TECH

Caltech Alumni Magazine Fall 2023

REEF RELIEF
Regenerating vital ocean ecosystems

NUMBERS GAME
The next generation of sports analytics

AI FOR ALL
How humanity will shape the era of artificial intelligence

MOON TO MARS
The power of galactic ambitions

Caltech | Alumni

2023
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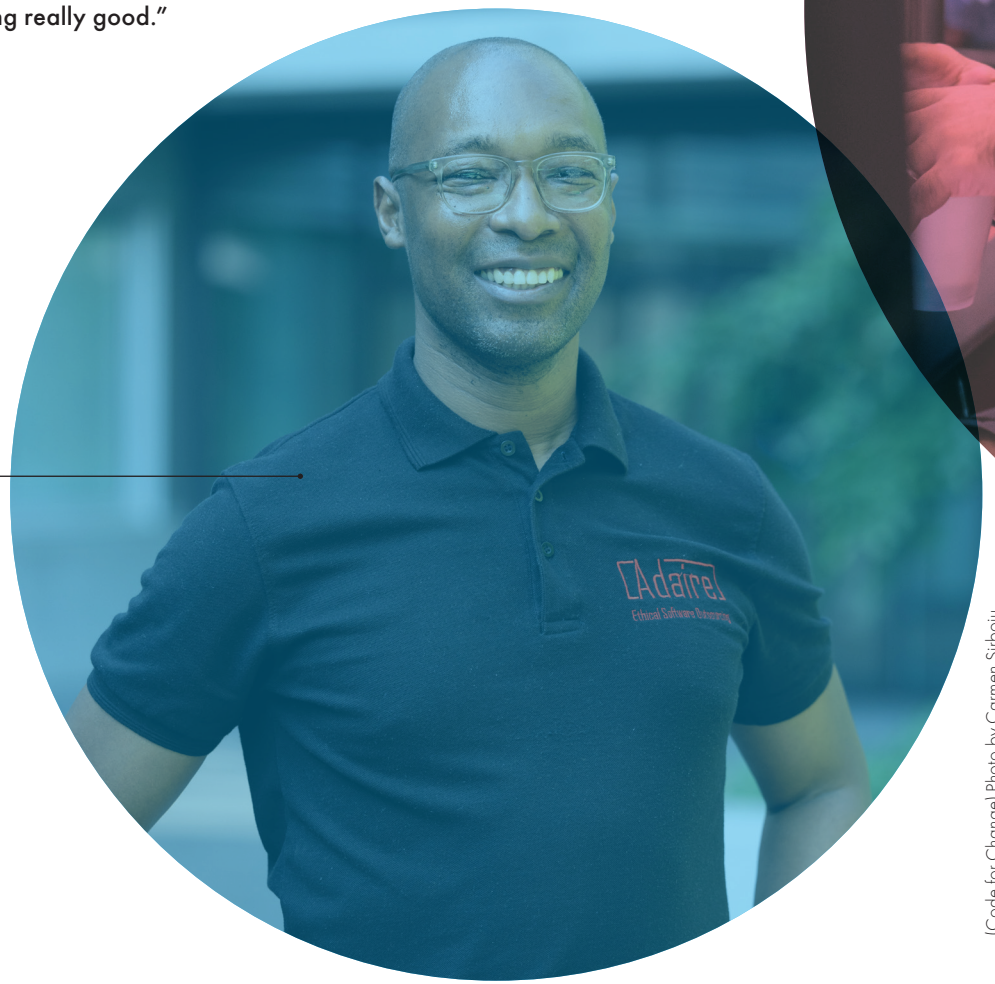

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[Code for Change] Photo by Carmen Sirbiu

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"Today, one third of businesses use AI. I'm guessing that will become most businesses within five to ten years. And the more people and businesses use AI, the more we will be debugging it and the better it will be trained to correct for bias."

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[From Moon to Mars] Courtesy of NASA; [AI For All] Courtesy of Zehra Cataltepe

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JEREMY ARNOLD

Jeremy Arnold is a freelance writer and copyeditor whose work has appeared in *Variety*, *The Hollywood Reporter*, and *Moviemaker*. He has written four books on classic film for Turner Classic Movies and Running Press, with his latest, a newly expanded edition of *Christmas in the Movies*, being published this fall. Jeremy appears periodically on TCM as a guest presenter and programmer, and has recorded audio commentaries for the Blu-ray release of nearly two dozen classic films.

JULIETTE BORDA

Ever since NYC-based illustrator Juliette Borda attended an ERA march when she was 11, she's been an advocate for equal rights. So working on projects about pioneering women (especially those working to prevent bias) such as Zehra Cataltepe has been a special thrill for Juliette throughout her decades-long career. Her work blends traditional painting on paper (in gouache, a water-based paint medium) with digital enhancement. But her work is crafted entirely without the use of AI!

WEBB CHAPPELL

Boston-based photographer Webb loves his job for shoots like the one in this issue of *Techer* where he spent time with Tom Goreau. "We connected on all things marine including both of us having spent time on the reefs of Grand Cayman, me as a divemaster, Tom studying the effects of climate change and island development on the coral," says Chappell. "Wonderful, informative shoot."

MAUREEN HARMON

Maureen is the managing partner at Dog Ear and a cofounder. She is also editor-in-chief, publications at Rice Business. Prior to Dog Ear, Maureen was the director of editorial and creative content for Denison University, overseeing the school's brand as well as print and web projects—including the University's flagship publication, *Denison Magazine*. She also served as the school's interim associate vice president of communications before stepping away to pursue Dog Ear full-time. Maureen began her magazine career as an associate editor (and later senior editor) at *The Penn Stater* magazine.

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COVER: Tom Goreau, PhD (MS '72)
Photograph by Webb Chappell

TRANSMISSION

From the Board Chair of the Caltech Alumni Association

JENNIFER LEE, PhD (PhD '10)
Board Chair,
Caltech Alumni Association

2023 has been the year of learning how to do things again. While much remains familiar, the fundamental differences of a post-pandemic world require us all to adapt and readjust, both personally and professionally.

As we navigate the new normal together, the Caltech Alumni Association is committed to fostering even stronger bonds within the Caltech and alumni community.

At the start of the year, the CAA Board of Directors approved a strategic investment designed to emphasize and revitalize alumni connection. In collaboration with CAA staff, we have not only brought back our hallmark on-campus events both online and in-person, including the **Alumni Weekend and Reunion Celebration** (alumni.caltech.edu/alumni-weekend) and **Seminar Day** (alumni.caltech.edu/seminar-day), but also brought CAA to you.

This year, we unveiled our "Caltech In…" with regional events in San Francisco, Washington, D.C., Boston, and San Diego (plus Chicago and Seattle in July 2022). As a result, we witnessed the gathering of more than 300 alumni spanning 63 years of Caltech classes (1960 to 2023) to meet, learn, and bring a bit of that Caltech spark to the communities in which Techers live, work, and play.

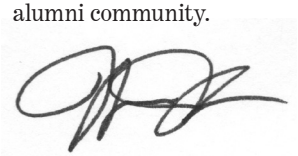
We also continued to address the unique challenge of bringing CAA far and wide—to scale up our reach in a short period of time. Our Caltech community is marked by a "can-do" attitude that specializes in overcoming seemingly insurmountable challenges (Ditch Day memories, anyone?). This resulted in **Tables for Techers** (alumni.caltech.edu/tables-for-techers), a worldwide, alumni volunteer-led weekend for Techers to gather socially with their local Caltech community at small events, enjoy a meal, and build new connections. More than 110 Techers across 23 states and six countries volunteered to host or co-host, and 457 Caltech community members registered to attend. We know that new and lasting connections were made across class years, majors, and experiences, and we look forward to continuing the Tables for Techers momentum in the years ahead.

Now that we are back to being active in our communities, what's next? As our alumni population grows each year (we added 518 new alumni to our midst at our 2023 Commencement!), the Board is focused on building more collaborative opportunities with our campus partners so that every Caltech student is aware of and can tap into the power of the Caltech network, starting the minute they arrive in Pasadena. This increased engagement will better connect the Caltech campus with our 25,282 alumni around the world.

And we'd love your help. If you haven't already, please consider signing up for PeopleGrove (portal.alumni.caltech.edu) so that you can share your expertise with our Caltech community and perhaps make a difference for some of our newest Caltech colleagues.

Finally, in the spirit of reconnection and revitalization, the Board and the CAA staff would like to make sure we reach out to and hear from Techers everywhere. If you need to update your contact information, please do so via the Update My Contact form (alumni.caltech.edu/update-contact-info). To help us reduce operating costs for conducting CAA business, please consider opting in for electronic voting by completing and following the return instructions on **CAA's Consent to Use of Electronic Transmissions form** (alumni.caltech.edu/electronic-ballot-request).

