



Lifted the Fog on Smog

In the 1940s, Caltech chemist Arie Haagen-Smit became the first scientist to directly link smog to automobile exhaust, ultimately prompting the formation of the California Air Resources Board. Since then, Caltech researchers have continued to influence air-pollution management with new insights into urban smog formation and discoveries about the origin, chemistry, and evolution of particles in the atmosphere.



Fought Lead Contamination

Attempting to calculate the age of the earth (4.55 billion years), Caltech geochemist Clair Patterson unexpectedly discovered that toxic lead contaminated everything from his lab instruments to canned fish, ocean water, Antarctic ice, and, most alarmingly, the human body. Despite skepticism about his findings throughout the 1960s, Patterson's research drove efforts to remove lead from gasoline and to implement environmental protections including the Clean Air Act of 1970.

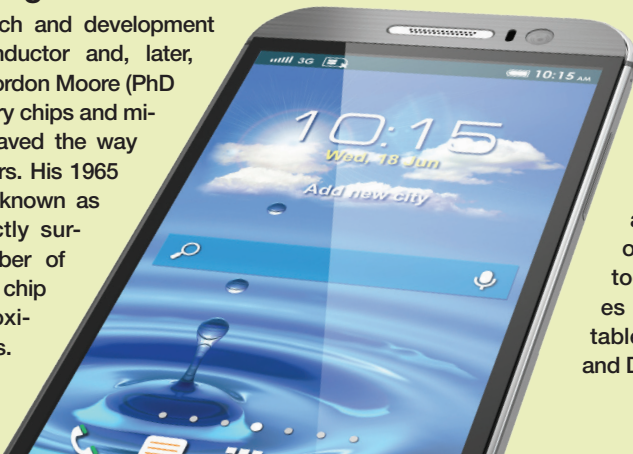
Directed Evolution

In the 1990s, Caltech chemical engineer Frances Arnold pioneered the technique of directed evolution, which mimics the process of natural selection to create new enzymes that can be used in medicine, neurobiology, and alternative energy. For example, Arnold has used directed evolution to engineer enzymes that can convert plant waste into fuel.

Pioneered Chip Design

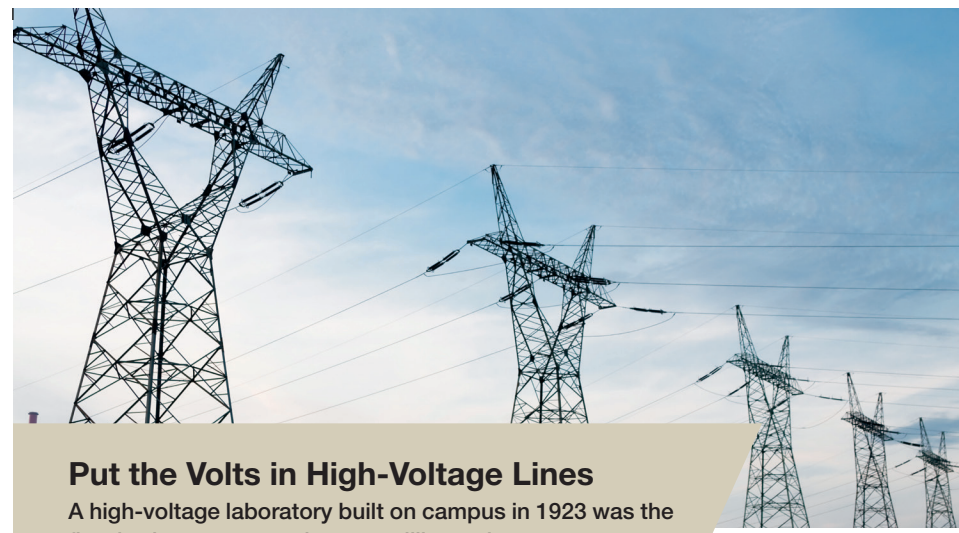
Caltech engineer Carver Mead (BS '56, MS '57, PhD '60) validated the science behind Moore's Law in 1972. Through a process known as very-large-scale integration (VLSI), Mead made it possible

for tens of thousands of transistors to be packaged on a single silicon chip. VLSI revolutionized electronics, enabling the building of processors that today drive devices such as laptops, tablets, smartphones, and DVD players.



