Machines that heal
Wireless neural implants

New 3D printer
Using light to shape objects

Berkeley ENGINEER

SHIFTING GEARS
The promise and peril of self-driving vehicles

Why a world with AI needs more EQ

It's exciting for me to head into graduation season for the first time as dean of Berkeley Engineering. As I consider the breadth of career options for our graduates, I see the need to augment our programs to better prepare engineering students to succeed in a dynamic and unpredictable world that is increasingly dependent on engineered devices, processes and systems.

A 2017 report about the changing workforce by the McKinsey Global Institute indicates that all workers will need to adapt as their occupations evolve with increasingly capable machines. In the age of artificial intelligence (AI), workers will spend more time on activities that require social and emotional skills, creativity, high-level cognitive capabilities and other skills that are relatively hard to automate. There is growing evidence of the importance of a high emotional quotient (EQ) as a predictor of success and organizational performance.

It is clear that a high EQ will be necessary for individuals to succeed in a rapidly evolving workplace. This is not to say that core competency in technical skills is not important, but rather that EQ is what makes a leader stand out among peers of comparable IQ. In a World Economic Forum Future of Jobs report, "human skills" such as emotional intelligence, leadership and social influence are qualities that will see increased demand in the future.

While Berkeley Engineering degree requirements already include studies in the humanities and social sciences, we should also embed within engineering courses training that augments EQ, such as effective communication. That is why I am piloting a new course, The Art of STEM Communication, this semester. This course teaches undergraduate engineering students how to communicate to the general public the importance and impact on society of engineering and science research at the university.

For graduate engineering students, I also have enlisted resources within the Fung Institute for Engineering Leadership and the Haas School of Business to offer a short course this semester on Communications for Engineering Leaders. The goal of this course is to help students develop interpersonal communication skills for effective leadership, with an emphasis on communicating with authenticity, persuasion and advocacy.

I welcome all members and friends of the Berkeley Engineering community to join me in supporting these educational initiatives to empower our students to succeed as innovators and to be effective leaders in our global society, toward a brighter future for all.

—Tsu-Jae King Liu
DEAN AND ROY W. CARLSON PROFESSOR OF ENGINEERING

> Emotional intelligence, leadership and social influence are qualities that will see increased demand in the future.

Dean Tsu-Jae King Liu and Oski welcome newly admitted students at Berkeley Engineering's Cal Day event in April.

Adam Lau
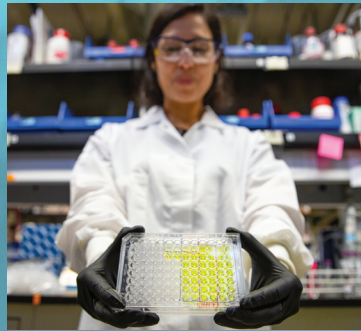
in this issue

Berkeley**ENGINEER** SPRING 2019

> **COVER PHOTO:** THE EASTERN SPAN OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE

PHOTO BY **ADAM LAU**

👁 See more timelapse images of Bay Area roadways on Instagram: **@berkeley_engineering**

PRODUCT DESIGN
New 3D printer

A new 3D printer from the lab of **Hayden Taylor,** assistant professor of mechanical engineering, has the potential to transform product design. Instead of building an object layer by layer, as other 3D printers do, this printer uses light to shape solid objects out of a viscous liquid in a matter of minutes.

Nicknamed "the replicator" by its inventors — after the *Star Trek* device that can materialize any object on demand — the 3D printer can create objects that are smoother, more flexible and more complex than what is possible with traditional 3D printers. It can also add new materials to an existing object, such as adding a handle to a metal screwdriver shaft, something current 3D printers have difficulty with.

To create an object, the researchers plug an off-the-shelf video projector into a laptop, which they use to project a series of computed images onto a rotating cylinder. The cylinder is filled with a printing resin that forms a solid when exposed to a certain threshold of light.

The resin is composed of liquid polymers mixed with photosensitive molecules and dissolved oxygen. Light activates the photosensitive compound, which depletes the oxygen. Only in those regions where all the oxygen has been used up do the polymers form the "cross-links" that transform the resin from a liquid to a solid. All uncured resin can be reused, so the technique generates almost no material waste.

Courtesy the researchers
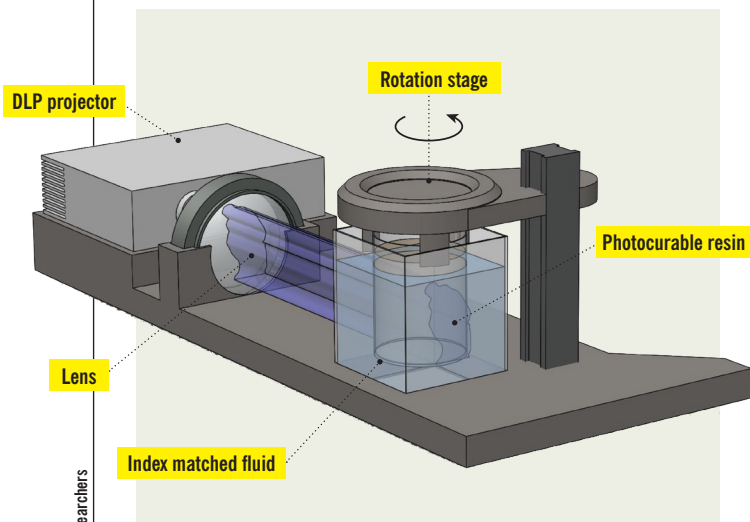
ADAPTED FROM AN ARTICLE BY KARA MANKE, UC BERKELEY OFFICE OF PUBLIC AFFAIRS

Adam Lau

OUTREACH
Next-gen engineers

About 350 students from across the East Bay descended on the Berkeley campus in March for Engineering for Kids (E4K), a one-day science, technology, engineering and math (STEM) event for low-income fourth- to sixth-grade students.

The annual event is organized and hosted entirely by Berkeley students. The attendees built graphic circuits to light LEDs, marshmallow catapults and CD hovercrafts to learn about the mechanics of friction and momentum.

By providing the young students with exciting and memorable experiences in science and engineering, the E4K team hopes to inspire a new generation of innovators and entrepreneurs. As a follow-up, the organizers distribute surveys during the closing ceremony to students and parents, as well as email parents and chaperones after the event.

For **Cara Wolfe,** a computer science undergraduate student who is leading E4K's efforts this year, some of her favorite moments are when parents call or write notes to the E4K organizers to tell them how this event sparked an engineering curiosity in their child. "Last year, one mom emailed and told us that after attending our event, her son went to the library and checked out a mechanical engineering book and now wants to be an engineer," she said. "Knowing that we inspire these kids to become excited and curious about STEM is one of the reasons I do this, and I know that this is true for many of the organizers as well."

The science of war games

A first-of-its-kind online game is revolutionizing the field of war-gaming. Developed by Berkeley researchers in collaboration with colleagues from Lawrence Livermore National Laboratory and Sandia National Laboratories, this multi-player video game was custom-built to explore how nuclear weapons influence decision-making in a conflict.

Over the past century, small groups of military leaders and policymakers in the United States have played through scenarios of international conflict, and their insights influenced decisions about policies, strategies and tactics. But this approach has key shortcomings.

"Because you have a limited player set and only play through a few scenarios, you don't really get enough data from these scenario-based discussions to draw statistical inference. You may only get an idea of how these specific people would react," said **Bethany Goldblum** (M.S.'05, Ph.D.'07 NE), a researcher in the nuclear engineering department.

To overcome these limitations, the researchers leveraged state-of-the-art game engines and Amazon's cloud computing platform to develop an online, multi-player game that can examine the dynamics of nuclear deterrence and conflict escalation by collecting data from thousands of games.

To build the game, the team relied on undergraduate and graduate students in the electrical engineering and computer sciences department and the School of Information. Under the guidance of

Jonathan Whetzel from Sandia National Laboratories, the students created a game called SIGNAL from scratch and had a prototype in four months.

"The premise of the game is our research question: How does the introduction of different weapon capabilities escalate or de-escalate conflict?" said Whetzel. "So each player in our game is controlling a particular country, and the goal is to have the most influence in this fictional world. You can do this by building your population, investing in infrastructure or controlling resources via alliances or military force."

While playing online, each player's scores are updated in real time so they can see how their actions are impacting their position in the world. The data collected are anonymized and can be used as input for machine learning algorithms to create models of optimal behaviors given an experimental condition. These models can then create autonomous players that operate according to strategies in training data, as well as human-machine and machine-machine game play.

"SIGNAL is the first execution of this large-scale experimental gaming approach for examining conflict in a world with nuclear weapons," said Goldblum. "This flexible gaming environment can be used to explore a variety of research questions and mimic various aspects of warfare."

Berkeley's effort on the project was a cross-disciplinary collaboration between the departments of electrical engineering and computer sciences, nuclear engineering, political science and the Goldman School of Public Policy.
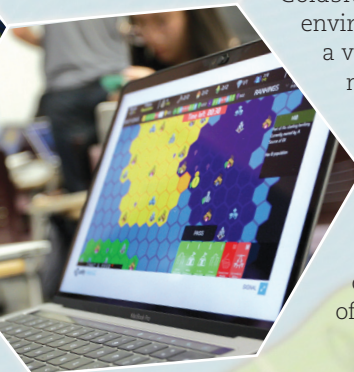
Lorenzo Vidali; Sandia National Laboratories

MACHINE LEARNING

Protecting health data privacy

Anil Aswani, assistant professor of industrial engineering and operations research, thinks today's fitness tracking might lead to tomorrow's privacy threat. He and his colleagues have demonstrated that artificial intelligence can identify individuals by learning daily patterns from step data — collected by activity trackers, smartwatches and smartphones — and then correlating that information with demographic data.

