Fall 2025

Caltech
magazine

perseverance

What it takes to build the breakthroughs of the future



Contents

Features



Left: **Thomas F. Rosenbaum** speaks with a guest at his inauguration as Caltech's ninth president on October 24, 2014. Rosenbaum will step down next June after 12 years in office.

14
Where Perseverance Meets Discovery
The challenges and rewards of pursuing research over long periods of time.

20
A Conversation with President Rosenbaum
The Institute's leader reflects on his final year as president and how both he and Caltech have evolved during his presidency.

23
Inside Look: Thomas F. Rosenbaum
Step into the office of the president and learn about the objects that personify his life story and work.

26
Investigating Ice at the Far Ends of Earth
Caltech researchers explore firsthand the impacts of rising temperatures at the poles.

31
The 2025 Distinguished Alumni
The awardees are Deborah D.L. Chung (BS '73, MS '73), Athanassios Fokas (PhD '79), F. William Studier (PhD '63), and Donald Truhlar (PhD '70).

36
Insulin innovator
Led by founder and CEO Alborz Mahdavi (PhD '15), Pasadena's Protomer Technologies aims to revolutionize diabetes treatment.

Departments

2 **Letters**

4 **SoCaltech**

12 **In the Community:**
Untangling Entanglement, and More

13 **Origins:**
The Caltech Associates Turns 100

39 **In Memoriam**

40 **Endnotes:**
What has perseverance looked like in your field or career?

Online

How to reach a moon of Jupiter
Feature: **10 challenges for Europa Clipper**



Fire recovery continues
Story: **Caltech's Kim Yu helped launch Altadena Eaton Fire Recovery Fund**



Writing in the age of AI
Q&A: **Susanne Hall of the Hixon Writing Center**



Visit **magazine.caltech.edu**

Caltech
magazine

EDITOR IN CHIEF
Lori Oliwenstein

SENIOR EDITOR
Omar Shamout

ART DIRECTOR
Jenny K. Somerville

MANAGING EDITOR
Sharon Kaplan

ONLINE EDITOR AND
SOCIAL MEDIA COORDINATOR
Andrew Moseman

CONTRIBUTING WRITERS
DC Agle, Whitney Clavin, Lori Dajose, Marisa Demers, Andrew Moseman, Katie Neith, Chris Quirk, Omar Shamout

DESIGNER
Jenny K. Somerville

ONLINE DESIGNER
Sergio Solorzano

ILLUSTRATION, PHOTOGRAPHY, VIDEOGRAPHY
Randall De Chavez, Whitney Clavin, Lance Hayashida, Sergio Solorzano, Jenny K. Somerville, Bill Youngblood

COPY EDITOR
Sharon Kaplan

PRODUCED BY CALTECH'S OFFICE OF COMMUNICATIONS AND EXTERNAL RELATIONS
Shayna Chabner,
Associate Vice President, Strategy Implementation

Read *Caltech* magazine on the go at **magazine.caltech.edu**

Contact *Caltech* magazine at **magazine@caltech.edu**

Caltech magazine ISSN 2475-9570 (print)/ ISSN 2475-9589 (online) is published at Caltech, 1200 East California Boulevard, Pasadena, CA 91125.

All rights reserved. Reproduction of material contained herein forbidden without authorization. ©2025, California Institute of Technology. Published by Caltech.

Image credits: Image credits: Lance Hayashida: cover, 2 (left), 9 (bottom), 14–15, 18, 39 (right), back cover; NASA/JPL-Caltech: TOC (top right); Keats Elliot: TOC (middle right); Van Urfalian: TOC (bottom right); The Paul B. MacCready Papers/Courtesy of Caltech Archives: 2 (right); Image data by NASA/JPL-Caltech/SwRI/MSSS, Image processing by Gerald Eichstädt: 4–5; Caltech Robotics Club: 6 (bottom); Courtesy of Sandra Tsing Loh: 8; NASA: 9 (top); Christopher Michel: 10 (top); Aurore Simonnet (SSU/EdEon)/LVK/URI: 10 (bottom); Sergio Solorzano: 11; Randall De Chavez: 12 (top); Whitney Clavin: 12 (right, lower); Caltech: 13; Caltech: 17; Bill Youngblood: TOC (large), 20–25; Courtesy of W. Fischer: 26–27; Courtesy of A. Thompson: 29; Courtesy of Zhongwen Zhan: 30; Courtesy Deborah Chung: 32; University of Cambridge: 33; Broad Institute: 34; Courtesy of Donald Truhlar: 35; Leah Lee: 36; Bob Paz: 39 (top left); United States Department of Commerce 39 (bottom left); Shutterstock/Gorodenkoff: 40 (top); Shutterstock/Mironov Konstantin: 40 (bottom); Shutterstock/Jure Divich: 41.

Printed by Courier Graphics Corporation, Phoenix, AZ

MIX
Paper | Supporting responsible forestry
FSC® C007548



Left: The Olive Walk as seen on September 29, 2025, the first day of instruction in the 2025–26 academic year.

Letters

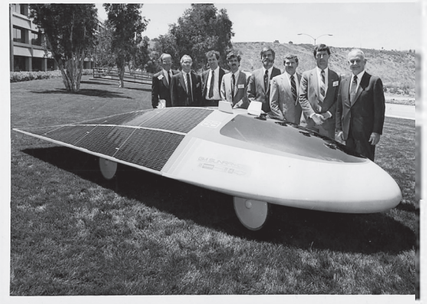
Sunraycer's Story

As a proud Caltech alumnus, it grieves me to point out that, contrary to the article in the Spring 2025 issue of *Caltech* magazine, the solar electric car that won the World Solar Challenge in 1987 was not the "Caltech" Sunraycer. Although the multi-organization team that designed, constructed, and raced the car was heavily seeded with Caltech alumni (as described in detail in the "Sunraycer Odyssey" article by Paul MacCready in the winter 1988 issue of *Engineering and Science*) and testing in the on-campus GALCIT 10-foot wind tunnel played a role, other organizations deserve primary credit. To wit, as described in Wikipedia, "The Sunraycer was a joint collaboration between General Motors, AeroVironment, and Hughes Aircraft."

Full disclosure: I was vice president and board director of AeroVironment at the time but am one Caltech (and GALCIT) alumnus who did not play a direct role in the Sunraycer project.

–Ivar Tombach (BS '63, PhD '69)
CAMARILLO, CA

Editor's note: The article in question, "Computer, Start Your Engine," has been updated online to reflect the parties involved in its creation.



Members of the Sunraycer project team pose with the vehicle at the Hughes Aircraft headquarters in Los Angeles in August 1987.



Give Smarter: Tax Savings Meet World-Changing Research and Education

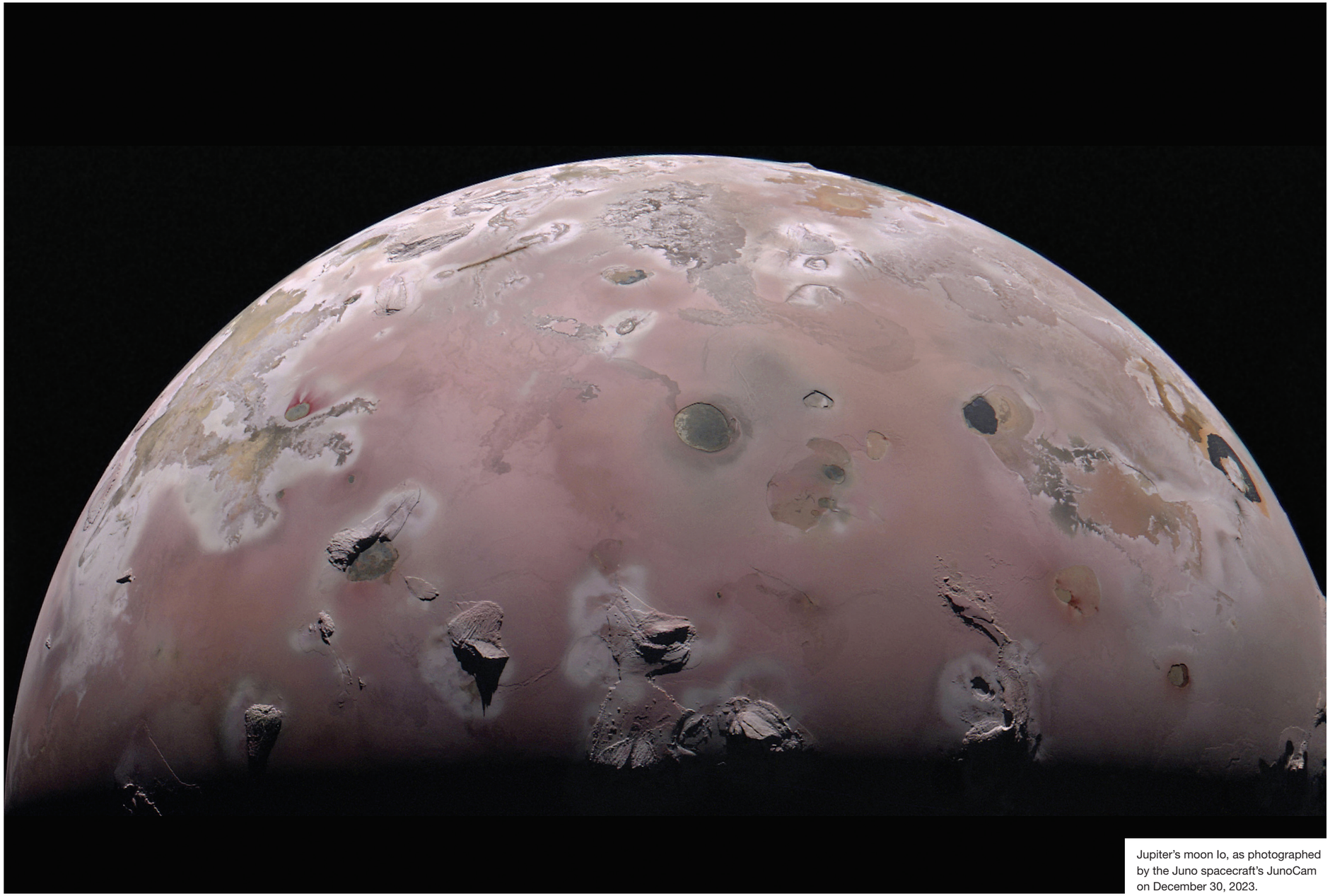
Make a gift of publicly traded stock or mutual funds that have appreciated in value, and save in two ways:

- Receive an income tax deduction for the full market value of your securities.
- Avoid the capital gains tax that would be due if you sold the securities.

Benefit from dual tax savings while supporting world-changing research and education. You can also make a gift using appreciated securities through a charitable remainder trust or a charitable gift annuity, which can provide lifetime income along with an immediate charitable tax deduction.

Caltech's Office of Gift Planning is here to help.
To start a conversation, contact us at **(626) 395-2927** or **giftplanning@caltech.edu**.
Learn more at **giftplanning.caltech.edu/stocks**.

Caltech



Jupiter's moon Io, as photographed by the Juno spacecraft's JunoCam on December 30, 2023.

SoCaltech

- Bon appétit, Techers
- Amplifying a 75-year radio career
- Cruising campus on a couch; and more

Turning up the Heat

In November 2023, NASA's Juno spacecraft was a month away from its closest encounter yet with the surface of Jupiter's moon Io. Coming within roughly 930 miles of the most volcanic world in our solar system, the orbital pass would allow Juno's instruments to generate a firehose of data about variations between Io's volcanoes.

There was only one problem: Juno's camera, known as JunoCam, had stopped working. By the spacecraft's 55th orbit on November 22, 2023, nearly all of JunoCam's visible-light color images had been corrupted by Io's radiation. The problem, the team knew, would only get worse as the spacecraft flew deeper and deeper into the heart of Jupiter's radiation fields.

"Our images were full of streaks and noise," says JunoCam instrument lead Michael Ravine of Malin Space Science Systems. The Juno mission is managed by JPL, which Caltech operates for NASA. "We tried different schemes for processing the images to improve the quality, but nothing worked. With the Io close encounter bearing down on us in a few weeks, it was Hail Mary time."

The JunoCam images began to show hints of radiation damage during orbit 47. The team then tried heating the camera as part of a process called annealing, in which a material is heated for a specified period and then slowly cooled. The idea is that heating can reduce defects in the material. New images initially turned out crisper, but the damage soon returned. "The only thing left we hadn't tried was to crank JunoCam's heater all the way up and see if more extreme annealing would save us," Ravine says.

Test images showed little improvement the first week. Then, with the close approach of Io only days away, the images began to improve dramatically. By the time of the crucial pass on December 30, 2023, the images were almost as good as the day the camera launched. They captured detailed views of Io's north

continued on page 6

Turning up the Heat

continued from page 5

polar region that revealed mountain blocks covered in sulfur dioxide frosts rising sharply from the plains and previously uncharted volcanos with extensive flow fields of lava.

