Communities need to be involved in decision-making. So we have to improve the information they receive and — equally important — ensure that the information is understood so they can make their own decisions.

So the institute advocates for better access to information about potential risks and impacts?

Yes, the driver to establish the Institute for Resilient Communities was the need to connect community involvement with research and science and education and training. Berkeley RadWatch and the DoseNet project are two great examples of our efforts to provide information about environmental radiation within a local and global context.

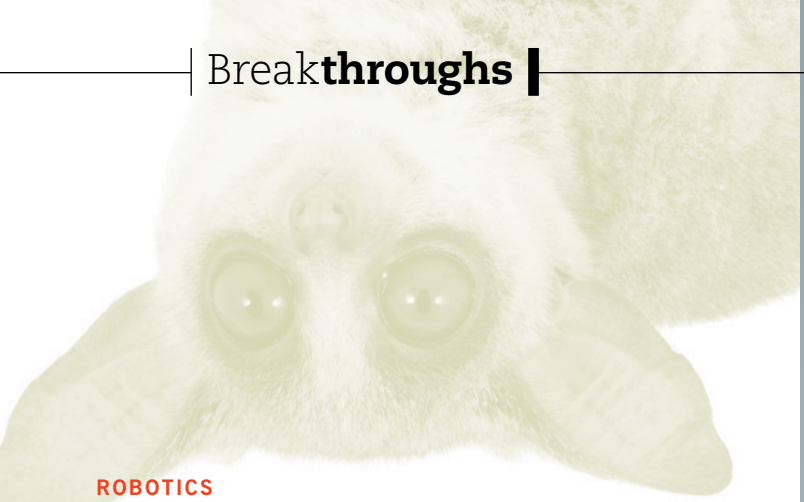
Does this idea of resilient communities extend beyond your work in Japan?

Absolutely. Initially, and even still, this work is driven by Fukushima and its aftermath. What's fascinating is, if you look more broadly at the concerns of the public about advanced technologies, you find the same issues. So it's not just nuclear power, or radiation per se. Community resilience is a global issue, and all communities can take steps to identify and prepare for threats, both manmade and natural.

We started with nuclear radiation because that is our area of expertise, and we can have technologies to address those concerns — but we recognize that many other challenges exist. In the future, we hope to enhance resilience by informing the public about advanced technology. In many circumstances, the risk associated with and the consequences of not adopting advanced technologies is far greater than the risk or consequences of adopting them. This is why it is so critical to have an open dialogue between scientists, educators, community leaders and residents.

Courtesy the researchers

ON THE GROUND: Institute for Resilient Communities director Kai Vetter and deputy director Rebecca Abergel, a staff scientist in the chemical sciences division at Berkeley Lab, (seated side-by-side at center), tour the Daiichi Nuclear Power Plant in 2016 as part of the International Symposium for Resilient Communities in Koriyama City. After gearing up in protective clothing, participants were able to get very close to the damaged reactor units.



ROBOTICS

High jump

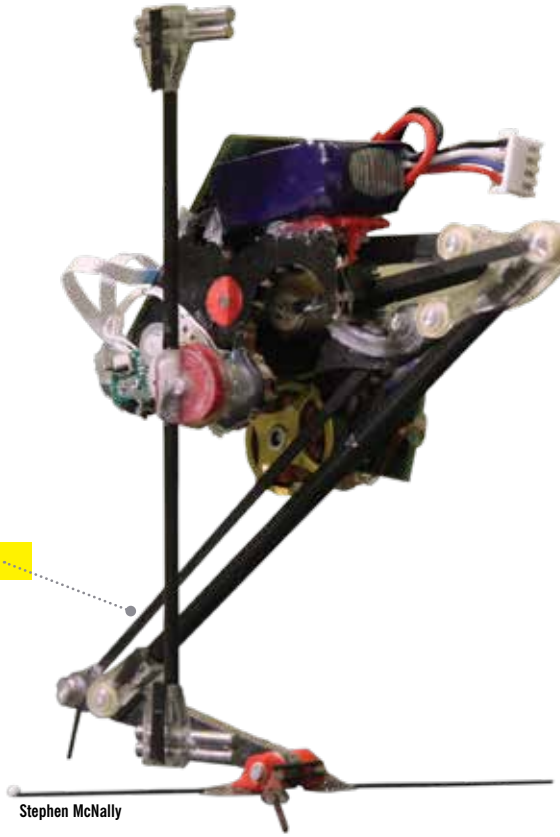
When it comes to vertical jumping, the galago is the top performer of the animal kingdom. This small primate has a special ability to store energy in its tendons so that it can leap to heights not achievable by its muscles alone; in just four seconds, it can jump five times to gain a combined height of 8.5 meters (27.9 feet). Inspired by this ability, Berkeley engineers have designed a small robot that can leap into the air and then spring off a wall, or perform multiple vertical jumps in a row, resulting in the highest vertical jumping agility ever recorded for battery-powered robots. The robot, known as Salto, uses a motor to drive a spring, which loads via a leg mechanism to create the kind of crouch seen in the galago. By using power modulation, Salto doesn't need to wind up beforehand; as soon as it jumps, Salto is ready to go again. **Duncan Haldane,** a robotics Ph.D. candidate, led the work as part of the Biomimetic Millisystems Lab of **Ronald Fearing,** professor of electrical engineering and computer sciences. The researchers hope that one day Salto can be used to jump around rubble during search and rescue missions.

BIOMETRICS

Reading minds

Max Curran

Looking for better cybersecurity? Forget about typing in passwords or scanning fingerprints. The next frontier of identity verification is passthoughts, the recognition of unique brainwave patterns that occur when we perform mental tasks. Now, in a significant advancement of this technology, electrical engineering and computer sciences and School of Information professor **John Chuang** and his research team at the BioSENSE Lab have created a passthought reader that can authenticate the wearer by reading their brainwaves. Wearing the device, users can log into their devices and accounts when they picture a specific thought. This new wearable uses an ordinary set of earbuds fitted with electroencephalograph (EEG) sensors, unlike previous versions that placed electrodes across the user's forehead or scalp. The researchers plan to develop a real-world version of the device, as well as fine-tune its accuracy to be more responsive to the wearer's mental and physical states.

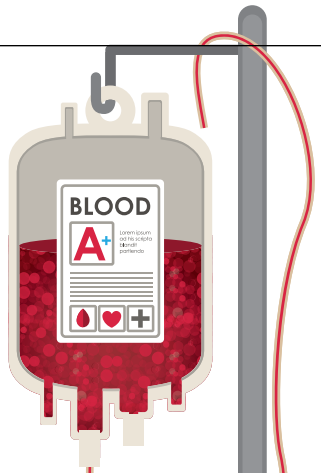


Stephen McNally

SALTO

GALAGO

Galago senegalensis
A species of nocturnal primate, galagos, also known as bushbabies, are found throughout East Africa as well as in woodlands and bushlands in sub-Saharan Africa. They stand 7-8 inches high and weigh from 5 to 10 ounces. Its tail, longer than the combined length of the head and body, assists the animal's strong leg muscles to power its jumps.



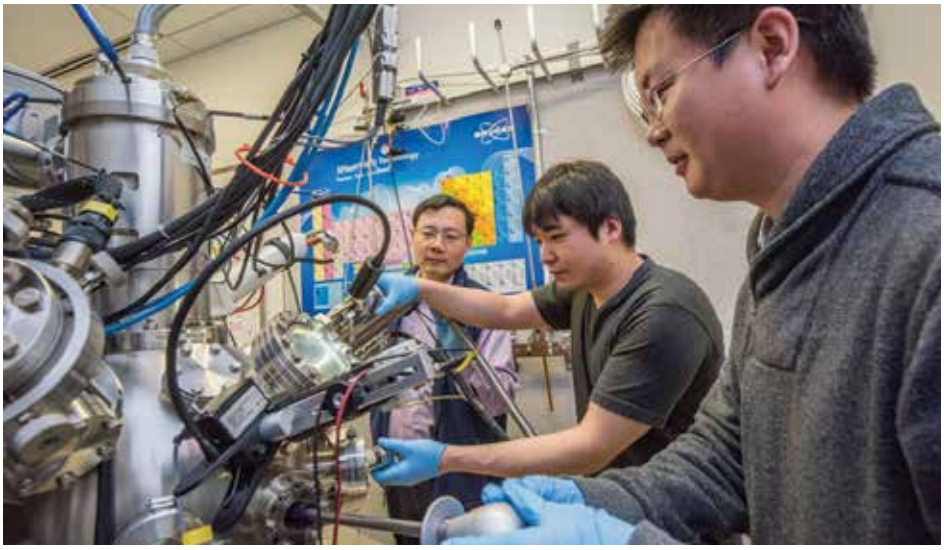
DIAGNOSTICS

Safer transfusions

With serious trauma comes the risk of acute traumatic coagulopathy (ATC), a biological response that impairs blood coagulation, increases bleeding and multiplies the death rate by four. ATC is challenging to diagnose quickly, often requiring massive blood transfusions that are not targeted to the patient. Rushed transfusions in emergency medicine situations can lead to mortality rates as high as 70 percent. But bioengineering professor **Adam Arkin,** researcher **Amor Menezes** and their team have used control theory to develop a simple, fast diagnostic model that could personalize the treatment of ATC patients. This model requires only a few concentrations of rapidly measurable coagulation proteins in a blood sample. In a recent *in vitro* study, they accurately predicted an hour-long laboratory test and rapidly determined individual transfusion requirements to control a driver of coagulation. The researchers hope that this new model will result in lifesaving medical care for ATC patients.