The team used large data sets from the National Health and Nutrition Examination Survey and found that machine learning could accurately identify most subjects based on activity data. Their results led them to conclude that privacy standards from the Health Insurance Portability and Accountability Act (HIPAA) need to be revisited and reworked.

"The results point out a major problem. If you strip all the identifying information, it doesn't protect you as much as you'd think," Aswani said. "Someone else can come back and put it all back together if they have the right kind of information."

Aswani said that the problem isn't with the devices, but with how information captured by the devices can be misused and potentially sold on the open market. As advances in artificial intelligence make it easier for companies to gain access to health data, the temptation for companies to use it in illegal or unethical ways will increase.

"Ideally, what I'd like to see from this are new regulations or rules that protect health data," he said. "But there is actually a big push to even weaken the regulations right now. For instance, the rule-making group for HIPAA has requested comments on increasing data sharing. The risk is that if people are not aware of what's happening, the rules we have will be weakened."

ADAPTED FROM AN ARTICLE BY JOHN HICKEY, UC BERKELEY OFFICE OF PUBLIC AFFAIRS

DID YOU KNOW?

NEARLY 1 IN 5 BERKELEY ENGINEERING UNDER-GRADUATE STUDENTS ARE PELL GRANT RECIPIENTS. BERKELEY ENGINEERING IS EDUCATING MORE STUDENTS — AND MORE LOW-INCOME STUDENTS — THAN PEER PRIVATE INSTITUTIONS.

THERMOELECTRICS

Heat-powered hat

Pranav Vaidhyanathan, an electrical engineering and computer sciences student, remembers summer blackouts in his hometown of Chennai, India. It wasn't unusual for electricity to be out for as long as 20 hours. Mechanical engineering student **Alex Yamada** could commiserate. Growing up on Oahu, Hawaii, Yamada remembers how the island would frequently lose power — especially after a big storm — primarily because of aging infrastructure.

Both were taking INDENG 185, a lab where they were challenged to develop technology for a global startup. Thinking back to their experiences, they teamed up with economics major **Justin Kim** to develop WeLumen8, a baseball cap with built-in LED lights powered by human heat.

While there are tiny thermoelectric generators that are commercially available for wearables, these can't generate enough voltage to power LEDs. So to make the LEDs on the cap shine brightly, the WeLumen8 team developed a novel supercapacitor that amplifies the small amount of voltage from these commercial generators to 3.3V. WeLumen8's technology also efficiently converts the heat energy from the body, unlike other efforts to do so.

Q+A on the future of food

Ricardo San Martin is research director of the Alternative Meats Program at the Sutardja Center for Entrepreneurship and Technology (SCET). This first-of-its-kind program supports students and entrepreneurs as they develop novel solutions to address the impact certain foods can have on the environment, human health and animal welfare.

"I am very familiar with the emotions around the topic of plant-based meats," said San Martin. "Two of my children are vegans, the third is carnivore."

We sat down recently with San Martin to discuss how sustainable food technologies might influence the next generation of what we eat.

A study last year concluded that global greenhouse gas emissions could be cut nearly in half if humans switched to a plant-based diet. Do you anticipate that the future of food will be mostly plant-based?

Nobody knows what the future of food will look like. But we do know that this movement will not happen if current habits stay the same. Currently, there is no indication that people are changing their habits to eat less meat.

For many, food is a personal statement. Eating alternative meats is a personal statement, just like driving an electric car. You can feel that you are saving the planet by eating an alternative to meat, but how many people want to make that statement? It is uncertain.

This is a global problem that will need local solutions. The American solution will not necessarily work in Asia because people have local preferences, flavors and traditions around food.

Do you think the future of alternative meats will be something like the plant-based substitutes for meat, such as products from companies like Impossible Foods or Beyond Meat?

We are at the very beginning stages of this industry. Alternative meats, today, are where the internet was 10 years ago. Anything is possible.

Start-ups like Beyond Meat and Impossible Foods are further along and have been more innovative, but they are a long way from saturating the market. Unlike everyone else, they studied the structure of meat and the sensation of eating it — the taste, texture and context — and then looked at things in nature that would imitate that. But this doesn't necessarily mean that this is the way to go. We know that people will try something once out of curiosity. But will they replace meat with it? Nobody knows.

Many of my students come to the realization that alternatives don't necessarily have to mimic meat at all. It can be a new type of food with similar nutrients and proteins to meat.

SCET has been offering the Alternative Meat Challenge Lab since 2017, with each class comprising about 45 students. How have you structured the program?

My goal is to set up the best learning environment for me and my students. That means having conversations with meaningful consequences. About 40 percent of my class consists of company experts discussing real-world challenges in the alternative meats industry with our students.

The students are also divided into teams and compete against each other to develop the most innovative plant-based meat. In addition to creating a product, we also think about whether people will eat it and how you should package and market this. Most of the world is not waiting for this; we are going to have to convince them to try it.

This is a holistic problem and the solution will not come solely from technology. UC Berkeley is a great place to do this work because people are very conscious about this topic, and there are so many interdisciplinary opportunities. The diversity of our student body is also something that can be leveraged. Students can talk about the food that their grandma cooked and local flavors of their country. With [the program's] new funding, we will be offering more classes to students of all majors.

> "*Many of my students come to the realization that alternatives don't necessarily have to mimic meat at all. It can be a new type of food with similar nutrients and proteins to meat.*"

BATTERIES

Going to extremes

New research by Berkeley engineers may soon make it more practical to use battery-powered vehicles and devices in extreme temperatures, such as icy-cold winters in Minnesota or stifling-hot summers in Death Valley. Led by **Chris Dames,** professor of mechanical engineering, the researchers developed a thermal regulator that can improve the performance of lithium-ion batteries outside of what's now considered to be the optimal window — typically 20 to 40 degrees Celsius. Their system uses nickel and titanium alloy wires, attached to the lithium-ion battery pack, that soften below 35 degrees Celsius but stiffen and contract above 35 degrees Celsius. At higher temperatures, the stiffened wires pull the batteries tightly into contact with a heat sink designed to cool the batteries down. At cooler temperatures, the softened wires allow the battery pack to lift away from the heat sink with the help of compressed springs; the resulting air gap provides insulation that keeps the batteries warm by slowing the dissipation of waste heat. Testing showed that at minus 20 degrees Celsius, the regulator increased the battery temperature to 20 degrees Celsius just by retaining the battery's self-generated heat. At 45 degrees Celsius, the regulator kept the batteries from overheating by limiting the temperature rise to about 6 degrees through constant heat dissipation.
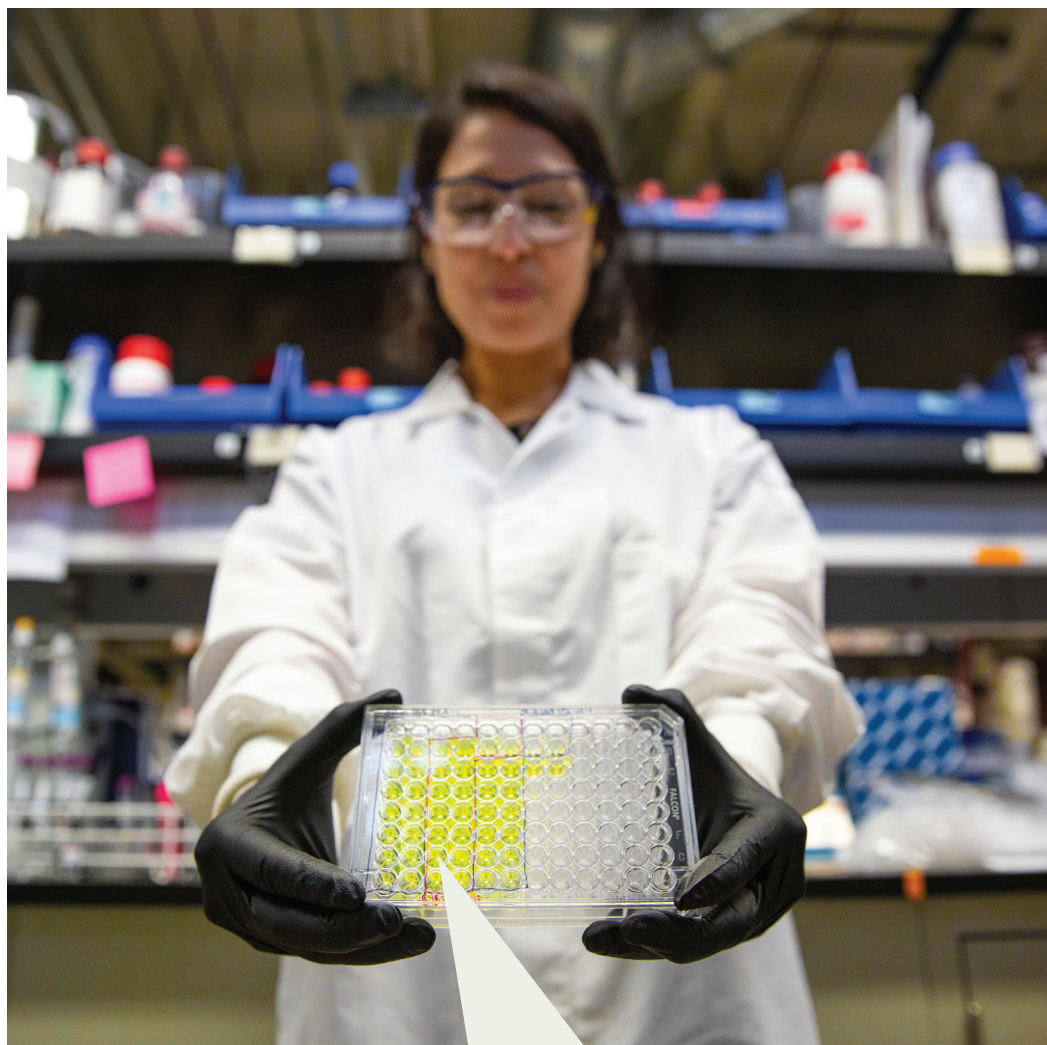
Stephen McNally