Since the experiments with JunoCam, the Juno team has applied variations of the annealing technique to several Juno instruments and subsystems.

"Juno is teaching us how to create and maintain spacecraft tolerant to radiation, providing insights that will benefit satellites in orbit around Earth," says Scott Bolton, Juno's principal investigator from the Southwest Research Institute. "I expect the lessons learned from Juno will be applicable to both defense and commercial satellites as well as other NASA missions."

Learn more

Couch on the Move

Making your way to class just got a lot more comfortable. The Caltech Robotics Club has crafted a robo-couch that sits on two wheels connected to an electric motor, plus two other unmotorized wheels that share the couch's weight. A rechargeable battery supplies power to the sofa, which can hit 10 mph. "Our goal is to make the couch even more unique," says club member Donny Lu (far left), an undergrad. "We want this to take you from your dorm to your class autonomously."

Read more



Four Questions for :

Caltech radio astronomer Sandy Weinreb

Sandy Weinreb has spent most of his career perfecting the design of radio astronomy receivers, small critical components of radio telescopes that amplify and digitize feeble radio waves from the cosmos. Weinreb joined Caltech in 1999 and is currently an emeritus research associate in astronomy at the Institute. He spearheaded development of uncooled low-noise amplifiers that will debut on Caltech's Deep Synoptic Array (DSA-2000) radio telescope, an array of thousands of dishes to be built in the Nevada desert over the next couple years. The amplifiers are groundbreaking because they do not require cooling with expensive cryogenic refrigerators. "Personally, I think Sandy has a legacy of instrumentation development in radio astronomy that is second to none," says Gregg Hallinan, a Caltech professor of astronomy, DSA-2000's principal investigator, and director of the Institute's Owens Valley Radio Observatory, where a team has been building prototype radio dishes for the DSA. Here, we speak with Weinreb, now 88, about his background and work.



1. What drew you to radio astronomy?

By age 12, I was fixing radios and TVs in repair shops (at right) to help my parents pay the rent. I became interested in radio astronomy while looking for a summer job at MIT as an undergrad. I looked through the Boston phone book and ended up finding a company run by Harold (Doc) Ewen, who discovered the interstellar hydrogen line at Harvard in 1951. This was a big deal in radio astronomy. This hydrogen emission line allows astronomers to study galaxies across the universe. When I visited Ewen's company, I remember that he was sitting on a platform, like a Buddha, with people around the outside who were building receiver components. Somebody explained I was from MIT and looking for a job. Doc said, "Let's give him a buck and get him going." Ten years later, I worked at the National Radio Astronomy Observatory (NRAO) in West Virginia as head of the electronics division.

2. Why are amplifiers so important in radio astronomy receivers?

Low-noise amplifiers determine the sensitivity of the observations. We want to detect faint radio waves from the universe, but our amplifiers can produce their own background noise, like a hiss. We developed ways to minimize that noise by cooling the device.

3. What prompted you to start working on uncooled low-noise amplifiers?

I knew that future radio astronomy observatories would utilize arrays of small antennas that could be combined to provide images of the radio sky. However, each antenna would require an expensive cryogenic cooler that would dominate the cost and limit the number of antennas, which would then limit the number of pixels in the image. Gregg Hallinan told me about the DSA and that he and his team intended to image a large area of sky. To be affordable, this required large numbers of uncooled low-noise amplifiers.

4. How did you figure out how to make them?

I started by looking at superior transistors with much lower noise being developed using indium phosphide semiconductors by groups in the US, Sweden, and Switzerland. I also knew that the usual solder method for printed circuit packaging increased the noise, so I turned to wire bonding of a bare transistor chip. This requires much skill to handle the millimeter-sized chip. The low-noise amplifier design was further improved by Caltech research engineer Kiran Shila [PhD '25] as part of their PhD thesis using machine learning techniques.

Tables for Techers: A Record Year



Sandra Tsing Loh (BS ’83) feeds her brother, Eugene Loh (BS ‘80), a cricket during a Tables for Techers dinner in July at her home in Pasadena.

This July, more than 800 Caltech alumni, students, postdocs, and faculty gathered throughout the country and worldwide to share stories and meaningful conversation as part of the annual Tables for Techers event.

In homes, on farms, and in restaurants, more than 150 hosts and cohosts created spaces that welcomed guests to enjoy a meal and Caltech camaraderie. Tables included participants of all ages, house affiliations, majors, and career paths. “It was great fun,” says Sandra Tsing Loh (BS ’83), who hosted an “eco-themed” table in Pasadena. “We especially appreciated the mix between the older generation and the younger generation. There was a great geographic mix too—from Hunan, China, to Grenoble, France. On top of that, four out of 17 guests walked here—so eco-friendly!”



Aspiring Astronaut

Geologist Lauren Edgar (PhD ’13) has been selected by NASA to join the 2025 astronaut candidate class. Edgar has worked with the U.S. Geological Survey studying Earth, the Moon, and Mars through remote sensing and field techniques to support human and robotic exploration of the solar system. She has more than 17 years of mission operations experience supporting the JPL-managed Mars Science Laboratory and Mars Exploration Rovers. Most recently, she served as NASA’s deputy principal investigator for the Artemis III Geology Team, helping to define the lunar science goals and geology activities NASA astronauts will conduct while on the Moon.



A Quantum Quarter Century

“Having IQIM at Caltech has been really helpful for recruiting students, postdocs, and also faculty involved in quantum science on campus. Twenty-five years ago, people who worked on quantum gravity and people who worked on quantum computing and quantum information did not interact. That has changed a lot. Our activity has also become highly interdisciplinary and now cuts across physics, applied physics, computer science, electrical engineering, chemistry, and materials science. That’s one of the things I’ve found most exciting.”



–John Preskill
Caltech’s Richard P. Feynman Professor of Theoretical Physics and director of the Institute for Quantum Information and Matter, on IQIM’s 25th anniversary





Remembering David Baltimore

“Looking at the many chapters of David’s scientific life beginning as an undergraduate at Swarthmore, through times at MIT, the Salk, Rockefeller, and ultimately at Caltech, the through-line aspiration was the rigorous pursuit of what is new, true, and fundamental, in his own work and in the work of others. Mostly he succeeded, and when he did not, he always learned.”

Barbara Wold (PhD ’78),
Caltech's Bren Professor of Molecular Biology and Merkin Institute Professor, on Nobel Laureate David Baltimore, Caltech President Emeritus and the Judge Shirley Hufstedler Professor of Biology, who passed away on September 6, 2025.

See also “In Memoriam,” page 39

On Its 10th Birthday, LIGO Verifies a Stephen Hawking Theorem

Ten years after the National Science Foundation Laser Interferometer Gravitational-wave Observatory’s landmark detection of gravitational waves, the observatory’s improved detectors are routinely observing roughly one black hole merger every three days. In 2025, the twin LIGO detectors “heard” the signal of one such powerful collision with unprecedented clarity. The data enabled scientists to distinguish multiple subtle tones ringing out like cosmic bells across the universe (imagined at right as intertwining musical threads spiraling toward the center). By analyzing the frequencies of gravitational waves emitted by the merger, the team from LIGO and its international partners (Virgo in Italy and KAGRA in Japan), in a study led by Katerina Chatziioannou, assistant professor of physics and a William H. Hurt Scholar at Caltech, provided the best observational evidence captured to date for what is known as the black hole area theorem. This idea, put forth by Stephen Hawking in 1971, says the total surface areas of black holes cannot decrease.

Read more



Curtis Lee (second-year undergraduate)

#SoCaltech is an occasional series celebrating the diverse individuals who give Caltech its spirit of excellence, ambition, and ingenuity. Know someone we should profile? Send nominations to ***magazine@caltech.edu.***

Lee, who grew up in Hong Kong and went to high school in England, began cooking at age 11. At 15, Lee trained with Michelin-starred chef Maxime Gilbert in Hong Kong, and he was a stagiaire at several top restaurants in London, including Muse by Tom Aikens and The Fat Duck. In total, he has trained under chefs who hold a combined 42 Michelin stars. At Caltech, Lee is a teaching assistant in SA 16 Cooking Basics. He plans to double major in chemical engineering and business, economics, and management.

“Last year, I wanted to start playing with fermentation. So, I made a list of things I wanted to make and thought, ‘What’s the best way to make them?’ I was reading around online and found that I needed to have good control of temperature and humidity, so I decided to make my very own fermentation chamber using a speed rack, PID [proportional–integral–derivative] controller, and small heater. I started to make soy sauce, kombucha, sauerkraut, kimchi, and hot sauce! I’m not much of a baker, but I’ve been working on sourdough and pastries recently. The fermentation chamber really comes in handy to keep my starter happy or to proof my croissants.

I love learning about different cuisines from around the world. Even if you don’t know anything more about a place, if you’re able to talk to someone about a very niche dish from their homeland, they get so surprised. Then they tell you things you don’t know, and you learn even more. Many of my housemates in Avery are Indian, and I met some of their parents when I was in the kitchen cooking Indian food. So, I talked to them about it. I like to use the proper names for everything, and they got so excited. I just love that.”

In the Community

Untangling Entanglement, and More



A group of students from four Los Angeles-area universities, including Caltech, came together last summer with the shared goal of building non-scientists' understanding of quantum science and its applicability and use throughout society.

"The public has been led to believe that quantum science is this really funky, almost magical, mystical thing that exists," says Madison Howard, a physics graduate student at Caltech. "We wanted to help demystify quantum science by hosting events where people could learn about what it actually means for something to be quantum in a meaningful and accurate way."

Inspired by the International Year of Quantum Science and Technology, a worldwide initiative to increase public awareness of quantum science and its applications, the team of students from Caltech, USC, UCLA, and Chapman University developed a 10-week series called Summer of Quantum in LA. At Caltech, Howard worked with fellow graduate students Huma Jafree, Taylor Knapp, and Thomas Zacharias to create engaging programming that explained quantum concepts such as superposition and entanglement to people of all ages and expertise levels.

June events included "Quantum for Everyone," a public talk in which 80 guests experienced hands-on demonstrations led by Frank Rice, lecturer in physics and manager of Caltech's sophomore physics lab, and attended short, accessible talks about the frontiers of quantum research from graduate students Piero Chiappina and Hannah Manetsch, and postdoc Lisa Drummond. Forty participants also visited Caltech labs that perform pioneering work in quantum science, including the Nonlinear Photonics Laboratory led by Alireza Marandi, professor of electrical engineering and applied physics. Additionally, Howard helped host a quantum-themed board game night at Odyssey Games in Pasadena.

> "We wanted to help demystify quantum science by hosting events where people could learn about what it actually means ..."
>
> —Physics graduate student Madison Howard

In July, the team welcomed more than 150 children and adults to campus for "Quantum for Kids," which featured demonstrations and interactive activities for young learners led by students from Caltech, USC, and Chapman. Events at local bars also brought together those studying quantum science with curious members of the community in a casual atmosphere.

"We wanted to have good outreach and awareness about what it means to be on the cutting edge of quantum research and really build a community around it, both with people who are involved and people who are interested," Howard says. "Organizing so many different types of events gave us the opportunity to meet people where they're at but also to tailor the content toward different backgrounds and interests."

Meanwhile, Howard and Zacharias said the planning process not only helped them grow their quantum network across universities but also strengthened their connections on campus.

"We had a really positive response and saw that so many people, from students to professors to the administration, want to support events where we are trying to bridge the gap between scientists and nonscientists," says Zacharias, who estimates that at least 50 members of the Caltech community helped make Summer of Quantum a success.

He adds that it is crucial for students to develop communication skills so they can discuss their research in an accessible manner. "We are doing things that can hopefully help society in different ways, such as impacting health by creating better medical therapies or by improving computational power," Zacharias says. "All of us are trying to push quantum science and technology further so it can be useful for everyday people."

–Katie Neith

Origins The Caltech Associates Turns 100

On March 9, 1926, retired railroad magnate and art collector Henry E. Huntington invited 100 of Southern California's most influential men and women to his home in San Marino. Although he had hosted many gatherings of the area's social and business leaders, this one would prove to be historically significant for a nearby institution—and the world.

Not long before, the Caltech Board of Trustees had recognized the need to raise flexible funds to aid and advance the recently renamed California Institute of Technology's welfare by forming a new organization: the Associates of the California Institute of Technology. When 100 donors had each agreed to contribute $1,000 per year for 10 years to the Institute, Huntington held the Associates' first formal meeting at his home.

In the years following the group's founding, the Associates has continued to grow its membership base and cemented its importance in connecting individuals with the Institute and its pioneering researchers. Associates members have provided unrestricted support to propel some of the world's most promising discoveries, grow Caltech's physical footprint, and expand its societal reach.