MATERIALS

The rule-breaker

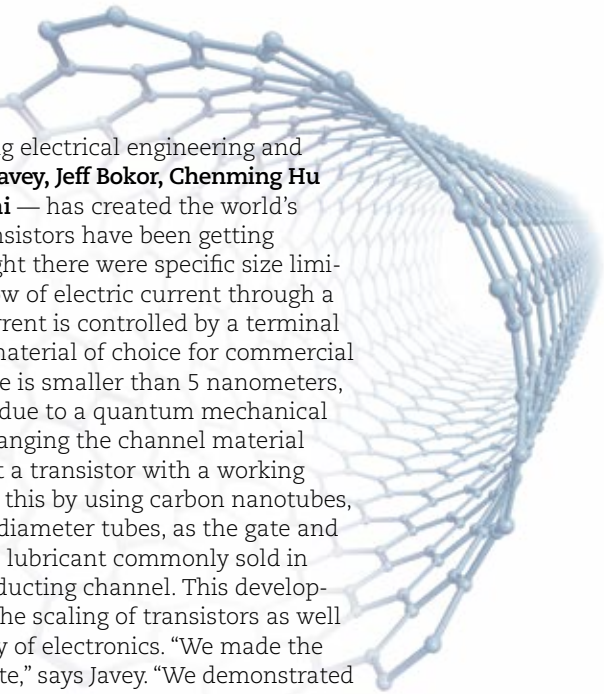


Marilyn Chung/Lawrence Berkeley National Laboratory
© 2010 The Regents of the University of California, through the Lawrence Berkeley National Lab.

Berkeley has long been known as an unconventional place. So it's fitting that scientists here recently identified an outlier in the materials world. The study, led by **Junqiao Wu,** professor of materials science and engineering, found that electrons in the metal vanadium dioxide can conduct electricity without conducting heat, unlike most other metals. The team also learned that they could control the metal's ability to conduct electricity and heat by mixing it with other materials. Another bonus: vanadium dioxide is transparent below 30°C and absorbs infrared light above 60°C. The researchers anticipate a wide range of potential applications for this technology, including thermoelectric systems that convert waste heat from engines and appliances into electricity, as well as window coatings that improve the energy efficiency of buildings.

TRANSISTORS

Small wonder



A team of researchers — including electrical engineering and computer sciences professors **Ali Javey, Jeff Bokor, Chenming Hu** and graduate student **Sujay Desai** — has created the world's smallest transistor. Although transistors have been getting smaller, scientists had long thought there were specific size limitations. Transistors rely on the flow of electric current through a semiconducting channel; this current is controlled by a terminal called the gate. In silicon — the material of choice for commercial transistors today — when the gate is smaller than 5 nanometers, the current cannot be controlled due to a quantum mechanical effect called tunneling. But by changing the channel material from silicon, the researchers built a transistor with a working 1-nanometer gate. They achieved this by using carbon nanotubes, naturally grown as 1-nanometer diameter tubes, as the gate and molybdenum disulfide, an engine lubricant commonly sold in auto parts shops, as the semiconducting channel. This development could be key to advancing the scaling of transistors as well as the performance and efficiency of electronics. "We made the smallest transistor reported to date," says Javey. "We demonstrated a 1-nanometer gate transistor, showing that with the choice of proper materials, there is a lot more room to shrink our electronics."

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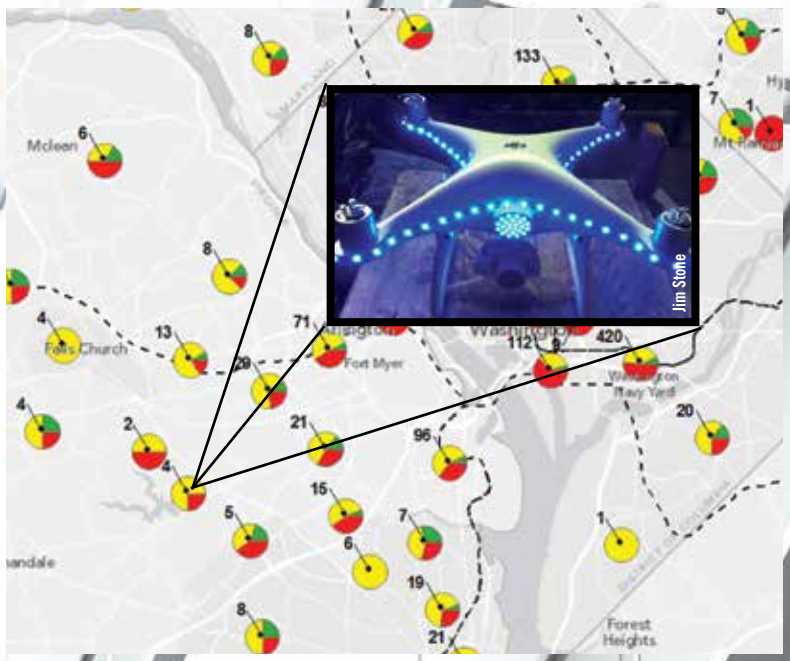

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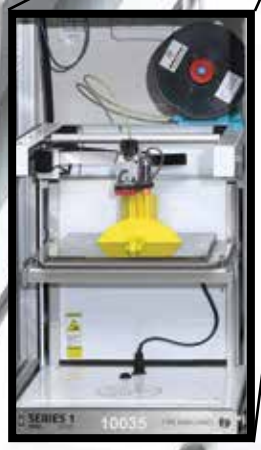


SMART MOVES: CALIFORNIA'S NEXT-GEN INFRASTRUCTURE


Nikolay Asparuhov

STORY BY PAUL PREUSS • PHOTOS BY NOAH BERGER
GRAPHICS COURTESY THE RESEARCHERS

Mention infrastructure and what comes to mind are the physical components that hold a society together, the roads, bridges and dams, power lines, railroad tracks, cell-phone towers and all the rest. But soon the word will mean something much bigger and much smaller: a resilient infrastructure that can manage the energy, water, transportation and other human needs on scales from individual homes to whole cities and entire states. The infrastructure will be everywhere — and right at our fingertips.

Ask Berkeley Engineering researchers to characterize next-generation infrastructure, and they'll tell you about communication: artificial intelligence; machine learning and data stored in the omnipresent cloud; affable robots and other material objects threaded with electromagnetic waves, sounds and images; a continuous flow of information and response. Not to mention the Internet of Things — make that the Internet of Everything.

"What's enabling these infrastructure changes is our ability to compute faster, to share information faster and to provide that information to users very quickly," says electrical engineering and computer sciences (EECS) professor Claire Tomlin. The result is a kind of dual-identity infrastructure, a field of physical matter permeated with interactive intelligence.

It's the stuff of science fiction, with ideas coming fast. EECS professor Costas Spanos predicts self-monitoring buildings so smart they band together and form bargaining alliances. He says, "It is entirely possible for intelligent buildings to coordinate with other buildings and act as a single agent in negotiating with electric power companies."