DIAGNOSTICS

Detecting superbugs

Antibiotic-resistant bacteria strains kill as many as 700,000 people worldwide each year. But now, a test developed by Berkeley researchers can quickly identify these so-called "superbugs," helping doctors prescribe effective antibiotics and possibly limiting the spread of these dangerous pathogens. Called DETECT, the test uses a patient's urine sample to diagnose antibiotic-resistant infections by identifying enzymes called beta-lactamases, the molecular signature of antibiotic-resistant bacteria. The test works in a matter of minutes, does not require expensive instrumentation and is simple enough to be applied in a point-of-care setting — unlike other available techniques.

The team, including scientists from the lab of bioengineering professor **Niren Murthy** as well as researchers from the School of Public Health, are working to perfect the technique so that it can also be used to detect specific strains of bacteria as well as bacteria in blood samples. Eventually, they hope to commercialize the technology into a rapid diagnostic device that works in a multitude of medical settings.

Adriel Olmos

Sensors get flexible

Yasser Khan

Existing blood-oxygen sensors — known as oximeters — are known for being rigid and bulky, and they only work on thin parts of the body, like fingertips or earlobes. But a team led by **Ana Claudia Arias,** professor of electrical engineering and computer sciences, has now developed a flexible sensor that can be used over large areas of skin, tissue and organs, giving a new way to detect blood-oxygen levels throughout the body. The sensor's organic electronics are printed on bendable plastic that molds to the shape of the body, allowing it to be placed anywhere. Consisting of an alternating array of organic light-emitting diodes and photodiodes, the sensor measures oxygenation in tissue by shining red and near-infrared light into the skin and then detecting the ratio of light that is reflected back. The researchers say the sensor could enable doctors to monitor wounds as they heal in real time, check the oxygenation of skin grafts and transplanted organs, or even constantly track blood oxygen levels in patients with diabetes, respiration illnesses or sleep apnea.

ENERGY

New hydrogen fuel catalyst

A powerful new hydrogen fuel catalyst developed by Berkeley engineers relies on a surprising ingredient: gelatin, the same material that makes Jell-O desserts jiggle. Composed of nanometer-thin sheets of metal carbide, this catalyst works just as efficiently as platinum to generate hydrogen fuel from water, but at a much lower cost than the rare and expensive metal. To create the catalyst, the researchers, led by mechanical engineering professor **Liwei Lin,** simply mixed water, gelatin and a metal ion — either molybdenum, tungsten or cobalt — and then let the mixture dry. As the gelatin dried, it self-assembled into flat layers of the metal ion. When the mixture was heated to 600 degrees Celsius, the metal ion reacted with the carbon atoms in the gelatin, forming large sheets of metal carbide. The unreacted gelatin burned away. The researchers say this new catalyst is also a greener way of generating hydrogen than the widespread method of using water gas, which produces carbon dioxide as a byproduct. And because the process is relatively simple, it could be easily scaled up to produce large quantities of the catalyst, making this a potential game changer for hydrogen fuel generation in the future.
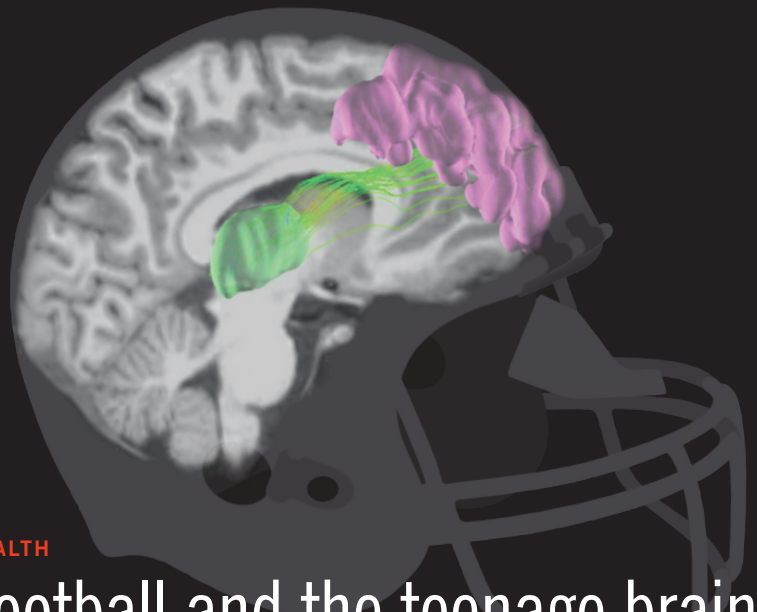
HEALTH

Football and the teenage brain

A single season of high school football may be enough to cause microscopic changes in the structure of the brain, according to research by electrical engineering and computer sciences professor **Chunlei Liu,** senior author of a multi-university study. To assess the effect of repetitive head impacts, the research team used two types of magnetic resonance imaging (MRI) — called diffusion kurtosis and quantitative susceptibility mapping — to take brain scans of high school players before and after a season of football. Although all participants wore helmets, and none sustained a concussion, the researchers still found intricate changes in the structure of the grey matter in the front and rear of the brain, where impacts are most likely to occur, as well as changes to structures deep inside the brain. The changes corresponded with the amount and location of head impacts, as measured by accelerometers mounted inside the players' helmets. The researchers also tested the players' cognitive function, but found no changes during the study. Because the players are young and their brains are still developing, it is unclear whether the changes to the brain identified in this study will be permanent. Still, the researchers recommended caution, as well as frequent cognitive and brain monitoring, for young people who play impact sports.

Shifting Gears

The integration of self-driving vehicles requires nuanced policy decisions—now

STORY BY ANN BRODY GUY • PHOTOS BY ADAM LAU

1 | To get started, confirm your pickup location

2 | Let Waymo know where you want to go

3 | Accept by pressing the Request Ride button

4 | You'll soon be on your way....

Courtesy Waymo
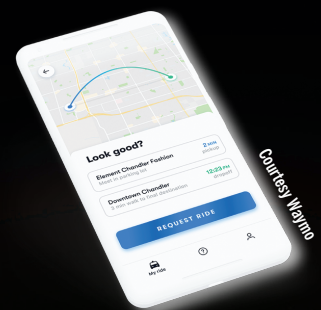
Users of ride-sharing apps like Lyft and Uber will find this interface familiar, but it hails something novel: a Waymo One self-driving Volvo SUV. The ride service, currently limited to a set of "early riders" around Phoenix, Arizona, launched last December. A month later, the 2019 Consumer Electronic Show's glut of autonomous vehicles, or AVs, included consumer-market cars parading along the Las Vegas Strip and a Mercedes-Benz concept car with switchable bodies — a multi-passenger taxi and a cargo hold for freight. The French company EasyMile is testing its driverless electric shuttles in Europe, Singapore and the United States.

These fast-paced advances and investments are part of a revolution. With roughly 30 companies now developing fully automated vehicles, the convergence of vehicle automation and sharing is creating the biggest disruption to mobility since gas-powered vehicles hit the road. The gee-whiz technology gets a lot of attention, but the real thing to watch, experts says, is us, the traveling public. When driverless vehicles begin integrating into an increasingly complex transportation ecosystem — one that includes partially automated vehicles, sharing and pooling services, not to mention delivery vehicles, robots and drones — the public's travel behavior will shift as we adjust to new mobility choices. What will the impacts be on traffic and transit? How will jobs and land use shift? Will services be equally available to everyone or just another amenity for the wealthy?

For 20-20 hindsight, look to automobile adoption, which changed land use from a dense urban core to suburban sprawl, and splintered the social structure into those who could afford cars and those who had to rely on transit. It introduced traffic congestion and increased pollution. It cost transit-related jobs, but also created a whole new economy around vehicles and fuel.

"We have to decide where we're going and put policies in place to get there," says civil and environmental engineering professor Joan Walker (B.S.'91 CE), who specializes in travel behavior. If we want low congestion, low emissions and social equity, she says, we must start now. That means discarding cartoonish images of either Jetsons-like free-flowing traffic or a dystopian horror show of empty vehicles, called "zombies," locked in perpetual traffic jams. The reality, experts say, falls into a complex middle ground: A gradual integration that society can optimize with measured policies that address consequences — both wanted and unwanted — of how we make travel choices.

KILLING ZOMBIES

Congestion is a big unwanted consequence. With population and urbanization on the rise, travel demand is increasing, especially in dense areas. Strategies like HOV lanes and carpooling are meant to reduce low-occupancy vehicles on the road. But personal AVs, especially when they're zombies — traveling empty after a passenger drop-off, circling or just picking up a pizza — complicate the picture.