In 1926, when the Associates started, the Institute's campus comprised just five buildings, and the Institute only offered courses in engineering, chemistry, and physics. Associates William G. Kerckhoff and his wife, Louisa Eshman Kerckhoff, funded a biology laboratory, which began construction in 1928.

The Division of Humanities, now the Division of Humanities and Social Sciences, was formed in 1926 and endowed by eight Associates. The division was then housed in a building funded in 1927 by Joseph B. Dabney and his wife, Louise E. Dabney. In the late 1920s, construction began on the Palomar Observatory, a dream of Caltech Trustee and Associate George Ellery Hale, who secured funds from the Rockefeller Foundation to build the facility's 200-inch telescope near San Diego.

Today's housing system, a staple of undergraduate life at Caltech, had its start in the 1930s, when Associates members, believing small residences were best for students, donated funds to build the South Houses. Architect Gordon Kaufmann designed the South Houses, as well as the Athenaeum (photo below), Caltech's faculty and social club, which opened in 1930 thanks to a gift from Trustee Allen Balch and his wife, Janet Jacks, who were Associates members.

Today, the Associates' membership has grown to more than 1,000 households. Over the past century, Associates have given more than $73 million in unrestricted annual membership gifts and more than $2.5 billion to the Institute to support facilities, research, faculty, and students.

As the Associates moves into its second century, the group is honoring its past by creating the Associates 100 Legacy Circle. The Legacy Circle will comprise 100 individuals or households, each making an unrestricted commitment of $150,000 over the next 10 years, an echo of the Associates' original and influential contributions.

–Omar Shamout



Where Perseverance Meets Discovery

On the power of persistence and building ‘cathedrals’ in science.

By Andrew Moseman



One way or another, Hirosi Ooguri says, string theory will be put to the test. The concept, which suggests one-dimensional vibrating strings are the fundamental particle of the universe, will be proven or disproven through experimentation. The thing is, Ooguri says, it just might take 2,250 years to do so.

To explain, Ooguri proposes a little thought experiment: Only two years elapsed between the arrival of quantum mechanics in the 1920s and the proposal of quantum field theory, a theoretical framework that enables the field of particle physics to jibe with Albert Einstein’s special relativity, the famous $E=mc^2$ theory that explains the relationship between energy, mass, and the speed of light. But it took another 50 years to fully construct the standard model of particle physics, and a further 40 to verify that model experimentally via the discovery of the Higgs boson.

By comparison, it took 50 years just for physicists to propose the idea of string theory as the way to unite quantum mechanics with Einstein’s general relativity, the theory that adds the complicating factor of gravity to special relativity. (Caltech’s John H. Schwarz, the Harold Brown Professor of Theoretical Physics, Emeritus, is regarded as a founder of string theory.) As Ooguri points out, one could take this to mean that the string theory problem is 25 times harder than quantum field theory. Therefore, it stands to reason that the next steps—building a theoretical model and proving it via experiment—might also take 25 times as much time: i.e., a cool millennium apiece.

Of course, Ooguri, Caltech’s Fred Kavli Professor of Theoretical Physics and Mathematics and the Kent and Joyce Kresa Leadership Chair of the Division of Physics, Mathematics and Astronomy, does not really believe scientists will be in the dark until the 43rd century about whether string theory is a path to the one true “theory of everything.” But his back-of-the envelope estimate is meant to prove a more general point: Solving big problems takes a little perseverance. Or, sometimes, a lot.

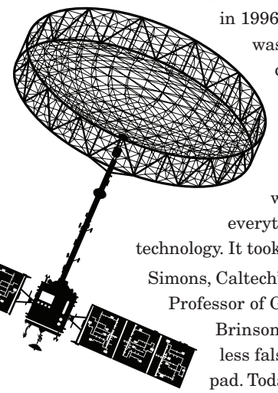
This basic truth underlies the mission to answer the big questions in astronomy, biology, chemistry, renewable energy, and every other field of scientific endeavor. In 2016, Caltech professor of planetary science Konstantin Batygin, together with Mike Brown, the Richard and Barbara Rosenberg Professor of Planetary Astronomy, Terence D. Barr Leadership Chair of the Center for Comparative Planetary Evolution, and director of the Caltech Center for Comparative Planetary Evolution, proposed that certain celestial motions in the far reaches of the solar system could be explained by a heretofore-unseen Planet Nine. The two have spent much of the last decade refining calculations to better pinpoint where such a planet might be found. Whenever that starts to feel like a long time for a planet hunt, Batygin likes to remind himself of how long other such “hunts” have taken. For instance, a century passed between Albert Einstein’s suggestion of gravitational waves and their detection by the National Science Foundation Laser Interferometer Gravitational-wave Observatory (LIGO), a Caltech–MIT collaboration whose success led to the 2017 Nobel Prize in Physics. “Nature has no obligation to reveal itself to us on timescales that we want,” Batygin says. “It’s going to take as long as it’s going to take.”

That kind of stick-to-itiveness abounds at Caltech, where researchers are known for their willingness to tackle audacious challenges that others might avoid, even when the answer or the solution might not come during the scientist's career—or their lifetime—if it is ever worked out at all.

In fact, perseverance is not tied to a specific project or line of inquiry; it is the essence of science itself. The quest for knowledge is unending because every achievement—and setback—yields new questions. It may have taken LIGO a century to prove Einstein right, but that did not mean its scientists stopped investigating gravitational waves. By the same token, research that aims to advance society must also persist despite experiments that fail, missions that are scrapped, and necessary tools that have yet to be invented.

Get Me Off This Rock

Scientists whose work requires data gathered from space often rely on expensive and ambitious telescopes and satellites, which have to be conceived and then built before they can even begin to collect the data they need to interrogate cosmic mysteries.



When Mark Simons joined the Caltech faculty in 1996, fresh out of graduate school, he was keen on the idea of using a tool called a synthetic aperture radar to image Earth in unprecedented detail. At the time, he was assured that NASA would attempt to launch an SAR satellite within the next three years given everything that could be learned via this technology. It took 30.

Simons, Caltech's John W. and Herberta M. Miles Professor of Geophysics and director of the Brinson Exploration Hub, has seen countless false starts on the way to the launchpad. Today, he is a science team member and the co-lead for solid earth science on the NASA-ISRO Synthetic Aperture Radar (NISAR) satellite mission, an orbiter that is poised to deliver the data Simons has sought since *Seinfeld* was on the airwaves. NISAR will help protect communities around the world by providing a dynamic view of how the earth moves in three dimensions with unprecedented detail and measuring the signatures of some of the planet's most complex processes, including seismic events, ice-sheet and glacier flows, natural hazards, sea-level rise, and groundwater issues. On July 30, 2025, NISAR was launched into orbit aboard the Geosynchronous Satellite Launch Vehicle Mark II rocket used by the Indian Space Research Organisation. "For all of us who deal with space missions, waiting is the name of the game," Simons says. "But when you finally get the data you yearned for, it all becomes worth it."

Engineer Harry Atwater is similarly well acquainted with these kinds of grand challenges, which he compares to "cathedral building." Centuries ago, with no modern equipment and with artisans painstakingly carving pieces by hand, many of Europe's iconic gothic cathedrals were under construction for decades if not centuries. Grandfathers laid the foundations for projects their great-grandchildren would complete. Atwater says it is certainly possible to tackle a problem whose solution could change the world, knowing full well that you may not even be alive to see it cross the finish line.

Atwater is involved in many projects, including as one of the principal investigators working on the Space Solar Power Project (SSPP) alongside Caltech's Sergio Pellegrino and Ali Hajimiri. Its goal is to collect the Sun's energy in orbit, where there is no worry of interference from cloud cover or nightfall, and beam it back to Earth. The Caltech SSPP team launched a demonstration mission in 2023 that managed to do just that, proving the concept could one day work on a much larger scale. Atwater also heads the Liquid Sunlight Alliance (LiSA), a multi-university partnership to develop liquid fuels that could displace fossil fuels by combining carbon dioxide and water in chemical reactions powered by sunlight.

"As my career went along, my conviction to take on these kinds of grand-challenge problems rose," Atwater says. "Maybe it comes down to thinking about your own finite abilities and your own mortality—that as long as you have a limited amount of time and resources, you should attack the most challenging problems."

Most importantly, Atwater says, perseverance requires action. Rather than sitting idly by, scientists must figure out what next step a particular problem requires and create "cycles of learning," wherein lessons learned feed into the next iteration of a project or prototype. "Sometimes, the learning goes from nonexistent to primitive to partial rather than complete," Atwater explains.

Earlier in his career, Atwater spent decades developing improved thin-film photovoltaics (materials that convert light into electricity) that are cheaper, lighter, more efficient alternatives to previous bulky cells used in solar panels. Now, his solar cell work continues as part of SSPP, for which he is developing ultralight high-efficiency photovoltaics optimized for space conditions and compatible with an integrated modular power conversion and transmission system. "Those cycles of learning are very important," he says.

Did You Know?

Harry Atwater is also part of Breakthrough Starshot, an initiative launched in 2016 that aims to design miniature space probes propelled by ultrathin lightsails that can eventually reach our nearest star system, Alpha Centauri.

Shake It Out

Seismologist Lucy Jones says her 1983 arrival in Southern California was perfectly timed. Now a visiting associate in geophysics, Jones came to Caltech as a researcher with the US Geological Survey (USGS) at the cusp of a dozen years of particularly strong seismic activity. The 1987 Whitter Narrows earthquake reached a magnitude of 5.9, and the devastating 1994 Northridge quake scored a 6.7. After so much shaking, Jones, now the founder of the Lucy Jones Center for Science and Society, believed the Big One was right around the corner.

"I really thought when I came here that the big San Andreas earthquake would happen during my career," she says. Instead, little has changed since the 1980s. Jones is certain that the Big One will happen and that, thanks to the work done over these many years, seismologists will be at the ready. But, she acknowledges, that time could come tomorrow … or 50 years from now. And so, Jones has learned to be at peace with that uncertainty. "We don't get to make our own experiments," she says. "We have to wait until the earth gives us what it's going to give us, and then we figure out how to make use of it."



Above: **Lucy Jones** talks to media at the ShakeAlert launch event in 2019.

"The only way I'll know if I'm right is if I live to see it."

–Seismologist Lucy Jones on her research into what might happen during the Big One.

In order to be ready when an event does occur, seismologists at USGS and the Caltech Seismological Laboratory have partnered for decades to develop tools like the Southern California Seismic Network (SCSN), which is made up of more than 400 seismic stations throughout Southern California. These sensors have provided valuable datasets that researchers have analyzed in order to, among other things, compare today's events to those in the past. These sensors also enable ShakeAlert, an earthquake early warning system launched in California in 2019 that is now used in Oregon and Washington as well, to provide seconds or even minutes of warning to facilities and the public before shaking starts. Paired with automated responses that will shut off gas lines before shaking starts, ShakeAlert helps prevent the fires that typically damage cities after a major earthquake.

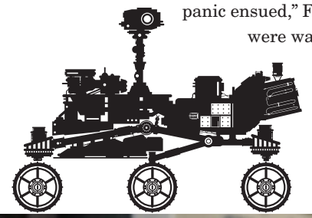
While other work continues, Jones knows that the information from the Big One will help scientists enormously in their quest to understand what is happening deep within Earth and make society more earthquake resistant for the future. However, she has learned better than to seem to publicly root for a shake.

"I went on the Conan O'Brien show at one point, and I said, 'I've gotten down to just hoping that I live to see it.' And he said, 'We'll agree to disagree on that one.' He was right. But the thing is: I've done a bunch of papers along the way, hypothesizing about what's going to happen with the big earthquake on the San Andreas, and the only way I'll know if I'm right is if I live to see it."

Get Me Off This Other Rock

The Mars 2020 Perseverance rover, a mission led by JPL, which Caltech manages for NASA, is aptly named. If there is anything that requires perseverance, it is imagining, building, and then landing a rover on the surface of another world.

Ken Farley, the W. M. Keck Foundation Professor of Geochemistry at Caltech and the Perseverance rover's project scientist, helmed the team of scientists and engineers who were charged with figuring out how to build a rover that could survive the harsh Martian environment and accomplish the mission's science goals. But no matter how prepared you feel, unpleasant surprises emerge in the run-up to launch day, Farley says. In the case of Perseverance, it turned out that the caps on the rover's sample collection tubes did not fit. "Absolute panic ensued," Farley recalls, "because we were way too far downstream for this not to work."



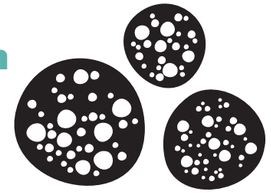
Below: **Ken Farley** next to a mass spectrometer in his lab.