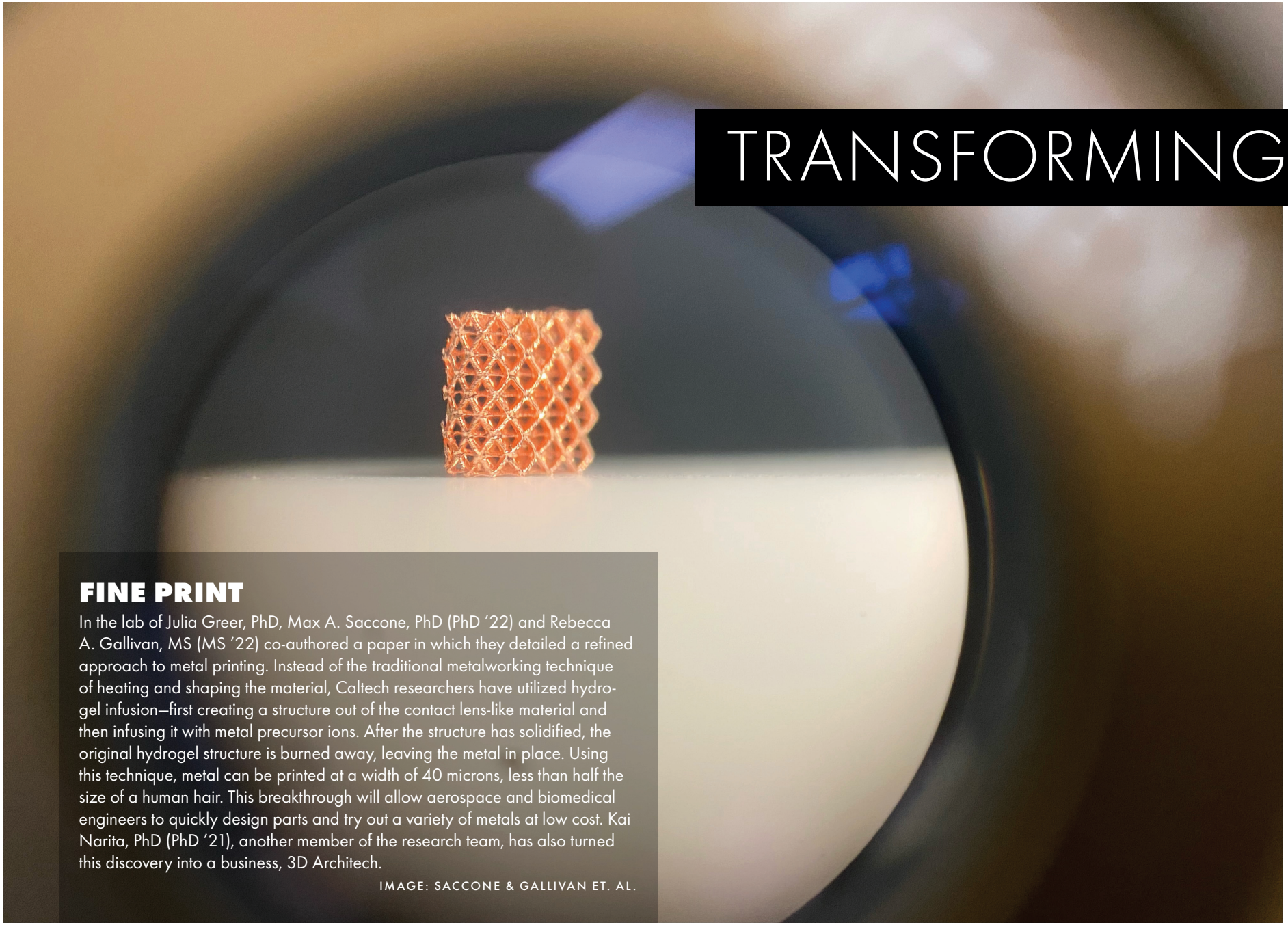
This will help CAA ensure that we focus our resources on what we and all Techers are working to achieve–deeper alumni connection to ensure the success and well-being of every member of the Caltech alumni community.



JENNIFER LEE, PhD (PhD '10)
Board Chair, Caltech Alumni Association

(Jennifer Lee) Photo by Andrea Starr

TRANSFORMING



FINE PRINT

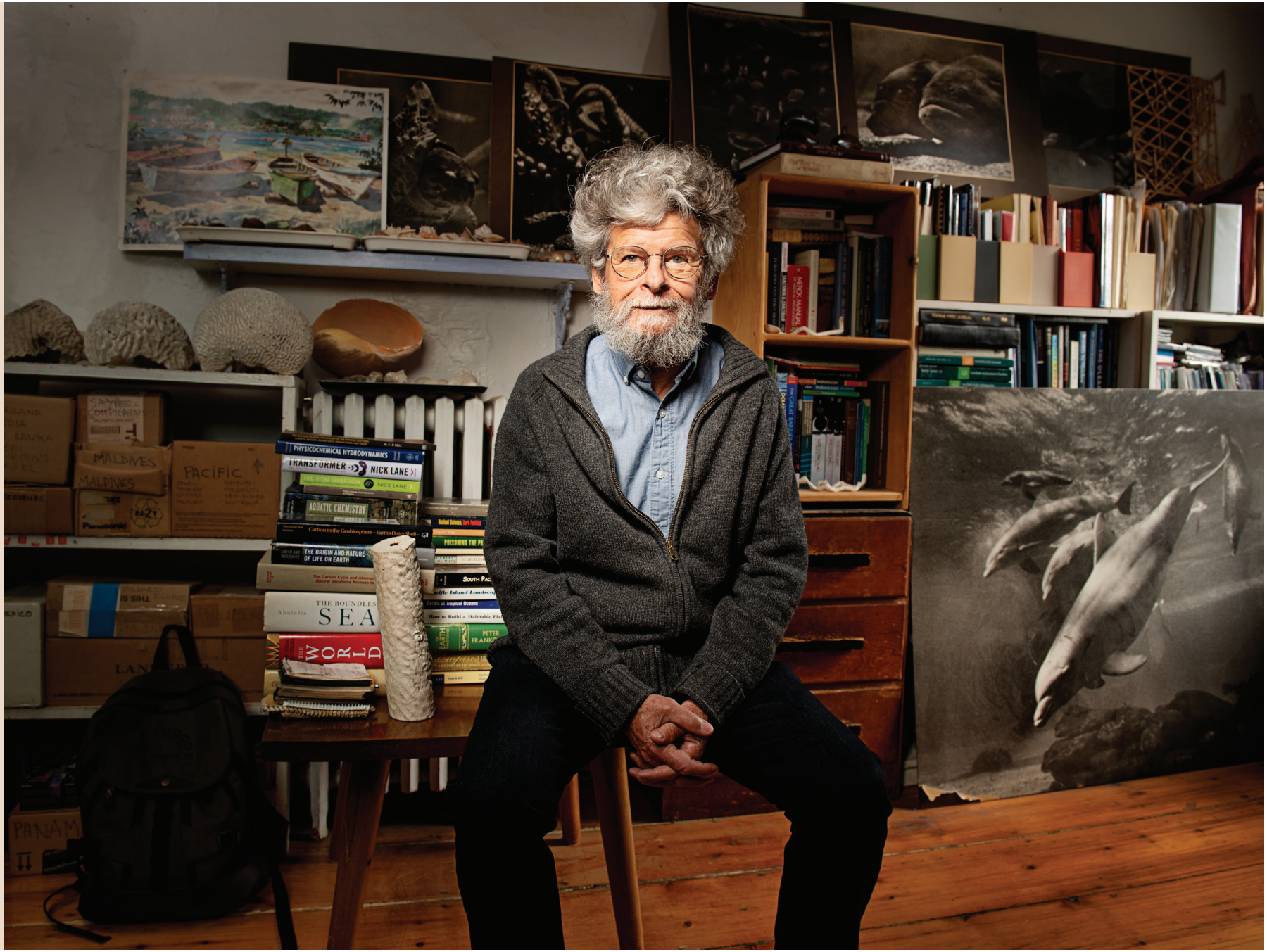
In the lab of Julia Greer, PhD, Max A. Saccone, PhD (PhD '22) and Rebecca A. Gallivan, MS (MS '22) co-authored a paper in which they detailed a refined approach to metal printing. Instead of the traditional metalworking technique of heating and shaping the material, Caltech researchers have utilized hydrogel infusion—first creating a structure out of the contact lens-like material and then infusing it with metal precursor ions. After the structure has solidified, the original hydrogel structure is burned away, leaving the metal in place. Using this technique, metal can be printed at a width of 40 microns, less than half the size of a human hair. This breakthrough will allow aerospace and biomedical engineers to quickly design parts and try out a variety of metals at low cost. Kai Narita, PhD (PhD '21), another member of the research team, has also turned this discovery into a business, 3D Architech.

IMAGE: SACCONE & GALLIVAN ET. AL.

reef relief

BY MARISA DEMERS • PHOTOGRAPH BY WEBB CHAPPELL

How Tom Goreau's, PhD (MS '72) electrifying technology is helping local communities rebuild the world's coral reefs


PHYSICOCHEMICAL HYDRODYNAMICS
NICK LANE
AQUATIC CHEMISTRY
THE ORIGIN AND NATURE OF LIFE ON EARTH
MALDIVES
PACIFIC

"We can regenerate an ecosystem full of fish and grow a beach back at a fraction of the cost."

Tom Goreau, PhD (MS '72) is a trauma surgeon for the ocean. Since the late 1980s, Goreau and his colleagues have installed more than 700 electric reefs to protect delicate coral ecosystems renowned for their biodiversity and beauty—and increasingly stressed and weakened by climate change. Between 1957 and 2007, over half of the coral reefs in the world died, according to research published in 2021. And, if global temperatures rise further, scientists predict that all of them will be wiped out.

"We can help put coral reefs on life support," Goreau says, "but the problem won't go away until global warming itself disappears. That's the issue."

OCEANS SHIELD US from the harshest effects of climate change. They absorb greenhouse gasses and heat from the atmosphere and convert them into life-giving oxygen or store them deep in the sea. This process comes at a cost to the ocean's chemistry: Seawaters are warmer and more acidic. While some plants and animals will survive in these harsher conditions, many others, including corals, will not. These fragile creatures face other dangers, too, including sewage runoff, coral diseases, and overfishing, which make their survival even more challenging.

Goreau's answer to this critical threat is Biorock, an invention that is as ingenious as it is simple. Steel rods, configured into various formations—domes, rings, and slopes—are tethered to seabeds. Once in place, power sources, often from solar panels floating above on boats, generate low-voltage electricity. Weak electrical currents cause minerals to grow and cover the steel with limestone rock that is two to three times harder than concrete. Coral fragments attached to the electric reef grow faster and survive high temperatures, giving them a new chance to flourish and propagate.

Today, Biorock reefs are in more than 40 countries in the Atlantic, Pacific, and Indian oceans. Coral reefs that once were bleached and barren have regained their vibrant hues and now offer food and shelter for an array of marine life. Like natural coral reefs, Biorock systems also promote biodiversity and fisheries, while reducing wave energy to help prevent flooding and beach erosion.

Goreau was inspired to create Biorock by the late Wolf Hilbertz. The architect sought to eliminate building materials that had large carbon footprints, such as Portland cement and concrete, by growing solid structures in the sea. He imagined underwater factories producing walls, roofs, and foundations from limestone. The green building concept never gained traction, but Goreau invited Hilbertz to work together on coral reef regeneration.