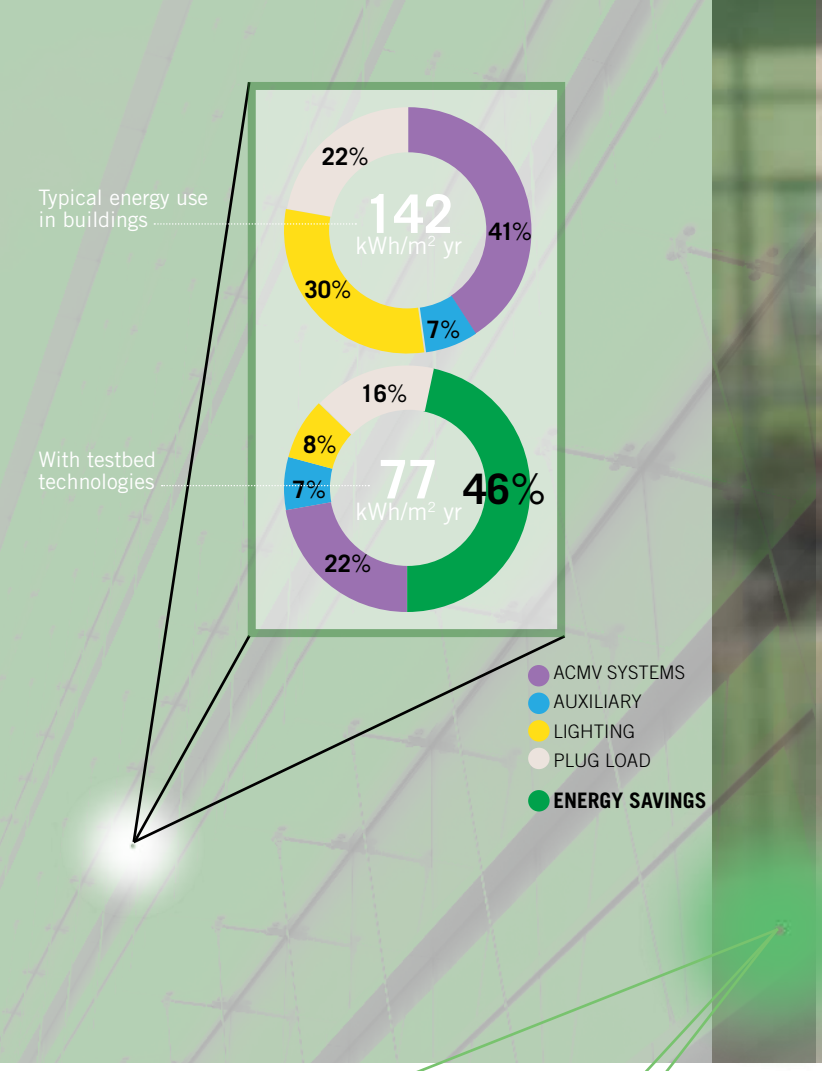
Imagine a robot taxi, "your autonomous valet," as Scott Moura, professor of civil and environmental engineering (CEE), calls it. It's not just a vehicle of convenience. After your valet drops you off, it goes and parks where it can plug itself into the grid, helping store electrical energy.

If the valet happens to be a flying taxi in a sky full of drones, it will be part of an urban traffic challenge that air traffic control expert Tomlin is already grappling with. One solution she's studying: lanes like those in a swimming pool, except in 3-D, using altitude as well as surface maps. The lanes separate drones that deliver packages, say, from others reserved for passengers or police and paramedics.

Closer at hand is the time when a physical structure, embedded with sensors and a means of processing the input, communicates with users about its aches and pains. Recent headlines teem with avoidable situations. A bridge in Big Sur could have sent urgent warnings about too much rain before storm damage cut off the coastal highway.

Like creative thinkers everywhere, Berkeley researchers well understand the limits of imagination — that whatever they dream up now is just the beginning of an unpredictable reality. What's different is that within a very short time, this infrastructure will literally have a mind of its own.

Berkeley Engineer asked a dozen researchers to name the visionary infrastructures they would like to see developed to improve the lives of Californians. The ideas range from far-out moonshots to shovel-ready (or keyboard-ready, or soldering-iron-ready) projects, not to mention some fixes that have gone begging for years. Brace yourself for a launch into the future.



COSTAS SPANOS leads a Singapore-based project to optimize energy efficiency in buildings.

BUILT ENVIRONMENT

SUPER-SMART BUILDINGS

Buildings consume 70 percent of the world's electricity. Smart buildings designed with advanced technologies, like translucent concrete or sensor networks that can track occupancy and monitor usage, can dramatically reduce power consumption and lower costs. Using a testbed in Singapore, Spanos and colleagues have found up to a 46 percent energy savings with such new methods. To retrofit older buildings, they have designed simple and inexpensive approaches like the "Building in a Briefcase," a kit of self-powered sensors and software.

REPAIRING DAMS AND LEVEES

Storms, rising seas and earthquakes threaten California's water infrastructure, from the nation's tallest dam, Oroville, to 1,115 miles of levees in the Sacramento-San Joaquin River Delta. Like many water systems, these are aging; the earthen dam approaching 50 years, the levees 150, yet cities as far south as Los Angeles depend on both. The possible price of failure: thousands of lives lost, tens of millions of people without water. Advanced-sensor monitoring that makes dams and levees smart is an essential first step, but safety requires more. CEE professor Mark Stacey, who probes mismatches among agencies grappling with neglected water infrastructure, says, "the barriers lie on the socio-economic and political side, not the technology."

TRANSPORTATION

THE HYPERLOOP

Planes, trains or cars can't get you from San Francisco to Los Angeles in half an hour, but maybe the Hyperloop can. Elon Musk's idea for propelling passengers through a 350-mile-long tube at near sound speed inspired a Berkeley student team who built the Berkeley Hyperloop ("bLoop") pod with technological advances in levitation and acceleration. In January, they took the pod to the SpaceX Hyperloop Pod Competition in Hawthorne, California, described by faculty advisor Tony Keaveny as "an incredible three-day learning opportunity for the team, inspiring continued competition and work toward a better future for transport."

DRONE EXPRESSWAYS

In a future when even small cities have thousands of delivery drones in the air, control theorist Tomlin's EECS research team envisions "rail-to-drone" expressways, converting railroad rights-of-way to aerial corridors where closely-spaced fleets of drones travel safely. Amazon and Google are developing avoidance technologies and working with the FAA on air traffic control strategies, such as reserving airspace from 200 to 400 feet for high-speed transit. Tomlin seeks to integrate control theory with machine learning so drones can react quickly and flexibly to unexpected encounters.

AUTOMATED TRUCK PLATOONING

Slipstreaming truck platoons cut fuel consumption and pollution by reducing drag; closely-spaced convoys ease congestion. But how will motorists react to a string of 18-wheelers a few car lengths apart barreling down the highway? Research engineers Steven Shladover and Xiao-Yun have studied truck automation for California PATH (Partners for Advanced Transportation Technology) for close to 20 years; their modeling and full-scale experiments show how platoons can smooth out traffic flow disturbances. Recent tests at Canada's motor vehicle test center demonstrate that platooning can reduce truck fuel consumption significantly and is bringing the dream of fast, safe, efficient cargo transport to nascent reality.

STREET SMARTS

Driverless shuttles, smart on-demand ride services and traffic control systems that respond to changing conditions on the street — these are a few of the ideas Berkeley researchers are pursuing in partnership with the City of San Francisco and private companies to improve urban transportation. The challenge is to reduce congestion, speed the flow of traffic on main arteries and reduce fatalities. Says Susan Shaheen, co-director of the Transportation Sustainability Research Center, "San Francisco is a hotbed for innovation," the perfect place to test new ideas, experiment and get feedback.