The team got down to work and, well, persevered. Eventually, they figured out that heating the tubes to kill any Earth-borne life and prevent contamination had warped the tubes' shape. At the eleventh hour, the team devised, in Farley's words, "an extremely aggressive solution that solubilizes the organics." This method allowed them to sanitize the tubes and circumvent the need for heat. That was far from the mission's only speed bump, of course. After all, its scheduled launch date was July 2020, which meant Farley and company had to navigate a space launch amid the height of the COVID-19 pandemic, navigating social distancing, Zoom calls, and more.

Farley understands the importance of stepping back and recognizing that each forward step along the way is part of a continuum of discovery. "The pathway to Perseverance actually goes back decades," he says, referencing the influence of all the NASA missions that put orbiters around Mars and rovers of growing complexity on its surface. A cornerstone of Farley's perspective has been learning to see experiments, studies, and missions as more than binary successes or failures—and knowing not to pin a project's worth on whether it discovers what you had anticipated. While we hope Perseverance will one day find further evidence of Mars's historic habitability, evidence of its absence will be instructive too. "Science isn't about discovering something specific," he says. "It's about learning the way the world works. If you find no evidence for life, that itself is important."

Sticking to the Plan



Taking one scientific step forward at a time has created a lifetime of curious exploration for Marianne Bronner, Caltech's Edward B. Lewis Professor of Biology and director of the Beckman Institute. Bronner studies neural crest cells, a kind of stem cell that can develop in many different directions to form peripheral neurons and support cells, heart tissues, or even cancer cells. Because vertebrates have neural crest cells and invertebrates do not, learning more about these cells can help researchers understand how they contribute to the evolution of complex body forms. Bronner notes that, unlike putting a probe in space, there is no "finish line" to this work. Rather, it speaks to the way basic science adds to our body of knowledge in a way that other scientists can later build upon.

For instance, following the discovery that stem cells can migrate to the heart and form cardiac muscle, Bronner's lab published a paper showing that zebrafish, which can typically regenerate heart tissue that has been lost, cannot do so if its neural crest cells are killed off. This year, Bronner and colleagues sought to find neural crest cells in the heart of a jawless fish called the lamprey—and failed. They stuck with it, however, and eventually found the cells in an organ called the endostyle located in the necks of larval lampreys; the endostyle develops into the lamprey's thyroid as it grows. Ultimately, this finding helps explain the evolutionary origin of the thyroid and underscores the importance of neural crest cells.

"We call it delayed gratification," Bronner says. "Especially in biology, because it's so very complex, we never get complete answers about the mechanisms of how things work. We get partial answers, and they get more and more detailed. But you can keep working at progressively more finely tuned levels. You have to pose your question in a way that you can get a reasonable answer you can have confidence in, but you also have to realize that you're never going to understand everything."

Fact:
The Bronner lab uses lamprey, slimy parasitic eel-like fish, as a model organism because modern lamprey share some characteristics with the earliest vertebrates.

The Psychology of Perseverance

The question of why humans persevere with a particular project over long periods of time despite numerous challenges piqued the curiosity of Sneha Aenugu, a graduate student in the lab of John O'Doherty, the Fletcher Jones Professor of Decision Neuroscience. "This question has been understudied because most psychology or neuroeconomics experiments deal with one-shot decisions," Aenugu says, "which is strange, because our goals are often like that. Typically, they are not accomplished in a day or so; rather, it takes time, and the world does not stay constant in that time."

In 2025, Aenugu and O'Doherty published a paper in *PLOS Computational Biology* about a game they designed to test how people decide to persist with one long-term goal or strategy even when it might be beneficial to switch to another. Aenugu compares the experiment to one of her favorite board games, *Settlers of Catan*, where one player who is pursuing a particular strategy to accumulate points by building the longest road might notice another player doing the same thing, forcing the first player to decide whether to abandon their original strategy and try something else. As a whole, Aenugu and O'Doherty found, players tended to stick with the original plan even when it was not the optimal strategy. And it turned out that this happened more often with humans than with the various algorithms Aenugu programmed to play the game. Perseverance, as it turns out, is part of human nature. "When participants start making progress toward a goal," she says, "they value it higher."

Batygin, the astronomer, still places high value on Planet Nine, and he says the newly opened Vera C. Rubin Observatory in Chile might finally allow astronomers to spot it. But it is also possible the planet is too dim even for a telescope with better mirror design, camera sensitivity, and speed than any that have come before. It is also possible that Rubin's field of view in the Southern Hemisphere simply does not include the area where Planet Nine is hiding. Either case would be instructive, Batygin says.

In the meantime, he is busy working to unravel some of the other mysteries of the cosmos, like the makeup of the interior of Jupiter, or unanswered questions about the gravity of objects in the Oort Cloud far beyond Pluto. "Every time I'm working on a new problem, that problem is the most important thing in the universe," he says.

Batygin and others credit Caltech for allowing them the freedom to explore those mysteries, which, he says, makes it easier to persevere through intellectual journeys full of frustrations and wrong turns. The long game of discovery—or learning, as Farley prefers—requires patience from both scientist and institution, and the belief that big dreams can be achieved, even if it takes generations, because the journey itself is the point.

"I'm very much an optimist," Atwater says. "Maybe I'm a naïve-ist there as well. But I think some combination of optimism and purposefulness is important. If you were pessimistic about everything, you probably wouldn't be in the research game."

A Conversation with President Rosenbaum

Caltech's leader reflects on questions **big** and **small; past, present,** and **future.**







Thomas F. Rosenbaum, the Sonja and William Davidow Presidential Chair and professor of physics, is in his 12th and final year as Caltech's ninth president. Rosenbaum's time as president has encompassed two full terms and part of a third—the longest anyone has served in the position since Lee DuBridge, who had the job for 23 years (1946–69).

"Clearly, this isn't the year I envisioned," Rosenbaum says, seated at the wooden conference table in his office, reflecting on how he had imagined his final months as president when he first began contemplating retirement.

The challenges facing American colleges and universities over the past year have been well documented: from cuts in federal support of university-led research to a potential reduction in indirect cost rates on federal research awards. Yet, Rosenbaum has remained steadfast in his approach. "Many of the core principles remain unchanged," he says. "This moment offers a chance to reaffirm our deep commitment to academic freedom, scientific inquiry, and the pursuit of truth and discovery."

Rosenbaum's steady leadership and dedication to Caltech's core mission and values have also guided the Institute through a global pandemic and a devastating natural disaster in a manner that underscores his commitment to cultivating a thriving, supportive, and inclusive community of scholars that is a destination of choice for the brightest in science, engineering, and technology.

Since Rosenbaum took office in 2014, increases in financial aid and scholarship support have made a Caltech education more affordable, and the student experience on campus has been enriched with an ever-wider variety of co-curricular experiences.

"Under Tom's guidance, and as a result of the enhancements he has overseen to the student experience, including increasing the Institute's investment in student scholarships, fellowships, and supporting programs, Caltech is better equipped to attract the brightest and most talented future scientists and engineers," says Dave Thompson (MS '78), chair of Caltech's Board of Trustees.

During Rosenbaum's tenure, many Caltech researchers have garnered prestigious prizes and honors, a direct result of having the resources and freedom to create, experiment, and define new areas of inquiry. In addition to three Caltech faculty members who were awarded the Nobel Prizes (two in 2017 for the detection of gravitational waves and one in 2018 for the creation of a bioengineering method that leverages the principles of evolution to develop new and better enzymes in the lab), Institute researchers have received National Medals of Science, Breakthrough Prizes, Kavli Prizes, MacArthur Fellowships, and other significant honors.

Caltech magazine recently joined Rosenbaum for an inside look at his office and the objects he keeps on display (see page 23), as well as a discussion of how his past experiences have shaped the office of the president, both physically and philosophically.

At your inauguration, you named five Caltech hallmarks that would "yield intellectual magic": excellence, ambition, focus, intimacy, and perspective. Have they stood the test of time?

These are Caltech qualities that have borne up superbly under all kinds of pressures and need to be preserved. Eleven-plus years later, I would like to take the liberty to add "fearlessness" to the list—no fear in pursuing the most impactful problems out there no matter the obstacles.

How has Caltech changed since 2014?

New buildings, new initiatives, great new students, postdocs, staff, and faculty. But the Caltech ethos remains the same: get better, not bigger, while creating knowledge for the ages and technologies that improve people's lives today.

The higher-education landscape is shifting radically as you wrap up your presidency. How do you think Caltech and this community can best meet the moment?

Continue to think big. I fear our country is losing its appetite for the transformative investments that change the world of science and technology, from cancer cures to moonshots to LIGO [the Laser Interferometer Gravitational-wave Observatory, which is funded by the National Science Foundation and operated by Caltech and MIT]. We need to step up.

What makes the intertwined nature of Caltech and JPL so special?

One of my favorite quotes is Freeman Dyson's riff on *Hamlet*: "There are more things in heaven and Earth than are dreamed of in our present-day science. And we shall only find out what they are if we go out and look for them." That is what campus and JPL do better together than any other place in the world.

What do you hope for the future of the Lab?

That the government maintains the nation's deep-space capability that resides at JPL and its people need to be

supported for the long term. We could bring those rocks home from Mars and potentially learn if microbial life existed somewhere beyond Earth!

During your presidency, Caltech's physical campus evolved significantly with the construction of new buildings to support expanding research programs in neuroscience, sustainability, quantum science, and more. How does this evolution mirror your broader goals and aspirations for the Institute?

We want to keep the core campus small and preserve our open and interactive culture but, at the same time, have an impact on the world in as many areas as we can. This requires state-of-the-art facilities on campus to pursue cross-disciplinary endeavors where Caltech either has a discriminating advantage, or the problem is so important that we have to play. In addition, we amplify our position and contributions by running large off-campus endeavors, such as JPL, the Keck telescopes, LIGO, and an earthquake early warning system.

During the last 11-plus years, you have focused in part on student life and expanding access to cultural experiences. Why was this initiative important to you?

I believe that college and grad school are about far more than getting a good job. Obtaining the quantitative skills to be able to make contributions to society is a necessary and laudatory goal, but as important is stretching oneself to develop lifelong passions. We can do both at Caltech.

How do you hope the faculty, students, and staff remember your leadership?

That Caltech was the place where they realized their full potential.

What has been your favorite part of being a university president?

The people! Where else do you have an excuse to interact with so many talented, accomplished individuals across the intellectual spectrum? Keeping Caltech going through social unrest, a pandemic, catastrophic wildfires, and executive orders has been trying. Fortunately, I can depend on a dedicated leadership team and a tight-knit community to help see us through.

How has the Caltech community shaped you as a leader? As a person? As a scientist?

We depend on one another, we prize the collaborations, and we savor the serendipitous interactions. It is a modality that cuts across the personal and the professional.

What one aspect of the role most surprised you?

The president is seen as the instantiation of the Institute. That goes with the territory but doesn't really represent what Caltech is about.

What scientific or technological breakthrough most surprised you?

The observation of gravitational waves by LIGO, the most sensitive instrument ever built. And not only the initial discovery but the fact that we are now observing a black hole merger a week, permitting astronomy on Kip Thorne's "warped side of the universe."

What was the quirkiest tradition you discovered here?

Blaring Wagner's "Ride of the Valkyries" at 7 a.m. during finals.

What are your plans after you step down?

I'd like to build up my lab group and learn some new physics. I also serve on two nonprofit boards, so I hope to continue to advance science and society through them.

What's on your reading list right now?

I just finished Dorothy Dunnett's eight-volume novelistic rendition of mercantile and military life in the late 1400s, *The House of Niccolò*. On my nightstand are essays by Zadie Smith and Christian Wiman, a historical novel by Hilary Mantel, and a biography of John Lewis.

Five rapid-fire questions to close:

What is your go-to coffee order?

Small cappuccino with low-fat milk (but fully caffeinated!).

Your favorite spot on campus?

My lab, followed by the Red Door.

Your hidden talent?

Hitting the occasional bucket from half court.

The most-used app on your phone?

New York Times. Maybe that will regularize when I step down.

Next on your bucket list?

Antarctica or Iceland. Not that I miss the cold.

Inside Look

President Thomas F. Rosenbaum



Caltech's president takes pride in the importance of ideas and objects within his office . . .

By Omar Shamout

. . . The life of a university leader involves meeting people. Lots of people. For Thomas F. Rosenbaum, a schedule of eight meetings a day is not unusual. Most take place in his office in the Parsons-Gates Hall of Administration, home to the Office of the President since 1983.

When Rosenbaum arrived at Caltech in 2014, his first order of business was to ascertain what makes Caltech tick. So, he met with the Institute community—faculty, administrators, staff, and students—and listened. "Culturally, Caltech has its own nature, language, focus, structure, and ambitions," he explains. "I had to learn about the ethos, and you do that by talking to people."