Goreau soon learned that inventing solutions was the easiest part of rehabilitating coral reefs. Installing electrified reefs on public property involves bureaucratic maneuvering, funding, and persistence. In response, Goreau established the Global Coral Reef Alliance in 1990, which empowers indigenous peoples to identify how to address climate change in their communities, learn how to build Biorock artificial reefs, and advocate for regeneration of coastal ecosystems. Some of Goreau's success stories are in Indonesia and the Maldives, whose economies rely on fishing and tourism. As coral reefs vanished, fish populations dwindled and beaches had retreated so much that buildings and trees were falling into the sea. Goreau and locals reversed that trend in months.

"People spend millions of dollars dumping sand on beaches, only for them to wash away at the end of the tourist season," Goreau says. "We can regenerate an ecosystem full of fish and grow a beach back at a fraction of the cost."

SHARING THE BEAUTY AND FUNCTION of coral reefs is a Goreau family profession. His late grandfather, Fritz Goro (who changed his surname after fleeing Nazi Germany), was one of the most acclaimed science photographers of the 20th century. During his four-decade career with *Life* magazine, Goro photographed Bikini Atoll and all 1,429 miles of the Great Barrier Reef. Using new techniques such as macro and underwater photography, Goro shared the captivating beauty and

Goreau pictured swimming over large table coral in shallow water in North Sulawesi, Indonesia. "Indonesia is the ocean's Amazonian rain forest, the center of global marine biodiversity. More kinds of corals, fishes, snails, and all forms of marine life are found there than anywhere else in the world," says Goreau.

Photo by Iain Robinson

intricate details of coral reefs with millions of readers.

Goreau's father, Thomas Fritz Goreau, discovered coral biology as a graduate student working on the Bikini Scientific Survey. While Goro snapped photos for the military, the young researcher collected samples of marine life before and after the U.S. dropped atomic bombs on Bikini Atoll. After earning his doctorate at Yale, Goreau and his wife, Nora Goreau, the first Panamanian marine scientist, moved to Jamaica. Surrounded by stunning coral reefs, they founded a research lab.

At 6 years old, Goreau joined his father on coral diving expeditions. Yet, when the time came to pick a college major, Goreau looked up to the stars. He studied planetary physics at MIT, planetary astronomy at Caltech, and biogeochemistry at Harvard.

His career plans in astronomy changed when his father died at 45 from cancer caused by nuclear radiation exposure at Bikini Atoll. He left behind a trove of uncompleted research, unanalyzed data, and a rich library of coral reef images. Goreau refused to abandon his father's unfinished work.

"My father knew more about coral reefs than anyone who has ever lived," Goreau says. "I had to continue his efforts and tell people what was happening to them and why."

✣ ✣ ✣

FOLLOWING IN HIS FAMILY'S FOOTSTEPS has been a mixed blessing. He shares his family's appreciation of coral reefs with new generations, as well as their commitment to understanding and repairing them. But Goreau has found the world is largely indifferent to these insights. Many of his projects languish for decades due to a lack of financial and government support.

Only now are funders approaching Goreau and the alliance. With additional support, Goreau can pursue large-scale projects for maximum impact, such as protecting atolls from global sea-level rise.

"Coral reefs, low islands, and coasts may disappear entirely if we don't act," he says. "I just hope it's not too late." ■

"My father knew more about coral reefs than anyone who has ever lived ... I had to continue his efforts and tell people what was happening to them and why."


SWITZERLAND
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var useSSL =
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gads.src = (useSSL ?
: 'http:') + '//www
var node = document.getElementsByTagName
node.parentNode.insertBefore(gads, node);

CODE FOR CHANGE

HOW ENTREPRENEUR KUDAH MUSHAMBI, MS/MBA (BS '00) IS REPROGRAMMING AFRICA INTO A TECH HUB

BY PEG MOLINE ILLUSTRATION BY VALERIE CHIANG

AFTER 22 YEARS IN THE TECH INDUSTRY, Kudah Mushambi, MS/MBA (BS '00) had identified a problem. He was living in Switzerland, and as he surveyed the region, which he calls DACH—the German-speaking countries of Germany (D), Austria (A), and Switzerland (CH)—he saw a booming demand for technology and digitalization services, but a lack of available talent.

The realization was well timed. Mushambi was at a career crossroads, and his former boss at Google, Andreas Henning, had just moved back to his native Germany. After mulling over the issue with his wife and Henning, he landed on a solution: Africa. It has the youngest and fastest-growing population of any continent, and Mushambi, who was born and raised in Zimbabwe, knew it had a vast reserve of untapped tech talent.

That opportunity is at the heart of Adaire, which Mushambi and Henning cofounded in 2021. "DACH is in the middle of a war for technology talent," Mushambi says, noting that the company's competitors are based in what he calls more traditional software-outsourcing hubs, like India, Southeast Asia, and Eastern Europe. "Right now, the African talent is invisible, at least on the global stage," Mushambi notes. The continent is ignored by boardrooms globally, he says; even some African companies would rather engage an Indian firm.

> "WE INTENTIONALLY MAKE IT OUR GOAL TO POSITIVELY CHANGE THE REPUTATION AND GLOBAL PERCEPTION OF AN AFRICAN TECHNOLOGIST."
>
> —KUDAH MUSHAMBI, CO-FOUNDER OF ADAIRE

But Africa, he says, "has eager, youthful, dormant, and un- and underutilized talent, keen to access new opportunities."

Fittingly, the name Adaire is inspired by a Namibian phrase, "Ada I re," which means, "Let's go." And Mushambi is ready.

STARTING THE STARTUP

ADAIRE SIGNED ITS FIRST CLIENTS in early 2022, and—in addition to the Zurich and Berlin offices—they've built a team of 10 employees who work in a centralized R & D center in Windhoek, Namibia. Initially the company is focused on relatively straightforward, traditional offerings: software, website, and app development. "All the normal technologies such as JavaScript, WordPress, and Wix," says Mushambi, along with graphic design and UI/UX services. The company will eventually provide back office, call center, and IT support.

The plan is to progress in steps, starting with the July 2023 launch of Adaire Academy—to find and recruit talent as well as offer education, re-skilling and upskilling—and progressing to a focus on newer tech such as data science and cyber security. Eventually, Mushambi wants to construct additional centers that can absorb greater numbers of talent. Within this middle phase, the company plans to offer 24/7 support for clients. The long-term goal, Mushambi says, "is to start building our own products and to generate IP using the talent we've assembled."

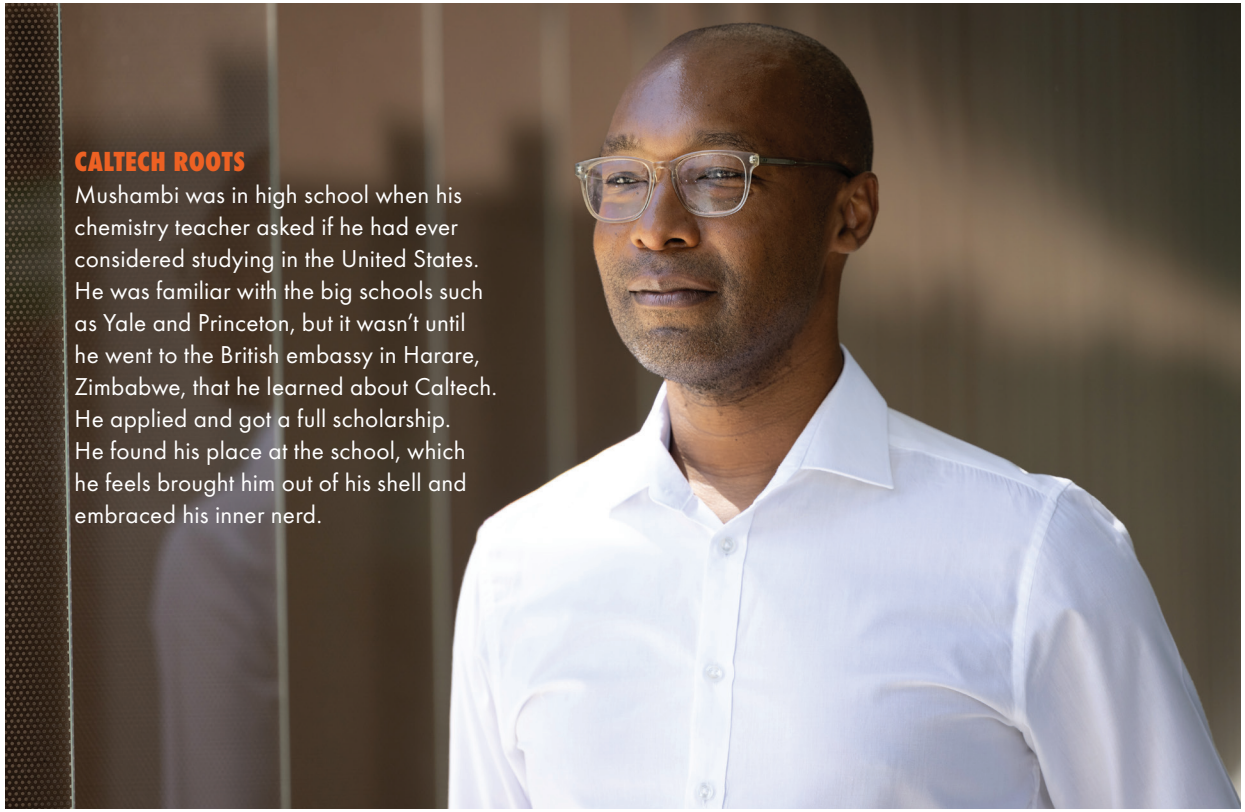
Mushambi answers negative perceptions of outsourcing or misplaced bias against African tech prowess with three

key strategies: "First, we embrace the word 'outsourcing.' The partners realized that the world understands the cost-focused value of outsourcing. Second, they decided to address any negative biases head on, and built in a strategy to proactively answer questions such as, 'Is the educational system in Africa good enough?' The answer is yes, and the purpose of Adaire Academy is to fill any gaps." Finally, Mushambi says, "We intentionally made it our goal to positively change the reputation and global perception of an African technologist."

But that will require finding and training a new generation of talent—an initiative that Mushambi notes is Adaire's biggest challenge. "A lot of people have traveled to Africa on holiday," he says. "Then, in Nairobi, for instance, they chat up their taxi driver only to find that she has a PhD in microbiology!" Adaire wants to track those people—through schools, technical academies, local presence, Ministry of Education incubators, and accelerators—and train them through Adaire Academy.