Made Computing Personal

As director of research and development at Fairchild Semiconductor and, later, co-founder of Intel, Gordon Moore (PhD '54) developed memory chips and microprocessors that paved the way for personal computers. His 1965 prediction, popularly known as Moore's Law, correctly surmised that the number of transistors on a single chip would double approximately every two years.



Put the Volts in High-Voltage Lines

A high-voltage laboratory built on campus in 1923 was the first in the country to have a million-volt power source. The laboratory helped Southern California Edison develop high-voltage transmission lines, which would furnish lightning protection to oil storage tanks and address other power needs of a rapidly industrializing Southern California.

Caltech scientists have been at the forefront of inquiry and innovation since the Institute was founded in 1891. Researchers and engineers on campus and at the Jet Propulsion Laboratory (JPL), which Caltech manages on behalf of NASA, have launched new fields of study and invented world-changing tools and technologies while seeking answers to the scientific questions that define the times.

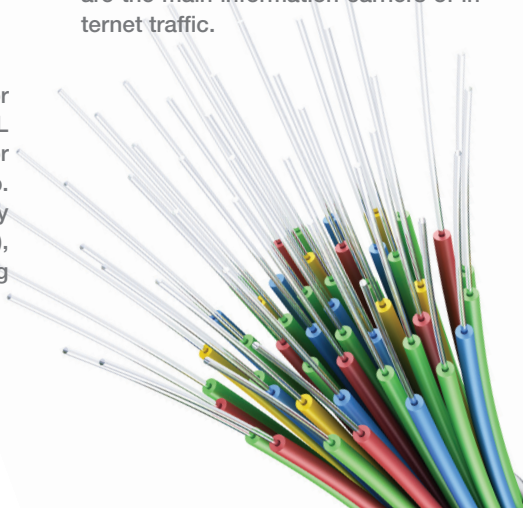
Over the years, Caltech has...

Connected the World

Fiber optic communications systems rely on distributed feedback semiconductor lasers, developed in the 1970s by Caltech's Amnon Yariv, an engineer and applied physicist. Today, such lasers are the main information carriers of internet traffic.

Put Cameras in Space— and Cell Phones

Tasked with miniaturizing cameras for future spacecraft, engineers at JPL invented a new kind of image sensor that functions as a camera on a chip. That technology, the complementary metal-oxide semiconductor (CMOS), is ultimately responsible for putting cameras in cell phones.



INNOVATION

IMPACT by the numbers

Caltech has an outsized impact on science, technology, and society. With a community of 300 faculty, 2,200 undergraduate and graduate students, and 600 postdoctoral scholars, the Institute is recognized as a leader in innovation. In the 2017 fiscal year, Caltech was associated with:

190

U.S. patents issued

1,928

active U.S. patents

16

new start-up companies

77

licenses (including options)

