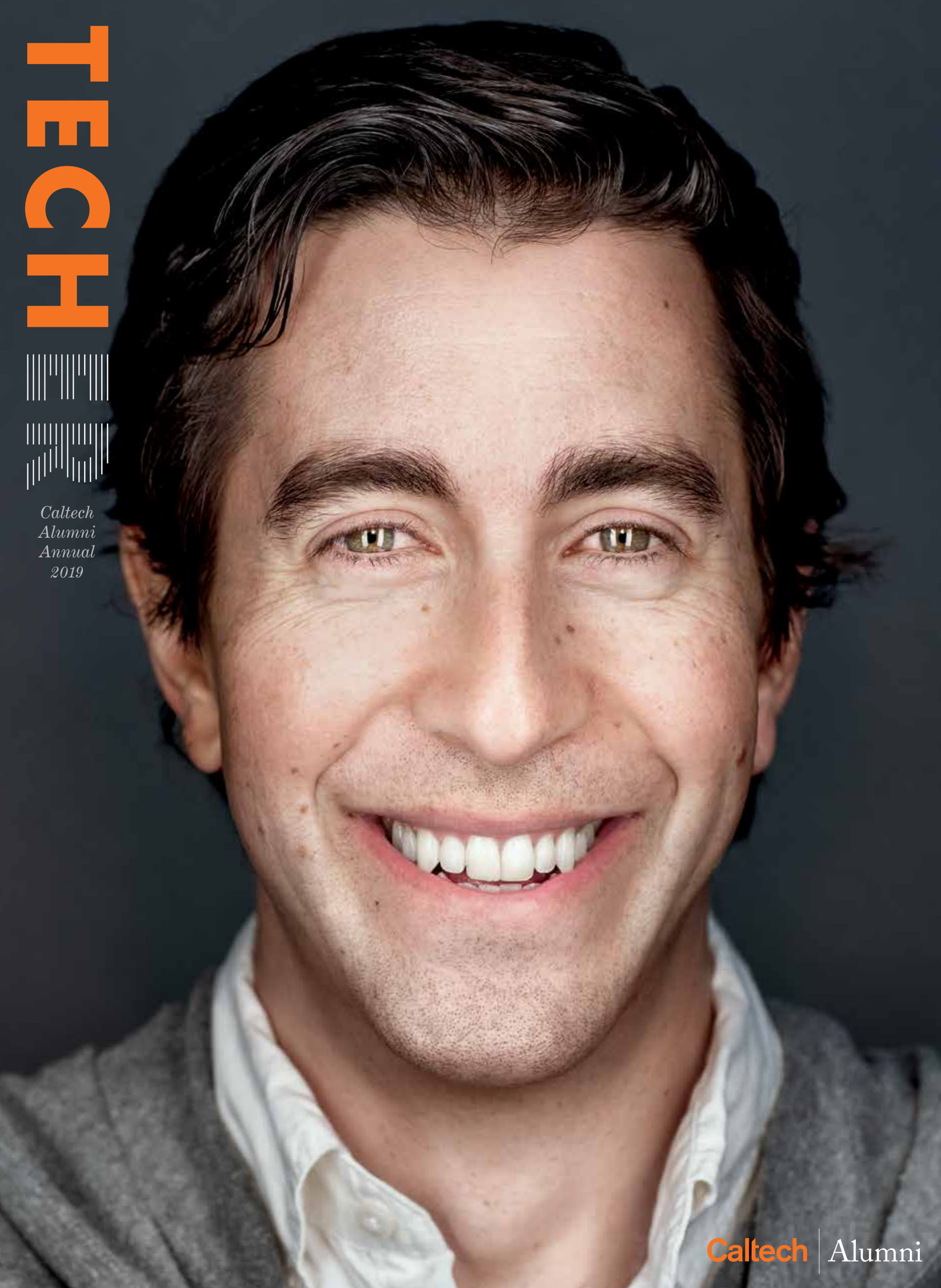
TECH

Caltech Alumni Annual 2019



Caltech | Alumni

2019

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From top: Courtesy of Katie Mack; Eric Millette

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is the editor of *Santa Clara Magazine.* His writing has appeared in *Orion*, *The Believer*, and *The Christian Science Monitor*, on KQED FM, and elsewhere. He occasionally serves as an election observer in the former Soviet Union and was once a three-time champion on *Jeopardy!* The stories he had the chance to cover here are filled with childhood wonder and cautionary tales: stars, water, and the future of A.I.

ERIN PETERSON

is an alumni magazine writer based in Minneapolis who has written for more than 50 universities, including Georgia Tech, Harvard, Cornell, and Princeton. She particularly enjoys talking to Caltech alumni because they tackle the planet's hard problems with tenacity and optimism, and they wouldn't dream of doing anything else.

APRIL WHITE

is an award-winning writer, editor, and researcher who focuses on history and food. She is a senior editor at *Smithsonian Magazine* and the author of "The Divorce Colony: The Strange Tale of the Socialites Who Shaped Modern Marriage on the American Frontier" for *Atavist Magazine*. She has also written and co-written a shelf full of cookbooks, including her newest, *Lemonade with Zest*.

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is a commercial and fine art photographer. He's an all-around shooter with a very personal take on portraiture, documentary and architectural photography, product design, and travel assignments. Mario's personal style is to create evocative images that demonstrate his love of storytelling and convey a deep connection to people and their environments.

ON THE COVER
JEFFREY MARLOW (PhD '16) searches for extreme life on Earth, looking for the limits of the biosphere to find out "what life is really capable of." See p. 36.
PHOTO BY SCOTT NOBLES

TECHER
Caltech Alumni Annual
2019

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TRANSMISSION

From the President of the Caltech Alumni Association

THE SHAPE OF THINGS TO COME

Panta rhei was Heraclitus' famous assertion that all things change, or "life is in flux." The only constant in life is change, and all things in life arise from one change and vanish into another.

This is especially poignant to me because I have seen that Techers the world over are agents of change. This year, we at the Caltech Alumni Association (CAA) are proud to announce changes that have begun close to home: our members have overwhelmingly voted to grant membership to all alumni without dues. With this move, we aim to be a catalyst for change in strengthening the relationship between Caltech and alumni around the world.

This magazine is one way we share and celebrate the changes that Techers influence and the impacts of those changes, big or small, global or local. In this issue, you'll learn how **Harold McGee** started a culinary revolution, get advice from **Fei-Fei Li** on building A.I. for the public good, and see how **Adrian Hightower** is taking on the water crisis at home and abroad. We're proud to share stories about Techers who are transforming our world. Hear from **Katie Mack** about the importance of keeping the stars within reach, follow **Kevin Noertker** as his electric plane prepares to take its first flight, and share your thoughts on what innovations will define the next generation.

As part of your own process of constant change, we invite and encourage you to participate in alumni events in person and online. There are more opportunities than ever to engage. Join us for Reunion Weekend and our 82nd Annual Seminar Day the third weekend in May, or sign up to attend one of our career webinars. Plus, we consistently launch new programs: the Caltech Alumni Advisors Network and Dinner with Techers are a couple of examples. Come out or log on, and catalyze someone else's impact or meet someone who catalyzes yours.

I look forward to seeing you in person and online in the coming year. Join me in helping to create the change in the world we want to see. I know that as Techers we are uniquely positioned with the skills, experiences, and talents to do so.

Yours in constant flux,

Chris Bryant (BS '95)

CHRIS BRYANT (BS '95)
President, Caltech Alumni Association

The story does not end here, however.
We invite you to grow your involvement with fellow alumni, personally and professionally. Join us at a regional event, seek out or offer career advice on the Caltech Alumni Advisors Network, or host a small dinner for students near campus—the ways to connect are limitless. Together, we can continue to build a stronger Caltech Alumni Association.

TO GET INVOLVED, GO TO: **ALUMNI.CALTECH.EDU**

Right: Bob Paz

SAVE THE DATE

Reunion Weekend
MAY 16–19, 2019

Celebrating classes ending in 4s and 9s
alumni.caltech.edu/reunion

Seminar Day
MAY 18, 2019

Come back to campus to learn about Caltech's latest groundbreaking discoveries
alumni.caltech.edu/seminarday

CAMPUS HIGHLIGHTS

JANUARY

FEBRUARY

MARCH

APRIL

MAY

JUNE

JULY

AUGUST

SEPTEMBER

OCTOBER

NOVEMBER

DECEMBER

[FEBRUARY 19]
CHEMISTRY PROFESSOR HARRY GRAY RECEIVES FEYNMAN TEACHING PRIZE
Harry Gray, the Arnold O. Beckman Professor of Chemistry, was awarded Caltech's Richard P. Feynman Prize for Excellence in Teaching in honor of his six-decade career at the Institute. Celebrated for his combination of thoughtful instruction and enthusiastic entertainment, Gray even lectured in a horse costume to keep his class engaged. Gray also created the "Solar Army," an outreach program through which hundreds of high school students meet weekly with Caltech grad students and postdoc mentors to search for new catalytic materials that might help make the production of solar fuels from sunlight more efficient and affordable.

[JUNE 7]
CURIOSITY ROVER FINDS ORGANIC MOLECULES ON MARS
NASA's Curiosity rover, built at the Jet Propulsion Laboratory, found new evidence—"tough" organic molecules in 3-billion-year-old sedimentary rocks near the surface and seasonal variations in the levels of methane in the atmosphere—suggesting that the planet could have supported ancient life. "With these new findings, Mars is telling us to stay the course and keep searching for evidence of life," said Thomas Zurbuchen, associate administrator for the Science Mission Directorate at NASA Headquarters.

[AUGUST 23]
CALTECH RESEARCHER HELPS SOLVE DECADES-OLD MATH PROBLEM
Spiros Michalakis, manager of outreach and staff researcher at Caltech's Institute for Quantum Information and Matter (IQIM), and Matthew Hastings, a researcher at Microsoft, solved one of the world's most challenging open problems in the field of mathematical physics. The problem, related to the "quantum Hall effect," was first proposed in 1999 as one of 13 significant unsolved problems to be included on a list maintained by Michael Aizenman, former president of the International Association of Mathematical Physics. "I hope that the solution to this problem will invigorate interest in the field of mathematical physics," Michalakis said. "As is often the case with proofs of significant problems in math, the solution leads to new ideas and techniques that open the doors to resolving several other important questions."

[JUNE 15]
"We need science more now than ever before. You must help fight for the soul, not just of our nation, but the soul of the planet."

–US Congressman and civil rights leader John Lewis speaking at Caltech's 124th Annual Commencement

[APRIL 30]
CALTECH GRAD RECEIVES FULBRIGHT FELLOWSHIP
Roohi Dalal (BS '18) received a Fulbright Fellowship to travel to the Netherlands and study what the distribution of galaxies in space can tell us about fundamental properties of the universe. "I really like applying mathematical methods to these big, fundamental questions we're trying to answer," Dalal said. "I think everyone wants to know where and how the universe started."

[SEPTEMBER 17]
BECHTEL RESIDENCE OPENS
The new Bechtel Residence, named for Caltech life trustee Stephen D. Bechtel Jr., is the first new undergraduate housing facility to open on campus in more than two decades. With the opening of Bechtel, Caltech is able to house all undergraduates on campus for the first time. The multiuse, multigenerational residence accommodates over 200 undergraduate students from all classes and was so popular that all available spaces were filled through a lottery system. With a mix of single rooms and suites, Bechtel provides students greater flexibility in shaping their residential experiences.

[MAY 8]
PROFESSOR AND CHAIR WINS ROYAL SOCIETY OF CHEMISTRY PRIZE
Jacqueline Barton, the John G. Kirkwood and Arthur A. Noyes Professor of Chemistry and the Norman Davidson Leadership Chair of the Division of Chemistry and Chemical Engineering at Caltech, was awarded the Royal Society of Chemistry's prestigious Centenary Prize for 2018, which is given to "outstanding chemists, who are also exceptional communicators, from overseas."

[NOVEMBER 15]
CHANG PRIZE AWARDED TO SEAN MCKENNA AND KYLE LAKATOS
The inaugural **Milton (PhD '69)** and Rosalind Chang Career Exploration Prize was awarded to **Sean McKenna (BS '17)** to explore how to tackle California's housing crisis, and to **Kyle Lakatos (MS '14)** to incorporate early childhood development services into community centers. The Chang Prize provides funding for recent Caltech graduates to fearlessly explore new career paths through innovative projects that have meaningful societal impact.

From top left: Caltech; Caltech, Caltech; Verity Smith; Caltech; NASA/GSFC; Caltech; Caltech; Bob Paz; Caltech (2); Rustam Hasanov

[MARCH 8]
RIVETERS WIN ME72 TANK WARS ON INTERNATIONAL WOMEN'S DAY
The annual Mechanical Engineering 72 (ME72) competition pitted undergraduates against each other in an epic series of robot battles dubbed "Tank Wars." Women outnumbered men in the competition for the first time in its 33-year history, and the Riveters, the only all-woman team, took home the coveted trophy without losing a single battle.