The conversations have continued ever since. "I still believe firmly in giving people the opportunity to express their views and introduce their ideas. It's important that you listen and that you be open to changing your mind. It's part of the fun of this job."

The president hopes his space reminds guests of Caltech's values, which he says mirror his own. "The objects around the room reflect various experiences I've had both as a scientist and as a science administrator. There's a mix of the professional and personal aspects that I hope comes through," he says. "One thing I love about Caltech is that we're not very hierarchical. We value people for their ideas, not for their positions. We know there are big stakes to what we do, and some of what's here reflects that."

This sentiment is particularly evident on a bookshelf where a model of the Mars Perseverance rover is perched as if scrambling down a stack of books, some of which are about New York City, where Rosenbaum grew up. The rover is a NASA mission managed by JPL, which Caltech has operated for the space agency since 1958.

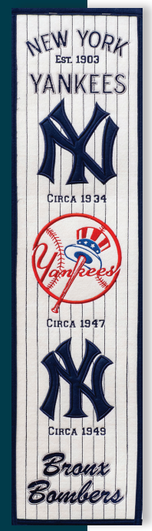
Humanity's exploration of space has had an outsized impact on Caltech research, and it made a seminal impression on Rosenbaum as a child in the 1960s. He credits the Apollo missions with inspiring him to pursue a career in science. "I was the perfect age to be influenced by the Apollo Moon program, and I followed it passionately," he recalls. "I have memories of lying on the living room floor on July 20, 1969, eagerly waiting to see Neil Armstrong step off Apollo 11. Science was fun but difficult; it was admired by society, and you felt like you could make a contribution."

"I have memories of lying on the living room floor on July 20, 1969, eagerly waiting to see Neil Armstrong step off Apollo 11."

Rosenbaum's contributions have come both as an administrator and as a condensed matter physicist. His research seeks to understand the connections between the microscopic world, dominated by quantum mechanics, with the macroscopic world, governed by classical physics. "I also look at how quantum materials transition between ground states," he says. "And whether it is possible to induce new nonequilibrium states."

While there are a few heavy-duty science tomes dotting the shelves, Rosenbaum keeps his physics materials in his Norman Bridge Laboratory research office. Many of the science books in his Parsons-Gates office are geared toward general audiences. "There are lots of books on the physics of golf, the physics of baseball, things like that," he says. "I've taught courses on the physics of sports. It's much more interesting for students to hear about throwing a football in a spiral rather than an abstract discussion of torque and angular momentum."

When he vacates the president's office next summer, he will move his books and memorabilia to new shelves in a different space. What he will lose is the opportunity to speak with as broad a swath of the Caltech community as he does now. "Caltech is special because of the people who are here," Rosenbaum says. "Although I'll be closer to my scientific colleagues, I won't have the same level of interaction with the rest of the talented people across campus. I'll miss that."



New York Yankees banner

Rosenbaum spent most of his formative years in New York City's borough of Queens, home of the New York Mets. So, how did he wind up as a fan of the archrival Bronx Bombers? "It is not logical, because I could bicycle to Shea Stadium—and I did. We would go watch the Mets," he says. "But the first baseball game I went to was in 1962, maybe '63, at Yankee Stadium. The Yankees won 9–1 over the Cleveland Indians, and I've been a Yankees fan ever since."



New Yorker cartoon by Sidney Harris (published July 16, 1973)

Rosenbaum has been reading *The New Yorker* magazine since he was in grad school, though the cartoons caught his attention much earlier. "I looked at the cartoons when I was a kid because my father had a subscription," he recalls. "Even though I'm a physicist, I'm a Luddite. I like to actually hold the printed version of *The New Yorker.* When I travel, I bring a stack of them with me." This framed cartoon was a gift from Rosenbaum's two sons. "I think you have to be a scientist to find it amusing," he says.



Wright brothers photo and Mars surface photo

Perhaps nothing in the president's office reflects Caltech's impact on science and engineering more strikingly than these two side-by-side images. The first is a photo from the *New York Times* archive of Wilbur Wright testing an early biplane on a sandy beach in Kitty Hawk, North Carolina, circa 1903; the second, a close-up image of Mars's sandy surface taken by NASA's Mars Reconnaissance Orbiter, a mission managed by JPL. Though the Wright brothers were not affiliated with Caltech, the Institute helped advance their astounding invention and propel humankind to the stars—and the Red Planet—opening new windows on the universe. "I like the contrast," Rosenbaum says.



Brass replica cannon

Rosenbaum made this cannon during his graduate studies at Princeton University, where he earned his PhD in 1982. "I learned how to use a machine shop to make equipment for my experiments," he says. "This was the project to be certified to work in the shop. The guy who ran the shop was named Bob Puglisi. When you were done, he'd take the cannon and slam it on the table. It was scary; if it didn't fall apart, you passed. I insist that all my students learn how to machine. In addition to learning the actual skill, you'll also learn enough so that when you go to a professional machinist and ask them to make you something, you'll understand the sensible limitations on your request."



Melted sand from the Trinity nuclear test and a brick from the University of Chicago squash court

Two pieces of Manhattan Project history can be found in Rosenbaum's office. The first is a piece of melted sand from the site of the Trinity nuclear blast in Los Alamos, New Mexico, a gift from David Groce (BS '58, PhD '63), a member of the Caltech Associates. The second is a sandstone brick from the squash courts underneath the University of Chicago's Stagg Field, the site of the first nuclear reactor, known as Chicago Pile-1. Rosenbaum received the brick while working at the university. "I also have a little piece of the graphite that was part of the nuclear pile, but I don't have that here in the office," he says.





Basketball signed by Caltech Nobel laureates

Rosenbaum, an ardent basketball fan, has asked every Caltech Nobel laureate he has interacted with since he arrived to sign this ball. "Tragically, three of the individuals who have signed this are no longer with us: Ahmed Zewail [Linus Pauling Professor of Chemistry], Bob Grubbs [Victor and Elizabeth Atkins Professor of Chemistry], and David Baltimore [President Emeritus and the Judge Shirley Hufstedler Professor of Biology]," he says. "Having their signatures here is very meaningful to me."

THE ICE AT THE FAR ENDS OF EARTH

Researchers know the planet's ice is melting; now, they are uncovering what that will mean for all of us.

By Lori Dajose (BS '15)

The town of Huslia, Alaska, is under siege—not by an invading army, but by water. Most of the homes in Huslia, which is located on the edge of the Arctic Circle, were built in the second half of the 20th century, a time when Alaska's climate was cooler and the frozen tundra near the banks of the nearby Koyukuk River was reliably hard. But as rising temperatures thaw the perpetually icy ground—called permafrost—beneath the town's foundations, its homes and businesses are sinking into mud, and the Koyukuk, no longer hemmed in by frozen ground, is shifting erratically, threatening the town with floods and erosion.

For the Yup'ik and Athabaskan people, the Native Alaskans who have made the region their home for millennia, these are unprecedented developments. In 2018, the Yup'ik coined a new word for the catastrophic ground collapse they were experiencing—usteq—meaning "to cave in." These conditions have now forced many of these people to move, making them some of the world's first climate refugees, along with others impacted by sea level rise.

Permafrost covers around 18 million square kilometers on Earth, with the vast majority located in the Arctic north. Usteq occurs due to the melting of this permafrost, which took tens of thousands of years to form but has been melting over the course of the last few decades. The millions of cubic miles of ice bound up in ice sheets and glaciers in Antarctica and Greenland are changing as a result of our warming climate as well.

Knowing what is coming is crucial to preparing to counter the effects of warming on the planet. Caltech researchers are conducting ambitious field studies to understand the physical properties governing these frozen regions so that national and local governments are better informed and prepared to respond. These projects include sending autonomous robots and drones to study glaciers from above and below, modeling river erosion due to permafrost thaw, and studying the basic physics of water and ice.

"We know ice is melting, but we don't yet know how much of it or how quickly," says geologist Brent Minchew (PhD '16), who returned to Caltech as a faculty member this year to continue his studies of glaciers and ice sheets. "We cannot solve a problem we don't understand. To know what kind of future we are looking at, we need to understand the physical phenomena driving these processes."

Conditions on Earth have been evolving for the planet's entire history, but the drastic changes experienced at the polar regions—temperature changes of up to four times the global average over the past three decades—are unusual because of how rapidly they are occurring. The Arctic has accumulated permafrost for 2 million years, and yet much of it may disappear in our lifetimes. The results of that melting are already evident: In Alaska, oil pipelines, US military installations, and entire communities are experiencing the ground caving in beneath them as the soil becomes soggy.

If the most extreme climate scenarios come to pass, warming at the polar regions could cause global sea levels to rise by dozens of feet, which would leave metropolitan regions across the planet under hundreds of feet of water. At the same time, the planet could see a quadrupling of carbon in the atmosphere, among other possible impacts.

Life Finds a Way

Melting permafrost is troublesome not only because of the direct damage it can cause to human infrastructure, but because it is a massive reservoir of stored carbon. As long as the ground stays frozen, that carbon is trapped. But when the frozen ground melts, the carbon that had been stored for eons can be mobilized and potentially released into the atmosphere as carbon



Accelerated permafrost thawing has caused the path of Alaska's Koyukuk River to shift dramatically.

dioxide and methane, thereby further speeding up the warming.

Geobiologist Woody Fischer studies permafrost in remote landscapes in Alaska, aiming to understand how its loss—and the subsequent release of carbon—will affect future climate scenarios. Permafrost cannot be observed with remote-sensing instruments, so Fischer and his Caltech colleague Mike Lamb, a geomorphologist, along with their research teams, have taken several trips to Alaska to gather samples of permafrost along eroding riverbeds.

The two are currently working with several towns in Alaska, including Huslia, to develop models of future river erosion so that communities can prepare and relocate as needed. "Unfortunately, there's really no stopping it, just adapting," Fischer says. "We see the rest of the biosphere adapting, and we have to be able to change along with it."

Among the organisms in the Alaskan biosphere adapting to their new ecosystem are beavers and white spruce, both of which are beginning to colonize areas of tundra that were previously uninhabitable. Salmon, whose populations have plummeted in Alaska's Yukon River due in part to climate change, are now found even farther north than before. "Salmon are a kind of vector animal that transport nutrients from the ocean into the land when they swim up rivers and die," Fischer says. "They're ecological founders in addition to being an important food source."

These developments offer some hope. As more plants and trees begin to grow in newly thawed ground, these organisms will absorb carbon from the atmosphere. Fischer's preliminary research suggests that the biosphere's greenery may be able to absorb most of the carbon released from the ground in the region, partially offsetting the climate effects of the melting and preventing worst-case scenarios.

Still, according to Carl Burgett, first chief of the Huslia tribe, the melting permafrost is threatening at least a third of the community's land. "With the new data we collected, hopefully a relocation plan can be funded for our community along with much-needed infrastructure," Burgett says. "It's been an honor working with Caltech and that they selected our little community to measure permafrost thaw."

Measuring Glaciers from Above

Even though permafrost thawing is devastating communities, it is not the water released from the frozen tundra that will significantly impact sea level rise around the world. Instead, that threat lies in the ice that largely takes the form of glaciers, which cover Antarctica and Greenland in thick ice sheets. Therefore, understanding how glaciers will be affected as the climate warms has crucial implications for predicting, adapting to, and mitigating sea level rise.

Did You Know?

Seven million cubic miles of ice are now threatened by our warming climate.

The most extreme estimates of sea level rise hinge on the behavior of one particular glacier in Antarctica: the Thwaites Glacier, which the media have dubbed the Doomsday Glacier. The size of Florida, Thwaites's collapse would expose a billion people to the risks of sea level rise this century.

That is why Minchew, the geologist, is working to better understand how ice sheets might evolve over human timescales. When he was a Caltech grad student working with geophysicist Mark Simons, Minchew studied the mechanics of how glaciers flow and deform the beds of soil beneath them. Now, as a faculty member, he aims to observe the ice sheets from the skies, using drones equipped with radar technology.

Minchew is developing solar-powered drones that will fly above Antarctica and Greenland over a period of months, collecting radar observations of glacier flow velocity, as well as the glaciers' elevation and how that changes over time. These detailed measurements will enable Minchew and his team to watch how fractures in the ice propagate, especially in response to the ebb and flow of ocean tides. "How quickly does the ice flow? Under what conditions does it fracture? How do the oceans and the ice sheets evolve together? These are the sorts of questions we'll be asking."

Minchew's observations will be supplemented by data from the NISAR (NASA-ISRO Synthetic Aperture Radar) satellite, which launched in July 2025. Simons, Minchew's graduate advisor and now director of the Institute's Brinson Exploration Hub, serves as a science lead on the mission (see page 14). NISAR carries two kinds of radars that will monitor soil moisture, forest biomass, and the motion of Earth's crust in addition to the behavior and evolution of ice sheets.