305

material transfer agreements

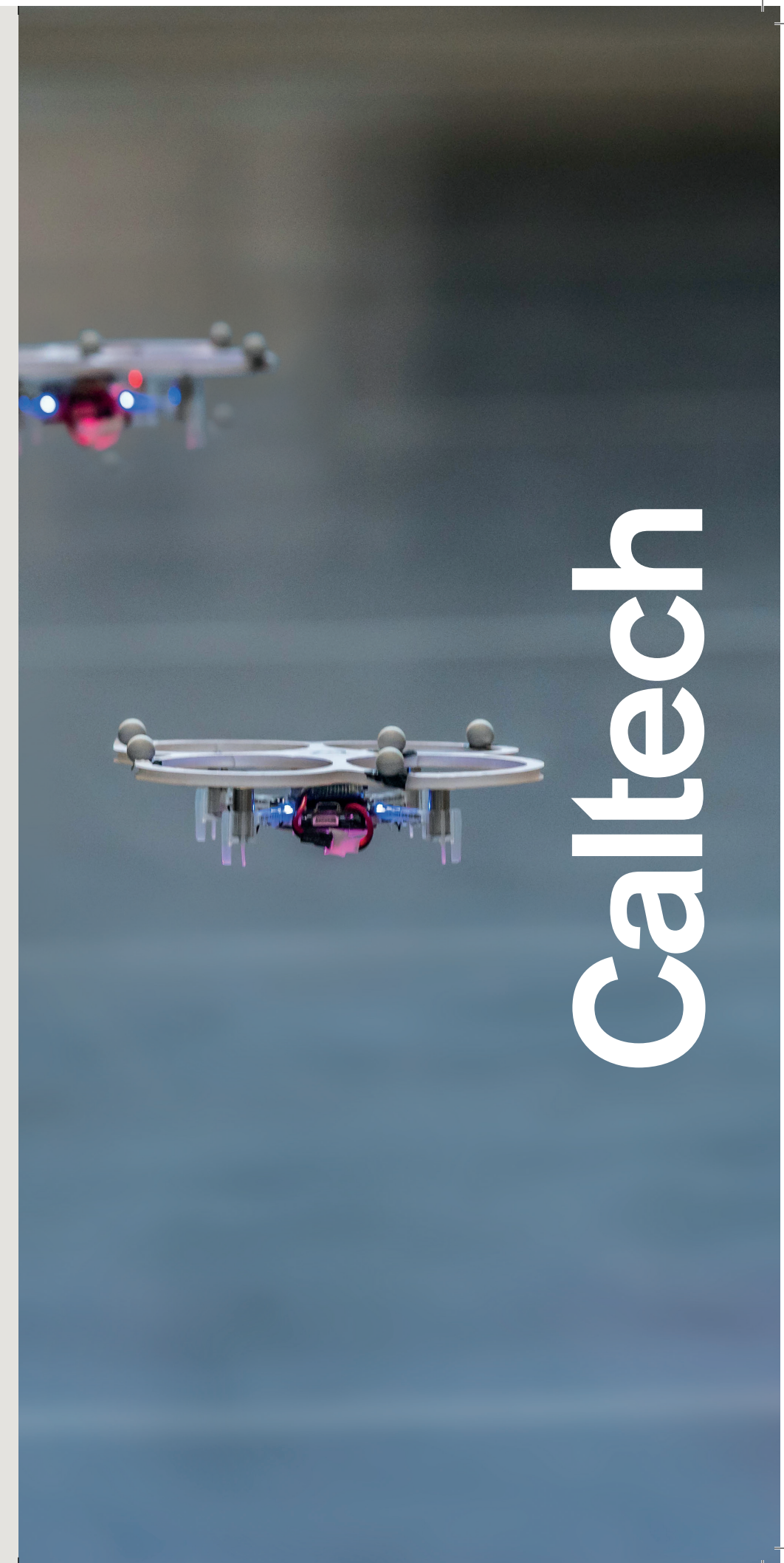
Caltech led its peers, with more than

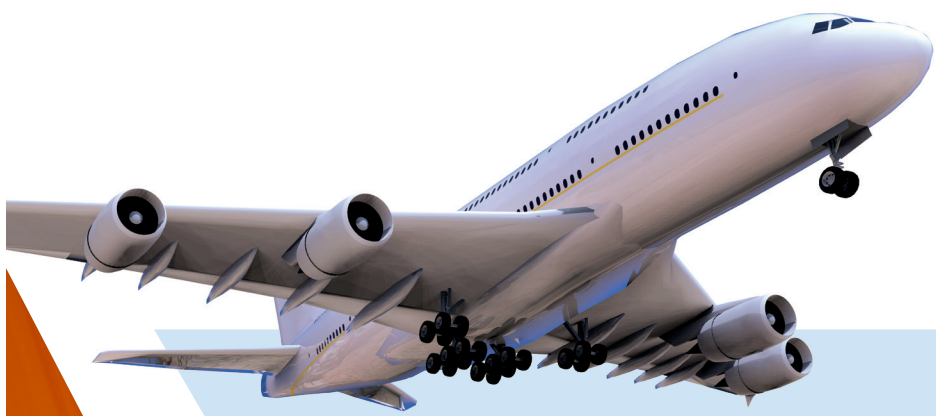
660

U.S. patents issued between 2012 and 2015.

www.caltech.edu

Cover: At Caltech's new Center for Autonomous Systems and Technologies, researchers are imagining, creating, and testing the next generation of drones, robots, and other autonomous systems.