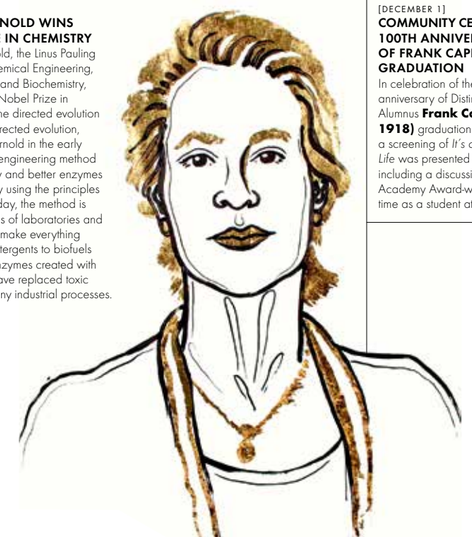
[OCTOBER 4]
DORIS TSAO AND SARAH STEWART BECOME MACARTHUR FELLOWS
The John D. and Catherine T. MacArthur Foundation selected two Caltech alumni as 2018 MacArthur Fellows. **Doris Tsao (BS '96)**, professor of biology, T&C Chen Center for Systems Neuroscience leadership chair and director, and Howard Hughes Medical Institute investigator; and **Sarah Stewart (PhD '02)**, planetary scientist and professor at the University of California, Davis, are the latest Caltech alumni to receive the so-called "Genius Grant." Tsao is recognized for uncovering the fundamental neural principles of primate vision, and Stewart is recognized for advancing new theories of how celestial collisions create planets and their natural satellites.

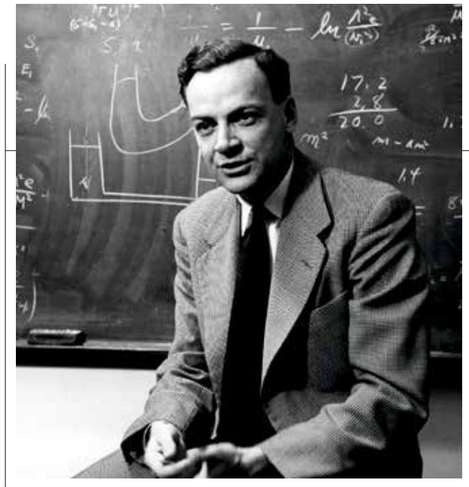
From top left: Caltech; Joy Manriti /Pexels CC0; Caltech Archives; John D. & Catherine T. MacArthur Foundation (2); Caltech; Connor Scothoo; Pixabay/CC0; Ill. Niklas Elmehed © Nobel Media; Caltech Archives

[APRIL 16]
RESNICK INSTITUTE HOSTS CLIMATE SCHOOL
To increase the understanding of climate science and mark the start of Earth Week, Caltech hosted a two-day series of lectures about climate and climate change in collaboration with the Resnick Sustainability Institute and the Ronald and Maxine Linde Center for Global Environmental Science. This first event of its kind drew students, staff, and faculty, as well as alumni and Caltech Associates, to the Beckman Institute Auditorium, where lecturers offered primers on the underlying science and mechanisms that drive climate change.

[MAY 17]
ALUMNI RETURN TO CAMPUS FOR REUNION WEEKEND AND SEMINAR DAY
The Caltech Alumni Association welcomed over 1,350 alumni and friends back to campus for four days of festivities during the 2018 Reunion Weekend and 81st Annual Seminar Day. Alumni relived their Caltech intellectual experience through lectures by Caltech professors and scientists, reconnected with their fellow Techers, shared memories, and discovered what has changed–and what hasn't–since their time on campus.

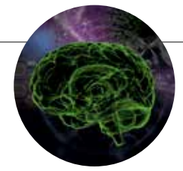
[OCTOBER 3]
FRANCES ARNOLD WINS NOBEL PRIZE IN CHEMISTRY
Frances H. Arnold, the Linus Pauling Professor of Chemical Engineering, Bioengineering and Biochemistry, won the 2018 Nobel Prize in Chemistry for "the directed evolution of enzymes." Directed evolution, pioneered by Arnold in the early 1990s, is a bioengineering method for creating new and better enzymes in the laboratory using the principles of evolution. Today, the method is used in hundreds of laboratories and companies that make everything from laundry detergents to biofuels to medicines. Enzymes created with the technique have replaced toxic chemicals in many industrial processes.





[MAY 24]
FRESHMEN SET CALTECH MEN'S TENNIS RECORDS AT NCAA CHAMPIONSHIPS
Caltech men's tennis freshmen Varun Shanker and James Wei rallied to claim a three-set victory and earn All-America status as the program's first representatives at the NCAA Championships in Claremont, California. In September, Shanker and Wei won the Intercollegiate Tennis Association West Regional Championship, making them the first pair of Caltech student-athletes to win an ITA regional tournament.

[MAY 11]
COMMUNITY CELEBRATES RICHARD FEYNMAN'S 100TH BIRTHDAY
On May 11, 2018, Richard Feynman—beloved Caltech physicist, Nobel Prize winner, and masterful storyteller—would have turned 100 years old. In celebration of the great physicist's 100th birthday, Caltech hosted a two-day event, May 11 and 12, featuring talks by top scientists around the world and Feynman's family and friends. Speakers included Feynman's sister, Joan, and daughter, Michelle, and Caltech scientists John P. Preskill and **Kip S. Thorne (BS '62)**.



[JUNE 28]
RESEARCHERS CREATE TOOL TO PREDICT INTELLIGENCE VIA BRAIN SCANS
Researchers from Caltech, Cedars-Sinai Medical Center, and the University of Salerno developed a machine-learning algorithm that can predict a person's intelligence from functional magnetic resonance imaging (fMRI) scans of their resting-state brain activity and blood flow. "We found if we just have people lie in the scanner and do nothing while we measure the pattern of activity in their brain, we can use the data to predict their intelligence," says **Ralph Adolphs (PhD '93)**, Bren Professor of Psychology, Neuroscience, and Biology, and Allen V. C. Davis and Lenabelle Davis Leadership Chair and director of the Caltech Brain Imaging Center.

[DECEMBER 1]
COMMUNITY CELEBRATES 100TH ANNIVERSARY OF FRANK CAPRA'S GRADUATION
In celebration of the 100th anniversary of Distinguished Alumnus **Frank Capra's (BS 1918)** graduation from Caltech, a screening of *It's a Wonderful Life* was presented on campus, including a discussion of the Academy Award-winning director's time as a student at Caltech.

PIONEERING

Touching the Sun

On August 12 at 3:31 a.m., NASA's Parker Solar Probe left Earth on a mission to touch the sun. **The probe is named for Caltech Distinguished Alumnus Eugene Parker (PhD '51)**, whose research revolutionized our understanding of the sun and interplanetary space. In the 1950s, Parker predicted the existence of supersonic solar wind, a flow of charged particles that stream off the sun, accelerating at supersonic speeds. "I'm proud of the fact that I thought of the solar wind," Parker said. "It was an exercise in pursuing curiosity, which is the main motivation for studying physics, from a personal standpoint."

The Parker Solar Probe will travel through the sun's atmosphere, closer to the surface than any spacecraft before it, providing humanity with the closest-ever observations of a star. It will touch the sun to study the source of solar wind, the sun's blistering corona—which, at several million degrees Celsius, is hotter than the surface of the sun itself. At the closest approach to the sun, the Parker Solar Probe will be the fastest spacecraft of all time, hurtling around the sun at speeds over 430,000 mph.

This is the first time NASA named a mission after a living person, and Parker was in Florida to watch the launch of his namesake spacecraft. Aboard the spacecraft is a memory card containing photos of Parker and his groundbreaking 1958 paper on solar wind. The card is inscribed with the following message from Parker: "Let's see what lies ahead."

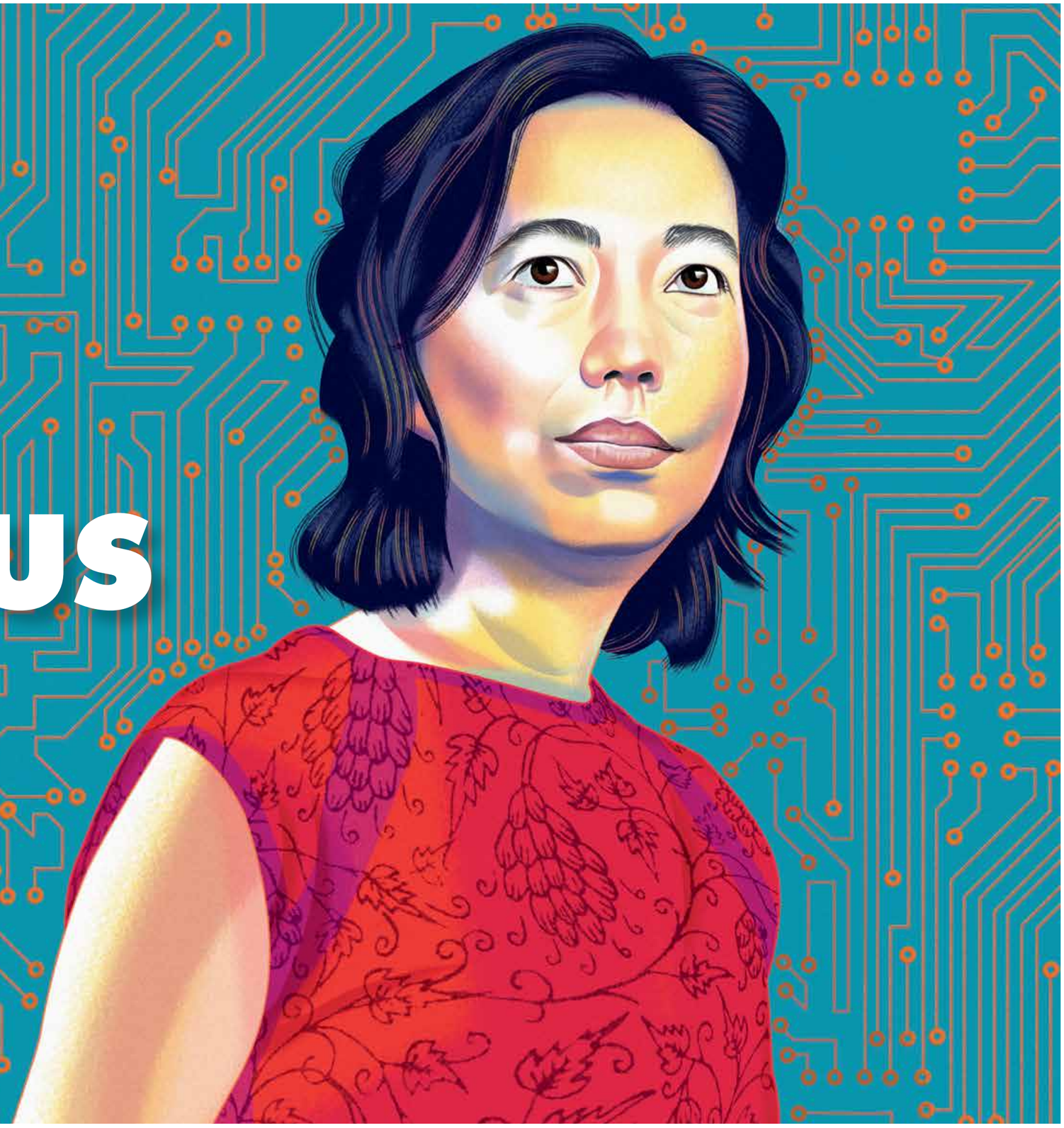
IMAGE: NASA/JOHNS HOPKINS APL/STEVE GRIBBEN

IT'S ON US

AS ARTIFICIAL INTELLIGENCE BECOMES MAINSTREAM, WHO WILL GUIDE IT?

AN INTERVIEW WITH FEI-FEI LI (PHD '05)
BY STEVEN BOYD SAUM

ILLUSTRATION BY NIGEL BUCHANAN



Artificial intelligence is a trending topic, but few have the bona fides of **Fei-Fei Li (PhD '05)**. The former A.I. leader and chief scientist for Google Cloud—where she oversaw research in A.I. and machine learning as well as led Google A.I.'s China Center—Li now directs the Stanford Artificial Intelligence Lab and co-directs the Stanford Vision and Learning Lab. Who better to answer our burning questions: Will A.I. replace our jobs? What else will it take over? And who will oversee its development—both technologically and ethically? Here she offers her thoughts on the world of A.I., its promising yet controversial future, and why empathy should play a major role in its design.

TECHER: You did a presentation at the Grace Hopper Celebration in 2017 wearing a T-shirt that read "A.I. will change the world. Who will change A.I.?" So, who *will* change A.I.?
FEI-FEI LI: As we see artificial intelligence impacting the real world, it's no longer a niche computer science, technical field. Policymakers, business leaders, educators, social scientists—they all need to take part and guide the future of A.I.

Also, as a technical field, A.I. thoroughly lacks diversity. It lacks women and underrepresented minorities. I'm the co-founder and chairperson of the nonprofit AI4ALL. We're committed to education. We're committed to diversity, especially starting with high school students. It's unthinkable that such an important technology that will influence humanity has such an imbalance in terms of the representation of people taking part.

A.I. doesn't belong to a niche group of people. A.I. doesn't belong to Silicon Valley. A.I. doesn't belong to tech giants or STEM or A.I. labs. A.I. belongs to everyone, and we want everyone to participate in changing it.

TECHER: You talk a lot about "human-centered A.I."—the idea that A.I. and humanity can co-exist peacefully. What does "human-centered A.I." mean from your perspective?
LI: Human-centered A.I. is made up of three major pillars that guide the thinking of the future of artificial intelligence. The first pillar revolves around human-inspired, next-generation A.I. technology. There's so much excitement about A.I., but it's a very recent field—only about 60 years old. It's actually still very narrow in terms of its capabilities. So we should continue to develop A.I. with inspiration from human intelligence, especially crossing fields like brain, cognitive, and behavioral sciences.