To develop the Academy curriculum, Adaire partnered with the public research university École polytechnique fédérale de Lausanne ("Basically, the Caltech of Switzerland," says Mushambi) to train promising technology students. The programs will actively recruit women, with a goal of achieving a 75% female workforce—which would be transformative, should Adaire achieve its mission of unlocking one million African software developers.

Growth, Mushambi says, requires a coordinated effort of fundraising, partnerships, internships, and mentorships. While there is a rich startup ecosystem in Switzerland, Mushambi found the community slim and federal support weak when he and his wife moved there four years ago. An alliance with the Swiss Startup Association has been an important early step, providing international networking opportunities as well as a way to strengthen local support and organization. The alliance has also brought them community, clients, and critical government validation.



CALTECH ROOTS

Mushambi was in high school when his chemistry teacher asked if he had ever considered studying in the United States. He was familiar with the big schools such as Yale and Princeton, but it wasn't until he went to the British embassy in Harare, Zimbabwe, that he learned about Caltech. He applied and got a full scholarship. He found his place at the school, which he feels brought him out of his shell and embraced his inner nerd.

Marketing campaigns that challenge prevailing opinions on African tech talent will be critical, too. "We need advocates who believe in that first project, who have the understanding that this is the starting point of something really good," Mushambi says. "People who understand the incredibleness of Africa."

IMPACT AND INCOME

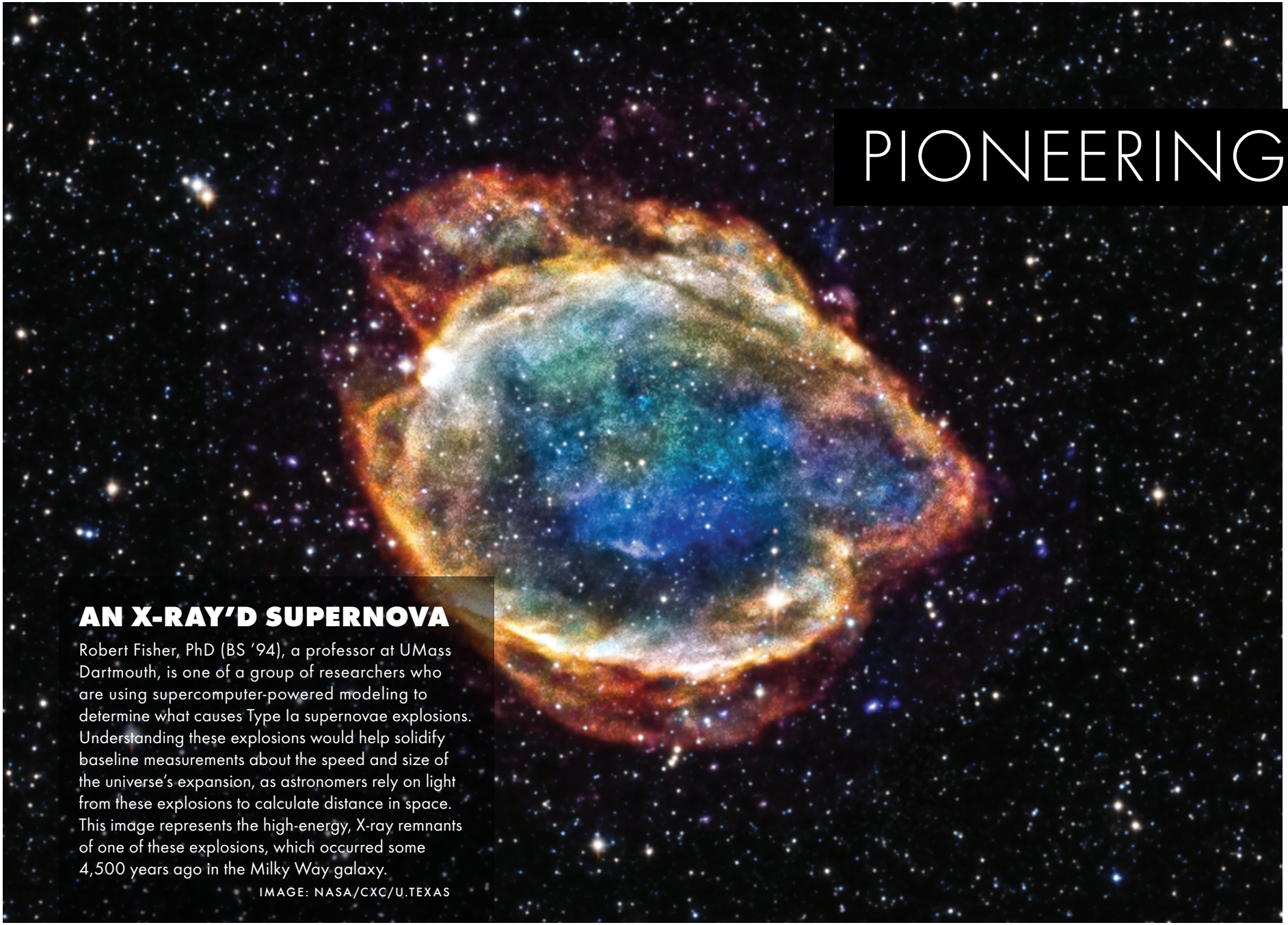
MUSHAMBI HAS HAD TO DEAL WITH skepticism from potential clients and recruits alike. A significant concern is whether the attention paid to having a positive impact detracts from delivering excellent service. And how are they different from the traditional centers?

That is why the partners came up with the tagline "ethical technology outsourcing" to shorthand what they are doing and communicate that there's a right way to do business and treat employees.

Mushambi hopes people will come to Africa and visit Adaire's state-of-the-art centers to get an appreciation of both the continent and the social impact the organization is having. "If we provide a safe and stable environment, everyone has a level playing field, which allows us to go above and beyond creating a professional experience for our customers, and endless opportunities for our teams." ■

Photo by Carmen Sirboiu

PIONEERING



AN X-RAY'D SUPERNOVA

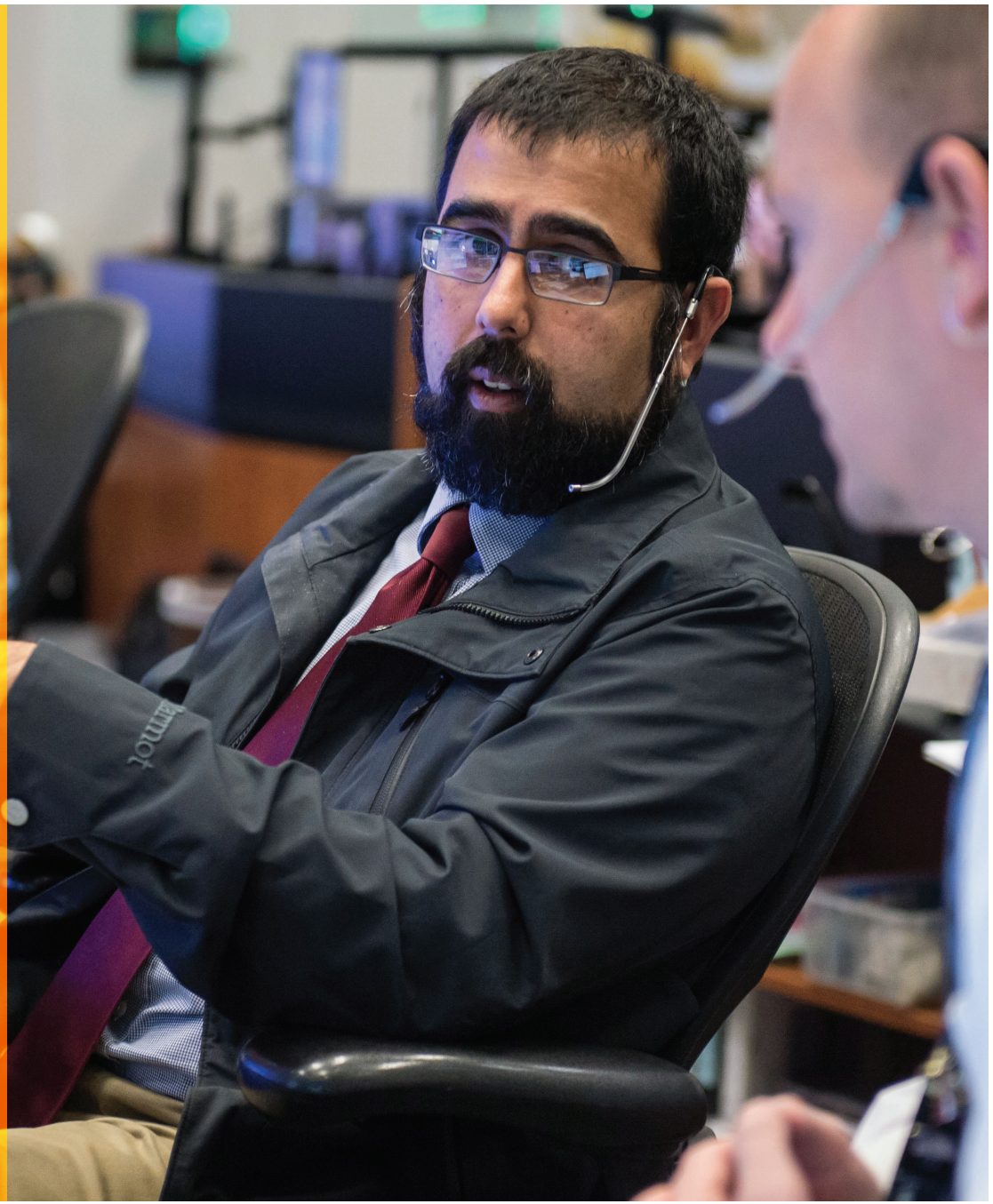
Robert Fisher, PhD (BS '94), a professor at UMass Dartmouth, is one of a group of researchers who are using supercomputer-powered modeling to determine what causes Type Ia supernovae explosions. Understanding these explosions would help solidify baseline measurements about the speed and size of the universe's expansion, as astronomers rely on light from these explosions to calculate distance in space. This image represents the high-energy, X-ray remnants of one of these explosions, which occurred some 4,500 years ago in the Milky Way galaxy.