"In the best-case scenario—without a Thwaites collapse and with aggressive decarbonization of the economy—we're looking at something like half a meter to a meter of sea level rise, a few hundred million people displaced, and major cities like Shanghai, Bangkok, Kolkata, Buenos Aires, and Miami largely underwater within my daughter's lifetime," Minchew says. "But there's a lot of uncertainty in those projections. We hope our work will take some of that uncertainty away."

The Physics of Water and Ice

Glaciers may seem like giant versions of the ice cubes in your freezer, but they are, in fact, incredibly complex. These kilometers-thick ice sheets are full of internal cracks and crevices, and they are topped with a layer of crusty, compressed snow, called firn, that can be tens of meters thick.

Scientists like hydrologist Ruby Fu are interested in studying how the water that forms when firn melts subsequently interacts with the rest of the glacier's underlying ice. Her team wants to observe whether that water will flow out to the ocean and contribute to sea level rise immediately, refreeze within the glacier, or percolate down to the glacier's base and act as a lubricant, speeding up the glacier's otherwise slow slide into the ocean.



Members of the IceNode project team deploy an autonomous underwater robotic vehicle in Alaska earlier this year.

Fu did not expect to study water and ice interactions when she joined the Caltech faculty in 2021, but the rapid changes at the polar regions instilled in her a sense of urgency. As a fluid mechanics expert, she knew she could contribute to understanding the processes that enhance or inhibit sea level rise.

"For centuries, people have been trying to figure out how water moves through the natural environment," Fu says. "Right now, with climate warming, we're trying to understand the movement of water in frozen glacier systems, especially in polar ice sheets. Our lab research will help explain how surface-produced meltwater might be introduced to the base of the ice sheet if it doesn't refreeze on its way down."

Fu, who has never been atop a glacier ("I don't even ski!" she notes), creates analog experiments in the laboratory to study how flowing water interacts with porous ice, because such behaviors cannot be seen through a massive and opaque glacier. The experiments are conducted in a homemade, ultracold refrigerator built by Caltech graduate student Nathan Jones to simulate the frigid environments of Antarctica and Greenland. Fu also aims to study how millions of snowflakes congeal into ice at once, a project for which she consulted with Caltech physics professor Ken Libbrecht, who is well known for his research on the crystalline structures of individual snowflakes.

In one experiment, water dyed a fluorescent green percolates down through a thin layer of tiny frozen glass beads that mimic firn. A camera captures the water's path, finding that it often travels quite far before freezing, particularly if the water was warm to begin with. "People tend to think about freezing as a very binary thing," Fu says. "We were taught in school that if it's below zero, water will freeze. But, in reality, freezing takes time and can be complicated. Water can, in fact, travel quite far in a cold and icy environment before it becomes frozen."

Fu's research offers insights into the conditions that other collaborators are attempting to model in the field. These researchers include Caltech environmental scientist and engineer Andrew Thompson, whose team will deploy technology in Antarctica as part of a project called SURGE (SUbsurface Robotics for Grounding zone Exploration) to measure glacial freezing and melting, supported by Fu's models of the basic physical properties occurring in inaccessible regions.

Measuring Glaciers from Below

It is rare to get the opportunity to take measurements in Antarctica, due to its hostile and remote environment. So, Thompson takes every chance he can to travel to the pole where, on board a massive research ship, he and researchers from around the world work 24/7 in frigid temperatures amid the sounds of cracking ice.

But these kinds of in-person voyages remain extremely expensive and infrequent, which is why Thompson is working with colleagues at the Jet Propulsion Laboratory, which Caltech manages for NASA, to develop and deploy a small underwater drone, called IceNode, that can attach to the nearly inaccessible underbellies of ice shelves (floating extensions of glaciers) and record ocean conditions at the ice–ocean interface. If this proof-of-concept project is successful, fleets of these vehicles could be deployed to various Antarctic ice shelves to measure temperature, salinity, density, and other properties of the water to reveal how quickly the glaciers are melting and what kinds of future scenarios humans must prepare for.

In particular, Thompson and his collaborators aim to understand a mysterious area known as the grounding zone, where ice, ocean, and seafloor all meet. As glaciers flow off the Antarctic continent and into the ocean, they eventually become thin enough to lift off the seafloor and float on the ocean surface. These ice shelves sit atop a region known as an ice-shelf cavity, which can reach tens of kilometers in length. Within these cavities, relatively warm ocean water circulates, melting the ice from below. These interactions between seawater, the ocean floor, and

the ice shelves are not simple, and most models of warming do not account for them. "Even the most advanced models are missing fundamental processes, specifically the ocean–ice interactions that occur where the warmest waters first touch the glacier," Thompson says. "Those interactions could be the difference between a meter of sea level rise in the next 80 years or two to three times that amount over the same period."

Seismic Signatures of Ice

While Thompson aims to measure water properties with SURGE, seismologist Zhongwen Zhan (PhD '14) is working on a project to bring the techniques of earthquake science to the study of glaciers. For over a decade, Zhan has been developing a new kind of seismometer system called distributed acoustic sensing (DAS) that uses fiber-optic cables—the same kind that provide high-speed internet to cities and towns around the world—as makeshift seismometers. The system shoots lasers down these cables and measures how the light bends as the cables vibrate during seismic activity. This movement provides information about the ground's structure.

Antarctica experiences very few earthquakes. Its glaciers, however, creak and tremble as they move, particularly as they rock up and down with the tides. This movement can be picked up by seismic sensors. Zhan aims to use his fiber-optic DAS system to measure how the grounding zone shifts due to the tides in order to better understand how the region may be melting with warmer waters.

In a separate project last year, Zhan and his team deployed their DAS technology in Iceland in order to provide warnings up to 30 minutes in advance of lava eruptions, whose vibrations are picked up by the fiber-optic cables.

"We've done a lot with DAS in the past, but this is different," Zhan says. "We're pushing the technology in ways we haven't before—designing for extreme conditions, building quickly, and aiming for real scientific return on a short timeline. We're not just testing a new instrument; we're trying to unlock a part of Earth that's been hidden."

Though prior DAS projects took advantage of fiber-optic cables already installed underground, the glacier project will require new cables to be specially deployed. The team is currently developing a lightweight, energy-efficient version of DAS that can withstand the harsh Antarctic environment.

Thompson's and Zhan's projects are both partially funded by the Brinson Exploration Hub, for which Simons serves as director. Launched in 2024 through a $100 million gift from The Brinson Foundation, the Brinson Hub empowers scientists and engineers from Caltech's campus and JPL to collaborate on boundary-pushing science projects that develop and test new research and instrumentation, and deepen our understanding of the universe. Two of the three projects in the Brinson Hub's first round of funding focus on Antarctica.

"Antarctica iss an ambitious place to explore," says Simons, the Brinson Hub director. "It's one of the last frontiers on the planet, yet it is key to understanding what the future of our world will look like."



Zhongwen Zhan (PhD '14), prepares to board a flight to Antarctica in 2023.

Woody Fischer is the Jean-Lou Chameau Professor of Geobiology. His work is funded by Caltech's Resnick Sustainability Institute (RSI) and the National Science Foundation (NSF).

Ruby Fu is an assistant professor of mechanical and civil engineering and a William H. Hurt Scholar. Her work is funded by the RSI and NSF, among others.

Brent Minchew is a professor of geophysics. His work is funded by the NSF and NASA, among others.

Mark Simons is the John W. and Herberta M. Miles Professor of Geophysics and director of the Brinson Exploration Hub. His work is funded by NASA, and others.

Andrew Thompson is the John S. and Sherry Chen Professor of Environmental Science and Engineering and director of the Ronald and Maxine Linde Center for Global Environmental Science. His work is funded by the Brinson Exploration Hub, RSI, NASA, and NSF, among others.

Zhongwen Zhan (PhD '14) is a professor of geophysics and the Clarence R. Allen Leadership Chair and director of the Caltech Seismological Laboratory. His work is funded by the NSF and the Brinson Exploration Hub, among others.

MEET CALTECH'S 2025 DISTINGUISHED ALUMNI

Caltech's annual Distinguished Alumni Awards—the highest honor the Institute bestows upon its graduates—recognize "a particular achievement of noteworthy value, a series of such achievements, or a career of noteworthy accomplishment." The 2025 luminaries include a trailblazer who helped launch the field of multifunctional structural materials and was one of the first women to graduate from the Institute; a multihyphenate mathematician and medical doctor whose contributions have advanced mathematical physics, biomedical sciences, and science communication; a biochemist whose breakthroughs in sequencing bacteriophage DNA led to technologies that extended millions of lives worldwide; and an influential theoretical and computational chemist whose work has established foundational methods for analyzing chemical interactions.

By Chris Quirk • *Awardee interviews conducted by the* Caltech Heritage Project.

DEBORAH D. L. CHUNG

BS ’73, MS ’73

MATERIALS SCIENTIST

For her research that helped launch the field of multifunctional structural materials; for her contributions to the development of smart concrete and other nanostructured materials with intrinsic capabilities potentially useful to society; and for her stalwart efforts to diversify science, technology, engineering, and mathematics.

A materials scientist with a fearless creative streak, Deborah Chung has forged a path in the field of structural materials that few had previously pursued. While researchers had historically investigated the mechanical properties and durability of such materials as concrete, steel, and fiber composites, Chung opted to explore these materials’ hidden functional properties, such as sensing, energy generation, energy storage, vibration damping, and electromagnetic shielding, among others “It sounded crazy, but I embarked on that direction of research, and that’s how I got into multifunctional structural materials,” she says. “I found it to be a gold mine.”



Chung, who was born in Hong Kong, also made history as one of the first four women to earn an undergraduate degree from Caltech in 1973. She transferred from Wellesley College following her first year. “I really liked the friendliness, the personal touch at Caltech,” she recalls. “People know you, and it feels like a big family. Even though I was very much a minority as a girl there, I didn’t feel special or abnormal at all. It was during graduation that I realized that they were making it kind of a big deal.”

Chung is now the SUNY Distinguished Professor in the Department of Mechanical and Aerospace Engineering at the University at Buffalo, The State University of New York, and director of its Composite Materials Research Laboratory, a facility she created in 1989. Her work has led to the development of materials such as smart concrete, which can detect deformation levels on its own without any built-in sensors, and her insights have opened new avenues for using structural materials.

At Caltech, Chung studied electrical engineering, enrolling in Carver Mead’s landmark Integrated Circuits course in 1972. However, it was her work with Pol Duwez, professor of applied physics and materials science, studying amorphous materials that served as a springboard into the field in which she is now an internationally recognized leader. “Through his research, I came to realize how much science and technology is embodied in materials science,” she says. “The breadth of basic scientific education and the early experience in research are two very valuable things that Caltech provided me and that have been highly important for my career. The basic science enabled me to learn new things throughout my journey in science.”

Chung was inducted as a Fellow of the American Academy of Arts and Sciences in 2023, and she won the University at Buffalo President’s Medal in 2024. Chung is a Fellow of ASM International and of the American Carbon Society and won the latter group’s Charles E. Pettinos Award in 2004 for outstanding research in carbon science. Among numerous other recognitions, Chung has won the Outstanding Inventor Award and the Chancellor’s Award for Excellence in Scholarship and Creative Activities from The State University of New York.

Chung also holds 23 patents and has written eight books on materials science. She also co-authored a book titled *Piloted to Serve* about her mother, Rebecca Chan Chung, who served as a nurse during World War II and took part in dangerous flights over the Himalayas.

Her current work includes research on structural inductance (a field she has launched), carbon fiber multifunctionality, 3D-printing monitoring, and steel-reinforced concrete corrosion monitoring. “In order to be a leader, one has to be creative,” Chung says. “And to be creative, one has to have the ability to cross disciplinary boundaries and jump out of one’s comfort zone.”

ATHANASSIOS FOKAS

PHD ’79

MATHEMATICIAN

For his contributions spanning science, medicine, and the arts, including advances in partial differential equations, mathematical physics, the life sciences, and nuclear imaging for diagnosis and discovery, and for his work explaining and enlivening science and mathematics for the public.

Hailing from the Greek island of Cephalonia in the stretch of the Ionian Sea that was home to Odysseus, Athanassios “Thanasis” Fokas is a polymath whose career evokes the inquisitive nature of the ancient Greeks. As a mathematician, medical researcher, writer, and public speaker, Dr. Fokas has made significant contributions across multiple disciplines in a career defined by a relentless curiosity.

An emeritus professor at the University of Cambridge, where he was the inaugural Chair of Nonlinear Mathematical Science, Dr. Fokas is now director of the Mathematical Legacy Program in the Department of Applied Mathematics and Theoretical Physics at Cambridge. As an undergraduate, he studied aeronautics at Imperial College London before pursuing applied mathematics at Caltech. Dr. Fokas was then inspired to tackle mathematical biology, earning his MD at the University of Miami.