WATER

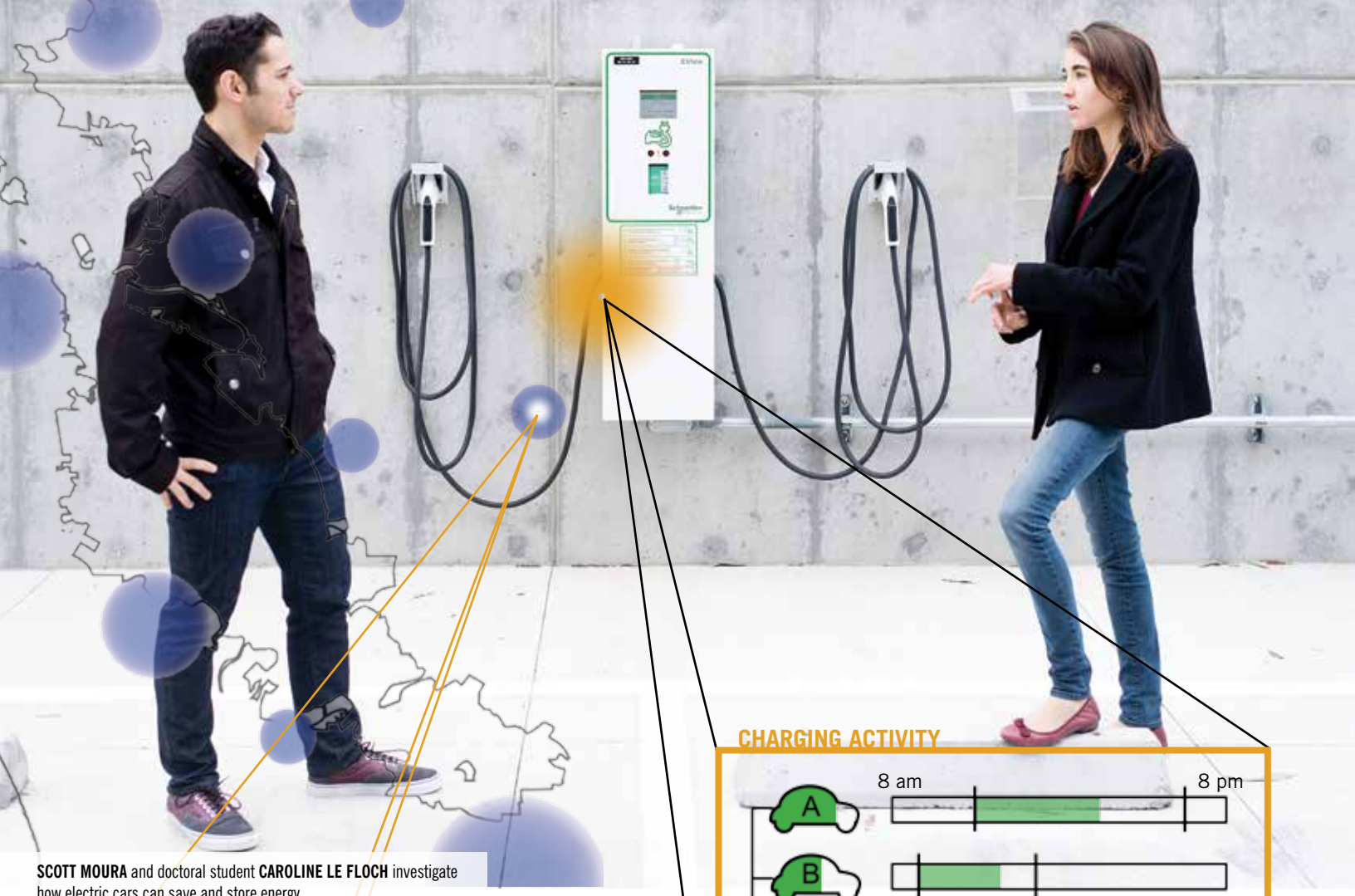
SMALL-SCALE MEMBRANE BIOREACTORS

Sometimes the answer is to go smaller, not bigger. CEE professor and *Water 4.0* author David Sedlak envisions reducing our dependence on centralized urban water treatment systems with on-site water recycling systems for housing complexes or neighborhoods. With technologies like reverse osmosis and electrochemistry, miniaturized bioreactors could turn sewage or greywater into clean water and reduce a city's water needs. Energy recovered from heat and the breakdown of organic compounds in wastewater could power homes. Nutrients and metals in wastewater could also be recovered. "Household-scale systems for reusing water already exist, but they're expensive," says Sedlak. "We need to accelerate research and development."

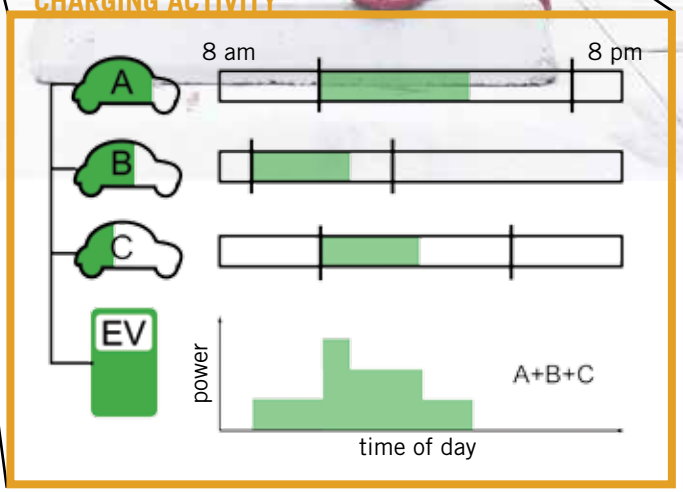
SIERRA SNOWPACK SENSORS

Two-thirds of California's water arrives as snow in the Sierra Nevada. Each winter, wireless networks of sensors, deployed by CEE professor Steven Glaser and his colleagues at UC Water, gather snow depth, soil moisture and other data atop the American River watershed; the information beams to Berkeley via cell and satellite. Glaser's goal for this intelligent infrastructure is to determine "the amount of water in the state, where it is and what it's doing." Water for farms and cities isn't the only question. Glaser's team works with hydroelectric operators for the most effective use of dams and reservoirs in supplying the grid and controlling flooding.

SUSAN SHAHEEN works with San Francisco transit agencies to develop public-private partnerships designed to improve mobility.



SCOTT MOURA and doctoral student **CAROLINE LE FLOCH** investigate how electric cars can save and store energy.



ENERGY

A MOVABLE GRID

What if thousands of electric cars and hybrids could return stored energy to the electrical grid? Like most personal cars in the United States, they're on the road only 4 percent of the time. Moura says, "Plug-in electric vehicles represent a flexible charging load that could smooth out demand fluctuations," increasing grid stability by making it easier to incorporate renewable sources like wind and solar, providing their owners personal blackout insurance, "and maybe make them money." Moura and CEE doctoral student Caroline Le Floch plan ways that coalitions of up to a million cars could optimize charging schedules around the clock, without sacrificing individual mobility.

SOLAR PANELS FOR ALL

Solar panels are essential for households that aim to produce as much energy as they consume. A team led by EECS professor Constance Chang-Hasnain has made key advances toward the manufacture of highly efficient but low-cost solar cells by growing nanoscale whiskery "forests" of expensive photovoltaics on cheap, widely available silicon substrates. Meanwhile, with a rebounding housing market, California's New Solar Homes Project offers financial incentives to builders and owners who incorporate solar systems in new homes; on both fronts, the goal of zero-net-energy homes is within reach.

COMMUNICATIONS

DATA SAVVY

Data scientists swim in rivers of information, their aim to sift gold from digital dross, write flexible and versatile algorithms, ask the right questions and deliver the best real-time answers. Data science is essential to integrate human choices with machine learning, develop new services, protect privacy and thwart cyberattacks. Already vital in complex infrastructure design, next-generation data management will be part of the infrastructure itself. Berkeley's large and diverse undergraduate Data Science Education Program prepares the way, says its co-founder and EECS professor David Culler, who also co-directs the Berkeley Institute for Data Science, "equipping students not just to consume data but to produce insight."

> “How can we inject sensing and control technologies into our communications, roads, energy grids and other infrastructures while protecting the security and privacy of the public?”
>
> — **SHANKAR SASTRY,** DEAN AND ROY W. CARLSON PROFESSOR OF ENGINEERING

DISRUPTIVE TECHNOLOGY

WHATEVER IT IS, YOU CAN PRINT IT IN 3-D

As 3-D printers get bigger and faster, they are able to mix and assemble different feedstocks to make things harder, softer, squishier or wigglier. Berkeley researchers crafted a prosthetic hand for Sophie, an active eight-year-old; in Europe, custom-fitted, 3-D-printed hearing aids almost outnumber the handmade kind. Says Björn Hartmann, faculty director of the Jacobs Institute for Design Innovation, “We don’t ask, ‘Can we make it?’ any more. We ask, ‘What can we make that’s worthwhile?’” New prosthetics combine plastic scaffolding with living cells to replace bone or soft tissue, and artificial organs aren’t far behind. Whole buildings are made with 3-D printers; whole cities may be next.

FILAMENT RECYCLING

100+
3-D printers on campus

600 lbs./year
Filament trash generated on campus

Mechanical engineering student **NICOLE PANDITI** (Class of ’18) co-founded the 3-D Printer Filament Reclamation Project to create a closed loop of printer waste on campus.

IN THEIR VISIONARY PROGNOSTICATIONS of the new kinds of infrastructure to come, our contributors were well aware of the world we live in now, where economic, political and social concerns are the major determinants of what can happen and how fast.

Spanos notes that “in competitive industries like semiconductors, if you demonstrate something convincingly, the industry picks it up.” Not true in construction, where incentives or policy mandates are essential. As a consequence, engineers and designers present policy drafts to appropriate government bodies, says Spanos, and “if they adopt it, it becomes a requirement.” It’s hoped that smart buildings and zero-net-energy homes will soon follow.

On the other hand, autonomous vehicles may be here soon — so soon, Tomlin admits, that “sometimes it feels like the mavericks out there are pushing things.”

Industry leadership can be all to the good, she says, but there are caveats. “Changing the physical infrastructure, the concrete, is expensive. Changing the information is cheap. In designing the information, we need experts who have studied the dynamics of the physical layer and know the implications of what control decisions might do.” Companies selling drones and robot cars may not be the best at making these decisions. “Government has to be there to regulate.”

For humans, the challenge is different for each of us. We have to learn to relate — no, it’s more than that — to *integrate* ourselves with smart objects, from smartphones to smart buildings, from a melting snow bank to the drone that delivers the newest best-seller. The next generation’s infrastructure will take many forms. It’s high time we got ready for them all. BE

ASSEMBLY INSTRUCTIONS

7 STEPS TO BUILDING A BUSINESS AT BERKELEY

In January, with state bill AB-2664, the State of California awarded Berkeley $2.2 million to boost innovation and entrepreneurship on campus.