The second pillar is focused on a single word, "enhance"—as opposed to "replace." There's a lot of worry, and rightfully so, that automation is at odds with human jobs. And I think that's a really important topic. But I think the opportunity as a technology is that there's so much more we can do to use A.I. to *enhance* human capabilities, to augment them, to take humans out of harm's way, to make human productivity better and more efficient. Take healthcare, for example. I just spent months with my mother in a hospital after a major surgery. It was an interesting experience because I've been doing research in A.I. in healthcare for six years. And as a patient's family, it became real to me. Doctors, nurses, and clinicians need time to be with patients. Now we can aim assistive technology at that need. And we can use A.I. to take humans out of harm's way in rescue situations. We can use A.I. to enhance personalized education. We can use A.I. to make more fair and more efficient decisions.

And then the third pillar is what I call "A.I. social impact." It's critical that we recognize that all of human society will be impacted by this technology. That means we've got to get the social scientists, the economists, the legal scholars, the ethicists, the historians, the philosophers—all of them—to participate in understanding what kind of impact this technology will have, what kind of policy recommendations we should make, how we should guide this technology so it is not biased, and how we can protect privacy in the A.I. era. These issues cannot possibly be resolved by just technologists. It requires a societal dialogue and effort.

TECHER: How can we address some of those challenges in the design of A.I.?
LI: In the past few years, it's been recognized that machines are at risk of having biased results when the data input is not fair. And this could cause great harm and unfairness to people's lives. So machine-learning fairness is a major research area in academia. I know my colleagues at Stanford, at Princeton, and at Google are all working on this, and there are mathematical algorithmic approaches being explored. There's always policy recommendations that are being discussed.

As I age, I also realize how important empathy is. We're technologists, but we're humans first, and we should have empathy. And we should design our technology with that in mind.

TECHER: How do we ensure that there's earned public trust in the advances we're making in A.I.?
LI: A lot of effort has to be made. Machine-learning algorithms need to be fair, need to be transparent, need to be clearly explained and understood—the dialogue needs to continue. Google rolled out A.I. principles as a step toward that, but it's a multidimensional effort. Earning public trust in A.I. is not a one-time thing. It is continuous and long term—as in start now and never stop. And it needs to be in the minds of business leaders as much as the technologists themselves.

"Earning public trust in A.I. is not a one-time thing. It is continuous and long term—as in start now and never stop."

Courtesy of Google

TECHER: What are the problems you're working on now? And what are you hoping to tackle in the next 10, 15, 20 years?
LI: I'm particularly excited to look at the healthcare delivery process. I know A.I. and machine learning have started to make waves in big-data healthcare, such as radiology, medical imaging, and healthcare records. As a career vision scientist, I actually took a different perspective and looked at the care delivery in the physical space of healthcare, like hospitals, clinics, senior homes, ICUs, and so on. And once you look at that environment and all the human activity of clinician-to-patient care, there are two major issues. One is that healthcare delivery can be highly inefficient. A nurse in the ICU does more than 100 different tasks, and it's exhausting. Some of these tasks—charting, endless typing into a computer—takes time away from patient care. And this kind of inefficiency can be assisted by A.I. technology. Voice input, for example.

Another issue in healthcare is human error. Hospital-acquired infection alone kills more than 90,000 people every year in the United States—three times as many people killed by car accidents. And how do we monitor that process? How do we give feedback to our clinicians who should be practicing proper hand hygiene?

A.I. can be explored to create smart hospitals and smart senior homes. It's a very recent exploration, but my team has been at the forefront of this. We just published an opinion piece in the *New England Journal of Medicine* and are publishing machine learning and healthcare research papers on this topic. And there is just so much to be done in that area.

TECHER: Your work has been described as "democratizing A.I. and machine learning for everyone." How are you trying to achieve this?
LI: Mostly through my work at Google Cloud, where I continue to work as a consultant. Cloud is a huge computing platform that can deliver the power of computing services to billions of people, literally, through businesses. And we develop A.I. products that could be served through this Cloud platform.

Machine learning is still so new that very few developers in the business world know how to code it. So most of the solutions have been through APIs where you don't have to code, and you're just putting your input in and getting the result. For example, image recognition: You're putting an image into Google's vision API, and you get labels like "dogs" and "trees" and "cars." But there's a huge gap between generic labels like dogs and trees to specific brands of shoes or brands of houses or furniture. We've got a lot of wildlife preservation biologists, for example, wanting to just look at different animals, and they need what we call custom models. But they don't have the talent to code them. So lowering the bar for businesses to create these customer models is a huge step toward democratizing A.I.

TECHER: You've talked about the impact on businesses with this one product. What's the potential for how A.I. might alter our economy globally?
LI: A.I.-related services and products have had explosive growth. They're making billions of dollars and are projected to grow exponentially. Whether you're in e-commerce or healthcare or manufacturing or financial services or media entertainment or agriculture, you need to deliver better services and products to customers—and that process needs better data analytics, better decision-making, better personalization, better recommendations. All this will be using A.I. So every industry that shapes human lives will more or less be impacted by A.I.

TECHER: What are your hopes for the future of A.I.?
LI: It's so hard to ask a scientist to predict the future, but I want to see more innovations in A.I. in healthcare. I want to make sure that as A.I. reaches people's lives, that it is fair, transparent, and that it really makes a positive impact in healthcare delivery, in solving the challenges of our aging society, and in delivering healthcare to more people by making it more accessible.

"A.I. doesn't belong to a niche group of people. A.I. doesn't belong to Silicon Valley. A.I. doesn't belong to tech giants or STEM or A.I. labs. A.I. belongs to everyone, and we want everyone to participate in changing it."

On Astrophysics, Stardust, and Our (Teeny Tiny) Place in the Universe

***Katie Mack (BS '03)**, a theoretical astrophysicist at North Carolina State, studies some of the most complex topics in the cosmos—dark matter, galaxy formation, and the origins of the universe. But she is best known for her ability to bring those ideas back down to earth. Her ability to communicate complex science to the general public has made her an in-demand interview for radio, television, and podcasts, and she has written for* Scientific American, Slate, *Time.com*, Sky & Telescope, *and Australia's* Cosmos Magazine. *Here, Mack talks about the importance of keeping the stars within reach.*

BY KATIE MACK (BS '03)

AS TOLD TO STEVEN BOYD SAUM

Here is a thread I posted on Twitter one Friday night:

- *I feel the need to tell you a thing about being stardust.*
- *Yes, you are made of stars. Yes, you, in particular.*
- *Mostly.*
- *All that carbon, oxygen, nitrogen, etc.—that was all made in stars. Most of your body is made of that stuff: atoms that a star forged inside itself or at the moment of its unimaginably violent death.*
- *So, yes, you are stardust. But only if you count by mass. If you count the number of atoms in you, most of those?*
- *Hydrogen.*
- *Never part of a star at all.*
- *Most of your atoms have been in the universe for 13.8 billion years.*
- *Most of your atoms were forged in the Big Bang itself.*
- *I think it's cool that we are made of stars, that our planet and our bodies and everything we touch can only exist because of the nuclear alchemy in the hearts of stellar infernos.*
- *But I think it's MUCH cooler that most of our atoms have been in the cosmos all along.*
- *You are stardust. And you are the ashes of the Big Bang. And you are, at every imaginable level, a creation of the Universe, vast and beautiful and suffused with unbridled power.*

"It's mind-boggling just how much there is out there that we still need to know—everything that's being discovered, new ideas in science. There's so much I want to explore and study and calculate."

Courtesy of Katie Mack

When I was growing up, my mom was really into science fiction. I used to borrow her books and magazines. I was always excited about things like *Star Trek*, and I read *A Brief History of Time* and did a lot of reading about physics and astronomy. I was fascinated by big-picture questions: How does the universe begin? What are black holes? What is space-time?

I remember when I first started to think of the world as a planet—that we are a rock in space. It is not always something that you think about in your daily life. If you do, you get a feel for where you fit into the larger universe and the fragility of human life. The atmosphere is only about 100 miles thick. That's not much.

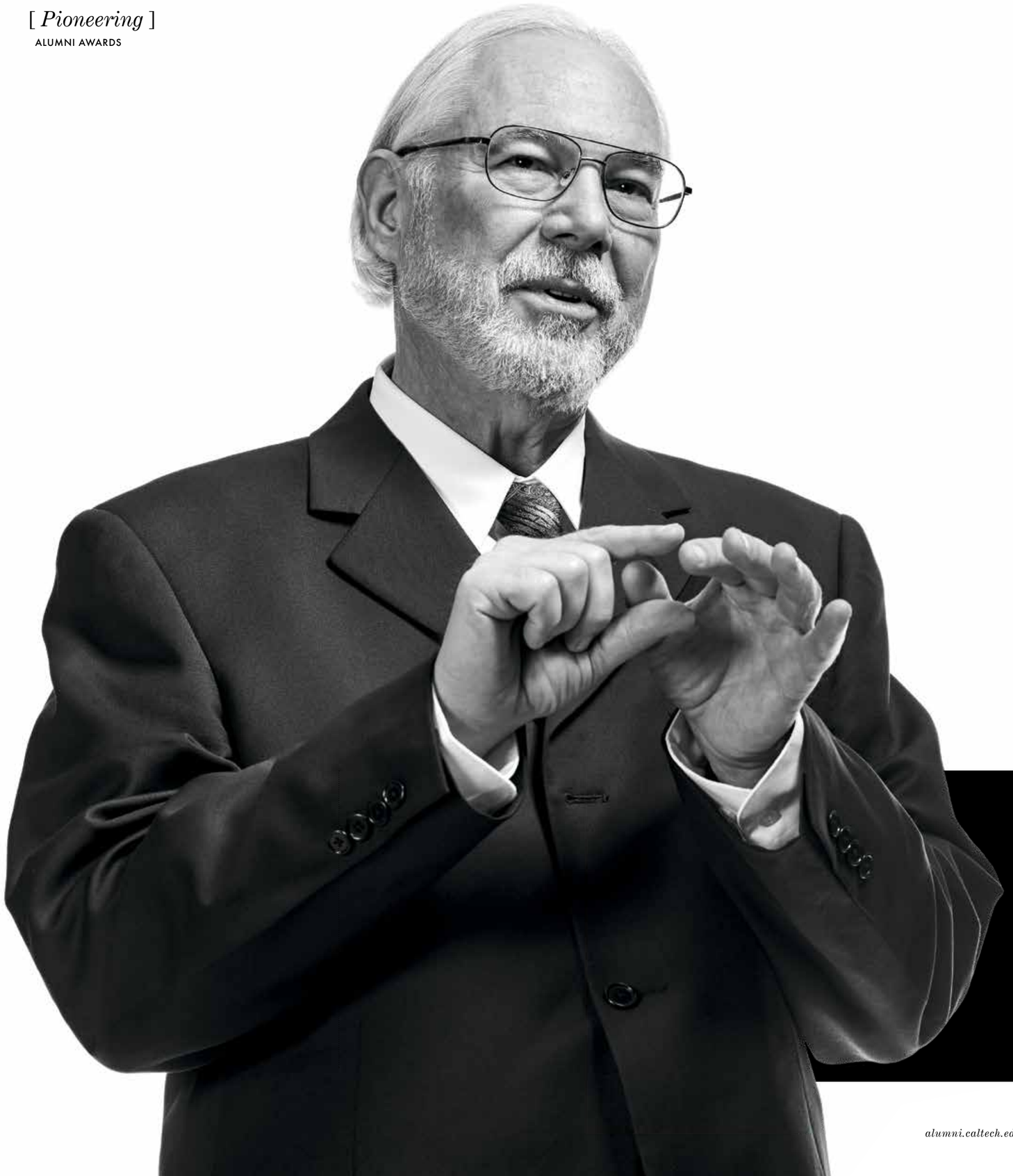
I like being able to help people see the universe in a different way—or understand physics concepts that they haven't thought about. You have a special kind of power when you understand something that was always opaque before. I like to help people find that power for themselves.

Take dark matter, for example. We don't know exactly what dark matter is made of. But, observationally, it's surprisingly simple: It's just matter—stuff that has mass—that happens to be invisible. When you talk about it like that, it doesn't sound as exotic. But then there's a lot of detail you can get into: how it's distributed in the universe, how we know it's there, how we're trying to figure out what it's made of. There are so many pieces of evidence for it, but we still don't know what it is. So the quest to figure it out is like solving a mystery.

Or take black holes. Why is it important that we understand black holes? For one, they're ubiquitous in the universe. There's a massive black hole in the center of every large galaxy. They're extreme objects, with properties that nothing else has. They change the behavior of space and time. So, more than just the end state of a star, foundational questions of physics are tied up in the way that black holes interact with space and time and information.

We use black holes to study gravity, to study how matter builds up in the universe. Hopefully, soon we'll be able to use other kinds of gravitational wave detectors to study how galaxies form, because we'll be able to catch larger black holes colliding. Even now, we're testing the parts of general relativity associated with gravity by watching the collision of black holes—sometimes a billion light years away.

It's mind-boggling just how much there is out there that we still need to know—everything that's being discovered, new ideas in science. There's so much I want to explore and study and calculate. I'm in the wonderful position that I get to pursue my curiosity. There's just too much interesting stuff in the world; that's my biggest problem.