IMAGE: NASA/CXC/U.TEXAS

FROM MOON TO MARS

AMIT KSHATRIYA, MA (BS ’00), WHO IS LEADING NASA’S PLANNED RETURN TO THE MOON, ON THE POWER OF GALACTIC AMBITIONS

BY APRIL WHITE



AS THE HEAD OF THE AGENCY'S NEW MOON TO MARS PROGRAM OFFICE, AMIT KSHATRIYA, MA (BS '00) HAS A HISTORIC CHARGE: RETURN ASTRONAUTS TO THE MOON FOR THE FIRST TIME IN MORE THAN HALF A CENTURY, IN PREPARATION FOR HUMAN EXPLORATION OF MARS. IT'S AN ENORMOUS UNDERTAKING, A $7.5 BILLION BUSINESS EMPLOYING SOME 10,000 PEOPLE ALL FOCUSED ON SOME OF HUMANKIND'S BIGGEST QUESTIONS. "WHAT IS OUT THERE? WHAT DOES IT MEAN ABOUT THE ORIGINS OF LIFE? WHAT DOES IT MEAN ABOUT WHETHER WE'RE ALONE OR NOT IN THE UNIVERSE?" KSHATRIYA MUSES FROM HIS OFFICE IN HOUSTON.

"EVERYONE YOU MEET, EVERYONE CARES ABOUT THE MISSION," KSHATRIYA SAYS TODAY. "PEOPLE DOING PROCUREMENT, PEOPLE CLEANING THE FLOORS. IT DOESN'T MATTER WHAT YOUR ROLE IS OR HOW LONG YOU'VE BEEN HERE. EVERYONE FEELS LIKE THEY ARE PART OF THIS AMAZING THING."

KSHATRIYA HAS BEEN LOOKING TO THE STARS FOR TWO DECADES.

He has worked on NASA's space shuttle program and on the International Space Station, and he served as a NASA flight director, one of just about 100 people to lead Mission Control since its establishment in 1965. But his interest in space has definitively terrestrial origins: a sense of hometown pride and childhood memories of a historic shuttle launch.

Kshatriya grew up in Houston. "Everyone that grows up in Houston believes that the program is super important," he says. "It's a civic thing, but also you kind of feel connected to the rest of the country." Each time the United States sent astronauts into space, the world's eyes turned to the nearby Johnson Space Center, home to NASA's Mission Control.

He was still in elementary school in January 1986, when, 73 seconds after takeoff, NASA's Challenger space shuttle exploded, killing all seven crew members. The tragedy had the unexpected effect of inspiring Kshatriya. He remembers watching the investigative hearings into the disaster, in particular the testimony of Richard Feynman, then a professor of physics at Caltech. Feynman sat before the cameras with a glass of ice water and a piece of an O-ring, which had been designed to seal a joint in the Challenger. On live TV, Feynman showed that in cold temperatures, such as those on the morning of the ill-fated launch, this small piece of rubber lost its flexibility, a tiny flaw that had led to massive failure. For Kshatriya, the demonstration was evidence that his respect for the United States and NASA was well placed: "We had a government that could sit there and question itself and have one of the most amazing scientists in the world stare down this committee and say 'we need to get better.'"

Still, Kshatriya did not yet see himself in Mission Control. "I was more interested in playing baseball for the Astros than actually being a part of NASA," he says of his earliest career ambitions. But Kshatriya's parents, both Indian immigrants, stressed the impor-

Previous spread: Amit Kshatriya (right) plays a pivotal role overseeing NASA's efforts to send humans to the Moon and build a long-term presence there—an effort that began with the launch of the Artemis 1 mission in 2022 (left).

Left: Kshatriya (middle) asks questions of participants during the Artemis II Mission Integration Review, a checkpoint in the lead-up to the first crewed Artemis mission.

Photography: Courtesy of NASA

tance of an education in math and science; his mother was a chemist and his father an engineer. Kshatriya began to see that as a path to "what I really wanted to do: be a part of big things." That desire led him to Caltech. He first studied physics and later mathematics, but the most important lesson, he says, was humility. "You realize very quickly that you are not nearly as smart as you think you are," Kshatriya says. "To me that was super liberating."

After graduating from Caltech, Kshatriya returned to Texas to pursue a graduate degree in mathematics and to care for his ailing father and woo his now-wife. In the challenging job market of the mid-2000s, Kshatriya pursued opportunities in the oil and gas industry and the medical sector before joining United Space Alliance, NASA's primary contractor on the space shuttle program. That was the summer of 2003, just six months after the space shuttle Columbia broke up on reentry into the Earth's atmosphere over Texas, killing seven crew members. "One of my first assignments was to read the Columbia Accident Investigation Board report," Kshatriya says. According to the report, one of the factors in the disaster was the organization culture of NASA, and soon Kshatriya would become a part of the effort to improve it.

"Everyone you meet, everyone cares about the mission," Kshatriya says today. "People doing procurement, people cleaning

"ALL THE PROBLEMS WE HAVE—CANCER, THE ENVIRONMENT, ALL THE THINGS THAT WE NEED TO DO—WILL BE SOLVED BECAUSE OF THAT KIND OF INSPIRATION."

the floors. It doesn't matter what your role is or how long you've been here. Everyone feels like they are part of this amazing thing." That attitude is essential when you have two spacecraft flying side by side at 18,000 miles an hour, 250 miles above the Earth, says Kshatriya, describing a 2012 SpaceX mission to the International Space Station. He was a part of the team that operated a robotic arm to connect the crafts and resupply the space station. "We thought a lot about the things that could go wrong," he says. "It's kind of fraught with peril." The successful mission earned Kshatriya the Silver Snoopy, an award presented by NASA astronauts to someone who has made an outstanding contribution to the safety of human space flight.

On this late spring day, Kshatriya is about to launch into a three-day mission integration review of all the products that need to be built for Artemis II, which is the second mission of a four-part effort to establish a long-term human presence on the Moon as a step toward exploration of Mars, with additional Moon missions to follow. The uncrewed Artemis I mission was a successful test of the Orion spacecraft, NASA's new space exploration vehicle and its most powerful rocket, the Space Launch System. The crewed Artemis II mission will conduct additional tests before the Artemis III mission lands astronauts in the Moon's southern polar region, which may be home to substances that will help scientists create a source of water. Artemis IV will return astronauts to the Moon's surface and build the Lunar Gateway, a space station in orbit around the Moon, which can be used as a base for longer missions.

These Artemis missions are, at their core, about scientific discovery. "What we're trying to do is expand people's brains," Kshatriya says. Global leadership—what Kshatriya describes as "making sure that the exploration of space is covered by our values as a democracy"—is also an important motivation. But for Kshatriya, the most vital reason to return to the Moon is the same thing that turned his attention to the stars: inspiration.

The memories he treasures most from his time in Mission Control aren't populated by astronauts, but by the children of his coworkers who came to visit a room most have only seen on TV and in movies. "They would walk in and they would look up on the front room board, and they would see astronauts bouncing around, doing experiments, and they would stop. They'd do a double take." Kshatriya loved to take the time to explain what they were seeing. "At some point there's a realization that what they're seeing is actually happening. And this is something that they can be a part of. And whether or not they decide that they want to be a part of the space program, they recognize that you can do incredible things," Kshatriya says. "All the problems we have—cancer, the environment, all the things that we need to do—will be solved because of that kind of inspiration." ■

Jolly Patro (Class of 2023) and Eugene R. Wilson
at the Torchbearers Appreciation Luncheon on April 15, 2023

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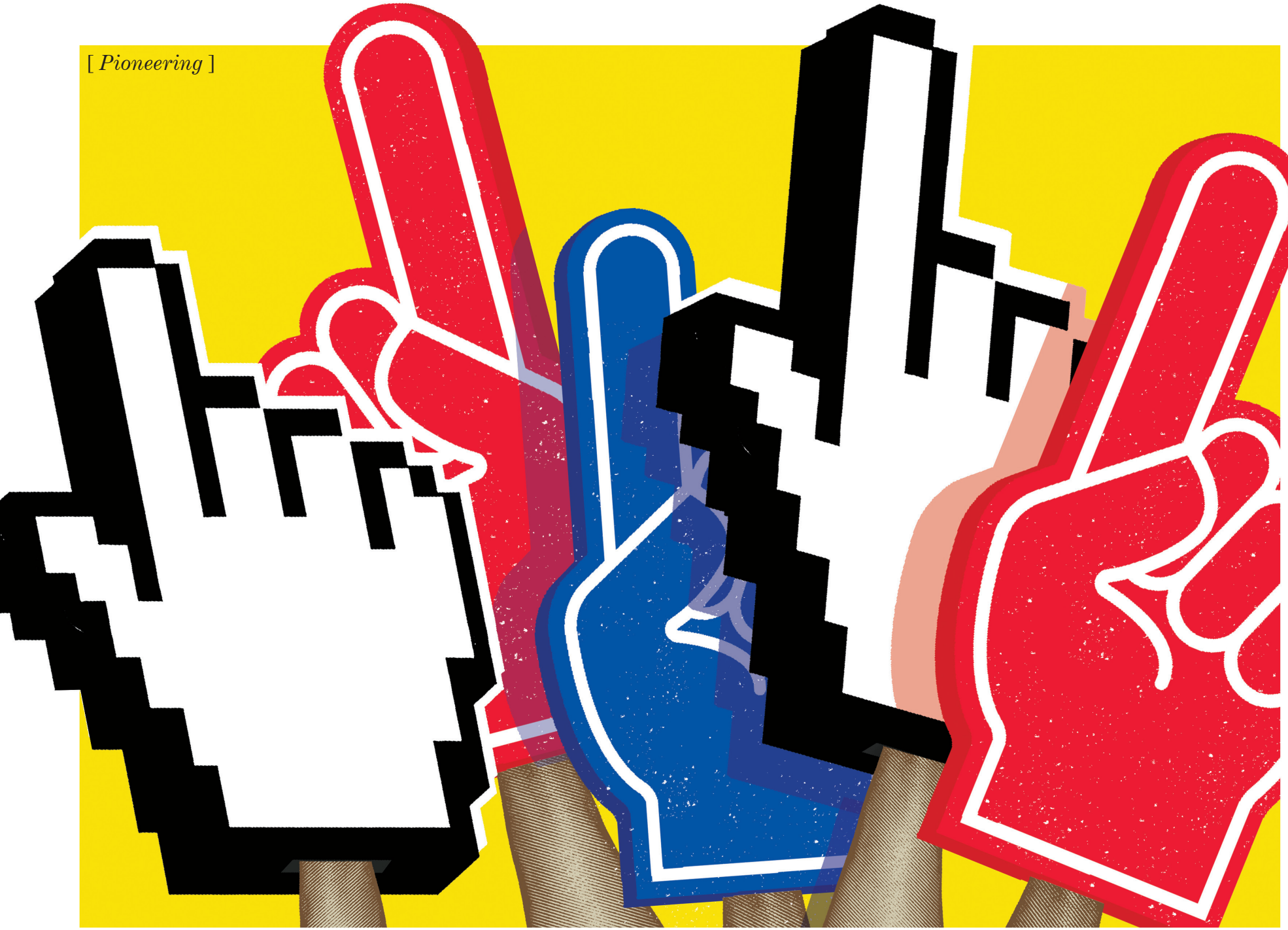