Put the Wind Beneath, Well ... Everything

Researchers have used Caltech's John W. Lucas Adaptive Wall Wind Tunnel and its historic 10-foot predecessor to test everything from military and commercial aircraft to Olympic bicycles and electric cars. Insights made possible by the tunnels have led to more fuel-efficient vehicles and inspired research on hypersonic technology.

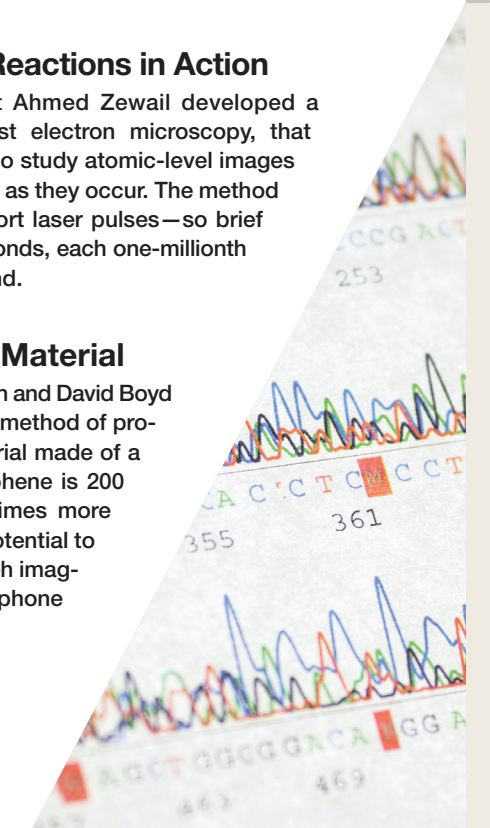
Caltech research continues to drive giant leaps forward in knowledge about the world, the universe, and the human mind.

Captured Reactions in Action

Caltech chemist Ahmed Zewail developed a technique, ultrafast electron microscopy, that allows researchers to study atomic-level images of chemical reactions as they occur. The method relies on extremely short laser pulses—so brief they last mere femtoseconds, each one-millionth of one-billionth of a second.

Produced a Wonder Material

Caltech physicists Nai-Chang Yeh and David Boyd created a commercially feasible method of producing graphene, a wonder material made of a single layer of carbon atoms. Graphene is 200 times stronger than steel, several times more conductive than silicon, and has the potential to transform electronics manufacturing. Yeh imagines, for example, a graphene-based cell phone screen that generates its own power.



Made Sense of the Brain's Split Functions

Caltech psychobiologist Roger Sperry's split-brain experiments revealed the separate functions of the brain's two hemispheres: the left half controls verbal and mathematical functions as well as analytic and sequential reasoning, while the right controls spatial and conceptual reasoning, visualization, and creativity.

Delved into the Science of Decisions

Caltech researchers launched the field of behavioral and social neuroscience, providing experimental insights into how individuals choose between healthy and unhealthy foods, why consumers pay more for goods they can touch, and why (and when) people are willing to take risks.

Turned Thoughts into Action

In 2015, Caltech neuroscientist Richard Andersen demonstrated that a neuroprosthetic device, implanted in the part of the brain that controls the intention to move, helps paralyzed patients more easily control robotic limbs. For example, patients have used their minds to direct a robotic arm to pick up a cup of water and lift it to their mouths.



Helped the Blind See

Caltech electrical and medical engineer Yu-Chong Tai helped develop a retinal prosthesis that allows blind patients to see again through electrical stimulation. The prosthesis acts as biological photoreceptors normally do, stimulating neurons in the retina to create an image.