THE 2018 DISTINGUISHED ALUMNI AWARDS

Caltech recognizes five of its graduates who highlight the breadth of fields in which the Institute's alumni have gone on to become leaders—ranging from physics and engineering to foreign policy and motion pictures.

First presented in 1966, the award recognizes a particular achievement of noteworthy value, a series of such achievements, or a career of noteworthy accomplishment.

PHOTOS BY MARIO DE LOPEZ

GARY DEMOS

(BS '71, ENGINEERING SCIENCE)

Image Essence LLC

For his pioneering achievement in the development of computer-generated imagery (CGI) for use in motion pictures and in digital film scanning and recording.

Gary Demos saw computers as a storytelling medium decades before anyone else. He realized computers could revolutionize the film industry and set out to make that happen by building the technology he needed along the way. His work was so far ahead of the field that at times there was not yet a commercial use, but he looked years ahead to what could be possible and waited for the world to catch up.

Of all places, Gary Demos became fascinated with the potential of digital films at Caltech. Visiting fellow John Whitney Sr. gave a presentation on the computer graphics he had made using an IBM computer. "He was using film in a way I had not seen before," says Demos. At a time when computers were almost universally thought of as engineering and science tools, Demos was seeing computers used as an artistic tool.

After leaving Caltech, Demos found himself at the forefront of a new field, where the tools needed to do the job right didn't exist—so he built them. He went on to become a pioneer in the development of CGI, now a central component of Hollywood films, for movies such as *Tron*, *Futureworld*, and the first entirely CGI movie, *The Last Starfighter*. He has been honored with scientific and engineering awards from the Academy of Motion Picture Arts and Sciences for his work on CGI and digital film scanning and recording. In 2006, he received the Gordon Sawyer Award, an Oscar awarded for a lifetime of technical achievement. Demos keeps his Academy Awards on his desk, "where I can stare at them when the coding gets tough."

—Liz Rauer

READ MORE ABOUT OUR DISTINGUISHED ALUMNI AT ALUMNI.CALTECH.EDU/DAA-2018

JESSICA MATHEWS

(PHD '73, BIOCHEMISTRY)

Distinguished Fellow, Carnegie Endowment for International Peace

For her contributions to shaping and advancing cooperation between nations on international policy in the areas of nuclear proliferation, human rights, global health, and the environment.

The Vietnam War was raging, and the country was reeling, but Caltech in the 1970s remained "a quiet oasis of scientific immersion," recalls Jessica Mathews. After spending a year working on the national political stage, Mathews had come to Caltech for a doctorate in biochemistry, studying development in cellular slime molds. For her, it was a time of thinking about very little else except science.

But as she finished her degree, Mathews knew she didn't want to spend her life sequestered in the lab. A new fellowship, the Congressional Science Fellows, had just been started by the American Association for the Advancement of Science and was opened for its first year of applicants. Mathews applied and was among six chosen to spend a year contributing to federal policymaking.

"When I got to Congress, there were 10,000 staffers on Capitol Hill. Ninety-eight percent of them were lawyers. The lawyers and I both spoke English, but only I spoke science. This is when I realized I had a second language."

Mathews has used that second language, that empirical approach to the world, throughout her career in science policy, tackling issues from global poverty to nuclear safety. Now, she urges scientists to speak their second language outside of the walls of their scientific institutions.

"We need to push back against this ugly idea that there's no difference between facts and opinions," she says. "This is not optional for those of us who care about the future of science."

—Lori Dajose

ARTHUR B. MCDONALD

(PHD '70, PHYSICS)

Professor Emeritus, Queens University

For his discovery of neutrino oscillations and demonstration that neutrinos have mass, both of which have changed our understanding of the building blocks of particle physics and of the cosmos as a whole. In 2015, McDonald was awarded the Nobel Prize in Physics.

In the deepest nickel mine in North America, Art McDonald and his team built an ultra-clean lab to search for some of the smallest and most elusive particles in the universe. Ten stories tall, two kilometers underground, and filled with heavy water, the Sudbury Neutrino Observatory (SNO) was designed to detect neutrinos—a subatomic particle with no charge and a mass so small it was an open question whether it had any mass at all.

SNO was built to detect these tiny particles, which are a fundamental building block of the universe. It has two ways to do it, one that is only sensitive to electron neutrinos, and one that records all neutrinos, regardless of their type. McDonald and his team set out to answer the question: "Is the number of electron neutrinos as produced in the sun the same as the total of all three types? … In point of fact, what we found is that there were only one-third of the total that had survived as electron neutrinos."

Like three decades of studies before it, SNO detected only one-third of the electron-type neutrinos predicted to come from the sun (the "solar neutrino problem"), but the total number of all types of neutrinos matched the theory. McDonald's conclusion, for which he was awarded a Nobel Prize with Takaaki Kajita, was that neutrinos must change types, or "flavors" as they travel from the sun through the earth (a phenomenon called neutrino oscillations) and, therefore, must also have a nonzero mass. The fact that these particles have a nonzero mass means that their influence on the evolution of the universe can now be taken into account.

McDonald and the SNO Collaboration set out to solve the solar neutrino problem and wound up changing the laws of physics as we knew them. His team's direct and precise observations showed the incompleteness of the Standard Model of physics and opened up a new frontier in particle physics.

— Liz Rauer

RONALD H. WILLENS

(BS '53 PHYSICS, MS '54 MECHANICAL ENGINEERING, PHD '61 ENGINEERING SCIENCE)

Retired

For his innovative and revolutionary contributions to advanced internet connectivity and telecommunications. He pioneered the Remote Authentication Dial-in User Service (RADIUS) as an access server authentication and accounting protocol, which was adapted by the Internet Engineering Task Force (IETF) standards.

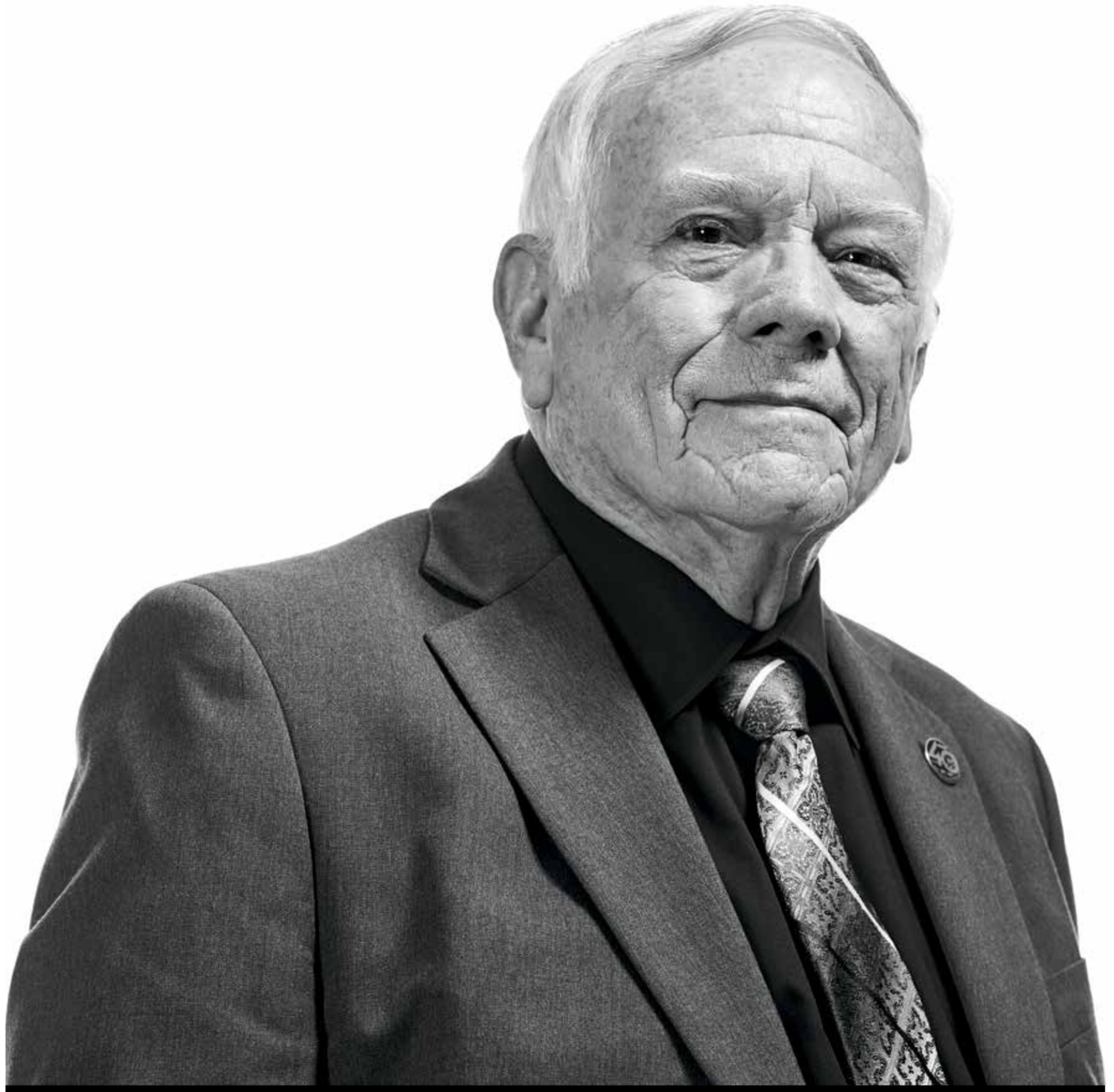
To Ronald Willens, "the golden rule of entrepreneurship is a combination of two major factors. One, a person that has a solution, and two, a person that has a need."

Willens became an entrepreneur later in life. Instead of retiring early from a successful career at Bell Labs when it was sold, Willens co-founded Livingston Enterprises with his son, Steven. He saw a need for companies to satisfy government regulations regarding hazardous chemicals and saw a solution, so he said to himself, "I'm going into computer software."

Solving one need after another, Livingston went on to become a global leader in systems that remotely and securely connect computers to large corporate networks and internet service providers. At Livingston's peak, just before it was acquired, the majority of the world was using either its hardware or software to access the internet. Livingston generated several internet standards we still use today. "Even on your home routers, there are things that we originally wrote."

Ronald Willens successfully transformed his career over and over again. At Caltech, he discovered metallic glass and became an associate professor of materials science. At Bell Labs, he excelled in the interdisciplinary research environment, building the world's strongest rare-earth magnet of the time. Now, Ronald and his wife, Joanne, are philanthropists, supporting cutting-edge innovations in medical technology. He said, "Caltech gave me the confidence that I could move from one area to another. I felt I could succeed in any of the fields that I moved into."

—Liz Rauer



GARY A. FLANDRO

(MS '60, PHD '67, AERONAUTICS)

Professor Emeritus, University of Tennessee Space Institute; Chief Engineer and Vice President, Gloyer-Taylor Laboratories

For his seminal contributions to the design and engineering of multi-outer-planet missions, including the Grand Tour, the course set for the epic explorations of the Voyager spacecraft.

In the 1960s, human space exploration began to transform from science-fiction dreams into reality. Yet, though Americans were quite literally shooting for the moon, there remained a realm of the solar system that simply seemed too impossible: the exotic outer planets, Jupiter, Saturn, Uranus, Neptune, and Pluto. To visit these worlds with spacecraft would simply take too much time—a trip to Neptune, for example, would require 50 years of flight.

In 1965, Gary Flandro was a Caltech graduate student working at JPL, trying to determine a way to use the gravity of the planets like a slingshot to boost a spacecraft's speed, which would enable it to explore farther. He discovered that, in the late 1970s, the outer planets would be aligned in a way that would permit a single spacecraft to encounter each in turn. Through many hundreds of trajectory calculations—done using a slide rule and simple computer programs—Flandro discovered a practical way to explore the outer solar system.

"On a wonderful day, I was in Building 180 at the JPL, and I finally discovered that you could do this," he says. "The best trajectory I found would get you all the way out to Neptune in about seven years. I said to myself, 'Boy, this ought to get everybody's attention.'"

And it did. The subsequent mission was dubbed the Grand Tour and remains to this day mankind's most far-reaching journey into space. It was also a true once-in-a-lifetime opportunity, for the planets would not align in the same way for another 175 years.

—Lori Dajose

TRANSFORMING

Transformative Instrumentation

Built close to the summit of Mauna Kea in Hawaii, the W.M. Keck Observatory—powered by twin 10-meter optical telescopes, the largest of their kind—is one of the most influential ground-based observatories operating today. It leads all others in scientific publications per telescope as well as in the impact of those publications in the field of astronomy. It has been essential in seeking answers to the most fundamental questions in science: How did the universe evolve? How old are the oldest stars in our galaxy? How do solar systems form? Where is the missing mass of the universe?

Carrying out this exciting science requires not only a telescope, but a suite of back-end instrumentation. Keck's near-infrared camera works with the Keck Adaptive Optics system in Laser Guide Star mode (pictured here) to produce the highest spatial resolution possible from ground-based images. The lasers improve the images produced by the telescope by helping to correct for atmospheric turbulence, removing the twinkle from the stars. Caltech engineers and scientists are currently involved in building the next-generation adaptive optics system for Keck, which will further improve image quality and continue to offer greater insight into some of the galaxy's greatest mysteries.