NUMBERS GAME

Sports analytics icons Ari Kaplan, BS (BS '92) and Dean Oliver, PhD (BS '90) on the next era of game-changing data

By Dan Morrell

Illustration by Gary Neill

DEAN OLIVER

ARI KAPLAN

THIS year marks the 20th anniversary of Michael Lewis's *Moneyball*—a book that captured a rising tide of data analysis in baseball and ushered in a metrics-driven era in the sports world and beyond. **Dean Oliver, PhD (BS '90)** an engineering consultant and aspiring basketball analyst at the time, landed a job at the Seattle Supersonics soon after the best-selling book was published and tracked down fellow Bay Area resident Lewis to buy him lunch. "When I was trying to get a job in basketball, I would say, 'Did you read *Moneyball*? If you want to know how to do that in basketball, here's how,'" recalls Oliver, now an assistant coach with the Washington Wizards. **Ari Kaplan, BS (BS '92)** a longtime baseball front office analytics consultant and one of the earliest analytics acolytes, has watched the industry explode over the past two decades. "When I started working for a team, I was one of only a handful of people employed by an organization to do anything even remotely close to analytics," says Kaplan. "And now teams across sports have 10, 20, 30 or more data and analytics staffers."

In this joint interview, we talk to these two forefathers of the movement about the past, present, and future of quantified competition.

When we talk about the data-driven revolution in sports, we tend to focus on front offices' use of metrics. How has it impacted how athletes approach performance?

Ari Kaplan: From day one, when I was an undergrad at Caltech and [former Dodgers GM] Fred Claire let me into the dugout, I went from being a fan to sitting next to stars like Eddie Murray, Kirk Gibson, and Orel Hershiser. And players back then loved the idea of statistical analysis, because they conceptually loved getting proper credit for their work. That was the first phase. The next leap was strategy: getting information players can use to either understand the strengths, weaknesses, and habits of their opponent, or to develop as an athlete themselves.

Dean, on the basketball side, was there a reticence to embrace statistics? Or did the players immediately see the value?

Dean Oliver: It was more gradual, and it is still working its way into the player development realm. But over the last few years, I've had the opportunity to work more closely with players. [Former Wizards forward] Kristaps Porzingis had his best year this year, and he and I worked together on three-point shooting, shot choice, and different elements of his rebounding. And it's detailed stuff, not "you need to rebound better." Often it is positioning: he's going too far out as opposed to sticking around the basket. So there are mechanical elements that can be tweaked with the data that we have right now. And as data evolves, you can get more into some of the detailed mechanics.

How has artificial intelligence impacted your work?

Oliver: Machine learning changed basketball roughly 10 years ago. The video tracking data that started coming in from the NBA—where AI had converted images into dots—wasn't available league-wide originally; individual teams were actually paying for it. The company that provided it started giving out some of the data to academics. And those academics said, "Oh, I know what to do with this. Let me use this to evaluate rebounding and how much the positioning matters." Then they expanded it to ask, "Can I use this data to identify a pick-and-roll or a post up?" The automatic tracking of all that dramatically changed analysis in the NBA. Now every team has access to that same information, and they have consistent measures of it. Machine learning gave a kind of a language to the moving dots, and that language was then translated to the coaches, to management, and to analysts like me.

Kaplan: Human talent evaluators have their roles in this work, too. Jerry Krause, who was the Bulls GM and my personal mentor in Chicago for many years, was non-analytical and non-mathematical, but a genius at seeing which players he thought would succeed and which he could give up on. Artificial intelligence and machine learning can now look at the words that talent evaluators like him write in a text report and pick up clues—perhaps, for instance, certain phrases that tend to be more predictive of how a player might do in the long term.

Oliver: I want to note that we're not just doing data science here. Machine learning is data science. I'm actually working with professors and the basketball coach at Caltech, for instance, on developing some theory around how people interact in a team setting and the value of players in a team setting. It has required some of the deepest math that I've done since Caltech, and it's fascinating stuff. I'm looking at roles on a team, with some players who take more shots and then role players who have to be more efficient. In theory, no player can maintain their efficiency completely as they shoot more and more because they're going to take worse and worse shots. And so we put those things together to get an idea for how to balance the players on a team.

What are the metrics that front offices are thinking about these days as they're weighing player decisions?

Kaplan: One thing they might be considering is how to evaluate which players to sign long-term. The old way was to just look at a player in isolation. But each ballpark has different dimensions and weather conditions, and if you are on a team where you're the sole star, opponents are going to pitch around you to get to an easier player. So teams are now looking at what would happen in context—if they took a certain player and put them in their team with its existing characteristics.

I'm also working on something called multimodal evaluation, where you take many different types of information—both subjective things like scouting notes and injury history along with objective data—and put it into an AI-powered engine to get individualized development recommendations. That's the next big, solvable challenge.

Oliver: The consideration of analytics by the front office is important, but I've always felt like the success of an organization is also dependent on how it deals with a situation when the analytics don't agree with the eyes, and you have to have that tough conversation about how to reconcile it. That's not necessarily a quick exercise, but in a front office, you need to go through that and hopefully get it right before the draft or the trade deadline. ■

ENRICHING

THE SCIENCE OF ART

Fernando de Goes, PhD (MS '11, PhD '14) won an Academy Scientific and Technical Award in February for his work developing Pixar's Fizt2 elastic simulation system. Fizt2 uses advanced mathematics to help simulate anisotropic energies, which have different physical properties when measured in different directions, and enable artists at Pixar to realistically distinguish the difference between, say, a firm suit and a soft shirt across different body types. His work, seen in this image from 2020's *Onward*, is naturally complex and sophisticated—and the foundation for some of the world's most lovable characters.

IMAGE: DISNEY/PIXAR

QUANTUM LEAPS

Eric Ostby, PhD (MS '04, PhD '09) on the current state of quantum computing—and the shape of things to come

BY MAUREEN HARMON

PHOTOGRAPH BY NADIA TYSON

THOUGH Eric Ostby, PhD (MS '04, PhD '09) was aware of the concept of quantum computing in his undergrad years and in his years at Caltech, it wasn't a field he planned to pursue. "I thought quantum computing was a fascinating field for the future," says Ostby, "but not something that was applicable today."

He changed his mind when he joined Google as a product manager in its quantum computing group. It was there that he became part of a seminal moment in the field when his team announced in 2019 that they had achieved "quantum supremacy," meaning that they had created a machine that could do a well-defined task much faster than a classical computer.

TODAY, Ostby is vice president for product development at Rigetti Computing, a company that develops systems and hardware to support quantum computing—helping usher in a tech revolution that once looked fantastical. In this conversation with *Techer*, he discusses the innovations that quantum computing could make possible, and what it will take to get there.

Eric Ostby in front of ORNL's Summit supercomputer while at Rigetti.

How do you explain your job to your young children?
Eric Ostby: I tell them it all just comes down to math. A classical computer is really a tiny processor with the capacity to do relatively basic math—and that math allows my daughter to watch videos on a phone. A quantum computer can do much more complex math, and it can do it fast. Let's say, for example, you want to figure out how many square feet you have in a room. One option is to do a lot of addition, I might tell the kids. You could take a one-foot square tile and go around the room and add up all the squares it would take to fill the room. Think of that as classical computing.

But we can solve that square-foot problem much more quickly with an advanced form of math: multiplication. Four tiles down the room and six across is 24 feet.

Quantum computing is using advanced math so we can take a shortcut to the answer. A quantum computer could help us figure out the best way to get to Mars or it could help us design a drug to address some types of cancer. I tell my kids that I'm working to build those machines.

You talk a lot about the quantum computers' ability to solve problems that don't seem solvable today. Give us an example.
EO: Today we can't simulate the chemistry of even small molecules. We can do methane, we can do helium, but we can't simulate larger molecules over 50 valence electrons. The classical techniques break down when the molecules get more complex. So chemical companies today have to do a lot of approximate calculations and thousands of experiments every day on a small scale. They're constantly testing because they don't have efficient ways to get to the answers.

But with quantum computing, there's promise that you could actually do those simulations and computations without needing to run thousands of experiments. So, for biopharma, quantum computing holds the promise for accelerated drug development.

What's one of the biggest challenges we face with quantum computing?
EO: Classical computation is like a coin. You have heads or tails. (Think ones and zeros.) And a coin sitting on a table is a very stable

thing. You put a coin heads up on a table and it stays there; it doesn't change. But take that same coin and spin it on the table: that's quantum computing. It's fast, and it's a mixture of heads and tails (ones and zeros) existing at the same time. The problem is, the coin will eventually stop spinning—it can't hold that state forever.

So one of the challenges we face is creating more stable states for qubits—the unit of information in quantum computing that is similar to a bit in classical computing—so we can run longer computations to solve more challenging problems. Think of it this way: Classical computers are like the family car. They can run around a racetrack for hours and days without breaking down. A quantum computer is like a very fast race car, a super car, but it can only make it halfway around the track before it breaks down. We want to get that super car to be able to go around the track as long as the family car—and then we can really go far in that race.