That's because AVs undermine a trade-off central to behavioral economics: Time is money. Every car on the road contributes to congestion, but when you sit in traffic, wasting your time, you're paying a price for adding to the problem. That personal pain creates a strong incentive to avoid driving, Walker explains — maybe by choosing transit next time. "A self-driving car changes the equation," she says. Taking your AV still costs you time, but that pain is lessened because you can use your time productively while the car performs the driving task. Zombies upend the equation completely. "If your car is in the traffic jam without you, you're not paying any personal price for the trouble you're causing everyone else," she says.

To study real-world effects of such behavioral concerns, Walker and a research team simulated AV ownership by providing 13 subjects with chauffeurs for a week. Eighty-three percent of households increased their vehicle miles traveled, taking both more and longer trips. Chauffeurs traveled alone (zombies) on 21 percent of trips. Despite obvious caveats — the novelty, a small sample — the findings indicate an alarming travel increase, including low- or zero-occupancy trips, when AV owners don't pay time and inconvenience costs.

A penalty fee is one way to make AV users pay a cost for putting vehicles on the road. One such "zombie tax," a per-mile charge on empty vehicles, is already being studied by the Massachusetts legislature.

Using technology to fill empty seats with passengers or freight can increase the efficiency of cars on the road. Zombies are just a new form of deadheading — single-occupancy trips that result when a taxi or truck driver delivers a load, then returns to a base alone, explains Susan Shaheen, an adjunct transportation engineering professor who co-directs Berkeley's Transportation Sustainability Research Center. Apps to generate demand for those empty seats are already on the market.

"Induced demand is the notion that if we build it or make it easier and cheaper for you to travel, you'll travel more," Shaheen explains. "So it's not just a question of those zero occupancy miles, but do AVs create a demand for even more trip-making by making it easier to travel?"

GETTING THE PRICE RIGHT

That's why sharing modes figure so prominently into AV development. Sharing reduces low-occupancy trips, and the added mobility options could help discourage private vehicle ownership. A 2010 study by Shaheen and her colleague Elliot Martin found that 25 percent of roundtrip car-sharing members sold a private vehicle and another 25 percent delayed purchasing a new vehicle. Their 2016 study of car2go's one-way sharing service found that 2 to 5 percent of members sold a vehicle and 7 to 10 percent delayed a vehicle purchase. In an unrelated 2016 survey, 40 percent of ride-sharing users stated they had reduced their driving.

"I think we've already started to see what the future looks like through shared mobility," Shaheen says. "What happens to people's behaviors when they don't need to own a car? Automating these modes can take us a step beyond that."

When Walker recently booked an Uber, the ride-sharing app offered her a pooling option — a lower price to share her trip with other travelers. But, she confesses, the pool price wasn't low enough to entice her to forgo a private ride.

When autonomous ride-sourcing fleets hit cities, she says, finding the pricing sweet spot will be critical. Too expensive and people won't try it, much less make it a go-to option. Too cheap, and people might take so many trips that congestion will increase. And once pricing and other strategies shift demand, tweaks will be needed, Shaheen's research shows. "We're human. We adapt," Shaheen says. "We'll need to make adjustments to rebalance supply and demand."

Access is another key policy lever for preventing congestion, experts say. Rules can limit curbside pickup and drop-off access to high-occupancy vehicles, especially in high-demand areas like downtowns. Such right-of-way policies are already in force at airports, where signage points travelers to app-based ride service locations.

THE SAFETY HURDLE

The idea isn't simply to reduce travel, Walker stresses. "The added mobility AVs will bring is a great thing. It can bring freedom to people who are older or disabled; it gets us to jobs, entertainment, shopping. We can multitask." There's also a promise of added safety if human error — the cause of 94 percent of accidents, according to the National Highway Traffic Safety Administration — is subtracted from the picture.

That's still a big "if." Many researchers think we have a long way to go before the safety potential is realized.

"Automated systems will make mistakes. We're replacing human driving errors with human engineering and software-coding errors," says retired Berkeley research engineer Steven Shladover, who chairs the Transportation Research Board's

Vehicle-Highway Automation Committee. He also sees enabling cars to communicate with each other and the infrastructure — traffic signals, emerging traffic queues and tricky geography like blind curves — as a critical safety hurdle to clear before fully automated cars are ready for complex driving environments.

Trust and ethics issues — Are we comfortable with no driver's seat? Must vehicles "choose" between crashing into the school bus or the senior citizen? — also receive research and media attention. But Shladover thinks trust will develop naturally as people gain experience with lower levels of automation.

Walker also sees these human factors as the lowest barrier to implementation. "The value proposition is so high that people will get used to it — just look at smart phones. If 10 years ago someone asked us to carry a device that tells companies where we go and what we buy, would we have agreed? People would say, 'No way!' But we do it because it provides such a value," she says. "AVs are going to be like that — if they're safe enough. We have to get over that safety hurdle."

MOVING EVERYONE FORWARD

Shared mobility research also raises social-equity concerns. In a 2016 survey, a quarter of respondents said they would have taken public transit if ridesourcing wasn't available. Such drops in ridership can degrade transit, and reduced frequencies and options often hit low-income people and communities of color harder. The public transportation system is required to serve everyone, but mobility companies are private, and so is their data about ridership and pricing response. "Shared mobility blurs the line between public and private transit," Shaheen observes in several papers.

Subsidies are a way to ensure that lower-income people can afford these services, Walker says, with companies and riders sharing the financial burden. There's also a role for universities and interdisciplinary research centers — such as Berkeley's Institute of Transportation Studies, where Shaheen and Walker are faculty members — to mediate the public-private line. "We can analyze multiple private-sector companies with a focus on the public good rather than just the private good," she says.

For the most realistic view of how AVs will roll out, Shladover says, look to the pilot programs: limited routes without complex driving environments. So, like Waymo One, shuttles will serve neighborhoods or campuses and likely start in weather-friendly Sun Belt states.

Those conditions also support an approach centered on human mobility, not the media-friendly technical glitz of, say, the Consumer Electronics Show. Without a focus on cities and their residents, a 2018 Knight Foundation mobility grant announcement said, "We risk designing cities for new kinds of cars, rather than for people." The grant supports driverless shuttles in Miami, and, in San Jose, linking AVs with transit and downtown.

More pilots like these can help researchers and the public understand the formidable societal challenges as AV integration continues to unfold.

"The conversation needs to go beyond the dystopian and utopian paradigms, or are AVs shared or privately owned, into something much more nuanced," Shaheen says. "What are we talking about creating? It's our moral responsibility to think through socioeconomic issues."

And, as Waymo One tells its riders: We'll soon be on our way. So policy action is needed now, before dysfunction becomes a new norm.

"The thing about behavior is that that once it's entrenched, it's really hard to change," Walker says. "As engineers we often think that we can build our way to desired outcomes. But we need to deal with the demand side — the people and the behavior — it's not just technical. We can't engineer our way out of these problems." BE

GOING WITH THE FLOW

Berkeley researchers are addressing the emerging era of self-driving vehicles on multiple fronts, including a tool that uses machine learning to manage traffic where autonomous, partially-automated and manual vehicles share the road. Their project, called Flow, is the first time deep reinforcement learning has been integrated with traffic-simulation tools.

"Flow solves large-scale, multi-vehicle problems by providing cloud integration of industrial simulation software with state-of-the-art machine learning libraries," says Alexandre Bayen, professor of electrical engineering and computer sciences and director of the Institute of Transportation Studies. "We've made it open source so the development community can continue to build on it, and we've created leaderboards so groups around the world can compete on the best performance of their algorithms."

A novel feature of the system is automated cars using data from nearby smart vehicles or infrastructure to manage traffic, effectively becoming mobile traffic-managing robots. For example, an automated car could use its speed and position to control nearby vehicles as they merge. Or it could pace its speed to help prevent the random, human-caused slowdowns that increase travel time and frustrate drivers.

The study specifies highly detailed scenarios that engineers can use to solve traffic challenges like bottlenecks and intersection control. The solutions become shared baselines — benchmark scenarios on which researchers can compete — that are critical to making progress.

Researchers aim to tackle increasingly complex scenarios, with the end goal of having the system manage traffic at citywide scale. They also plan to study potential downsides and unintended consequences of this technological approach.

Courtesy Waymo

👁 See video at **engineering.berkeley.edu/magazine.**

Machines that heal

Microsystems that monitor and treat in real-time

STORY BY LINDA VU • PHOTOS BY ADAM LAU

"Pacemaker for the brain," called WAND (wireless artifact-free neuromodulation device)

Imagine a tiny, wirelessly-powered device that can be safely implanted in the brain to restore useful functions for people disabled by a spinal cord injury, stroke or cerebral palsy. A micromachine that could also be used to prevent epileptic seizures — or even treat symptoms of Parkinson's or Alzheimer's diseases.

Neural dust

Recent breakthroughs in brain-machine interfaces have brought medical advances such as these to the verge of reality. And Rikky Muller, assistant professor of electrical engineering and computer sciences (EECS) and co-director of the Berkeley Wireless Research Center, is at the forefront of this miniaturized revolution in healthcare. She is using her expertise in integrated circuits to build tiny, implantable devices that are intelligent, safe and so minimally invasive that they can last over the course of a patient's lifetime.

"I'm absolutely passionate about finding treatments and maybe someday cures for neurological diseases," says Muller. "Almost everyone knows someone impacted by neurological diseases like epilepsy, Parkinson's or Alzheimer's. That's why this is such an important area to invest time and resources into."