PHOTO: © ANDREW RICHARD HARA

THE SHAPE OF THINGS TO COME

Caltech alumni have never been content to try to peer into the future. They want to create it. These five alumni are doing just that. From better planes to blockchain, from impact investing to ethical labor, they're creating the engines that will transform our future.

BY ERIN PETERSON

ILLUSTRATIONS BY MARIO WAGNER

KOHL GILL WANTS A FACTORY RESET

The LaborVoices founder helps workers around the world find their strength in numbers.

Years ago, when Kohl Gill (BS '98) was working at the State Department on a science policy fellowship linked to labor rights and corporate social responsibility, he noticed something surprising. In the busy factories of South Asia and the Middle East, thousands of people who were working in sweatshop conditions owned technology that might just be able to dismantle these inhumane organizations: their cell phones.

"I wondered if I could create a Yelp-like system where workers could tell me what's going on in the factories," he says. Such transparency wouldn't just be a boon for the workers. It would also benefit companies that were committed to providing humane working conditions but couldn't oversee the work at every factory where their goods were produced.

In that moment, the idea that now propels LaborVoices was born.

Gill and his team first put out fliers and connected with workers as they walked out of factories in India at the end of their shifts.

Now, they've collected tens of thousands of phone numbers of these workers across 12 countries and surveyed workers regularly, gathering deep insight about working conditions at factories around the world. Over the years, they've learned about unsafe spaces, abysmal pay, and suspicious after-work shenanigans. "We've learned, for example, that one shift might be fine, but an unauthorized overnight shift might be like a sweatshop," Kohl says.

Today, multinational companies such as Adidas rely on LaborVoices to help them suss out what's really going on in the factories that produce their goods—which allows them to take swift action to fix problems or change suppliers as needed.

Gill, meanwhile, dreams of an even bigger impact where workers can expect good jobs at fair pay. "My vision is a world in which every worker can find a job that moves them up out of poverty and creates great products for all of us to enjoy," he says. "That holds a huge amount of value for everyone."

TAMMY MA BRINGS LASER FOCUS TO NUCLEAR FUSION

Her work at the National Ignition Facility may lead to clean and plentiful fusion energy.

In a world of imperfect energy production options—greenhouse gas-emitting fossil fuels and weather-dependent solar and wind power—nuclear fusion has long held unique promise. Unlike nuclear fission's occasionally dangerous atom splitting, fusion's atom-combining energy production offers a solution that is clean, safe, and limitless. The only problem? Scientists still have to crack its code. **Tammy Ma (BS '05)**, an experimental plasma physicist at the National Ignition Facility within the Lawrence Livermore National Laboratory, is a key member of the most powerful fusion code-breaking team on the planet.

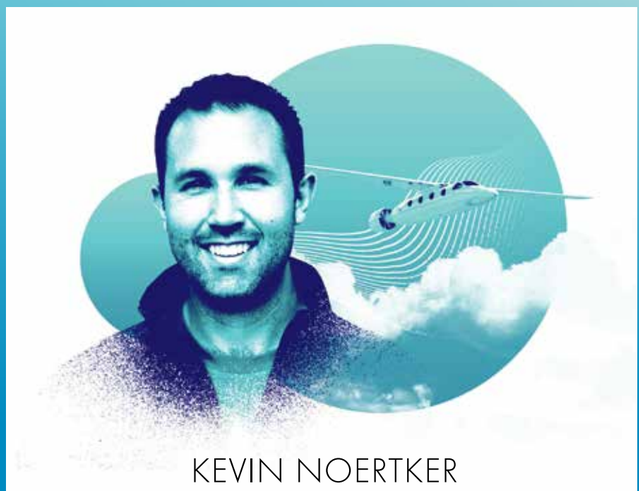
With the help of the largest laser in the world, Ma and a team of about 100 other physicists are working to create sun-like heat and fusion through a range of nuanced experiments. "There are about 10,000 different physics parameters that we can change from experiment to experiment," she says. "Our job is to figure out what experiments to do, do the computer simulations that pull in the data, check our models, and design the next experiment." Ma leads and executes many of these tests.

Ma is quick to credit the work of her team, but there's no question she's one of its shining stars. In addition to landing a prestigious Presidential Early Career Award for Scientists and Engineers, she is also a recipient of the Department of Energy Early Career Award, an honor accompanied by $2.5 million to support her research.

Even better, Ma and the team have seen tantalizing progress in recent months. Record-breaking experiments have doubled fusion energy output from experiments conducted just a few years earlier. Fusion power is quickly moving from the lab to real life.

Ma brings a scientist's caution to fusion-based predictions, but she is a decided optimist. "All energy technologies we've used have had about a 30-year cycle to adoption, but eventually it gets seeded into the grid. I am hopeful that it will happen during my lifetime."

"It's common in software startups not to try to build something perfect upfront. But with airplanes, you can't just deliver them and decide to iterate when you find out that they're falling out of the sky."



KEVIN NOERTKER HAS ELECTRIFYING AMBITION

Ampaire's co-founder wants to make the skies cleaner, quieter, and more affordable with fleets of electric airplanes.

Kevin Noertker (BS '09) had a plum job at aerospace contractor Northrop Grumman in late 2015 when a former colleague, Cory Combs, approached him with a big idea. Would he be interested in helping found a startup that would bring electric airplanes to market?

Noertker found the idea irresistible. "I always judge an opportunity based on three criteria," Noertker says. "Is it meaningful? Is it challenging? Is it visible?"

Combs' idea checked every box, and in 2016, Noertker, Combs, and Ryan Bilton founded Ampaire, a company that develops electric aircraft. It's a company that, if successful, could make an enormous impact. Compared to today's planes, electric aircraft would eliminate tailpipe emissions entirely while slashing fuel costs by 90 percent, maintenance costs by half, and noise by two-thirds.

To pursue their admittedly expensive dream, Noertker grabbed a dirt-cheap room rental (the other two moved back with their families), scrounged free office space for the team, and worked tirelessly to drum up interest and investment capital. They've assembled a top-notch on-the-ground team and fleet of advisors. And they've carefully built, tested, and improved on their ideas to electrify aircraft within the strict confines of the highly regulated airline industry. "It's common in software startups not to try to build something perfect upfront," he says. "But with airplanes, you can't just deliver them and decide to iterate when you find out that they're falling out of the sky."

Their smart and thoughtful work is paying off. Ampaire's first electroprop plane is being retrofitted now, will be flying soon, and is on track for certification in 2020. The company is backed by Techstars, and Ampaire is also a portfolio company of the Los Angeles Cleantech Incubator. Last fall, Ampaire was named the top aerospace startup at the Hello Tomorrow Global Summit, an event that attracted more than 3,000 entries.

While Noertker is pleased by the accolades, he has a far larger vision in his sights. He wants to use technology to create a cleaner way to connect the world.

SERENA GUARNASCHELLI WON'T GRANT YOUR WISH

When grant funding fails to solve big problems in the developing world, the KOIS Invest partner finds new ways to provide organizations with the money they need to make progress.

Over the course of her life, **Serena Guarnaschelli (PhD '03)** has worked in refugee camps and at high-profile consulting companies, rubbed shoulders with people at the highest levels of traditional philanthropy, and buried her nose in books to earn a doctorate in behavioral finance. What she discovered was a giant funding problem that was ready to be solved. In many places, particularly in the developing world, annual grants support the work of organizations seeking to improve lives. The big mission of grant-funded organizations could be anything: treating tuberculosis, helping rehabilitate people who have lost limbs in conflict, or teaching farmers how to grow the most valuable crops on their land.

Yet grant funding often has counterproductive incentives. The annual funding makes it difficult for organizations to make long-term investments. And it may also create a cycle of dependency on grant funding, without addressing the long-term financial sustainability of the programs. While grant funding is useful to many organizations, it isn't always the best solution. "There isn't one financial instrument that is the best solution for everything," Guarnaschelli says. "The solution looks more like a menu of different options."

Guarnaschelli saw opportunity in impact investing, an exciting and fast-growing market in the financial industry. The big idea? Invest in ways that don't just have a financial return, but a measurable social or environmental impact. The concept helps connect investors with organizations that are doing good work, using both traditional as well as innovative funding structures to help them think bigger and serve more people more effectively.

As a partner at KOIS Invest, Guarnaschelli spearheads projects that allow investors to finance innovative social solutions in markets or sectors that would otherwise not be considered investable, such as physical rehabilitation in Africa or smallholder farmers in Southeast Asia. The upfront funding may allow organizations to make long-term investments and hire and train new staff, as well as test and implement efficiency initiatives. That initial investment can lead to lower ongoing costs, better products and services, and more sustainable business practices.

Grant funding, Guarnaschelli says, will always have its place. But providing organizations in developing countries with access to investment capital to tackle complex problems has significant benefits. "To me, this opens up a world of possibilities," says Guarnaschelli. "By deploying private capital, we can help organizations become sustainable."

VIRGIL GRIFFITH BETS BIG ON BLOCKCHAIN

The Ethereum research scientist and manager says those who see Ethereum as nothing more than cryptocurrency are thinking too small.

Long before Bitcoin's grand entrance into the popular culture lexicon, **Virgil Griffith (PhD '14)** was fascinated by cryptocurrency. As a graduate student in computation and neural systems at Caltech, Griffith read a captivating article by Vitalik Buterin in *Bitcoin Magazine* and emailed Buterin praising his ideas. Buterin noticed Griffith's Caltech address and asked if he might crash on Griffith's couch for a while when he was in California later that month.

At the time, Buterin had not yet made his name as the founder of blockchain platform Ethereum—he was just an eccentric 18-year-old tinkering with ideas. With some bemusement, Griffith agreed to host Buterin. After he arrived, the pair often spoke late into the night about the potential of blockchain technology.

Buterin later went on to co-found Ethereum—a distributed computing platform that makes it possible to use "smart contracts," which are essentially self-executing agreements. Ethereum is also the company behind the cryptocurrency known as Ether. (It shares similarities with Bitcoin but has additional features as well.)

As Vitalik worked to get Ethereum off the ground, Griffith knew he could help Buterin articulate the big ideas that propelled the platform. Griffith came into the organization as a research scientist writing journal articles and has since moved into management at the company.

For now, Ethereum is used primarily as a way to send money securely worldwide without a financial institution serving to facilitate the transaction and take a cut. But because of Ethereum's smart contracts feature, Griffith sees far larger potential. For example, Ethereum could be used for parametric insurance—when insurance payments are made not by an assessment of damage but by a triggering event. If winds in a Puerto Rican hurricane reached 100 miles an hour, for example, that might trigger an automatic and immediate payout to a homeowner, no claims adjuster needed.

Griffith also sees Ethereum as a way to expand financial opportunity—particularly to "unbank the banked." "Everyone loathes their bank," he says. "We are creating a future where even the banked have access to quick and cheap financial services. We're going to take away the financial chains faced by 'banked' people across the world."

Corporations Could Be the Best Weapon in Combating Climate Change

BY NICOLA PEILL-MOELTER (PHD '97),
DIRECTOR OF SUSTAINABILITY INNOVATION AT VMWARE
ILLUSTRATION BY EDMON DE HARO

There is this popular, long-held notion that business and the environment are at odds. That conservation is a fight against capitalism and its rabid thirst for profits is at the expense of the environment. That commerce is an unstoppable force that must be reined in for the sake of the future of the planet.

As a lifelong environmentalist, I get that.

I grew up in a small, rural village, 100 miles northwest of New York City—close to but really a world away from the urban environment. I was raised in an environmentally conscious household, appreciating my natural surroundings, conserving water and energy, and recycling and composting long before those practices were commonplace.

Those values stayed with me. After getting a chemical engineering degree and taking a job in the field, I decided to merge my passion for the environment with my profession. I headed to Caltech to earn a doctorate in environmental engineering science, wanting to address the world's most pressing challenges by getting ahead of them, rather than fixing the damage after it was done.

While at Caltech, I first came across the Rocky Mountain Institute, an energy and sustainability think tank. They had a unique thesis that was compelling to me: The path to wider and accelerated environmental change, they hypothesized, was finding the intersection of profit and sustainability—where solving our most pressing environmental problems also makes business sense.

In my previous role as the sustainability director at the cloud delivery platform Akamai Technologies, I worked to put this thesis into action. Akamai's network is supported by hundreds of thousands of servers in over 150 countries, and we've saved tens of millions of dollars engineering ways to operate this network more efficiently. But finding the business case to decarbonize Akamai's energy use was not so straightforward. My pitch to the executive team and the board: Clean-powered services is a feature that our customers value and will give Akamai a competitive differentiator. My proof was that over the past 10 years, there was a strong trend of large, global companies setting aggressive renewable energy and carbon emissions reduction goals to stabilize their energy costs and address climate change. And many of those companies were our customers, collectively accounting for a quarter of our annual revenue. Our executives and board, while not versed in sustainability or renewable energy, understood "customer demand," "service feature," and "competitive differentiation." Convinced of the value, they supported a goal to power 50 percent of our global network with renewable energy by 2020.

That's the lesson: There's no business case for the *concept* of sustainability. But when sustainability goals align with business values and objectives, it can boost both environmental progress and the bottom line.