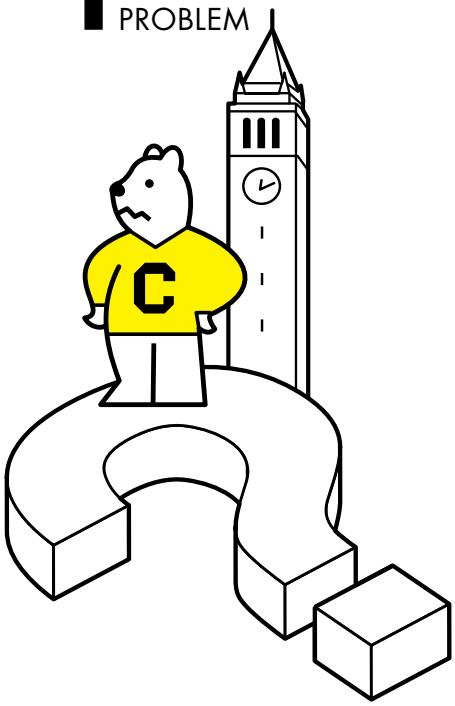
According to a 2016 report by the Bay Area Council Economic Institute, companies affiliated with the University of California have created more than 38,000 jobs and added over $20 billion in value to California's economy. At Berkeley alone, 536 students have launched 468 companies since 2010 — by far the most of any public university and second overall.

So what is Berkeley's secret? For starters, the Berkeley Method of Entrepreneurship out of the Sutardja Center for Entrepreneurship and Technology, Silicon Valley industry challenges, alumni mentorship, SkyDeck and CITRIS Foundry acceleration and incubation, access to world-class faculty and students and labs such as the CITRIS Invention Lab and the Jacobs Institute for Design Innovation — all have helped aspiring inventors leverage Berkeley's startup ecosystem while their ideas gain traction.

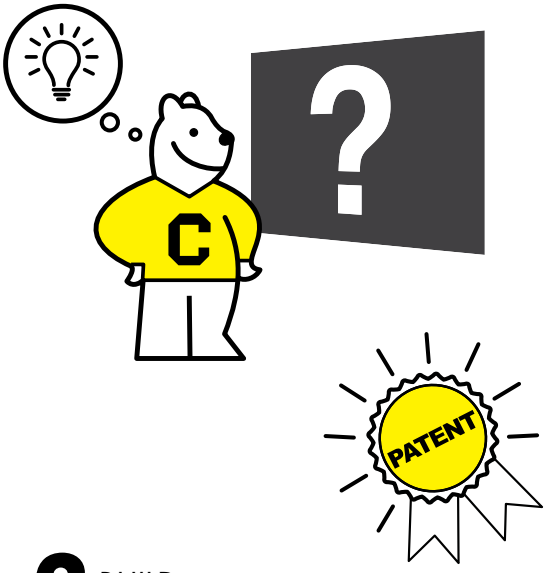
While there is no one way to launch a startup at Berkeley — every entrepreneur's journey is different — there are common steps, as Oski demonstrates.

BY KEITH MCALEER • ILLUSTRATION BY JASON LEE

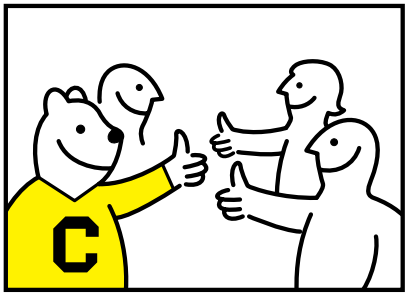
1 PROBLEM



2 IDEA/ DISCOVERY



3 BUILD A TEAM



TOOLS NEEDED

MAKER SPACES

- Jacobs Institute for Design Innovation
- CITRIS Invention Lab
- Etcheverry Machine Shop
- Marvell Nanolab
- Biomolecular Nanotechnology Center

COMPONENTS

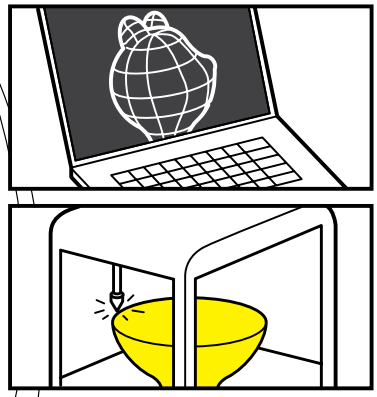
NEW VENTURE EDUCATION

- Sutardja Center for Entrepreneurship & Technology
- Fung Institute for Engineering Leadership
- Management, Entrepreneurship, & Technology Program
- Berkeley-Haas Entrepreneurship Program
- Blum Center Social Innovator OnRamp
- Startup@BerkeleyLaw

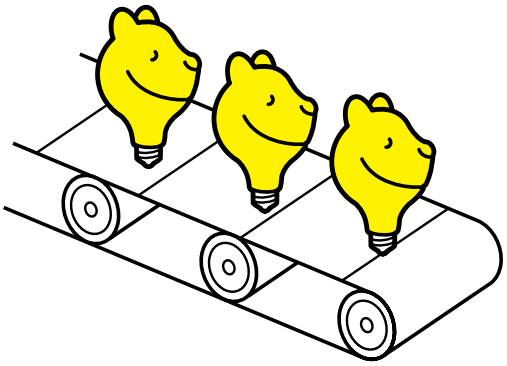
COMPETITIONS

- Big Ideas at Berkeley
- SCET Colliders
- Cal Hacks
- Learn2Launch
- LAUNCH

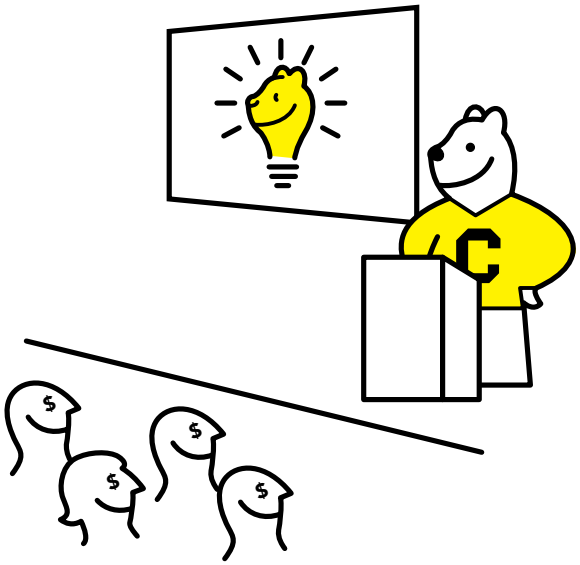
4 PROTOTYPE



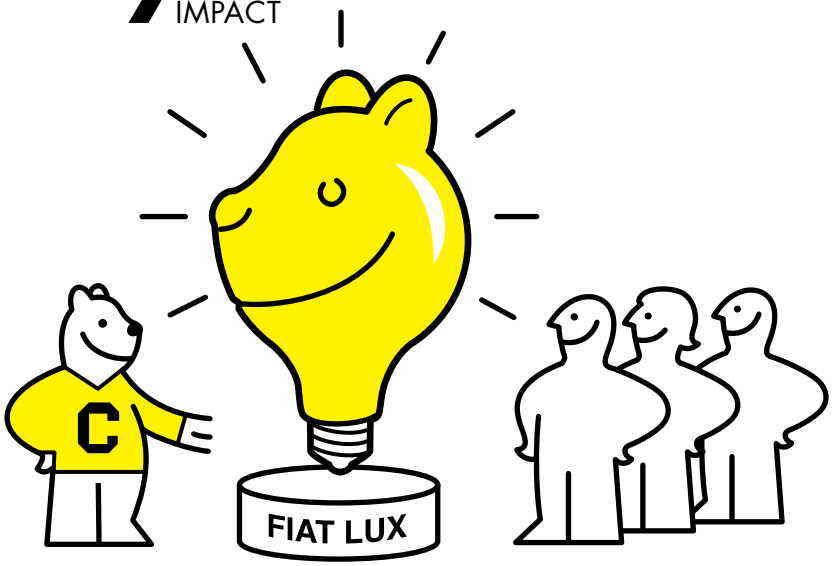
6 SCALE



5 PITCH TO INVESTORS



7 IMPACT



ACCELERATORS & INCUBATORS

- SkyDeck
- CITRIS Foundry
- Bay Area NSF Innovation Corps
- Cleantech to Market
- QB3

STUDENT GROUPS

- Free Ventures
- Sigma Eta Pi
- Venture Strategy Solutions
- Berkeley Entrepreneurs Association

ALUMNI NETWORKS

- Cal Founders
- Berkeley Founders Pledge
- Berkeley Startup Network

VENTURE CAPITAL

- AB-2664 UC Innovation & Entrepreneurship Expansion
- Berkeley Angel Network
- House Fund
- Dorm Room Fund

COMMERCIALIZATION

- Intellectual Property & Industry Research Alliances (IPIRA)
- Office of Technology Licensing (OTL)
- Berkeley Post-doc Entrepreneurship Program (BPEP)

See **begin.berkeley.edu** for more information about the Berkeley entrepreneurship ecosystem.

Katherine Yelick

NAE Class of 2017

A group of eight from the Berkeley Engineering community have joined 75 active and emeriti college faculty members in the National Academy of Engineering (NAE), one of the profession's highest honors.