Neurological diseases are notoriously hard to treat, and patients are typically prescribed pharmaceuticals for these conditions. But if they don't respond to drug treatment, there aren't many other options.

"This idea totally changed my perspective on healthcare — to have a device implanted that can alleviate symptoms and give patients back their quality of life, especially for extremely difficult disorders," says Muller. "I want to build devices that can help these patients."

Building brain-machine interfaces

Muller was working in the semiconductor industry, designing integrated circuits for consumer devices, when she first learned about the potential health benefits of brain-machine interfaces. Knowing that her expertise could be applied to building these devices, she began to voraciously read scientific papers and attend conference presentations on the subject. Eventually, with bachelor's and master's degrees in electrical engineering from MIT, she enrolled in Berkeley's EECS doctoral program, with a specific focus on integrated circuits and neuroengineering.

For her thesis, Muller worked closely with collaborators around campus, including EECS professors Jan Rabaey and Michel Maharbiz (Ph.D.'03 EECS), to build a micro-electrocorticography (ECoG) device. This small implant — as thin as plastic wrap and as flexible as a soft contact lens — can record neural activity and then transmit the data wirelessly for analysis, using ultra-low power circuits and a microfabricated electrode array.

According to Rabaey, this device was among the first in the field with wireless capabilities, which is important because it allows the surgical site to be closed after the device is implanted in the body, effectively minimizing the risk of infection. The high-density ECoG electrode sensors can also map regions of the brain's cortex with high resolution. The sensors eventually became the first product of Cortera Neurotechnologies, a company co-founded by Muller, Maharbiz, Rabaey and Peter Ledochowitsch (Ph.D.'13 BioE). Muller became Cortera's first chief executive officer in 2013, and later, its chief technology officer.

"Before this, people had been doing circuits for brain integration, but their devices were substantially larger and used a lot more power without having the wireless interface," says Rabaey. "Rikky is a really good circuits designer, and she helped us overcome a number of obstacles, so our devices could be significantly smaller and use less power, but still have wireless capabilities, data acquisition, application and noise filtering."

Rabaey admits that many researchers didn't initially realize the importance of making something really small. The density that Muller achieved allowed them to fit many additional electrodes in a device, allowing researchers to collect much more information. Her contributions also made these implants extremely power-efficient, running on microwatts per channel.

"Rikky...helped us overcome a number of obstacles, so our devices could be significantly smaller and use less power, but still have wireless capabilities, data acquisition, application and noise filtering."

Stimulating neural dust

Muller also played an important role in advancing the technology behind neural dust. Invented by a collaboration of researchers — including EECS professors Rabaey, Maharbiz, Jose Carmena and Elad Alon — neural dust was the first wireless, dust-sized sensor powered by ultrasound. Not only does ultrasound charge the device, it's also used to transmit data.

Muller helped to develop the neural dust platform by building an advanced wireless neural recorder that can record nerve or neural activity with a high degree of accuracy. Her team achieved this by designing a custom integrated circuit to transfer ultrasound charge to the nerve in a well-controlled and safe way. The device is called StimDust, short for stimulating neural dust.

In addition to building the platform, Muller also designed a custom wireless protocol that gives researchers a large range of programmability. The entire device is just 1.7. cubic millimeters in volume — the size of a grain of sand. That's an order of magnitude smaller than comparable active devices with similar capabilities.

"When most people think of wireless devices, they think of WiFi or Bluetooth as standard protocols. But we have to create our own protocols that make things extremely energy efficient," says Muller. "This is not a generic radio that can transmit any type of data; it's communicating something very specific, and since there's no place for data storage, we have to design custom chips to communicate safely and efficiently."

Muller hopes that one day StimDust will treat diseases like heart irregularities, chronic pain, asthma or epilepsy. She and her colleagues are also optimistic that neural dust can someday be implanted noninvasively, like through a syringe, and transmit data to a wearable device to monitor internal nerves, muscles and organs in real time.

When her team implanted a StimDust device on a cuff around the sciatic nerve in a rodent, they were able to control hind-leg motion, record the stimulation activity and measure how much

WAND's first iteration
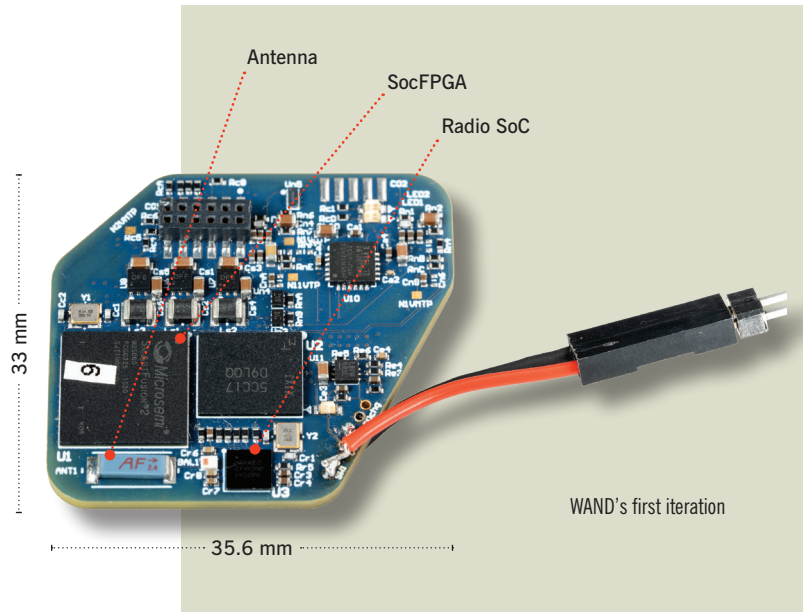
force was exerted on the hind leg muscle as it was stimulated. By gradually increasing the stimulation, they were able to map the response of the hind leg muscle, so they knew exactly how much stimulation was needed for a desired muscle movement.

She also helped build upon the original dust concept to create a 0.8 cubic millimeter device that can safely, precisely and wirelessly record from a peripheral nerve or neuron. Researchers can communicate with multiple implanted devices at once, which would allow them to record networks of neural activity in 3D. This has never before been demonstrated in such a minimally invasive manner.
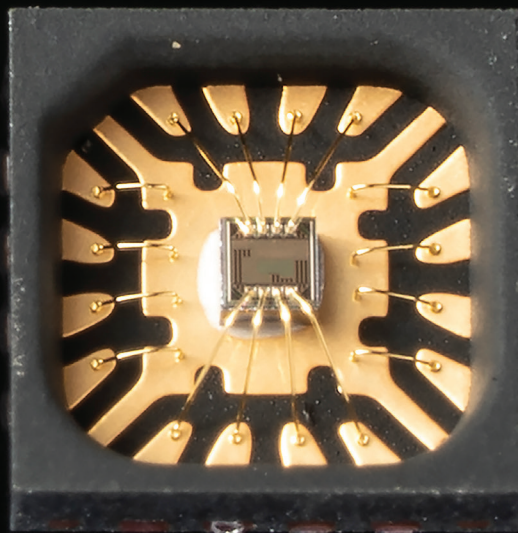
Interior view of neural dust chip
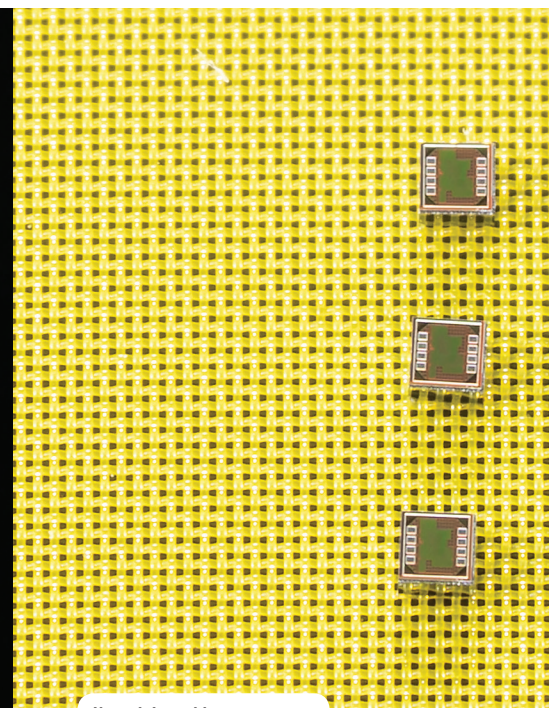
Neural dust chip components

> "When most people think of wireless devices, they think of WiFi or Bluetooth as standard protocols. But we have to create our own protocols that make things extremely energy efficient."

WAND's latest version, called WAND-mini

Pacemakers for the brain

The latest innovation that Muller has worked on is WAND, short for wireless artifact-free neuromodulation device. Comparable to a pacemaker for the brain, this device can monitor the brain's electrical activity and deliver electrical stimulation if it detects something wrong.

WAND is based on technology developed in a 2014 project that included researchers from Berkeley and Cortera. Muller began building on this work when she returned to Berkeley in 2016 as an assistant professor.

Because WAND is both wireless and autonomous, it could be trained to recognize the signs of a tremor or seizure, and adjust the stimulation parameters on its own to prevent the unwanted movements. Since the device is also a closed-loop system — meaning it can stimulate and record at the same time — it can adjust its stimulation parameters in real time based on a patient's neural state. As a proof of concept, researchers were able to recognize and delay movements in rhesus macaques.

"We wanted to enable the device to figure out what is the best way to stimulate for a given patient to result in the best outcomes. And you can do that by listening and recording the neural signatures," says Muller.