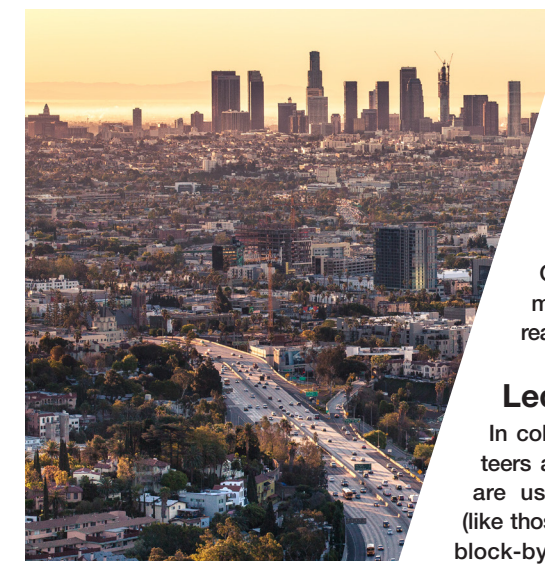


Championed the Treatment of HIV/AIDS

In the mid-1990s, David Ho (BS '74) discovered that HIV is never dormant but constantly mutates in order to continue its assault on the immune system. His insight led to the development of antiretroviral therapies that have dramatically increased the lifespans of HIV-infected patients.

Connected Bacteria to the Brain

Caltech microbiologist Sarkis Mazmanian discovered a connection between the microbiome—the bacteria living in the human gut—and the motor-skill deterioration associated with Parkinson's disease. This research is part of broader investigations on the manner in which good bacteria promote or protect human health.

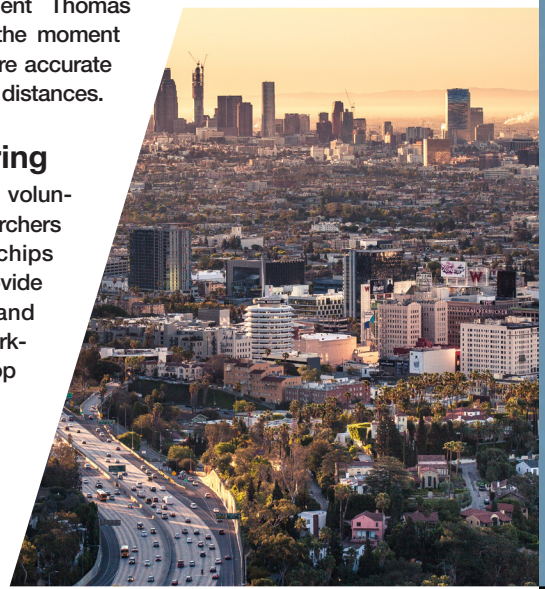


Built the Tools that Measure Earthquakes

In the 1930s, Caltech seismologists Beno Gutenberg and Charles Richter (PhD '28) developed the Richter scale, a numerical scale for measuring earthquake magnitude. Nearly 50 years later, Caltech seismologist Hiroo Kanamori and graduate student Thomas C. Hanks (PhD '72) developed the moment magnitude scale, allowing for more accurate readings of larger quakes at greater distances.

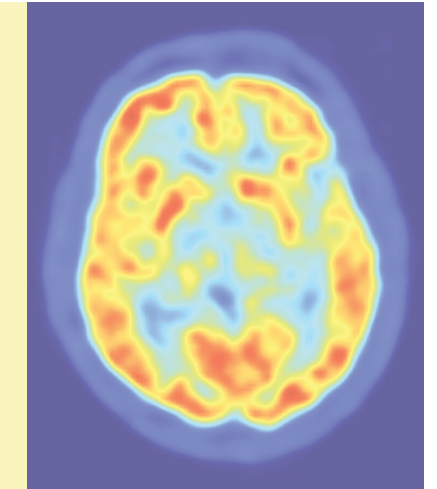
Led Earthquake Monitoring

In collaboration with colleagues and volunteers across California, Caltech researchers are using low-cost accelerometer chips (like those found in smartphones) to provide block-by-block estimates of shaking and damage during an earthquake, and are working with the U.S. Geological Survey to develop an earthquake early-warning system.