The smartest companies are using sustainability to inspire innovation. Nike recycles plastic to make its Flyknit footwear. P&G formulated the first enzymatic detergent that works in cold water—an attempt to eliminate the need for consumers to heat their wash water. The plant-based burgers of Impossible Foods and Beyond Meat aim to dramatically reduce the environmental impacts of animal-based foods. Tesla, with its focus on style, quality, and swagger, exploded the global market for electric vehicles that had previously been relegated to a fringe market. Companies that recognize the opportunity presented by our most urgent environmental challenges, and design solutions to address them, will outperform those that don't.

And if companies themselves don't see and seize the opportunity, investors are taking note of companies' risk exposures to the impacts of climate change. The increasing frequency and intensity of storms, floods, and fires are damaging infrastructure and disrupting supply chains. Longer and more severe droughts, shrinking aquifers, and degraded soils threaten all of agribusiness. And as the world weans itself off fossil fuels, transitioning to renewable energy and electric vehicles, oil and gas industries are in danger. Investors want to see that companies are aware of and resilient in the face of these risks and will look to invest in those that are.

"This shift in the corporate sector gives me hope. Now that the capitalist system is sufficiently motivated to address climate change, it can become a powerful force to accelerate progress."

This shift in the corporate sector gives me hope. Now that the capitalist system is sufficiently motivated to address climate change, it can become a powerful force to accelerate progress.

Don't get me wrong though. We have a daunting challenge in front of us, and it will take *everyone*—corporations, governments, and individuals—to make real progress. So I like to share my learnings with local communities. And while I'm practical about the challenges we face with climate change, I don't focus on the scary consequences, which understandably cause people to feel hopeless and tune out. I paint a vision of an amazing future that they can help create by taking action. Use your voice and vote with your dollar, buying from companies that are actively trying to reduce their carbon emissions; eating less meat; investing in renewable energy and electric vehicles; meeting with your legislators about enacting smart policy; and joining a grassroots organization.

The return on investment for our collective action will be priceless.

Courtesy of Nicola Peill-Moelter

What Innovation Will Define the Next Generation?

Techers share their thoughts on the ideas and inventions that will shape our world over the coming decades.

ILLUSTRATION BY JUDE BUFFUM

+ WHAT INNOVATION DO YOU THINK WILL DEFINE THE NEXT GENERATION?
Share your thoughts on the subject at **techer.caltech.edu/innovation**

Energy Harvesting
Technology for large-scale energy harvesting, such as harvesting the mechanical energy from ocean waves, road traffic movement, flag-like sheets moving in the wind, etc.
— DEBORAH CHUNG (BS '73, MS '73)

Offshore Wind Power
The advent of multi-10MW floating offshore wind turbines will cut the cost of production of such a no-fuel renewable energy that it should undercut any other way to produce electricity with or without fuel.
— ALAIN DELSUPEXHE (MS '80)

Gene Editing
Gene editing, together with improving identification of gene functions, is beginning to enable predictable genetic engineering of plants and animals. Early versions of technologies in this category already have been impacting plant and animal agriculture to a degree, but the future promises dramatic improvements in the exactitude, predictability, and safety of these technologies. As a result, we will see growing pressure to apply them to the human race.
— JOHN CROSS (PHD '76)

Transportation
As the world becomes more mobile, we are spending too much of our time en route. Something like a large-scale hyperloop network, hypersonic flight, or even short-distance space flight could be the next innovation. Of course, teleportation is the zero-time/zero-carbon ideal to aspire toward.
— DANA IONITA (BS '03)

Batteries
Batteries that are cheap, safe, reliable, and fast-charging, with 10 or more times the current capacity per volume. The effect of this on transportation and energy generation is mind-boggling. Fossil fuels would be confined to aviation, railroads, and seagoing ships.
— ORESTE LOMBARDI (BS '55)

Virtual Reality
Virtual reality is expected to help improve brain training for cognitive performance, including concentration, reasoning, learning, visualization, imagination, and insight. It will have a far greater impact on our lives than even the revolutionary effect of worldwide digital communication and will be coupled with A.I. and robotics to completely make over the human experience.
— LYNN GLOVER JR. (MS '64)

Simple Truth News
The public, overwhelmed and disgusted with "expert spin" (fake news), will stop watching it. Each person will choose a curated site that gives facts that truly affect him or her.
— DAN NEMZER (BS '69)

Robots
Autonomous humanoid robots will fundamentally alter the lives of the next generation by taking on most of the everyday functions at work and home and even forming relationships with their human counterparts.
— NEIL MALHOTRA (MS '90, ENG '92)

Quantum Computation
Quantum computation will change the future even more than classical computers have changed the world of today. It will be possible to model a complete human brain as it learns, integrates information, thinks, imagines, experiences all emotions, composes music, writes novels, is motivated to action (through robotic output), sleeps, and may allow us to specify the spatiotemporal patterns of information flow from whence sentience necessarily emerges.
— JERRE LEVY (PHD '70)

Immunotherapy
Immunotherapies for cancer, which will drive patients' own immune systems to fight cancer into complete omission.
— TAD SIMONS (MS '76)

Anti-aging Medicine
My hope is that the really big development will be serious progress in reversing aging.
— GEORGE RAPPOLT (BS '72)

TECHER
Foodies

The Food Lab

Harold McGee, the (somewhat reluctant) "godfather of molecular gastronomy," talks to us about the first workshop that brought cooks and scientists together, how it came to be, and how the science of cooking became popular.

BY APRIL WHITE

PHOTOGRAPH BY ERIC MILLETTE

Caltech Distinguished Alumnus Harold McGee (BS '73) would like to apologize for the term "molecular gastronomy."

"It's pretentious," he says of the mouthful of a phrase used throughout the 2000s to describe the newly trendy intersection of science and cooking. Coined for the First International Workshop on Molecular and Physical Gastronomy, a 1992 conference that McGee helped organize, "molecular gastronomy" unintentionally made the chemistry of cooking seem difficult, something best left to the experts. McGee, the author of *On Food and Cooking*, a standard required text in many culinary schools that's also used in university science courses for non-majors, has spent his entire career telling home and restaurant cooks exactly the opposite: "Cooking is something where you apply the science with your own two hands."

Why did science and cooking exist in isolation when you began writing about the topic in the 1970s?

There have been connections between science and the kitchen for centuries. The pressure cooker, for instance, was invented in the time of Isaac Newton. But that connection got lost in the first part of the 20th century. Scientists were focused on the industrialization of food. With the two world wars, there was an emphasis on food manufacturing and safety, rather than better ways to make a steak. And there was the development of home economics, which paid more attention to nutrition and hygiene than to pleasure and deliciousness.

What prompted the First International Workshop on Molecular and Physical Gastronomy in 1992?

It was the brainchild of a cooking teacher whose husband was a physicist. She and a colleague of his put together a meeting of scientists interested in cooking and cooks interested in science and asked me to help. It was a brand-new idea. There was a place in Italy that held scientific conferences that was happy to host it, but asked us not to call it "The Science of Cooking" because that didn't sound serious enough. At the time, molecular biology was the scientific field with the most prestige, and gastronomy is the Greek-derived term for the knowledge and appreciation of food, so "molecular gastronomy." I never thought the name would stick.

How did the science of cooking go mainstream in the 2000s?

It was the conflation of several unrelated things: a gradual rediscovery of its usefulness by culinary professionals, our conferences on traditional techniques, and chef Ferran Adrià's creative efforts at El Bulli in Spain. Journalists began to attend our meetings and also saw the things that Adrià was doing with foams and gels, which relied on some understanding of their chemistry, and he got tagged with the term molecular gastronomy. He was very unhappy about that, but it helped kick-start public interest in the subject. In 2007, *The New York Times* asked me to write a regular column called "The Curious Cook."

Will this renewed interest in science fundamentally change how we cook?

I think the new popularity of science in the kitchen has been a mixed blessing. Now that it is trendy to include a sentence or two about science in any food article, there's a lot out there that isn't reliable and a proliferation of clickbait that says, "Science says you are cooking wrong." That's just not the case. If you have been cooking rice a certain way all your life and it works just fine, you are doing it right. The principles of cooking haven't changed for thousands of years, and people discovered things that work by trial and error. What science can do is help us understand why they work and implement the practical discoveries people made over the millennia in more convenient ways.

FOODIES UNITE

Techers in the food and beverage industry offer up dinner and drinks for the perfect night in.

Bringing Germany Home

Tyson Mao (BS '06), co-owner of Wursthall, a German restaurant and *bierhaus* in San Mateo, California, serves up a recipe—courtesy of Wursthall's chef Kenji López-Alt—for a modern take on a traditional comfort food.

"At Wursthall, we serve the chicken in custom-made brioche caraway buns with caper aioli and a preserved lemon-cucumber relish. For a light dinner, I like to serve the schnitzel on its own with the cucumber relish extended into a light salad for a complete meal that's simple but elegant."

–KENJI LÓPEZ-ALT

BETTER COOKING THROUGH SCIENCE This recipe for chicken schnitzel comes from Wursthall's chef, Kenji López-Alt, who won a James Beard Award for his cookbook *The Food Lab: Better Home Cooking Through Science*.

From top: Courtesy of Tyson Mao; Courtesy of Kenji López-Alt

Courtesy of Diego Benitez

Chicken Schnitzel with Preserved Lemon and Cucumber Salad

NOTE: At Wursthall, we brine our chicken breasts in the brine left over from our sauerkraut, which helps the meat retain moisture as it fries and gives it a nice tangy flavor. If you have sauerkraut brine left over from homemade or store-bought sauerkraut, feel free to use it in place of the brine in Step 1. Pickle juice will work similarly well. For the breadcrumbs, we start with Japanese-style panko crumbs and then grind them up in a food processor until they're an extra-fine powder. The real key to great schnitzel is carefully drying the chicken between steps in the breading so that you don't build up too much flour or breadcrumbs. (You will end up with excess breadcrumbs that can be refrigerated and used within three days for any recipe that thoroughly cooks them.) After frying the schnitzel, the oil can be strained and reused for cooking.

TECHER *Foodies*

CHICKEN SCHNITZEL

SERVES 4

- 4 chicken cutlets, pounded thin
- Kosher salt
- Freshly ground black pepper
- ¾ cup flour
- 2 eggs, well-beaten
- 2 cups panko-style bread-crumbs, finely ground in a food processor or blender (see note above)
- 2 cups peanut or rice bran oil

1. Place the chicken in a large bowl, and cover with 1 quart of water. Add 1/2 cup kosher salt (or 1/4 cup table salt). (See note above if using sauerkraut or pickle brine.) Set aside for at least 4 hours and preferably overnight. Transfer the chicken to a rimmed baking sheet lined with paper towels or clean kitchen towels and carefully pat dry. Season with black pepper.

2. Place flour in a shallow dish or pie plate. Place eggs in a second pie plate. Place ground panko in a third pie plate. Season flour, eggs, and panko with salt and pepper.

3. Working one cutlet at a time, carefully lift cutlet with your left hand and transfer to flour. Turn to coat. Carefully lift with your right hand and transfer it to the egg plate. Use your left hand to turn the chicken to coat. Using your left hand, carefully transfer the chicken to the bread crumbs. Using your right hand, lift crumbs and pour them over the top of the chicken and pat down. Turn the chicken and pile more crumbs on top, repeating until no egg is showing. Transfer to a parchment or foil-lined rimmed baking sheet, and repeat with remaining cutlets.

4. Heat oil in a 12-inch skillet over medium heat until shimmering (it should register 325°F on an instant-read thermometer). Carefully slide two cutlets into the pan and cook, gently shaking the pan until the cutlets are golden brown on the first side, about 2 minutes. Carefully turn with tongs or a slotted spatula, and continue to cook until second side is golden brown, about 2 minutes longer. Transfer to a paper towel-lined plate. Cook remaining two cutlets (the first cutlets can be kept warm in a 250°F oven while the second cutlets are cooking).

5. Season cutlets with salt, and serve immediately with preserved lemon and cucumber salad.

PRESERVED LEMON AND CUCUMBER SALAD

SERVES 4

NOTE: Preserved lemons can be found at Middle Eastern grocery stores or some well-stocked Western supermarkets, such as Whole Foods.

- 2 large cucumbers (about 1 pound), peeled, seeded, and roughly diced
- Kosher salt
- 1 small red onion, thinly sliced
- 1 preserved lemon, seeds removed, skin and flesh finely chopped
- 1 tablespoon whole grain mustard
- 2 teaspoons white wine vinegar
- 1 teaspoon lemon juice
- 4 tablespoons extra virgin olive oil
- ¼ cup fresh dill fronds, roughly chopped
- 1 head green leaf or bibb lettuce, washed and drained, roughly torn by hand
- Freshly ground black pepper

1. Toss cucumbers with a big pinch of salt, and place in a colander. Let drain for 30 minutes. Meanwhile, cover red onions with water in a large bowl, and let sit for 10 minutes. Drain and rinse, and then add to bowl with cucumbers to drain.

2. Combine preserved lemon, mustard, vinegar, and lemon juice in a large bowl, and whisk to combine. Drizzle in olive oil slowly while whisking until dressing is emulsified. Add drained cucumbers and onion to the dressing. Add dill and lettuce, and toss everything to combine. Season to taste with salt and pepper. Serve with schnitzel.

Delicious. Now, What to Drink?

Diego Benitez (PhD '05), founder of Progress Brewing in South El Monte, California, knows a good meal is never complete without a complementary beverage. "I try to figure out the intricate and complicated relationship of physiological and psychological factors that determine taste preferences in people," says Benitez, who has 10 years of professional pairing experience. Here are his thoughts on the perfect pairings for this German meal.