The three faculty members (including one alumnus) named to the academy's class of 2017 are:

Gerbrand Ceder (Ph.D.'91 MSE), Chancellor's Professor of Materials Science and Engineering

Tsu-Jae King Liu, TSMC Distinguished Professor in Microelectronics and vice provost for academic and space planning

Katherine Yelick, professor of electrical engineering and computer sciences and associate laboratory director for computing sciences at Berkeley Lab

They are joined by these Berkeley alumni:

Ross Boulanger (Ph.D.'90 CE), professor and director, Center for Geotechnical Engineering, department of civil and environmental engineering, University of California, Davis

Andrea Jo Goldsmith (B.S.'86, M.S.'91, Ph.D.'94 EECS), Stephen Harris Professor of Engineering, department of electrical engineering, Stanford University

Jagdish Narayan (M.S.'70 MSE), John C.C. Fan Distinguished Chair Professor, department of materials science and engineering, North Carolina State University

And by two current Berkeley Engineering Advisory Board members:

Harry Shum, executive vice president of technology and research at Microsoft (foreign member)

Darlene Solomon, senior vice president and chief technology officer at Agilent Technologies

PHOTO COURTESY THE LAWRENCE BERKELEY NATIONAL LABORATORY

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2010+

Christopher Au (B.S.'14 IEOR) is a data engineer at Autodesk and a pro bono consultant for Foodies Without Borders, a nonprofit organization empowering underprivileged communities in Kenya by teaching sustainable farming and sanitation techniques.

Amanda Brief (M.Eng.'15 IEOR) is the co-founder and CEO of my.Flow, a company that aims to reduce the stigma around menstrual health and prevent toxic shock syndrome by developing a Bluetooth beacon that alerts tampon wearers to risky conditions.

Bryan Catanzaro (Ph.D.'11 EECS) has joined the Santa Clara-based graphics processor company NVIDIA as vice president of applied deep learning research. He first worked there as an intern and research scientist, then moved to Baidu before returning to NVIDIA.

Chun Ming Chin (M.Eng.'12 EECS), a technical program manager at Microsoft's Bing, leads a team of engineers on artificial intelligence projects and has authored a patent related to big data searches and advertising.

Lorenzo Einaudi (M.Eng.'12 IEOR) is managing the construction of a manufacturing facility for Houston-based Techint Engineering. Earlier, he spent three years in South America on the Pascua Lama Project, constructing one of the world's largest gold, silver and copper mines. He is also an avid runner, completing the New York Marathon last year.

Vidya Ganapathi (M.S.'12, Ph.D.'15), won the inaugural CITRIS Athena Early Career Award for her research accomplishments, including applications in solar cells for energy-efficient electronics and advanced imaging for surgical robotics. She completed predoctoral research at MIT and now works for Verily Life Sciences. She teaches and mentors girls and young women through programs such as Girls Who Code, Science Club for Girls and the college's Girls in Engineering summer camp.

Animesh Garg (Ph.D.'16 IEOR) is a postdoctoral researcher at Stanford, studying how to make robots smarter through deep reinforcement learning. He interned in India at JK Tyre Manufacturing and at India's National Thermal Power Corporation before moving to Stanford.

Han Jin (M.Eng.'12 IEOR) is co-founder and CEO of Lucid VR, a startup developing the first 3-D, 180-degree camera. Lucid VR hopes to make 3-D content creation more widely available, as well as to reduce costs for equipment and post-production. Lucid VR has raised $2.1 million and is partnering with Taiwanese camera manufacturer Wistron.

Caroline Le Floch (M.S.'14 CEE) was named a 2017 Women in Transportation Scholar for her contributions to the field of electrified transportation. She is currently a Ph.D. student at Berkeley.

Sean Roberts (B.S.'15, M.S.'16 EECS) joined the cloud service company Egnyte as a software engineer last fall. Egnyte has partnered with Microsoft to serve as the cloud storage provider for Microsoft customers.

Mansi Shah (B.S.'11 BioE) is a community and family medicine resident at Duke University. She recently described how the experience of working in Uganda has greatly influenced her perspective on medicine and life in a guest blog post on the Duke Family Medicine Division website, "Moving toward a radical medicine: on bringing international experiences home."

Justin Whiteley (B.S.'10 ME & NE), an electrochemist specializing in lithium-ion batteries and super capacitors, is the co-founder and CTO at Emergy, dedicated to carbon material synthesis through biofabrication. He holds several patents and has written more than 10 peer-reviewed articles.

2000+

Eric Cheng (B.S.'07 EECS & Bus. Admin.), who studied law at USC, has been promoted to partner in the Palo Alto and San Francisco offices of Kirkland & Ellis LLP. He focuses on intellectual property disputes with an emphasis on patent and copyright infringement and trade-secret misappropriation involving a wide range of technologies.

Eugene T. Chou (M.S.'03 IEOR) teaches in Dublin High School's Engineering and Design Academy in Dublin, California. The academy launched in 2010 to provide high school students with basic engineering knowledge and career opportunities.

Roland DeGuzman (M.S.'02 CEE) was awarded the Goethals Medal by the Society of American Military Engineers for his contributions in engineering, design and construction. A United States Navy commander, he has been stationed in Djibouti, Washington, D.C., New Hampshire and Virginia, where he has led several projects for the Virginia Department of Transportation and the Federal Highway Administration.

Timothy Hsieh (B.S.'04 EECS) went on to earn a J.D. from UC Hastings and became a judicial law clerk for the Honorable Roy S. Payne of the U.S. District Court for the Eastern District of Texas. He was named a "Rising Star" by *Super Lawyers* magazine in 2016 and is now pursuing a Masters of Law degree at Berkeley Law, specializing in law and technology.

Colleen Lewis (B.S.'05, M.S.'09 EECS) received her Ph.D. in science and math education at Berkeley and is now an assistant professor of computer science at Harvey Mudd College. She was awarded the 2016 Denice Denton Emerging Leader ABIE Award by the Anita Borg Institute, a nonprofit organization focused on the advancement of women in computing, for her efforts "to understand and remove both structural and cultural barriers to people pursuing computer science."

James Moon (Ph.D.'02 BioE), assistant professor at the University of Michigan, has received several awards for his research, including the NSF Career Award, the DoD Career Development Award and three NIH research project grants. He works on new drug delivery systems to improve the delivery of antigens and adjuvants to lymphoid organs to combat cancer, infectious diseases and autoimmunity. He launched the biotech company EVOQ Therapeutics and published a paper in *Nature Materials* about personalized cancer immunotherapy.

David Wagner (M.S.'99, Ph.D.'00 CS), a computer science professor at Berkeley, won the Outstanding Innovation Award from the ACM Special Interest Group on Security, Audit and Control. He is also a principal investigator for SCRUB, the Intel Science and Technology Center for Secure Computing at Berkeley, and principal investigator on the Defending Against Hostile Operating Systems project.

Nicholas Weaver (B.A.'95 CS & Astrophysics, Ph.D.'03 EECS) a security expert at the International Computer Science Institute at Berkeley, was interviewed by Leandra Bernstein of ABC affiliate 33/40 in Birmingham, Alabama about Russian responsibility for passing stolen DNC emails to WikiLeaks. "All the evidence, both public and still secret, points towards the Russians having stolen the emails, while there is effectively no evidence for any competing hypothesis," he said.

Jason Wu (B.S.'08 EECS) was featured in a Webby Awards article, "How a Small Troop of Techies Led the U.S. Syrian Refugee Surge," that tells the story of the humanitarian efforts of the United States Digital Service (USDS) to successfully vet and bring in some 85,000 Syrian refugees. After working as a product manager at Facebook, he joined the USDS to do something more meaningful, asking himself, "If I were one more person at Uber, how much of an impact would I make?"

1990+

Chris Bregler (M.S.'95 CS) won a 2016 Sci-Tech Academy Award last February. He and his business partner, Ronald Mallet, were recognized for design and engineering work on Industrial Light & Magic's Geometry

Timothy Downing

Four alumni named to Forbes' 30-Under-30 list

Four alumni have been named to the 2017 *Forbes* "30-under-30" list for their innovative contributions to science, healthcare and consumer technology.

ANKUR AGGARWAL (M.Eng.'12 EECS) teamed up with roommates to found TowerView Health, a company that produces smart pill boxes that send text messages to remind patients to take their medications. The idea was conceived after one of their roommates was diagnosed with cancer and had trouble keeping track of medications.

TIMOTHY DOWNING (Ph.D.'13 BioE) was named a science innovator for demonstrating how extracellular signals could influence the fate of cells — a discovery that could solve biomedical engineering challenges such as spinal tissue repair.

THIBAULT DUCHEMIN (M.Eng.'14 IEOR) founded Ava, a startup with an app that generates real-time, color-coded transcription to enable hearing-impaired people to navigate group conversations — a need previously unaddressed by consumer technology.

TIM WANG (B.S.'09 BioE) co-founded KSQ Therapeutics, a drug discovery company that uses his cutting-edge research on the gene-editing technology CRISPR to identify novel drug targets in oncology and immuno-oncology in the hopes of finding transformative therapies.

STORY BY STEVE MCCONNELL • PHOTO COURTESY UC IRVINE

Tracker, which blends digital and live-action elements in a scene. The tracker was most notably used in *Star Wars: The Force Awakens* to create the character Maz Kanata, a part played by Lupita Nyong'o.