Identified the Positron

Caltech physicist Carl Anderson (BS '27, PhD '30) provided the first empirical proof that antimatter exists with his discovery of the positron. Today's positron emission tomography (PET) scanners—which produce detailed 3-D images of metabolic activity in the body—are a result of his discovery.



Wrote the Book on Physics

Caltech physicist Richard Feynman—whose work set in motion the fields of nanotechnology, quantum computing, and quantum electrodynamics—authored and delivered a series of lectures that became one of the most popular physics books ever written, *The Feynman Lectures on Physics*.

Determined Most Atoms on Earth Were Created in Stars

Caltech physicist Willy Fowler, working with research fellow Margaret Burbidge and other colleagues, showed that all but the very lightest elements—making up everything from the ground underfoot to the air all around to human muscle and bone—were created by nuclear reactions within stars.



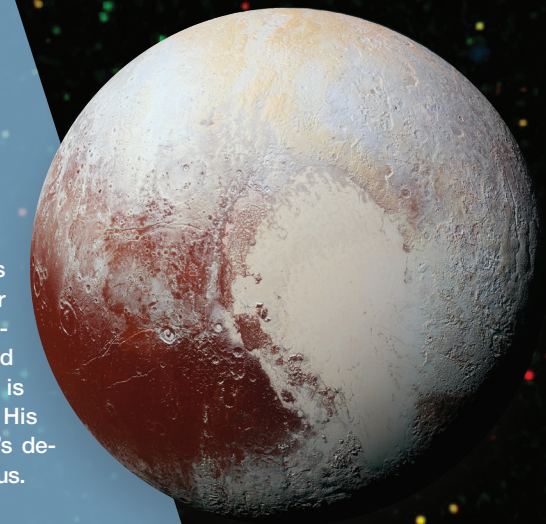
Found the Building Blocks of Matter

Caltech theoretical physicist Murray Gell-Mann and graduate student George Zweig (PhD '64) independently discovered quarks—subatomic particles that are the main components of protons and neutrons.

Demoted Pluto; Promoted a New Ninth Planet

Searching for distant objects at the edges of the solar system, Caltech astronomer Mike Brown discovered a dwarf planet, Eris, that is more massive than Pluto. His discovery triggered Pluto's demotion to dwarf-planet status.

Then, in 2016, Brown and Caltech planetary scientist Konstantin Batygin (MS '10, PhD '12) published theoretical evidence of a true ninth planet—one 10 times more massive than Earth—tracing a bizarre orbit around the sun. The announcement of a potential new Planet Nine ignited a worldwide, sky-wide hunt.



Launched the Lab that Launches Rockets

Students and researchers from the Guggenheim Aeronautical Laboratory at Caltech (GALCIT) were the driving force behind the creation of JPL in the 1930s. JPL, which Caltech manages on behalf of NASA, is the leading center for exploration of the solar system. Lab scientists launched the nation's first satellite, Explorer 1, in 1958; the twin Voyager spacecraft in 1977; and the Mars Science Laboratory in 2011, among many other missions.



Detected Ripples in Spacetime

Led by Caltech physicists Kip Thorne (BS '62), Ron Drever, and Barry Barish, along with MIT's Rainer Weiss, the Laser Interferometer Gravitational-wave Observatory (LIGO) made the first-ever detection of gravitational waves—ripples in spacetime—in September 2015. The detection, which came 100 years after Albert Einstein predicted the existence of gravitational waves in his general theory of relativity, opened a new window onto the cosmos, ushering in the field of gravitational astronomy.

Trained Eyes on the Skies

Caltech researchers have designed and built the world's most sophisticated telescopes and astronomical observatories, including the W. M. Keck Observatory, whose twin telescopes are currently the largest and most scientifically productive on Earth. The Keck telescopes have made possible the observation of young stars, ancient galaxies, and dozens of planets—some potentially habitable—outside the solar system.

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