Everyone seems to be talking about quantum computing, but we're still early in the field's history.

EO: It's not early days, exactly; I'd say we're getting into the Middle Ages. We have functional machines with limitations, and now we're working to improve their performance. If the field were a 20-chapter book, I think we're at least on chapter five.

How do the worlds of AI and quantum computing overlap?

EO: I'm actually getting that question a lot, even from my family. Technologies like ChatGPT have created models that are trained on an enormous amount of data. For example, ChatGPT basically downloaded all of Twitter for a couple years—all those conversations and comments. Then it scanned books, newspaper articles, and encyclopedias. It's trained on more information than you or I could read in our lifetimes and it's able to predict text by matching patterns that it has seen in the past. It can seem very human because it's basically regurgitating written human speech. But quantum computers are not large-data solutions. This is a common misconception in the field.

Even so, quantum computers could be useful for AI in generating new data that doesn't exist. One of the things that I'm working on at Rigetti is called generative quantum machine learning. This is an area of quantum computing where we can look at problems that have sparse data sets which we consider "rare events." One example might be the meteorite that wiped out the dinosaurs. We don't have a lot of data from that event, so machine learning isn't going to work very well because it has very limited data for training. But a quantum computer can generate missing data based on what we already know.

There are some theories in the field that a quantum computer works more like the human brain, which is essentially a learning model. As humans, we have experiences and we have memories, but we also form connections between those experiences and memories. This is a neural net and the idea is that a quantum computer could function as a neural net. I think it's an interesting area of long-term research to say, could we build a neural net with a quantum computer that's more human-like than what we have now? We haven't been very successful at producing something that models the human brain with classical computing. Tesla's autopilot is good, but it's nothing compared to a human driver. ■

"CLASSICAL COMPUTATION is like a coin. You have heads or tails. (Think ones and zeros.) And a coin sitting on a table is a very stable thing. You put a coin heads up on a table and it stays there; it doesn't change. But take that same coin and spin it on the table: that's quantum computing."

By Maureen Harmon • Illustration by Juliette Borda

STARTUP FOUNDER ZEHRA CATALTEPE ON HOW HUMANITY WILL SHAPE THE ERA OF AI

AI FOR ALL

IN 2017, ZEHRA CATALTEPE, PHD (MS '94, PHD '98) launched TAZI AI to create AI products and tools that are easy to understand and operate—and open the technology up to professionals in every field. This accessibility is key, says Cataltepe, not only to create technology that is better for the end user, but also to combat bias in its programming. "Right now," says Cataltepe, "my concern is: Whose voice will the AI hear? Will it only hear those rich or tech-savvy enough to adopt it and use it?" In this conversation with *Techer*, Cataltepe talks about the role we all play in the future of AI.

You were an academic before launching TAZI AI. Why did you make the leap to entrepreneur?

Zehra Cataltepe: After I graduated, I did a short postdoc, worked at a startup company, and then started working for Siemens Corporate Research. My work there was in creating AI-based predictive maintenance models to assist mechanical engineers. Our goal was to automatically predict faults and defects that could cost a company millions. The speed of AI-based predictions could significantly cut risk and maintenance expenses. However, I eventually switched to academia to do more independent research. The schedule also allowed me to be at home with my kids outside the work day. While in academia, I also consulted for industry research projects, wrote papers, and filed patents, but the time came when I had had enough of papers and projects. I wanted to see AI in industry again—as a product in real action.

What was the problem you were trying to solve with TAZI AI?

ZC: The usual AI methodology is that somebody gives you a dataset which shows the past behavior of their system, and you build an AI model based on that dataset. What happens in real life is that, after you've got your data, time passes and the world changes. You put your model into production and suddenly realize that it doesn't work as well as it worked in training. Consider how the domain experts, like the mechanical engineers I mentioned earlier, operate. They don't look at only the dataset. They have accumulated tens of years of experience on the specific problem you're trying to solve, as well as similar problems. Their knowledge is a lot more valuable than the mere sum of what is in the dataset. The other issue is bias and other problems with models that only become apparent in longer-term deployment. Right now, only data scientists know how to correct these issues in AI. A business owner has to find the issue and explain it to a data scientist, who then has to fix it. That's a difficult path.

My cofounder and husband, Tanju, came up with the idea of training AI while it is in production. Instead of waiting for it to fail and then retraining, we need the AI to be continuously learning and continuously updating itself, even when in production. This is how we humans operate. When we work at our jobs, we use a lot more than our school years, or our "training sets." We should also establish a symbiotic relationship between AI and human domain experts. AI can learn from human expertise and humans can learn from AI's ability to digest billions of data points immediately.

Think of AI as an employee in your company. You will do good work together if, and only if, that employee adapts to your needs. That is, only if you can understand how they're operating, and they, in turn, can respond to your feedback. If one of these things doesn't happen, you are not going to be able to work with that employee. So I see AI models as newbie apprentices in our organizations, which make us more capable and our jobs and lives easier.

What are the biggest challenges to combating bias in AI?

ZC: Everybody concentrates on bias in the data. But the bias in the data arises from bias in society. If you do nothing about that, your AI will be shaped by the biases in your data.

While people mostly account for the direct effects of variables such as age, gender, or race, bias can manifest via variables indirectly affected by or correlated with these variables. For example, ZIP codes and credit scores can be highly correlated with race. While there are regulations aiming to address these kinds of biases, there might be other, more complex biases that are not as evident.

A requirement of making sure that AI is really not biased against certain groups is making sure that the creators of AI represent a diverse range of human experiences and backgrounds. As an example, the creators of AI are currently mostly data scientists or engineers—and these people are mostly men. Even if they mean well, they are liable to not notice bias against women.

Another concern is accessibility. Our historical data contains bias, just like history itself. But if you make AI understandable and easy to use and update, then the population that is using and updating it will have the chance to correct biases in that AI. Most recent AI models (including the ones we have at TAZI) learn both from the data that we feed them and from the deployment-time behavior of a human in their operational loop. We thus need to make sure everyone can give feedback to AI to drive its future behavior. This requires both making AI products easier to use and update, and training people for specific AI-related tasks. Just as we learned to drive bikes, cars, trucks, planes to take us places, future generations will need to learn how to operate different AI models.

You have said that it is possible to fix bias. How long will it take?

ZC: As human beings, we are quite adaptable. If something works really well for us, we adopt it fast. Cell phones were adopted quickly and are continuously tweaked to make them better for the consumer. We will continue to make AI products more and more usable. I believe that some regulation is required, and is already on its way. The US usually has a good balance between innovation and protecting its people. I hope we will see this also for AI regulation.

Most importantly, we'll introduce more people to AI. Today, one third of businesses use AI. I'm guessing that will become most businesses within five to ten years. And the more people and businesses use AI, the more we will be debugging it and the better it will be trained to correct for bias. ■

SOLVING FOR THE ROOTS

TAKING THE PULSE OF URBAN FORESTS

By Jeremy Arnold

Photograph by Cary Wilton

For **Sara Beery, PhD (PhD '22)**, love for the natural world has been a passion since childhood. "I had a very tree-huggy upbringing," she says with a laugh. When she found herself at a crossroads at age 22, following the end of her career as a professional ballerina, Beery decided to devote her life to making even "one small impact" on mitigating the environmental and societal challenges wrought by climate change.

She pursued an undergraduate degree in electrical engineering and discovered new passions for math and computer vision, a type of AI that allows computers to analyze, interpret, and react to the content of various forms of imagery. "My eyes were opened to what those fields were going to be able to do for environmental and biodiversity monitoring at a very large scale," says Beery.

In 2020, as a student researcher at Google, Beery, her mentor Jonathan Huang, PhD, and their team began applying this science to create Auto Arborist, a massive dataset of 2.6 million trees in 23 North American cities that allows researchers to monitor the health of urban forests. Creating these maps, with trees identified by genus, required a complex combination of three modes of data: Google street-view photos, aerial imagery, and existing public tree censuses. "They were at different spatial and temporal scales," Beery explains. "One of the bigger challenges was figuring out how to work around the fact that not every tree that was reported to exist perfectly matched the imagery we see today."

Accurately monitoring the health of urban forests, says Beery, is critical as cities adapt to climate change. "Urban forests provide shade and evapotranspiration, and are vital to things like reducing wind speed, capturing stormwater runoff, and soil stability," she says. "It's environmental infrastructure that is really beneficial when you have extreme weather events." The monitoring can also lend insight into what kinds of trees planted now will be most beneficial in the years to come. "We're seeing climate change shift ecosystem zones, and ecologists predict, for example, that the species that are going to thrive best in New York City in fifty years are the ones that are currently thriving in North Carolina," says Beery.

In the future, the dataset will expand to cover additional cities in North America and around the globe and allow for more nuanced monitoring of the health and growth of trees over time. Beery's hope is that the more detailed models will enable cities to allocate their resources as effectively as possible to foster thriving, equitable, and actively managed urban forests. "That's the dream, but I do think it will happen," says Beery, who is beginning a professorship in AI & Decision Making at MIT this fall. "Anytime I know that the work my collaborators and I have done is truly useful and is actually providing some benefit—that's the best thing." ■

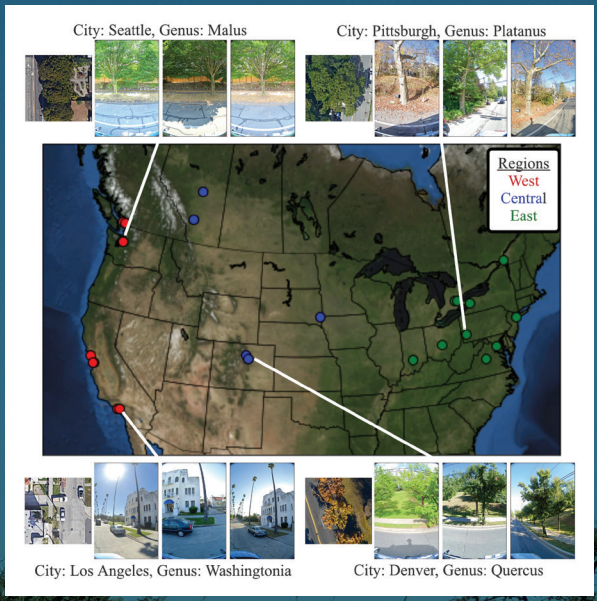
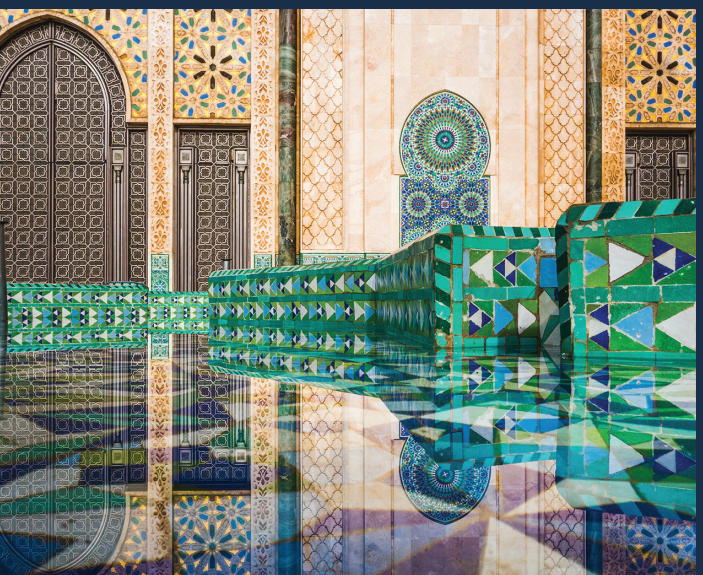


Diagram: Beery, Sara, et al. "The Auto Arborist Dataset: A Large-Scale Benchmark for Multiview Urban Forest Monitoring Under Domain Shift." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, 2022.

"We're seeing climate change shift ecosystem zones, and ecologists predict, for example, that the species that are going to thrive best in New York City in fifty years are the ones that are currently thriving in North Carolina."

"To visit Morocco is still like turning the pages of some illuminated Persian manuscript all embroidered with bright shapes and subtle lines."

– Edith Wharton



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SCHEMA

From the President and CEO of the Caltech Alumni Association

As President of the Caltech Alumni Association (CAA), I am honored to lead an extraordinary community of 25,800 Caltech graduates worldwide.

Even before Caltech earned its name in 1920 (Throop College of Technology, anyone?), CAA's mission has long been centered around an unwavering commitment to the success and well-being of all alumni–as well as the Institute that brought those alumni together.

That is why CAA is dedicated to building even more robust bonds between Caltech and its alumni community. In just the past year, as we emerged from the active phase of the global pandemic, CAA brought Alumni Weekend and Reunions back to campus, returned Seminar Day to campus and offered an online option for Techers to join from around the globe, launched the Caltech In… series to bring the Institute to six US cities, launched Tables for Techers with alumni volunteering to host in 23 states and six additional countries, delivered online events featuring the 2022 Distinguished Alumni Award recipients, and sold out Techer Alumni Tours to Egypt, Southern Africa, and the Galapagos (in partnership with the Associates of Caltech). And those are only a few highlights.

As we look back on all that we have achieved together over the past year, we are also reminded that CAA's mission extends far beyond the Institute's walls. Techers are not only active participants in its ongoing success–you embody the living essence of Caltech's legacy.

As Caltech alumni, your involvement inspires current students, faculty, and staff to push boundaries and strive for excellence. And as global citizens, with the unique set of skills, experience, and education that distinguish Techers, you are called upon as individuals and as a collective to work for the better of our communities and the world beyond.

From helping map the human genome to delivering the world's first surviving octuplets like our 2023 Distinguished Alumni Award recipients (alumni.caltech.edu/daa), Caltech alumni across the globe are working to embody CAA's and their alma mater's values, empower themselves and others, and foster a lifelong pursuit of learning and growth that leads to transformative advancements and positive change.

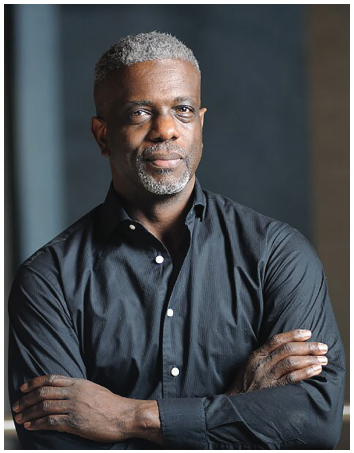
Meanwhile, CAA continues to work with alumni to establish a powerful support network that leverages our diverse perspectives and areas of expertise to forge strong, lasting relationships that, in turn, benefit the communities in which we live, work, and play.

Now, more than ever, the world needs Techers—global citizens who embrace the challenge of championing education, science, and technology to revolutionize industries, solve complex problems, and enhance the lives of our fellow neighbors across the world. Together, we can fulfill our mission, advance humanity, and shape a brighter, more prosperous future for all.

I invite you to engage with the Caltech community as we continue to work toward realizing these goals. Please share your expertise, do your part in mentoring the next generation, and continue to contribute to meaningful projects that help shape our world for the better.

I am deeply grateful for your steadfast support and dedication to our shared values and Caltech's mission. Let us embrace the journey, nurture our global citizenship, and be the driving force behind positive change. The world needs you. And as Caltech alumni, you have the power to make an indelible mark.

RALPH E. AMOS
President and CEO of the Caltech Alumni Association



RALPH E. AMOS
President and CEO of the Caltech Alumni Association

IN MEMORIAM

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

1944
Alvin Landry (CERT '44)
Frank Smith (BS '44)
Abe Zarem (MS '40, PhD '44)

1946
Robert Schrag (MS '46)

1947
Jonas Brachfeld (BS '47)
Jack Slaton (MS '47)

1948
William Carroll (BS '48, MS '49)
Wakefield Dort (MS '48)
Alfred Fay (BS '48)

1949
Keith Kohnen (BS '49)

1950
Walter John (BS '50)
Henry Shapiro (BS '50, MS '51, ENG '52)

1951
Ronald Caldwell (BS '51, MS '55)
Dean Daily (BS '51)
Ulrich Merten (BS '51)
Eugene Sevin (MS '51)

1952
Alexander Dessler (BS '52)
Alan Johnston (BS '52, PhD '56)
David Koons (BS '52, MS '55)
John McCourt (BS '52)
Samuel Middlebrook (BS '52, MS '56)

1953
William Alford (MS '49, PhD '53)
Neil Stefanides (BS '53, MS '54)

1954
Jerome Hershman (MS '54)
Eldon Knuth (PhD '54)
Gordon Moore (PhD '54)
Manuel Morden (BS '54, MS '55)

1955
Jack Rocchio (BS '55)
Philip Snelgrove (MS '55)

1956
J. Scott Davidson (BS '56)
Edward Fredkin (EX '56)
Richard Johnson (BS '56, MS '60)
Thomas Mitchell (PhD '56)
Eugene Nelson (BS '56)
Samuel Phillips (BS '56, MS '57)

1957
James Appleton (MS '57)
Frederick Harshbarger (MS '53, PhD '57)
Richard Kaufmann (BS '57)
Richard Petersen (MS '57)

1959
Edgar Irons (MS '59)
Dean Presnall (MS '59)
Robert Rinker (MS '55, PhD '59)
J. David Teal (BS '59)
John Walden (MS '59)

1960
William Davis (BS '60)
Carleton Moore (PhD '60)
Raymond Taylor (PhD '60)
Samuel Trotter (BS '60)
John Van Dyke (BS '60)
Donald Voet (BS '60)

1961
Guy Andrews (BS '61)
John Dienes (MS '58, PhD '61)
Albert Hybl (PhD '61)
Donald Lampe (MS '61)
William Mather (PhD '61)
William Parker (BS '61)
Thomas Smith (BS '61)

1962
Robert Coyer (MS '62)
Michael Lampton (BS '62)
John Porter (MS '62)

1963
Henry Abarbanel (BS '63)
Floyd Stuart (MS '62, ENG '63)

1964
M. Khairy Abdel-Gawad (MS '64)
Robert Christie (BS '64)
Donald Dick (BS '64)

1965
James Bardeen (PhD '65)
George Brackett (BS '65)
David Jackson (BS '65)
David Rennels (MS '65)
James Wu (MS '59, PhD '65)

1966
Julius Madey (BS '66)

1967
Bing-Man Fung (PhD '67)
G. Laurie Hatch (PhD '67)
Charles Molloy (BS '67, PhD '85)

1968
Robert Huskey (PhD '68)
John Klineberg (MS '62, PhD '68)
Craig SanPietro (BS '68, MS '69)

1969
David Hensley (PhD '69)

1970
Richard Lohman (BS '70)
A. Victoria Peterson (MS '66, PhD '70)

1971
Mark Hopkins (BS '71)

1973
Robert Stecher (BS '73)

1974
Frank Bobrowicz (PhD '74)
Lawrence Mohr (MS '74)
John Morton (BS '74)
William Murphy (PhD '74)

1976
Mark Miller (PhD '76)

1977
Claudia Spiro (BS '77, MS '77)

1978
Donald Miser (MS '78)

1988
Michael Warren (BS '88)

2008
Rupert Venzke (PhD '08)

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Beckman's PH Meter

The pH meter was patented by **Arnold Beckman, PhD (PhD '28)** in 1934 while working as a professor at Caltech. Beckman was asked by his friend Glen Joseph, PhD, who worked for the California Fruit Growers' Association (now Sunkist), to measure the acidity of lemon juice treated by sulfur dioxide. Building on his experience as a glass blower, his time working with electricity at Bell Labs, and his foundation in chemistry, he thought of using a rugged vacuum-tube voltmeter.

After creating the device, Joseph asked for a second one. Beckman decided to commercialize his idea. Enlisting the help of Caltech students **Henry Fracker, BS (BS '30)** and **Bob Barton, PhD (PhD '33)**, he manufactured these devices in a rented space on Colorado Boulevard. This would be the foundation for his company, National Technical Laboratories, where Beckman amassed a significant fortune selling scientific devices. At the time of Beckman's death, the foundation had given more than $400 million to a variety of charities and organizations, including Caltech, where his name can be found on numerous buildings and initiatives. In Beckman's own words: "I accumulated my wealth by selling instruments to scientists ... so I thought it would be appropriate to make contributions to science."

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