Paul Debevec (Ph.D.'96 CS), adjunct research professor at the USC Institute for Creative Technologies, is now a senior staff engineer in the Google VR Daydream team. A Cartoon Brew profile examines how his research into virtual cinematography, image-based lighting and the crafting of photoreal virtual humans has inspired several films, including *The Matrix, Spider-Man 2* and *Avatar,* along with games and real-time rendered content.

Oscar Dubón (M.S.'92, Ph.D.'96 MSE), engineering professor and associate dean for equity and inclusion at the college, received the Chancellor's Award for Advancing Institutional Excellence and Equity for his accomplishments in promoting diversity and inclusion throughout the university. He established the Center for Access to Engineering Excellence, which supports students from underrepresented backgrounds and promotes success and leadership in engineering. Dubón plans to use proceeds from the award to launch an engaged scholars program that will help high school students prepare for college success.

Andrea Goldsmith (B.S.'86 Eng. Math & Statistics, M.S.'91, Ph.D.'94 EECS), electrical engineering professor at Stanford, was elected to the National Academy of Engineering in February for her contributions to adaptive and multiantenna wireless communications. In 2005, she co-founded a company around her research; Quantenna went public last October, with company executives and early employees ringing the closing Nasdaq bell. She now chairs the company's technical advisory board.

Valerie Taylor (M.S.'86, Ph.D.'91 EE), computer science professor and senior associate dean of academic affairs in the College of Engineering at Texas A&M University, has been appointed the next director of the mathematics and computer science division at the U.S. Department of Energy's Argonne National Laboratory, effective July 1. She also serves as the executive director of the Center for Minorities and People with Disabilities in IT, and her work was recently featured in *Black Enterprise.* She was named a 2016 Fellow by the Association for Computing Machinery for her "leadership in broadening participation in computing."

Cynthia Tran Tillo (B.S.'97 IEOR), principal product manager at Adobe, optimizes customer experiences on their marketing cloud. Earlier, she worked at Hewlett-Packard. She credits Berkeley's diversity and intellectual freedom as factors in her professional success: "Thinking back, having the freedom and bandwidth to think, challenge and learn is truly amazing."

Claire Tomlin (Ph.D.'98 EECS), professor of electrical engineering and computer sciences, will receive an honorary doctorate from the KTH Royal Institute of Technology in Stockholm, Sweden, one of Europe's most prestigious technical universities. She has contributed to KTH's activities through collaborations in hybrid regulation systems, cyber-physical systems and neighboring areas of information and communications technology and software engineering.

1980+

Asad Abidi (M.S.'78, Ph.D.'81 EE) is the inaugural holder of the Abdus Salam Chair in the Syed Babar Ali School of Science and Engineering at Pakistan's Lahore University of Management Sciences, named in honor of theoretical physicist Abdus Salam, the first Pakistani and first Muslim to receive a Nobel Prize in science. As a professor of electrical engineering at UCLA, Abidi became known for groundbreaking research in single-chip radios. In 2008, he won the IEEE Pederson Award in Solid-State Circuits, named in honor of Berkeley EECS professor Donald O. Pederson.

Paul Jacobs (B.S.'84, M.S.'86, Ph.D.'89 EECS) was named the 2017 Alumnus of the Year by the California Alumni Association. Jacobs, executive chairman of San Diego-based Qualcomm Inc., was recognized as a forward-thinking business leader. Recipients receive their awards at the annual Berkeley Charter Gala in May.

Shielding ice sheets

These days, the to-do list of **Leslie Field** (M.S.'88, Ph.D.'91 EECS) is dominated by one major item: "I wrote 'habitable planet' on my task list," she says. "Otherwise, my kids are doomed."

Last winter, according to NASA, the area covered by Arctic ice hit a record low since scientists first started tracking ice-cap movements by satellite in 1979.

"I thought if I could do something about this, it would be huge," Field says. "I realized that replacing the layer of reflective ice that is being lost could be approached as a materials challenge."

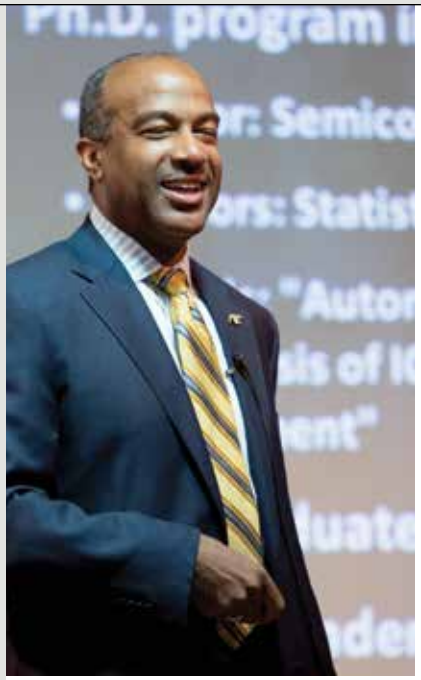
So she founded Ice911, a nonprofit organization dedicated to developing systems to be deployed on the planet's receding ice sheets.

Ice911's technology consists of salt-grain sized hollow glass spheres that boost the reflectivity of existing low-albedo ice (albedo is a measure of how much radiation is reflected). The material is sprinkled on vulnerable ice, and is essentially made of silica, the main component in sand. "It's embarrassingly simple as a concept," Field says. "Hollow glass spheres are everywhere — in paints and building materials, basically wherever there's a need to make things lightweight and not thermally conductive. Some of them are even bright white."

"This is just to buy time until we adopt new energy technologies and become more energy-efficient. If you are going to build a band-aid, then you have to make sure it's not going to do any harm, and be able to undo it in case there is some kind of unintended side effect," Field says.

And, given the substantial data showing that Arctic ice is hitting record lows, Field is motivated by a sense of urgency. "Our growing team is working on this as fast as we can, and with hope that this is just in time," she says.

STORY BY DANIEL MCGLYNN • PHOTO COURTESY ICE 911



New UC Davis chancellor

Gary May (M.S.'88, Ph.D.'91 EECS), the dean of Georgia Tech's College of Engineering, will become the seventh chancellor of UC Davis, after a unanimous vote of the UC Regents in February.

May, a native of St. Louis, Missouri, has been at Georgia Tech for nearly three decades, most recently as dean of the College of Engineering, which graduates more engineers than any other college in the United States.

May said it was Star Trek, Lego and Erector sets, comic books and science fiction that sparked his early interest in the STEM fields, one that, combined with his own drive, led him to mentors and role models who were crucial to his success.

He received his B.S. in electrical engineering from Georgia Tech before coming to Berkeley. In 2010, May was named Outstanding Electrical Engineering Alumnus by the Department of Electrical Engineering and Computer Sciences.

"In my classes and early in my career, it always concerned me how few people like me there were," May says. "By that I don't mean smart or determined or curious people. I mean African Americans, and people of color in general, and also women. That's when I became interested in finding ways to ensure equal access to education and opportunity. We need to nurture talent, for the good of the individual and for the benefit of us all."

PHOTO BY BRUCE COOK

Silvio Micali (Ph.D.'82 CS), the Ford Professor of Engineering at MIT and recipient of such prestigious prizes as the Turing Award, the Goedel Prize and the RSA prize in cryptology, has published a paper laying out a groundbreaking solution to the Byzantine Generals Problem, a computer science gauntlet dating back to 1982.

Peter Norvig (Ph.D.'86 CS), director of research at Google, was named an Artificial Intelligence Pioneer by *Forbes* in a profile that outlined his thoughts on human-machine partnerships and the disparate goals of neuroscience and artificial intelligence research. He returned to campus this spring for a CITRIS talk on software engineering with machine learning.

Mauricio G. C. Resende (Ph.D.'87 IEOR), a research scientist for Amazon, was named a 2016 Institute for Operations Research and Management Sciences fellow for his contributions to the development and application

Bob Jewett's double life

Bob Jewett (B.S.'75, M.S.'79 EECS) spent his undergraduate career — interrupted by a stint in the Air Force in Vietnam — and then his graduate studies at Berkeley. He built a distinguished career at Hewlett-Packard and its descendants, Agilent and Keysight, was awarded five patents in the area of signal generation and analysis and retired in 2015.