In the future, Muller and her team hope to incorporate learning into their closed-loop platform to build intelligent devices that can figure out how to best treat patients and remove the doctor from having to constantly intervene in this process.

"This area of research is all about rethinking the traditional. The devices that I create take a long time to develop because we're building these things from scratch," says Muller. "For me, the most exciting part of the process is seeing everything come together and work as it was designed to." ⬛

👁 See additional photos of this research at **engineering.berkeley.edu/magazine**
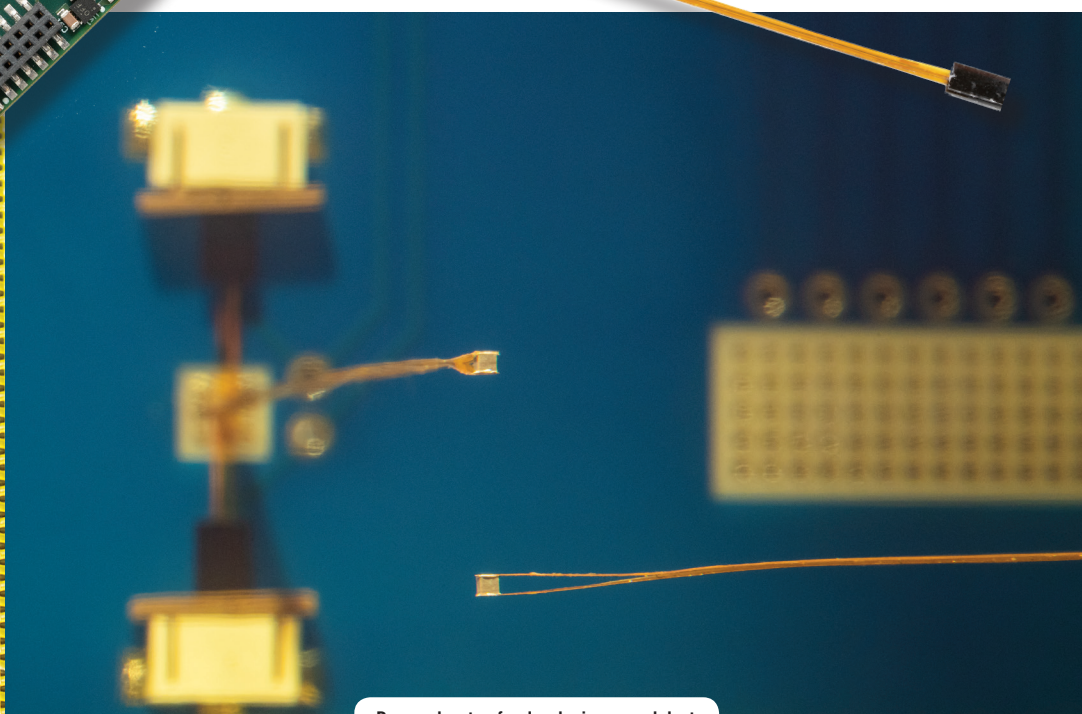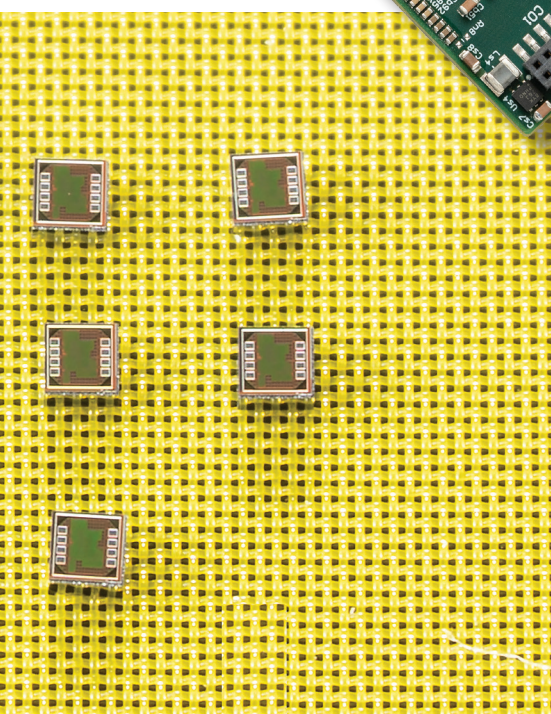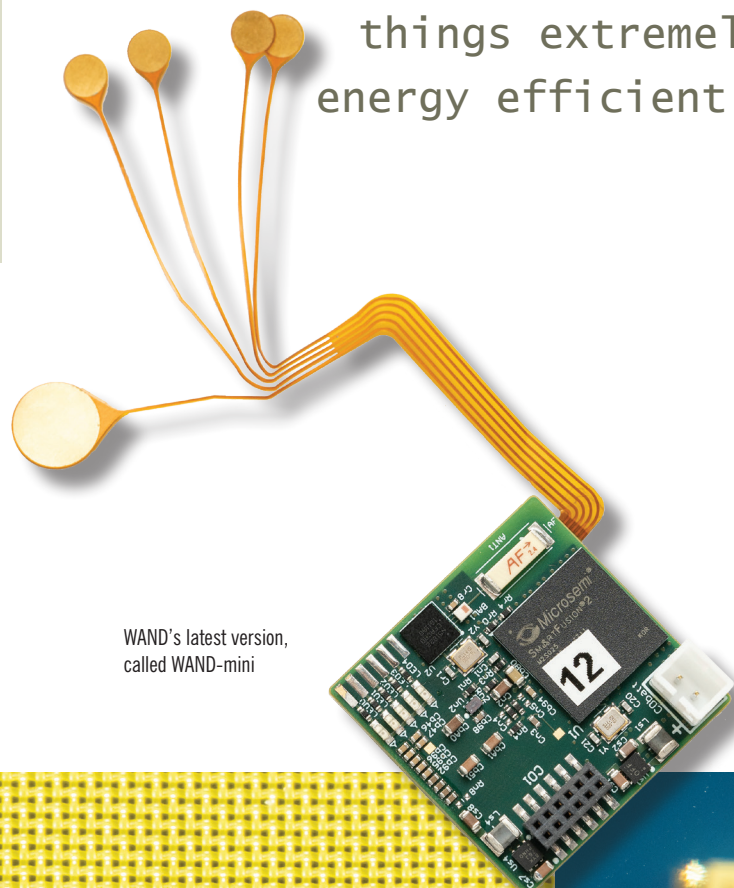
Research setup for developing neural dust

Eli Yablonovitch wins Franklin Medal

Eli Yablonovitch, professor of electrical engineering and computer sciences, was awarded the 2019 Benjamin Franklin Medal in Electrical Engineering for his innovative research. Yablonovitch is best known for inventing a class of materials called photonic crystals, which can be used to control light waves similar to the way semiconductors control electric currents. Today, photonic crystals are an essential component of digital communication in data centers, and they have been recognized for producing structural color in many living organisms. In addition to his work with photonic crystals, Yablonovitch famously introduced a numerical factor called 4(n squared). Sometimes referred to as the "Yablonovitch limit," this factor has been key in work that has improved the efficiency of almost all commercial solar panels worldwide.

PHOTO BY ADAM LAU

Pulkit Agrawal (M.S.'14, Ph.D.'18 CS) and **Jacob Andreas** (Ph.D.'18 CS) will join MIT's electrical engineering and computer science faculty this summer as assistant professors, while **Cathy Wu** (Ph.D.'18 EECS) will be an assistant professor in MIT's civil and environmental engineering department.

Electrical engineering and computer sciences professors **Elad Alon, Sayeef Salahuddin** and **Dawn Song** (Ph.D.'02 EECS) have been elected as fellows of the Institute of Electrical and Electronics Engineers. Alon was elected for contributions to mixed-signal integrated circuit design and methodology, Salahuddin for his research on low-power electronic and spintronic devices, and Song for her work in systems security and privacy.

Environmental engineering professor **Lisa Alvarez-Cohen** has been selected as a 2018 Association of Environmental Engineering and Science Professors fellow. She was selected for her contributions to the understanding of microbial transformation of high-risk xenobiotic chemicals, as well as the management of these chemicals through practices that protect the environment and public.

Bioengineering professor **Adam Arkin** and his team have disentangled some of the complex determinants for how bacterial genes are translated. Their work, which used a massive set of 244,000 synthetic sequence experiments, was published in *Nature Biotechnology.*

Kenneth Armijo (M.S.'08, Ph.D.'11 ME) received the 2018 Zia Award from the University of New Mexico Alumni Association. He is currently an energy researcher at Sandia National Laboratories and is an active supporter of STEM events in his local community.

Maria Artunduaga (M.T.M.'18 BioE), received the 2018 Entrepreneur of the Year Award at the inaugural Women in IT Awards in Silicon Valley in recognition of her achievements as the founder and CEO of Respira Labs. She was also named winner of the Early Career Award from the WITI@UC Athena Awards, along with Next Generation Engagement Award winners **Sally Winkler** and **Kayla Wolf** (both current bioengineering Ph.D. students) and Lifetime Achievement Award winner **Barbara Simons** (Ph.D.'81 CS).

Electrical engineering and computer sciences professors **Krste Asanović** and **Peter Bartlett** have been elected 2018 fellows of the Association for Computing Machinery, as have alums **Thomas Funkhouser** (Ph.D.'93 CS) and **Kimberly Keeton** (M.S.'94, Ph.D.'99 CS).

Glenn Ballard, associate adjunct professor of civil engineering and research director of the Project Production Systems Laboratory, has been elected as a member of the National Academy of Construction. Ballard was noted as a true innovator and was cited for his work as co-founder of the Lean Construction Institute and as the inventor of the Last Planner System.