BEER PAIRING:

A traditional late-19th-century Viennese Lager would be the perfect pairing for chicken schnitzel; however, the style is almost extinct in its original form and location. Some American craft breweries have been known to brew close interpretations with different levels of success. Bohemian Lagers with wide U.S. distribution—such as Pilsner Urquell, Staropramen, or Czechvar—are a close second. The light bready flavors in the beer complement the schnitzel, while the spicy, floral, noble hop aromas will accentuate the fresh citrus notes in the cucumber salad.

WINE PAIRING:

It is not surprising to think that an Austrian wine goes well with Austrian schnitzel. Grüner Veltliner is considered the leading varietal for Austrian wines; its sharp acidity and spicy citrus and stone fruit flavors make it a great pairing that will not completely obscure the schnitzel while highlighting the cucumber salad. A slightly more subdued alternative is Austrian Weißburgunder (Pinot Blanc). It is not as expressive as Grüner Veltliner, but some Austrian-made examples are fantastically complex and elegant while slightly austere in intensity. Austrian Weißburgunder would take a more supportive role with chicken schnitzel while allowing the brightness of the cucumber salad to shine.

Moonshot

Last year, Caltech's Center for Autonomous Systems and Technologies (CAST)—an interdisciplinary research center that is developing the next generation of autonomous robots—announced five ambitious goals to guide its work. One of these "moonshot" challenges has already taken wing: a robotic flying ambulance that could act as a rescue pod, safely carrying an individual out of a disaster area to the nearest hospital. A scale model of the ambulance can already fly autonomously, and engineers are training it to fly safely through high winds and navigate its surroundings without human intervention. "The moonshots are really a teaser to inspire and excite the scientists and students," says **Morteza Gharib (PhD '83)**, Caltech's Hans W. Liepmann Professor of Aeronautics and Bioinspired Engineering; Booth-Kresa Leadership Chair and director of CAST; and director of the Graduate Aerospace Laboratories. "But the best fruit will be the technologies we develop along the way."

IMAGE: EAS COMMUNICATIONS OFFICE

FEARLESS

THE HUNT FOR EXTREME LIFE

BY APRIL WHITE

PHOTOGRAPHED BY SCOTT NOBLES

When **Jeffrey Marlow (PhD '16)** was 10 years old, he stood at the edge of a gurgling hot spring that smelled of rotten eggs. "It was such a foreign, alien environment," he remembers of his family's visit to Yellowstone National Park. "The idea that life could exist in the springs was amazing. I had to know more." That adolescent spark of curiosity set Marlow, now a postdoctoral fellow in Harvard's Department of Organismic and Evolutionary Biology, on a quest for what he calls "extreme life": microorganisms that thrive in environments where humans would perish—places that are too hot or too cold, places that are unbearably acidic or under intense pressure, places without any oxygen at all. "Those microorganisms can tell us about the limits of the biosphere, of what life is really capable of," he says. "We don't know if life exists elsewhere in the universe, but by probing the limits of our own biosphere, we can start to see the boundaries of what's possible."

"You don't have to go to an active volcano to do real science. You can see your own environment in new ways and be amazed."

Marlow's hunt for extreme life has required some extreme living. During his time studying geobiology in Victoria Orphan's lab at Caltech and since, Marlow's research interests have taken him from the boiling Marum Crater lava lake, more than 1,000 feet down inside an active volcano on a small island in the South Pacific, to the cold, dark depths of Hydrate Ridge off the coast of Oregon. On that expedition, the research vessel *Atlantis* ferried a group of scientists some 60 miles from the shoreline, and the U.S. Navy's three-person submersible then carried Marlow and his colleagues another half mile straight down into the Pacific Ocean. "Everything moves more slowly down there," Marlow says, describing the languid attention the sea animals paid to this new man-made creature in their midst. The sub's headlights illuminated only a small portion of inky ocean. "You know you aren't getting the full picture," he says, "but your eyes are always drawn toward the edge of the light, trying to resolve what's just beyond your grasp and figure out how it all fits together."

What Marlow has been trying to figure out is how certain microorganisms inhabit deep sea cold seeps—fissures in the ocean floor that leak methane and other gases. The microorganisms Marlow is most interested in live under about three centimeters of ocean mud and consume methane, preventing the powerful greenhouse gas from entering the atmosphere. On the seafloor, Marlow and his fellow scientists look for the telltale sign of the methane-eating microorganisms, a white and orange carpet of other microbes attracted to their waste products. That's where the sub's pilot collects rocks and sediments. Back on the ship, it's easy to tell if the science team has found what it was seeking: The microorganisms reek of sulfide—that same rotten egg smell Marlow encountered on his childhood trip to Yellowstone.

It's not all adventure, notes Marlow, who was named a 2016 National Geographic Emerging Explorer. He had spent the previous sunny summer week in a "cold, dark room staring through a microscope for hours on end," working on a new project to map microbes that live in oxygen-free environments to understand how they interact. But Marlow recognizes the power of a good story to spread interest in the sciences. He writes articles with titles like "Hunting for Deep-Sea Worms in Oil-Dripping Rocks" (*Wired*) as often as he writes ones with titles like "Harnessing a Methane-Fueled, Sediment-Free Mixed Microbial Community for Utilization of Distributed Sources of Natural Gas" (*Biotechnology and Bioengineering*). He is as likely to be speaking at a TEDx conference as attending a microbiology symposium. And he is the founder and executive director of the Ad Astra Academy, a science education program designed to provide kids in underserved communities with a spark of curiosity like the one a family vacation provided for Marlow.

"You don't have to go to an active volcano to do real science. You can see your own environment in new ways and be amazed," he says.

From top: SOJ/Mary Lide Parker; Zubuyer Kaolin

Above: Jeffrey Marlow works with a tracer dye in the wet lab aboard the *R/V Falkor*. This dye allows researchers to better see fluid flow out of carbonate chimneys on the seafloor. Left: Marlow leads an Ad Astra Academy field trip in Cox's Bazar, Bangladesh. Opposite page: Approaching the lava lake at the bottom of the Marum Crater in Vanuatu.

Brad Ambrose

Taming the System

How Riot Games' Naomi McArthur keeps the peace in online gaming—and how those lessons can extend to real life

BY ALEXANDER GELFAND

PHOTOGRAPHED BY CHRISTINA GANDOLFO

Game designer **Naomi McArthur (BS '13)** might not have a badge and a gun. But in the world of multiplayer online games, she's the closest thing to a sheriff there is.

McArthur designs online behavior systems for Riot Games, the company behind *League of Legends* (LoL), one of the most popular video games on the planet. LoL boasted more than 80 million monthly active users in 2017 and is a pillar of e-sports, with professional gamers competing in North American, European, and Asian leagues. But some of its players can get a little salty—or worse. So McArthur and the rest of Riot's Player Behavior Team use a combination of data science and social science to maintain order in an unruly virtual world.

LoL belongs to a class of online games that pit teams of players against each other in pitched battle. While inspiring intense loyalty, such games also breed toxicity, with the most egregious offenders spewing racist, sexist, and homophobic slurs. And LoL, a fantasy game in which two five-player teams of mages, marksmen, and other champions struggle to destroy one another's castle-like base, is no exception, with aggrieved gamers complaining of harassment by opponents and teammates alike. It's the kind of thing that can tarnish a game's reputation and drive away users. (Riot has already banned several professional LoL players for in-game abuse.)

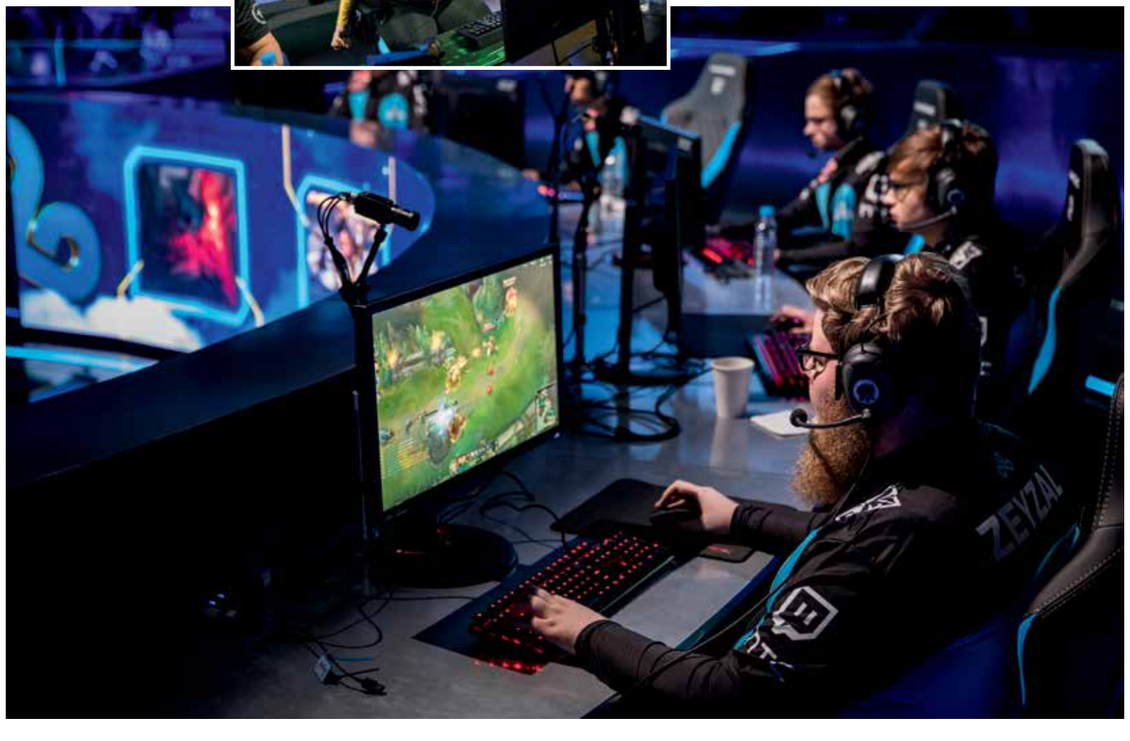
Some of this negativity, McArthur says, is fostered by the absence of normal curbs on nastiness. And some is due to the nature of the game itself.

Online gamers operate in a virtual environment where many real-world social constraints don't exist; where anonymity and a sense that trolling is the norm mean that people spewing hate speech never have to look their victims in the eye or face the disapprobation of their peers.

"The online community is the Wild West in a lot of respects," says McArthur, a lifelong gamer and former president of Caltech's League of Legends Club who has faced her share of sexism online.

What's more, weak players can drag down more competent teammates, thereby earning their enmity. "Mistakes made by a teammate can empower your rivals, who can use their newfound power to crush you," says **Bill Clark (BS '08)**, an engineering manager at Riot who plays LoL under the name LtRandolph.

And because many teams are temporarily assembled by matchmaking algorithms, players rarely have to see one another again, eliminating a powerful incentive to play nicely together. Things get even hairier when players speak different languages and harbor different cultural expectations. (Riot's European and Southeast Asian servers connect gamers from many different countries.)



Outside of e-sports events, such as the 2018 LoL World Championship in Seoul (pictured here), online gamers operate in an environment in which real-world social constraints don't exist—an environment in which they may never have to look opponents (or fellow teammates, for that matter) in the eye. As an online behavior systems designer for Riot Games, Naomi McArthur works to create a system of good sportsmanship in an exploding industry.

LoL Sports

McArthur and her co-workers blend quantitative techniques with social psychology to replace those missing behavioral guardrails and promote cooperation, penalizing bad behavior and rewarding good sportsmanship with A.I.-powered incentive systems.

Their work makes for interesting bedfellows. McArthur, who analyzed neuroscientific data using statistical methods while studying computation and neural systems at Caltech, worked for several years with a psychologist specializing in deviant behavior, and she often collaborates with academic researchers to reap behavioral insights whose relevance extends well beyond LoL.

McArthur recently co-authored a paper with a group of researchers at MIT that used game data to investigate "collective intelligence," or the ability of a team to perform a wide variety of tasks. Among their findings: Lasting teams perform better than temporary ones (see above re: playing nicely). So do teams with female members, who tend to be more socially perceptive than men. And the highly virtual, fast-paced nature of the game means that tacit coordination among teammates matters more than explicit communication.

These takeaways could help improve the performance of virtual teams operating in business, or even groups operating in real-world environments that share the game's intensity and reliance on rapid decision-making—such as emergency response teams and military combat units.

McArthur herself has come to appreciate the value of such research to everyday life. "It fundamentally helps you understand the interactions you have in your day-to-day environment with your peers and family, especially when it comes to cooperative behavior," she says.

But she's primarily focused on applying those lessons at Riot, where she has developed machine-learning models to analyze the reports that players submit on disruptive gamers and to match that data with particular kinds of in-game activity, creating—and enforcing—a set of data-driven community standards for acceptable behavior.

The system can identify an infraction and issue feedback to offending players minutes after a game has ended, explaining precisely how they misbehaved and handing out penalties ranging from temporary suspensions to permanent bans. A new name-detection feature can even identify vulgar or offensive player names and force users to change them—a costly process that requires spending either real money or hard-earned game currency.