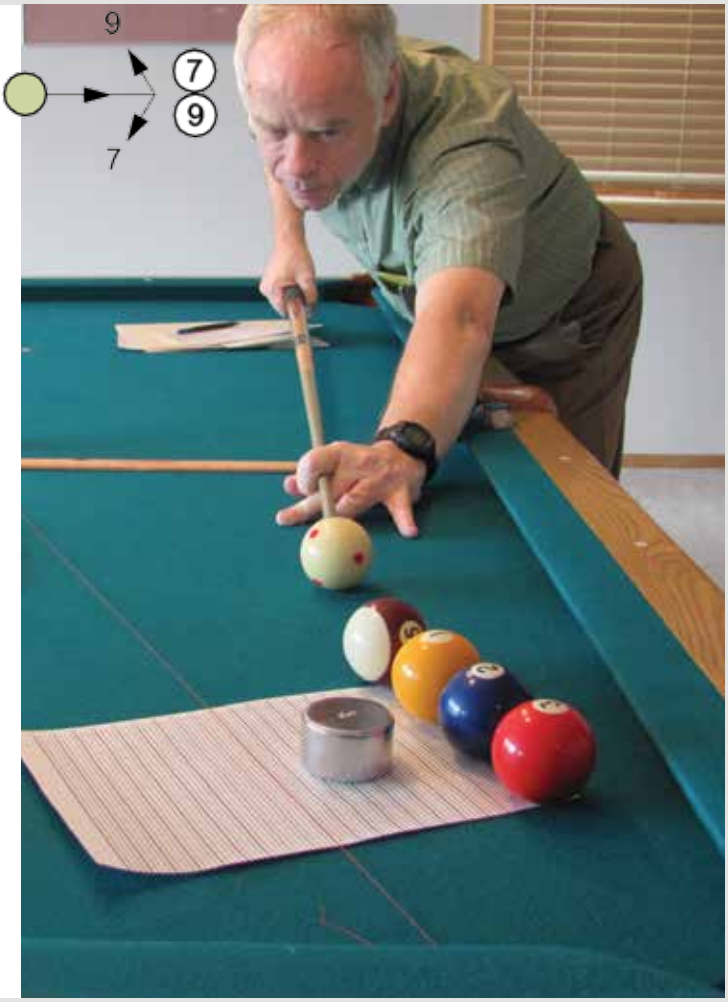
Jewett's billiards skills blossomed during his graduate years, and he began seeking the best way to teach cue sports to others. Players aren't born experts, and until the late 20th century, learning from pros was rare. Jewett describes most instruction as "Old Joe over in the corner at your local pool hall, who could show you some shots if you'd pay for his time at the table."

His instructional output includes hundreds of articles and instructional videos. He's the chief editor of the World Pool Billiards Association's *World Standardized Rules*. "I'm pretty much into rules," he says, while admitting that "most champions have never read them."

Last April, Jewett competed at the 2016 U.S. Open Straight Pool Championship in Connecticut. While he didn't take the top spot, he beat the U.S. champion 125 to 81.

Bob Jewett's double life, master of pool and expert engineer, gives him access to a satisfaction denied many: scientific insight into a sport as only a virtuoso can grasp it.

STORY BY PAUL PREUSS • PHOTO COURTESY BOB JEWETT



of metaheuristics for optimization problems.

1960+

James Dietrich (M.S.'66 CE) is retiring after 50 years of working in the oil industry. As a consulting reservoir engineer, he worked for 17 companies in 15 different countries. He reports that his choice to stay technical was a good one; he was able to "ride the wave of numerical reservoir simulation" from the field's infancy to its now exalted place in the petroleum industry.

Stephen W. Director (M.S.'67, Ph.D.'68 EE), provost emeritus at Northeastern University, has been elected a fellow of the National Academy of Inventors. A pioneer in the field of electronic design automation, he has patented methods for maximizing yield when manufacturing integrated circuits.

William W. Goldsmith (B.S.'63 CEE) is professor emeritus of city and regional planning at Cornell University. His book, *Separate Societies: Poverty and Inequality in U.S. Cities,* won the Paul Davidoff Award in 1993. In his 2016 book, *Saving Our Cities,* he argues that American cities should be recognized as places of opportunity and consequently given more public funding to improve infrastructure.

1950+

Ernst Valfer (B.S.'50, M.S.'52, Ph.D.'65 IEOR) has led a long and varied career at an aircraft factory, at the National Research Council, as a Berkeley lecturer, as a USDA-FS director of management sciences and as a research fellow at UCLA. He concluded his career as a founding member of the Community Mental Health Centers in Berkeley and Oakland.

1940+

Frank Kreith (B.S.'45 ME), professor emeritus at the University of Colorado, has been awarded the 2017 John Fritz Medal for his contributions to sustainable energy. Over his seven-decade career, he has researched and taught about renewable energy. His 2014 memoir, *Sunrise Delayed: A Personal History of Solar Energy,* describes his escape from Nazi-controlled Austria when he was 15 years old and spans the totality of his career.

Farewell

The college lost seven faculty members over the past year.

Vitelmo Bertero, professor emeritus of civil and environmental engineering and former director of the Berkeley Earthquake Engineering Research Center, died in October at the age of 93. A native of Argentina, he was considered a highly influential figure in earthquake research, pioneering countless studies and authoring over 370 papers and reports on the subject. He received the Berkeley Citation, the ASCE Nathan Newmark Award, the ACI Arthur Anderson Award, AISC T.R. Higgins Lectureship Award and the EERI Housner Medal. In 2006, he was named among the "top 10 seismic engineers of the 20th century" by the Applied Technology Council and Engineering News Record.

Nathan W. Cheung, professor of electrical engineering and computer sciences, died in March 2016 at the age of 66. He worked in research at the Exxon Research Laboratory and Bell Telephone Laboratories before receiving a Ph.D. in applied physics from CalTech in 1980; he joined the Berkeley faculty that same year. He co-founded the Silicon Genesis Corporation, the Plasma Doping Users Group and Silicon China Limited, and served on the advisory board of the SemiLEDS Corporation.

Ray Clough, professor emeritus of civil and environmental engineering, died in October at the age of 96. Clough developed the Earthquake Engineering Research Center at Berkeley and served as its director from 1973-77. Named a "Legend of Earthquake Engineering" at the World Conference of Earthquake Engineering, Clough coined the term "finite elements" in 1960, and the articles he authored are still considered the definitive texts on the subject of structural dynamics decades later. He was awarded the Prince Philip Medal from the Royal Academy of Engineering and was a member of the National Academy of Sciences and the National Academy of Engineering.

J. Karl Hedrick, professor of mechanical engineering and former department chair, died in February at the age of 72. Known for his contributions to nonlinear control theory and its applications to transportation along with nonlinear estimation and control, he directed the Partners for Advanced Transit and Highways (PATH) Research Center and the Vehicle Dynamics Laboratory. He was a member of the National Academy of Engineering, the Society of Automotive Engineers and the American Institute of Aeronautics and Astronautics, and was a fellow of the American Society of Mechanical Engineering.

James Hunt, professor emeritus of civil and environmental engineering, died in February at the age of 66. He joined the Berkeley faculty in 1980 and was best known for his work on contaminant transport in porous media, such as groundwater aquifers. Among several leadership roles on campus, he served as an associate vice provost for academic planning and facilities. He directed the Berkeley Water Center and the Institute for Environmental Science and Engineering, and is widely remembered as a devoted teacher and mentor.

Kenneth K. Mei, professor emeritus of electrical engineering, died in February at the age of 84. Born in Shanghai, he served as an interpreter in the Korean War from 1952-54 before earning three degrees at the University of Wisconsin. He joined the Berkeley faculty in 1962 and was also appointed professor of Buddhist studies in 1992. He retired in 1994 and became honorary professor at the City University of Hong Kong and adjunct professor at Shanghai University. Among many advances in computational electromagnetics, his measured equation of invariance (MEI) method in 1992 enabled large problems that were previously resolvable only by supercomputers to be solved by personal computers. His Ph.D. work on formulating Maxwell's equations into integral equations, now known as the "method of moments," is credited as the beginning of the era of computational electromagnetics and perhaps one of the most important techniques for analyzing scattering, antenna and microstrip circuit problems.

Jerome Sackman, professor emeritus of engineering science, died in December at the age of 87. Sackman held teaching positions at several universities, including Columbia University, Universidad Católica in Chile, Luleå University in Sweden and National Cheng Kung University in Taiwan. He won several awards in his field; among them the Berkeley Citation, the Nathan M. Newmark Medal and the Robert Ridgeway Award, along with mentions in *American Men and Women of Science* and *Who's Who in Science and Engineering.*

Professor Laura Waller, EECS

A lasting legacy

Standard microscopes — and even smartphones — now have powerful new ways to see the minuscule, thanks to the innovative work of electrical engineering and computer sciences professor Laura Waller. As head of the Computational Imaging Lab, she develops low-cost techniques that convert large amounts of visual data into the high-resolution images critical for medical diagnostics.

Last year, she became the first recipient of the Ted Van Duzer Endowed Professorship. Kishore Seendripu (M.S.'93 MSE, Ph.D.'96 EECS) funded the professorship in honor of his graduate advisor, professor emeritus Ted Van Duzer (Ph.D.'60 EE), an acclaimed electronics researcher, author and student mentor.

The professorship will support Waller's teaching and research, allowing her to take on new, risky ideas in her work. She feels grateful to be selected for this honor, as well as personally inspired.

"Being a part of this has made me think about how my students are my real legacy and my greatest metric for success," she says. "I only hope I can live up to Professor Van Duzer's example of helping students become successful engineers and good people."

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