A leading figure in applied mathematics, Dr. Fokas has been at the forefront in the field of nonlinear partial differential equations, which can be used to describe phenomena such as those arising in fluid dynamics and optical communications. He is best known for inventing the eponymous Fokas method, a transformative algorithmic technique that has numerous applications in mathematical physics. The citation of his 2023 European Academy of Sciences Blaise Pascal Medal states: “The Fokas method … is considered the most important development in the solution of partial differential equations since the works of Fourier, Laplace and Cauchy.”

Thanks to his medical expertise, Dr. Fokas has also developed improvements in nuclear imaging that have expanded its diagnostic capacity, advanced the understanding of protein folding, and introduced models explaining the cellular dynamics of leukemia and the spread of COVID-19.

At Caltech, Dr. Fokas studied with Paco Lagerstrom, a professor of aeronautics and then of applied mathematics. Lagerstrom played a very important role in his cultural development and his passion for the opera. The pair often went to art museums together and listened to live Metropolitan Opera broadcasts on weekends at Lagerstrom’s Pasadena home. “I have the reputation of a polymath,” Dr. Fokas says. “I would love to have a conversation with him now to see how I measure up; at the time, he knew much more about ancient Greece than me.”



Though he only intended to earn a master’s degree at Caltech, Dr. Fokas found a natural home and opted to complete his doctorate. “I found out that the Department of Applied Mathematics at Caltech was born by professors leaving the Department of Aeronautics and forming their own department, and this is what attracted me to Caltech,” he says. “I would not have been who I am without this great Institution. I am forever grateful.”

Dr. Fokas is a member of Greece’s Academy of Athens and all three major European academies. He is a Guggenheim Fellow as well as a fellow of the American Institute for Medical and Biological Engineering and the American Mathematical Society. He has received Greece’s Order of the Phoenix, the London Mathematical Society’s Naylor Prize, and the Kruskal Award/Lecture from the Society of Industrial and Applied Mathematics. Dr. Fokas has co-authored more than a dozen scientific books, as well as books aimed at the general public. He has given hundreds of presentations to academic audiences and the wider public on topics as varied as Fourier transforms, mathematics and truth, the continuum of unconscious processes and consciousness experiences, and the impact of Hellenic thought.

“I am attracted by two basic features: beauty and significance,” Dr. Fokas says. “In order to study a problem, it must involve a beautiful mathematical formalism, and it must be mathematically, physically, biologically, or medically important; otherwise, I am not interested.”

F. WILLIAM STUDIER

PHD ’63

BIOPHYSICIST

For the invention of technologies that have helped extend millions of lives through therapies, diagnostics, and vaccines; for his seminal work exploring the genetics and biochemistry of bacteriophage T7; and for his innovative techniques for high-throughput analysis of DNA, RNA, and proteins.

A quiet, reserved scientist who has always avoided the limelight, William Studier has a record of discoveries and innovations in the laboratory that were anything but modest. His work over a six-decade career laid the groundwork for therapies—including the COVID-19 vaccines—that have saved lives and enabled other breakthroughs in medicine and biology.



Now retired, Studier was a senior biophysicist and chair of the biology department at Brookhaven National Laboratory, where he worked for 54 years. Upon his arrival at Brookhaven in 1964, he continued his research into a specific type of bacteriophage known as T7, picking up work he had begun as a biophysics graduate student at Caltech. Bacteriophages, viruses that replicate in bacteria, are often used in DNA and RNA research.

Studier chose to study T7 because its short lifecycle allowed for speedy experimental results. He went on to invent systems, including a slab-gel apparatus, to analyze numerous bacteriophage T7 samples at once. Working with Brookhaven microbiologist John Dunn, Studier sequenced T7’s DNA. From that research, Studier developed a novel T7 expression system in the 1980s that made it possible to produce RNA quickly and efficiently. This work has since become the foundation of a vast swath of biomedical and vaccine research, and was used in the development of the COVID-19 mRNA vaccine.

The Nobel Assembly cited Studier’s research as instrumental in the scientific background for the 2023 Nobel Prize in Physiology or Medicine awarded to Katalin Karikó and Drew Weissman for their work in developing the COVID-19 vaccine. “Today, virtually every protein you want to produce in bacteria is made with a T7 system,” Venki Ramakrishnan, winner of the 2009 Nobel Prize in Chemistry, said in 2024 after Studier received the Richard N. Merkin Prize in Biomedical Technology for his lifetime of work on efficient and scalable technologies. “There’s not a single molecular biology or biochemistry lab I know that doesn’t use T7 systems.”

Studier’s work has always been driven by a desire to serve science. He gladly shared his findings with others engaged in the pursuit of knowledge. “You probably have rarely known anyone who had less self-promotion in mind,” says Susan Studier, his wife of 63 years, who spoke to the Caltech Heritage Project on behalf of her husband, who has aphasia. “He believes deeply in sharing knowledge.”

During his time as a graduate student, Studier worked with biology professors James Bonner, Robert Sinsheimer, and Max Delbrück, and chemistry professors Norman Davidson and Jerome Vinograd. “They were extraordinary role models,” says Susan Studier. “Bill has always been grateful for the years he spent at Caltech, not only for the outstanding faculty and focus on research but also for the students and postdocs he met and worked with. He made some lifelong friendships.”

Studier was elected to the National Academy of Sciences in 1992, one of his proudest achievements. Studier is also a member of the American Academy of Arts and Sciences, the National Academy of Inventors, and he was named a fellow of the American Association for the Advancement of Science. He holds 16 patents.

Throughout his career, Studier’s dedication to fundamental science never wavered. “I’ve always been interested in solving problems. There are many unknowns, but scientific investigation can provide definitive answers,” he told the Brookhaven Lab for a 2011 profile. “The motivation for my research is not commercial application. My interest is in basic research.”

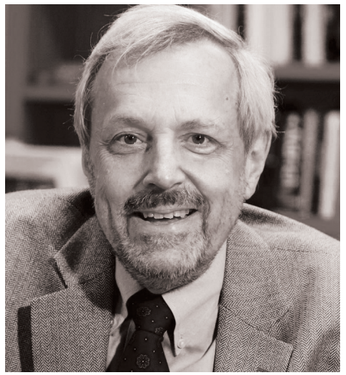
DONALD G. TRUHLAR

PHD ’70

THEORETICAL CHEMIST

For his discoveries in theoretical and computational chemistry, including the creation of models and measurements that have become cornerstones in the field, making him one of the most influential and cited researchers in the world.

When Donald Truhlar began his career in computational chemistry in the early 1970s, the field barely existed. “Before modern computation, people did pencil-and-paper theoretical chemistry,” Truhlar recounts. “You couldn’t really solve difficult problems without a lot of computation, so the availability of more powerful computational resources made a big change in theoretical chemistry.” When Truhlar began his graduate work at Caltech, such computation was done using punch cards. Now, computer simulations are used to solve problems, and Truhlar has become a luminary in the field he was instrumental in establishing.



Truhlar is now a Regents Professor and Distinguished University Teaching Professor in the Department of Chemistry at the University of Minnesota. He was named a Regents Professor in 2006, a designation that is the University of Minnesota’s highest recognition of excellence in scholarship and teaching.

As a doctoral candidate at Caltech, Truhlar worked with the late Aron Kuppermann, then a professor of chemical physics, developing methods that have become standard tools in research—such as using quantum mechanical scattering theory for analyzing collisions of electrons, atoms, and molecules. This involves solving the Schrödinger equation with scattering boundary conditions. “Aron always was willing to try the most difficult problems,” Truhlar says. “The key was developing methods that would be practical on the computer and would solve problems that were more difficult than problems that had previously been solved.”

The scope of Truhlar’s work over more than five decades has been vast and includes the development of an accurate quantum mechanical scattering theory for chemical reactions; the study of quantum effects like tunneling, coherence, and decoherence in semiclassical dynamics; advances in quantum mechanical photochemistry; and more. His work has had almost unparalleled influence in theoretical chemistry; his papers have been cited more than 250,000 times to date.

Truhlar grew up in the Chicago suburbs and received his bachelor’s degree from St. Mary’s College (now Saint Mary’s University of Minnesota) in 1965. His older brother was a physicist, and Truhlar began his undergraduate studies thinking he might pursue that field until a professor at Saint Mary’s gave him the chance to do organic chemistry research. He was drawn to Caltech for his graduate work due to its reputation for serious scholarship. “They had good laboratories and hired the best faculty members to advise the students,” he says. “The school had a real sense of excellence.”

Truhlar is a fellow of the American Association for the Advancement of Science, the Royal Society of Chemistry, the American Chemical Society, and the American Physical Society, and he is a member of the National Academy of Sciences (NAS). He has also received international awards from each organization. Truhlar is an honorary fellow of the Chemical Research Society of India and the Chinese Chemical Society. Some of his other top honors include a National Science Foundation Special Creativity Award, and the Schrödinger Medal of the World Association of Theoretical and Computational Chemists. In 2015, the American Chemical Society’s Physical Chemistry Division convened a symposium in honor of Truhlar’s contributions to computational chemical dynamics.

Today, Truhlar still develops practical methods to solve the most difficult quantum chemistry problems, such as those involved in density functional theory—an alternative to the Schrödinger equation for describing the electronic states of molecules and materials. “I want to do complicated problems in a more automatic way so that a wider community can use the tools I’m developing,” he says.



Nearly 10 million people around the world living with type 1 diabetes must perform a daily series of finger pricks, injections, and insulin pump applications in order to manage their condition. As a bioengineering graduate student at Caltech, Alborz Mahdavi (PhD ’15) believed molecular science held the power to transform the treatment of diseases. He was especially drawn to the scientific challenge of diabetes treatment and how to mimic biological processes for glucose management.

“This was a perfect problem for someone from Caltech to take on because it’s so technically challenging that most people would essentially write it off as impossible,” says Mahdavi, who studied with David A. Tirrell, the Ross McCollum-William H. Corcoran Professor of Chemistry and Chemical Engineering. “It was a problem that needed not only a solution but an elegant one. Building an extremely complicated molecule wouldn’t be practical for industry.”

While at Caltech, Mahdavi heard about the Grand Challenge Prize being offered by Breakthrough T1D, a nonprofit seeking innovative molecular-level designs for a new type of insulin that could sense major swings in blood sugar levels and trigger the body to deliver life-saving doses of the hormone. Mahdavi submitted a proposal and won the cash prize in 2013. He next launched a Pasadena start-up called Protomer Technologies to turn his idea into a real therapeutic.

The company aimed to develop a new synthetic molecule known as an agonist—a chemical substance that binds to a cell receptor and activates it to produce a biological response. In this case, Protomer’s drug would bind to the insulin receptor only when glucose levels rise, thanks to conditionally active binding moieties (parts of a molecule) that act as an “on” and “off” switch.

But Mahdavi and his team faced three major hurdles. The first was to create a synthetic molecule that could distinguish glucose from other sugars in the body. Another was to ensure that the therapeutic would interact with glucose but not so strongly that the agonist would become saturated and unable to detect subsequent spikes in blood sugar. The biggest concern, however, was overactivation: If a person were to indulge in glucose-rich soda or ice cream, the initial rush of sugar in the bloodstream could cause the therapeutic molecule to deliver too much insulin, dropping glucose levels precipitously and potentially causing hypoglycemia—a condition that requires immediate medical attention.

In the beginning, Mahdavi and his team focused on building new methodologies and tools to significantly increase the screening of potential therapeutic molecules and make it easier to identify which might be targets for modification; one such tool was their molecular evolution of peptide sensors (MEPS) platform. When one molecule did not work, MEPS allowed them to move on to the next candidate as quickly and efficiently as possible. “In searching for a solution, sometimes it’s hard to anticipate problems,” Mahdavi says. “We made no assumptions other than that we were not clever enough to predict every problem. Instead, my team and I took each concept and tried to fail quickly in every way possible until we ran out of failure modes.”

Mahdavi decided to base Protomer in Pasadena, a decision he believes helped the company to be successful. His mentor Tirrell, now Caltech’s provost and the Carl and Shirley Larson Provostial Chair, played an influential role in Protomer’s success. A decade before Mahdavi launched Protomer, Tirrell had launched his own biotech start-up and had appreciated the experience of developing a potential treatment for multiple sclerosis. He initially joined Protomer as a scientific co-founder, offering his perspective on how to approach the process of developing a synthetic receptor and speaking with potential investors.

“Alborz had a very good idea, and if his work could help people, I wanted to support it,” says Tirrell, who stepped away from Protomer when he became provost. “In general, there is a continuing effort at Caltech to make it appealing for our community to stay local and start their companies. Alborz and others have helped create an intellectually enriching and entrepreneurial environment here.”