McArthur and her colleagues have also introduced a system called "Honor" that rewards good sportsmanship by presenting players with badges they can carry from game to game, leveraging gamers' pride and competitiveness to encourage positive behavior. Misconduct will tarnish or break a badge, but the game's automated systems allow players to redeem themselves, reforging their badges through good conduct and restoring their honor.

"It's very Klingon," McArthur says with a laugh.

It's also effective.

"I feel encouraged to be a good player by the things that the Player Behavior Team has done," says Clark, "and I feel like my game is less toxic than it used to be."

To spread that love, Riot co-founded the Fair Play Alliance, a cross-industry initiative spanning more than 70 gaming companies dedicated to sharing research and best practices on ensuring fair play and reducing disruptive behavior. The goal is to make the online gaming space kinder and gentler overall, but it should pay dividends at home too.

"At the end of the day, we can clean our own yard," says McArthur. "But if we aren't cleaning up the entire neighborhood, people will just track things into our environment."

Courtesy of Adrian Hightower

Water World

Taking on the water crisis at home and abroad

BY STEVEN BOYD SAUM

When it comes to water, the story of Cape Town, South Africa, is a cautionary tale for Southern California and other areas across the United States, says **Adrian Hightower (BS '95, PhD '01)**. Cape Town, with a Mediterranean climate similar to the southern end of the West Coast, could soon be facing "Day Zero"—the day they run out of water. "The big difference between us and them is that we have a broader portfolio of resources," says Hightower, who heads up the education division for the Metropolitan Water District of Southern California. But, he warns, "we have an infrastructure for water that was based on last century's climate."

Hightower is trying to change that. A few years ago, amid California's historic drought, Hightower, who has a doctorate in materials science, moved from academia to the largest distributor of water in the United States, serving 19 million people. His role is twofold: He lobbies politicians and policymakers to shift the paradigm—helping them understand that building smart grids and resilient water infrastructure can take decades. And he prepares the next generation—who Hightower knows will play a major role in that paradigm shift—by working with school districts throughout the region posing questions for students to get them thinking in terms of solutions.

"When it comes to water infrastructure, the problem is not with the engineers … the problem is in policy. Who's going to pay for it? How are we going to finance it? Who gets the rights to it?"

Hightower knows that mindsets can change. He points to how recycling became second nature over a generation and how Californians use far less water per capita than a few decades ago.

Lessons from Africa loom large in Hightower's work. Over the years, he has taken high school students to West Africa—Mali and Ghana—and, more recently, to Uganda in East Africa. Since 2014, he has served on the board of Aid Africa, a nonprofit that works in Uganda deploying efficient cookstoves, building sheltered springs, drilling wells, and helping plant trees for food and fuel.

When it comes to water infrastructure, he says, the problem is not with the engineers—in the U.S. or in Africa. "The problem is in policy. Who's going to pay for it? How are we going to finance it? Who gets rights to it? Why should I invest in something that I'm not directly benefiting from?"

Those are big questions that anyone tackling infrastructure has to help people answer. But when it comes to Southern California's water solutions, Hightower points to a history of innovation as something that should inspire—as should younger generations approaching problems in a cross-disciplinary way that's second nature. At the same time, that needs to be balanced with a much deeper sensitivity to human rights and environmental concerns if you're solving problems on that scale. "Our responses are only going to have to be more extreme," he says, "and more coordinated."

#LifeAfterCaltech

The Caltech Alumni Association asked Techers to take over our Instagram account (@caltechalumni) and share their experiences and perspectives after graduation. From pursuing a passion for medical research to chasing nature photos while foraging for food along the way, alumni are showing us the diversity of their experiences in their lives after Caltech.

We invite you to share a glimpse of your life with us, your fellow alumni, and current students by using the hashtag **#LifeAfterCaltech** *on social media.*

JENNIFER YU (BS '93)

After Caltech, Jen Yu (@jenyuphoto and @userealbutter) worked at the Jet Propulsion Laboratory, earned a doctorate in geology, returned to work at Caltech in GPS, and eventually settled in the Rocky Mountains of Colorado with fellow Techer **Jeremy Darling (BS '96)**. After her breast cancer diagnosis in 2007, Jen left science and became a freelance photographer and food blogger.

"I share my love of wild things and wild places through my nature and landscape photography. Most of my work involves the American West, but the past few years I have remained close to home in the Colorado mountains."

ADRIANNE YANG (BS '00)

After Caltech, Adrianne Yang (@adrianne.yang) became an environmental engineer, honing her skills in site remediation, water quality monitoring, civil design, and mining water management. She is a registered professional engineer in the state of Washington and currently works at Jacobs Engineering as a water management modeler. She is also married to fellow alumnus **Yifan Yang (BS '00)** and mom of two kids, Sam and Rae.

"In my job, I need to be conversant with geochemists, engineers, statisticians, regulators, and my clients. My education at Caltech gave me the basis for succeeding at this aspect of my job. This LEGO mini figure sits on my desk to remind me of my roots."

DR. ANDREW FREDDO (BS '10)

After Caltech, Andrew Freddo (@amf913) pursued a passion for medical research and is now a first-year resident at the University of Colorado in the combined Internal Medicine-Pediatrics program. After residency, he plans a career combining both research and patient care, possibly in adult congenital cardiology.

"One of the biggest surprises and joys in my life after graduating Tech was finding the love of my life! He makes me laugh every single day, keeps me humble, and always is ready for new adventures. And now we're engaged … wedding date TBD!"

Engagement photo: Marie Calfopoulos / mariecalfopoulos.com

Gomplemenatry

Oh no! Something escaped from one of the campus labs and made some changes to the Gene Pool.

Can you arrange the contents as they were and identify the type of prankster that would do this?

ALAN DENG (BS '10), JOSH TOLLEFSON (BS '13), AND GEORGE WANG (BS '08)

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3) Gonatiner for ahe **Aime** Saone

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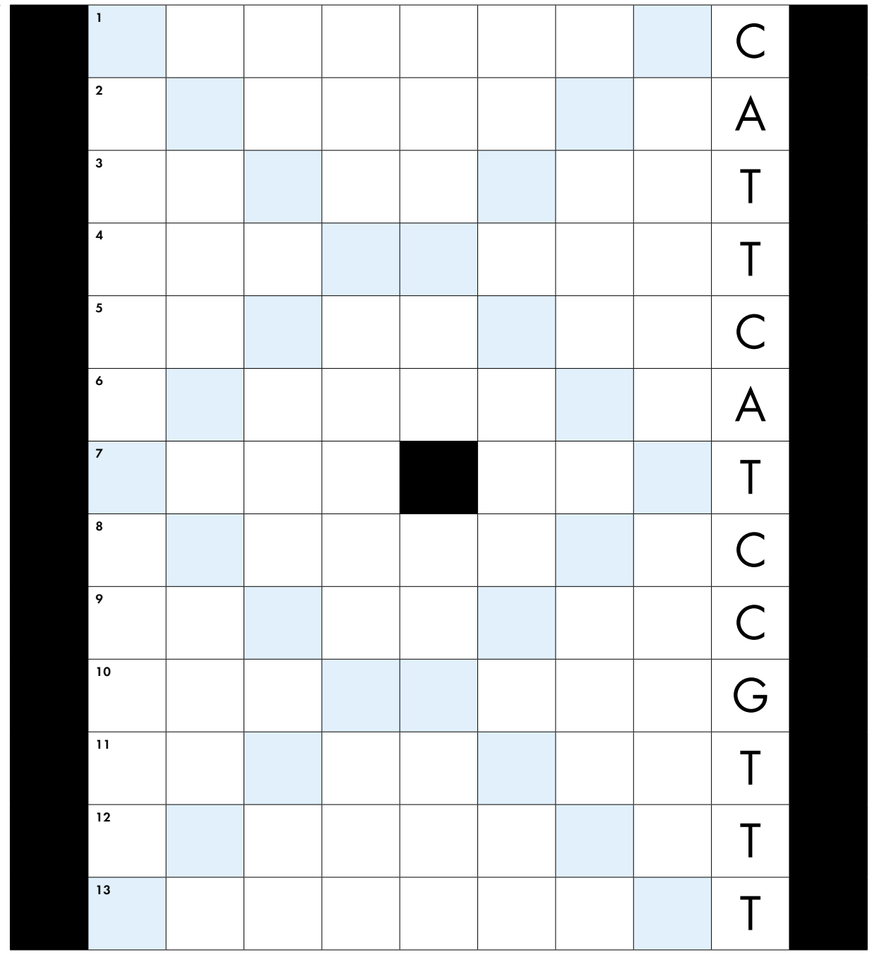

IN MEMORIAM

We mourn the loss of the following members of our Caltech alumni family

1941
Donald E. Dawson (BS '41)
Gilbert A. Jones (BS '41)

1942
Wendell W. Harter (BS '42, MS '47)

1943
Leonard S. Alpert (BS '43)

1944
Louis L. Gowans Jr. (EX '44)
Leon Trilling (BS '44, MS '46, ENG '47, PhD '48)
Joseph F. Wadsworth Jr. (MS '44)

1945
Brian B. Dunne (BS '45)
Lowell C. Parode (BS '45, MS '47)
William F. Paulsen (BS '45)

1946
Jerome S. Field (BS '46)
David C. Lincoln (BS '46, MS '47)
Donald R. Lindsay (EX '46)

1947
Kurt M. Mislow (PhD '47)

1948
Alan S. Bagley (BS '48)
Philip Blenkush (MS '48, ENG '49)
Lothrop Mittenthal (BS '48)

1949
Harold W. Davidson (MS '49, ENG '51)
Robert B. Funk (BS '49, MS '50)
Benjamin F. Howell Jr. (MS '42, PhD '49)
Donald R. Morrison (BS '49)
Gene D. Six (BS '49)

1950
William W. Haefliger (BS '50)
Bernard Rasof (MS '44, PhD '50)
William Schneider (MS '50)
William D. Squire (BS '50, MS '60, PhD '64)

1951
Richard K. Smyth (BS '51)
Bjorn A. Thorstensen (BS '51)
Fred E. Wood (BS '51)

1952
Waheed K. Ghauri (BS '52)
Edwin Welch (EX '52)

1953
Jack S. Anderson (MS '48, PhD '53)
Walter L. Pilant (BS '53)

1954
Carel Otte Jr. (MS '50, PhD '54)
Eugene Y. C. Loh (MS '53, PhD '54)

1955
Robert N. Clayton (PhD '55)
Alan L. Helgesson (BS '55)
Richard M. Jali (BS '55, MS '58)

1956
G. Louis Fletcher (BS '56, MS '57)
Gilbert W. Kirby Jr. (MS '56)
William T. O'Bryant (ENG '56)
Jerry R. Pixton (BS '56)
Gordon E. Zima (MS '52, PhD '56)

1957
Duane D. Erway (BS '57, MS '58)
Ernest J. Franzgrote (MS '57)
William B. Nichols (MS '54, PhD '57)
Ralph E. Pixley (PhD '57)
Robert A. Seltzer (MS '57)
Roy T. Stake (BS '57, MS '60)

1958
Frank B. Mallory (PhD '58)

1959
Richard H. Briceland (PhD '59)
Norman J. Zabusky (PhD '59)

1960
Meredith B. Mitchell (BS '60)

1961
M. Grant Gross Jr. (MS '59, PhD '61)
Mark H. Wagner (MS '61)
Kenneth W. Wood (MS '61)

1962
William R. Emerson (BS '62)
George A. Watts (ENG '62)

1963
Jacques Godin (MS '63)
John S. Letcher Jr. (BS '63, MS '64, PhD '66)
Louise G. Young (PhD '63)

1964
Arthur W. Merkl (PhD '64)
Jérôme M. Montet (MS '64)

1965
Joe C. Willis (MS '65)

1966
H. Wilhelm Behrens (PhD '66)

1967
Gary M. Johnson (MS '67)

1968
Norman M. Whiteley (BS '68)

1969
Jeffrey E. Flatgaard (PhD '69)

1970
William G. Bradley Jr. (BS '70)
Ray W. MacDonald (MS '70)

1975
Joseph G. Polchinski (BS '75)

1976
Denis W. Aull (MS '76)

1977
James Schlaffer (EX '77)

1979
Bruce D. Hubbard (PhD '79)

1980
Brian P. Doyle (BS '80)

1982
Mark A. Siddoway (PhD '82)

1987
John M. Williamson (PhD '87)

1997
Marlys Hammond (PhD '97)

2000
Eric E. Schultz (PhD '00)

2017
Manasa Ashok (BS '17)

Thatcher's Calculating Instrument

This cylindrical slide rule was designed to perform exact mathematical calculations for engineers, architects, actuaries, scientists, and financial institutions. With radii of 60 and 30 feet, the scales on this device could provide accurate calculations down to five decimal places at a time when regular slide rules could only provide results to the third place. Made out of ivory instead of boxwood, the plates would not warp or shrink over time or with changes in temperature. According to the accompanying instruction manual, Thatcher's Calculating Instrument could perform the "greatest variety of useful calculations with unexampled rapidity and accuracy," and "professors and students of schools and colleges will find it the most valuable aid to mathematical study that can possibly be desired."

ID #: *1999.00326*
Creation: *Jan 1, 1886*
Materials: *Ivory, wood, and metal*
Donated by: *Mrs. Chapin in memory of her husband, William F. Chapin (BS '41)*

DO YOU KNOW MORE about this specific instrument, or did you use one like it while you were at Caltech? Tell us at **techer.caltech.edu/from-the-archives**

Liz Rauer

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