Ruzena Bajcsy was celebrated with a commemorative bobblehead figure in her image at the 2018 Grace Hopper Conference. A pioneer in robotics and computer vision, she was recognized alongside legends including Grace Hopper, Annie Easley and Mae Jemison.

Dado and **Maria Banatao** were honored with UC Berkeley's Founders Award for long-term distinguished leadership and service to academic and philanthropic programs across the university. In 2005, they established the Dado & Maria Banatao Center for Global Learning and Outreach from Berkeley Engineering (GLOBE) to "bring the world's best to Berkeley Engineering and to bring the best of Berkeley Engineering to the world." Dado currently serves on the CITRIS advisory board and Maria is a UC Berkeley Foundation Trustee.

Yousef Bozorgnia (Ph.D.'81 CE) has been awarded the Bruce Bolt Medal from the Earthquake Engineering Research Institute for his extensive contributions to seismic research. The former director of the Pacific Earthquake Engineering Research Center, he is currently on the civil engineering faculty at UCLA.

Jonathan Bray (Ph.D.'90 CEE), civil engineering professor and faculty chair in Earthquake Engineering Excellence, was selected by the ASCE Geo-Institute to receive the 2019 Karl Terzaghi Award.

Michael Brenndoerfer (M.Eng.'18 EECS), now a senior software engineer at Fitbit, founded a cryptocurrency brokerage platform called Cryptonite, which allows users to trade every cryptocurrency directly with US dollars and manage all of their coins in one place.

Electrical engineering and computer sciences professor Connie Chang-Hasnain is the new director of the Berkeley Marvell Nanofabrication Laboratory. She is taking over for Ming Wu (M.S.'86, Ph.D.'88 EECS), who is stepping down after 10 years as director. Last fall, Chang-Hasnain was also elected as a fellow of the National Academy of Inventors.

Tomlin elected to National Academy of Engineering

Electrical engineering and computer sciences professor and alumna **Claire Tomlin** (Ph.D.'98 EECS) has been elected to the National Academy of Engineering for her "contributions to design tools for safety-focused control of cyberphysical systems." Her research focuses on applications, unmanned aerial vehicles, air traffic control and modeling of biological processes. With this selection — among the highest professional distinctions accorded to an engineer — Berkeley Engineering now has 73 faculty members in the academy.

PHOTO BY NOAH BERGER

Juan Banales (B.S.'13 ME) has been elected mayor of Pittsburg, California. At 27, he is the youngest mayor in the city's history. He has been a city council member since 2016 and previously served on the planning commission. At Berkeley, he was part of the student advisory council as well as the first LeaderShape cohort, which he credits for cultivating his interest in public service. "At the fundamental core of Berkeley Engineering and the university as a whole is a commitment to community and to be a well-rounded person," he said. "From professors to the body of research, the emphasis was always on how to use my education to be a good citizen."

PHOTO COURTESY JUAN BANALES

Ovijit Chaudhuri (B.S.'03 Eng. Physics, Ph.D.'09 BioE), now a mechanical engineering professor at Stanford University, has uncovered a previously unknown mechanism that cancerous cells use to break through the basement membrane, allowing the tumor to become invasive.

Electrical engineering and computer sciences professor **David Culler** and alumnus **Jonathan Hui** (M.S.'05, Ph.D.'08 EECS) have won the Association of Computing Machinery Conference on Embedded Networked Sensor Systems' 2018 Test of Time Award. The award, which recognizes papers that are at least 10 years old and have had a lasting impact, was for a paper that dispelled the notion that IP cannot run on wireless embedded sensors.

Fiona Doyle, vice provost of graduate students, dean of the graduate division and mechanical engineering professor, will retire this summer after 36 years as a Berkeley faculty member and administrator. She has had a long and illustrious career as a teacher and researcher within the College of Engineering, which she joined as its third female faculty member in 1983.

The Indian Institute of Technology has established the Soumitra Dutta Chair in Artificial Intelligence in honor of **Soumitra Dutta** (M.S.'87, Ph.D.'90 CS). He is the founding dean of the SC Johnson College of Business at Cornell University as well as the architect of the Global Innovation Index.

Deborah Estrin (B.S.'80 EECS) has been awarded a 2018 MacArthur Foundation fellowship, widely known as the "genius" grant. A professor and associate dean at Cornell Tech, she creates open-source applications and platforms that leverage mobile devices and network services to address social challenges.

Professor **Filip Filippou** (Ph.D.'83 CE), whose research focuses on the nonlinear analysis of structures, has been appointed to the Byron and Elvira Nishkian Chair in Structural Engineering in the Department of Civil and Environmental Engineering.

Allen Goldstein, professor of civil and environmental engineering and of environmental science, policy and management, and **Katherine Yelick,** professor of electrical engineering and computer sciences, were elected fellows of the American

Association for the Advancement of Science.

Diane Greene (M.S.'88 EECS), CEO of Google Cloud, has been named to *Data Economy*'s list of "America 50: the World's Top 50 North, Central and South American Influencers." She was also recognized this spring with UC Berkeley's Campanile Excellence Achievement Award, which is given to alumni who are pushing the edge of what's possible. She is currently a member of Berkeley Engineering's advisory board.

Electrical engineering and computer sciences assistant professors **Moritz Hardt** and **Sergey Levine** have been named 2019 Sloan Research Fellows, given to researchers whose early-career achievements mark them as being among today's very best scientific minds.

Kevin Healy, professor of bioengineering and of materials science and engineering, has been elected to the Biomedical Engineering Society Class of 2018 fellows for his exceptional achievements in the field.

Mechanical engineering graduate student **Hossein Heidari** won the $100,000 Shark Tank prize for best innovative technology at BASF Innovent 2018. He received the award for his work on computed axial lithography, a volumetric 3D printing solution invented in the Design for Nanomanufacturing Lab, which is led by **Hayden Taylor,** assistant professor of mechanical engineering (see page 2).

Ron Klemencic (M.S.'86 CE) was honored by the American Society of Civil Engineers as one of five Outstanding Projects and Leaders Award winners for 2019, in recognition of his contributions to the civil engineering design industry. The chairman and CEO of Magnusson Klemencic Associates, he is one of the world's leading structural design engineers of tall buildings, including the Salesforce Tower in San Francisco.

Alireza Lahijanian (B.S.'09, M.S.'10 ME) is the co-founder of Rbhu, an engineering and design consulting firm for large-scale sculptures and art at Burning Man.

Tsu-Jae King Liu, dean and professor of electrical engineering and computer sciences, was inducted into the Silicon Valley Engineering Council's Hall of Fame for her professional achievements and contributions to Silicon Valley. A member of Intel's board of directors, she was also recently named to *Women Inc.*'s list of Most Influential Corporate Board Members.

Urmila Mahadev (Ph.D.'18 EECS) has solved one of the most basic questions in quantum computation: How do you know whether a quantum computer has done anything quantum at all? She developed an interactive protocol by which users without quantum powers can employ cryptography to harness and drive a quantum computer, earning her best paper and best student paper prizes at the Symposium on Foundations of Computer Science.

Sanjay Mehrotra (B.S.'78, M.S.'80 EECS), president and CEO of Micron, has been elected chair of the Semiconductor Industry Association.

Teresa Meng (M.S.'84, Ph.D.'88 EECS) has won the 2019 IEEE Alexander Graham Bell Medal for her "technical contributions to and leadership in the development of
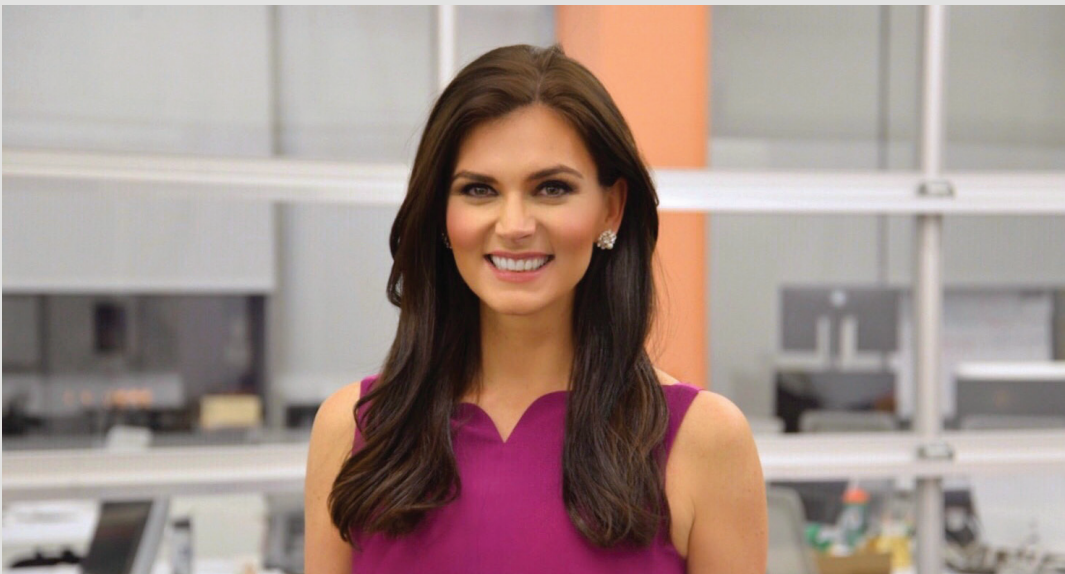
Alum's breakthrough endometriosis test

Heather Bowerman (B.S.'05 BioE) is CEO and founder of DotLab, a medical diagnostics company that has developed the first non-invasive test for endometriosis, a chronic and debilitating disease affecting 176 million women worldwide.

Endometriosis can present differently in each patient, making it difficult to diagnose. For decades, laparoscopic surgery has been the go-to approach for diagnosing the disease. However, that option can be costly and cause permanent scarring, and it carries the risks related to general anesthesia.

But DotLab's new test, DotEndo, identifies key microRNA biomarkers that are specific to endometriosis. Peer-reviewed clinical studies to date comparing the test to surgery have shown DotEndo to be highly accurate in detecting the disease.

Bowerman hopes this technology will lead to better outcomes for patients as well as bring much-needed attention to women's health: "I'm inspired by both the opportunity to positively impact patients — especially women suffering in silence — and by the persistent problem of gender inequality in research and clinical development."

PHOTO COURTESY DOTLAB

Two Berkeley Engineering alums were named to *Forbes'* 2019 "30 Under 30" list, which recognizes young trailblazers in North America.

Po-Jui (Ray) Chiu (M.Eng.'14 BioE), the co-founder of BioInspira, was on the list in the energy category. Inspired by a deadly natural gas explosion in his homeland of Taiwan, Chiu is developing accurate, inexpensive, power-efficient biosensors for detecting chemicals in the air.

William Tarpeh (Ph.D.'17 CEE) was named in the science category. As a doctoral student, Tarpeh developed a method to extract nitrogen from urine, turn it into a gas and combine it with water to make fertilizer. He is currently an assistant professor at Stanford University.

TOP PHOTO COURTESY PO-JUI (RAY) CHIU. BOTTOM PHOTO BY DANIEL MCGLYNN

wireless semiconductor technology," as well as the 2018 Association of Computing Machinery's SIGMOBILE Outstanding Contribution Award. She is the co-founder of Atheros Communications as well as a professor emerita at Stanford University.

Ed Morse, professor of nuclear engineering, has published a book, *Nuclear Fusion,* from Springer International Publishing.

Mike Nelson (Ph.D.'88 CS) is chief scientist at Xcalar, a big data processing and virtual data warehouse platform, where he will spearhead the company's cloud and software-as-a-service efforts.

Mechanical engineering assistant professor **Grace O'Connell** has been selected to receive the ASME 2019 Early Career Award for her "pioneering work in multiscale mechanics of musculoskeletal soft tissues."

Shmuel Oren, who recently retired as professor of industrial engineering and operations research and now serves as a professor of the graduate school, was awarded the Berkeley Citation, one of the university's highest awards for individuals "whose achievements exceed the standards of excellence."

Farhang Ostadan (Ph.D.'83 CE) received the American Society of Civil Engineers' Stephen D. Bechtel Jr. Energy Award for his work in the nuclear power industry.

Robert Pilawa-Podgurski, associate professor of electrical engineering and computer sciences, has received the 2018 IEEE Education Society Mac E. Van Valkenburg Award for his outstanding and innovative teaching.

Electrical engineering and computer sciences professor **Stuart Russell** has won the 2019 Association for the Advancement of Artificial Intelligence's Feigenbaum Prize for his contributions to the field of artificial intelligence, including its application to global seismic monitoring for the nuclear test ban treaty. He was also elected as an honorary fellow of Wadham College at Oxford University, his alma mater.

Alberto Sangiovanni-Vincentelli, professor of electrical engineering and computer sciences, has won the 2018 Association of Computing Machinery's SIGDA Pioneering Achievement Award for his lifetime contributions to electronic design automation.

Professor **Zuo-Jun "Max" Shen** is the new chair of the Department of Industrial Engineering and Operations Research, taking over for outgoing chair **Ken Goldberg.** Last year, he was also named an INFORMS fellow, an honor given to researchers who exemplify outstanding lifetime achievement.

Adnan Shihab-Eldin (B.S.'65 EECS, M.S.'67, Ph.D.'70 NE) was awarded the Elise and Walter A. Haas International Award, in honor of his "enduring passion to build up the modern higher education and scientific research system for Kuwait and the Arab world." He is currently director general of the Kuwait Foundation for the Advancement of Sciences.

Manu Sridharan (Ph.D.'07 CS) joined the faculty at UC Riverside as a tenured associate professor in the Department of Computer Science and Engineering.

Eric Steen (Ph.D.'10 BioE) won the Berkeley Chamber of Commerce's Visionary of the Year award for 2018. He is the CEO and co-founder of Lygos Biotech, which produces bio-advantaged chemicals using a low-cost microbial fermentation technology.

Ken Thompson (B.S.'65, M.S.'66 EECS) has been inducted into the National Inventors Hall of Fame, in recognition of his work as the co-creator of the UNIX operating system with Dennis Ritchie.

Allen Tsai (B.S.'00 EECS) is the founder of Pani, a smart-home company that builds products to help consumers and utilities measure, monitor and recycle water. Prior to Pani, he co-founded Azul Mobile and Ekata Systems.

Nuclear engineering professor **Jasmina Vujic** has been elected to the highest rank of fellow within the American Nuclear Society in recognition of her contributions to the advancement of nuclear science and technology.

Eicke Weber, professor emeritus of materials science and engineering, has been awarded Solar Future Today's Lifetime Achievement Award in recognition of his work in solar energy research.

Junqiao Wu, professor of materials science and engineering, was named an American Physical Society fellow for his pioneering research in semiconductor technologies.

Industrial engineering and operations research professor **Candace Yano** was awarded the INFORMS George E. Kimball Medal in recognition of her distinguished service to the institute as well as the operations research and management profession.

Tarek Zohdi, professor of mechanical engineering, has launched the Fire Research Group to explore effective engineering solutions for uncontrolled wildfires. The group is a collective of researchers from Berkeley Engineering, the Space Sciences Laboratory and Lawrence Berkeley National Laboratory.

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Mihran Agbabian (Ph.D.'51 CE) died in February at the age of 96. At Berkeley, he was the first doctoral student in the structural engineering program. After earning his degree, he worked as a structural engineer, starting his own consulting company, Agbabian Associates. He later became a professor at the University of Southern California, serving as chair of the civil engineering department and director of the environmental engineering program. In 1991, he became the founding president of the American University of Armenia in Yerevan. A member of the National Academy of Engineering, he received many honors for his work, including the Berkeley Distinguished Engineering Alumnus Award, Ellis Island Medal of Honor and the Movses Khorenatsi Medal from the Republic of Armenia.

G.D. Agrawal (M.S.'65, Ph.D.'66 CE) died in October at the age of 86. A prominent environmental activist in India, he began his career as an environmental engineering professor at the Indian Institute of Technology at Kanpur. He also served on India's Central Pollution Control Board and was co-founder of Envirotech Instruments, which developed devices for monitoring air pollution. He later became a staunch advocate for the Ganges River, working tirelessly to protect and revive the famous waterway.

Gale Dougherty (B.S.'40 CE) died in August at the age of 100. He served as a major in the U.S. Army during World War II, then received his master's degree in hydraulics and structures from the University of Iowa. For 30 years, he was a hydraulics engineer for Southern Company Services, where he managed hydroelectric projects throughout the southern United States. A fellow of the American Society of Civil Engineers, he was a leader in developing performance standards for hydraulic turbines.

Hormozd Gahvari (M.S.'06 CS) died in October at the age of 34. In 2014, he earned his doctorate in computer science at the University of Illinois at Urbana-Champaign. He then joined the Center for Applied Scientific Computing at Lawrence Livermore National Laboratory as a postdoctoral fellow.

Ralph "Gary" Gray (B.S.'53 CE) died in May 2018 at the age of 88. Following graduation, he served in the U.S. Army as a specialty orthopedic technician, creating prosthetics for wounded soldiers. He received a master's degree in civil engineering from MIT, then worked as an engineer and architect in the Bay Area. He also taught engineering seminars, worked as an expert witness and served on committees revising seismic building codes.

Russell Ludwig (B.S.'41, M.S.'42 CE) died in August at the age of 98. During World War II, he worked at North American Aviation and served in the U.S. Public Health Service. He started his career as a sanitary engineer, designing sewer facilities in California, before becoming president of ES International, where he managed engineering projects around the world. He eventually established his own firm, Encibra, in Brazil, and served as a consultant for numerous global health projects.

William Shaw (B.S.'48 CE) died in January at the age of 92. He worked for the California Department of Water Resources for many years before earning his master's in public administration from Harvard University. He went on to have an engineering career that spanned the globe, working in Pakistan, Panama, Iran and Indonesia.

Forrest Smith (B.S.'42 CE) died in January at the age of 98. Following his graduation from Berkeley, he volunteered for the military and served as an officer in the 20th Air Force in the South Pacific during World War II. After the war, he started at Chevron, where he held managerial roles both here and abroad. He later became the executive vice president of Clean Bay Inc., an industry-wide organization formed to clean up oil spills, where he received numerous commendations for his work.

Jack Wing (B.S.'51, M.S.'60, Ph.D.'63 EE) died in September at the age of 89. After earning his bachelor's degree, he worked for Boeing and Bendix, including an assignment with MIT Lincoln Laboratory. He returned to Berkeley for graduate studies, and after receiving his doctorate, he launched his career with TRW, retiring as project manager after 30 years with the company.

Bart Nagel

ADAM LAU PHOTO

The Cal Rover Team tests their "Mars Rover" on Memorial Glade.

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