Mahdavi also connected with Bassil Dahiyat (PhD ’98), the founder, president, and CEO of Pasadena biotech firm Xencor. Dahiyat showed Mahdavi how to build a drug-development program from the ground up. Mahdavi also met regularly with Mikhail Shapiro, Caltech’s Max Delbrück Professor of Chemical Engineering and Medical Engineering and a Howard Hughes Medical Institute Investigator, who offered advice. The two shared an office at MIT while Mahdavi worked as a research associate before graduate school.

“I don’t think people appreciate how lonely it is to be a start-up CEO,” Mahdavi says. “When things aren’t going well, it is helpful to have a close circle of trusted people to reach out to. The type of support that people at Caltech have for each other helps make sure we’re all successful.”

Lilly acquired Protomer in 2021, helping to accelerate clinical development. Today, Protomer’s glucose-sensing molecules are in clinical trials. As vice president of Lilly Research Labs, Mahdavi and his team are now using MEPS to fight or cure other critical diseases. The Caltech alum also shares his expertise while serving as a mentor to the Institute’s aspiring entrepreneurs. “The Institute’s faculty and alumni believed in me,” Mahdavi says. “That is the best form of support you can have, and I hope to do that for others.”

Family Membership Through Generations

The benefits of belonging to CEFCU last a lifetime!



Putting members first for 75 years.

CEFCU exclusively serves the extended Caltech community and their families. Membership is open to Caltech, Jet Propulsion Laboratory, and The Huntington employees, contractors and volunteers, as well as Caltech undergraduate and graduate students, the Caltech Associates, Caltech Alumni Association, CARA, TMT, Polytechnic School, and immediate family (by blood or marriage) of current members.

800/592-3328 • www.cefcu.org

CALTECH EMPLOYEES Federal Credit Union

Must qualify for CEFCU membership to join. Minimum $5 deposit and one-time $5 membership fee due upon opening any CEFCU share account. ***Federally insured by NCUA.***

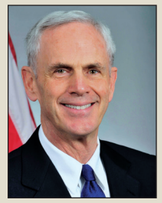
In Memoriam

To learn more about their lives and work, visit **magazine.caltech.edu/post/in-memoriam**.



Sunney Chan (1936–2025)

Chan, Caltech's George Grant Hoag Professor of Biophysical Chemistry, Emeritus, passed away on May 5, 2025, at age 88. He began his Caltech career as an assistant professor of chemical physics in 1963. He received tenure in 1968 and was named the George Grant Hoag Professor in 1992. Chan's research evolved from fundamental studies in chemical physics to the investigation of biological molecules, including the base stacking of nucleic acids, the dynamic structures of membranes, and the function of membrane proteins. His work made extensive use of nuclear magnetic resonance, a noninvasive, highly sensitive method that exploits the magnetic properties of atomic nuclei. Chan also served as executive officer for chemistry from 1978 to 1980 and again from 1989 to 1994. He was master of student houses from 1980 to 1983.



John E. Bryson (1943–2025)

Bryson, former United States secretary of commerce, environmental advocate, and a life member of the Caltech community, passed away on May 13, 2025, at age 81. Bryson was named to the Caltech Board of Trustees in 2005 and served until 2011, when he was confirmed as secretary of commerce. He was reelected to the board in 2013, became a senior trustee in 2015, and a life member of the Caltech community in 2017. During his Board tenure, Bryson chaired the Audit and Compliance Committee, served as vice chair of the Nominating Committee, and was a member of the Executive Committee, the Institute and Alumni Relations Committee, and numerous other committees supporting the campus and its community. He and his wife, Louise Bryson, established the John E. Bryson Fellowship Fund to support graduate students, with an emphasis on those studying alternative energy sources and sustainability.



David Baltimore (1938–2025)

Baltimore, President Emeritus and the Judge Shirley Hufstedler Professor of Biology at Caltech and a co-recipient of the 1975 Nobel Prize in Physiology or Medicine, passed away on September 6, 2025, at age 87. Baltimore was awarded the Nobel Prize for his discovery that the genetic material of tumor viruses could make DNA from their RNA genome, changing the widely held perception that genetic information could only be transferred in one direction, from DNA to RNA. Baltimore's research contributed to the understanding of the molecular basis of the immune response and shaped advances in biotechnology and the development of national science policy regarding recombinant DNA research and the AIDS epidemic. Baltimore served as Caltech's seventh president from 1997 to 2006, a tenure marked by the completion of a fundraising initiative for the biological sciences, the construction and dedication of the Broad Center for the Biological Sciences, and the launch of a $1.4 billion capital campaign. After retiring as president in 2006, Baltimore remained on the Institute faculty and went on to establish a new methodology to help fight cancer, develop a new highly effective gene therapy to prevent HIV from infecting individual cells in the immune system, and create a new methodology for producing transgenic mice. He also joined with others in pursuing a global effort to create an HIV vaccine.



Endnotes

This issue's cover story deals with perseverance in science (see page 14), so we asked alumni:

What has perseverance looked like in your field or career?

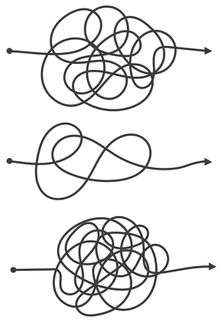
It took 52 years between my 1973 graduation from Caltech and my 2025 Caltech Distinguished Alumni Award. Research perseverance was of prime importance during this long journey. My research went from graphite to concrete, and from electronic materials to structural materials. This diversification took guts and effort, but it enabled me to pioneer the field of multifunctional structural materials. Thanks to my Caltech education for enabling me to learn new things throughout my career.

Deborah Chung (BS '73, MS '73)
BUFFALO, NY



If I saw Perseverance in my field, it would mean I'm on Mars.

Tyler Housel (MS '86)
LANSDALE, PA



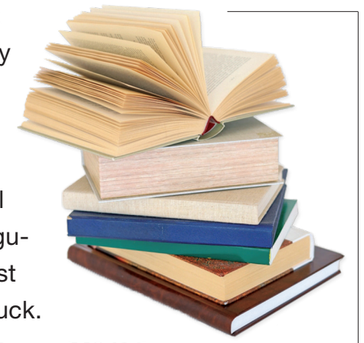
In aerospace, sometimes perseverance is the willingness to rework the solution for a problem many, many times. Often, problems involve having to satisfy multiple requirements or constraints, such as speed, throughput, timing/synchronization, stability, and environmental factors. And although the initial solution might seem like the most elegant functionally, it may fall short in one or more of the other areas. So, you may have to abandon your first, second, or even 10th "baby" before striking the right balance, which may also involve having to set your ego aside as well. Generally, however, I think that perseverance, ultimately resulting in success, is one of the best forms of gratification in any field.

Demetrios Missios (BS '88)
LONG BEACH, CA

Trying (and mostly succeeding) to investigate the questions and do the things that interest and excite me rather than chase the latest fashions or more money.

Bob Fisher (BS '74)
EDINBURGH, SCOTLAND

I am an author and have published about 20 books, mostly popular science. I cannot tell you how many times my book proposals have been rejected by publishers! Generally, I give myself 24 hours to feel down and depressed. Then I pick myself up, dust myself down, and get my agent to send it out again. Obviously, you need to be self-critical and take on board positive and legitimate criticism. However, to succeed as a writer, you will need an ability to deal with rejection. Arguably, this will need to be one of your most important traits after talent and a lot of luck.



Marcus Chown (MS '84)
LONDON, ENGLAND

Literally, a six-wheeled, 1 ton Mars rover! Figuratively, a team of talented scientists and engineers working together over a decade to design, build, and operate the most sophisticated rover ever sent to Mars. This team launched and landed a rover on Mars during a global pandemic and has now worked daily for over four years collecting and documenting rock samples that will transform our understanding of Mars and the solar system.

Katie Stack Morgan (PhD '15)
VALENCIA, CA

I ended up doing my PhD in social sciences, one of the very first doctorates in entrepreneurship. A new field has to fight to gain traction, especially in intellectual credibility. While I didn't finish at Tech, it gave me some powerful tools to help me persevere. It taught me so much about how to do science right, *and* it taught me how to be a scientist. Both are central to the success I've had despite spending very little time in traditional academic jobs. But Tech also taught me collegiality—there need not be a downside to helping even a rival.

Norris Krueger (EX '74)
BOISE, ID

Connect with us

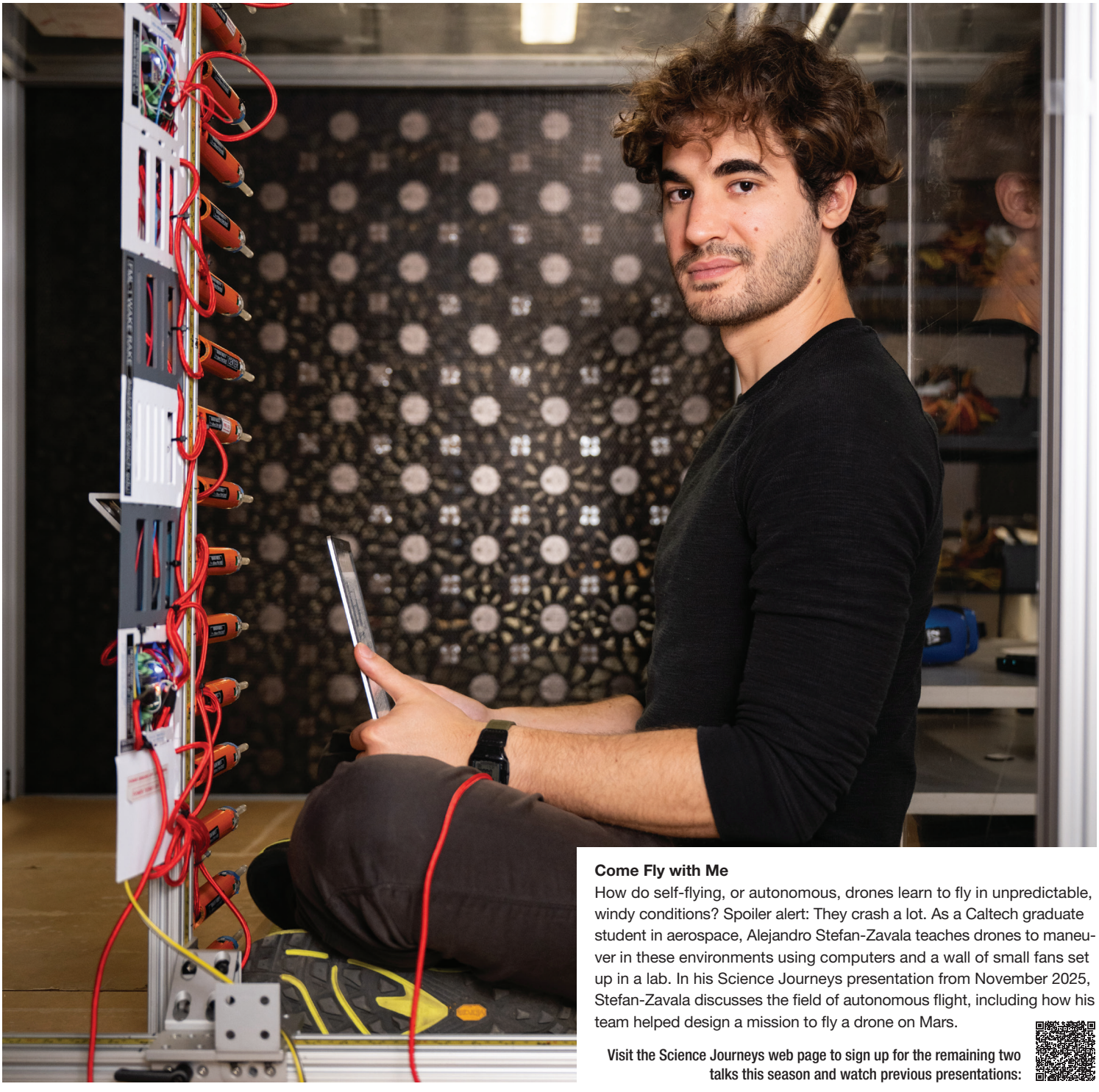
Join the conversation

Email us at **magazine@caltech.edu**

And remember to get social:

Caltech
magazine

1200 East California Blvd., Pasadena, CA 91125



Come Fly with Me

How do self-flying, or autonomous, drones learn to fly in unpredictable, windy conditions? Spoiler alert: They crash a lot. As a Caltech graduate student in aerospace, Alejandro Stefan-Zavala teaches drones to maneuver in these environments using computers and a wall of small fans set up in a lab. In his Science Journeys presentation from November 2025, Stefan-Zavala discusses the field of autonomous flight, including how his team helped design a mission to fly a drone on Mars.

Visit the Science Journeys web page to sign up for the remaining two talks this season and watch previous presentations: