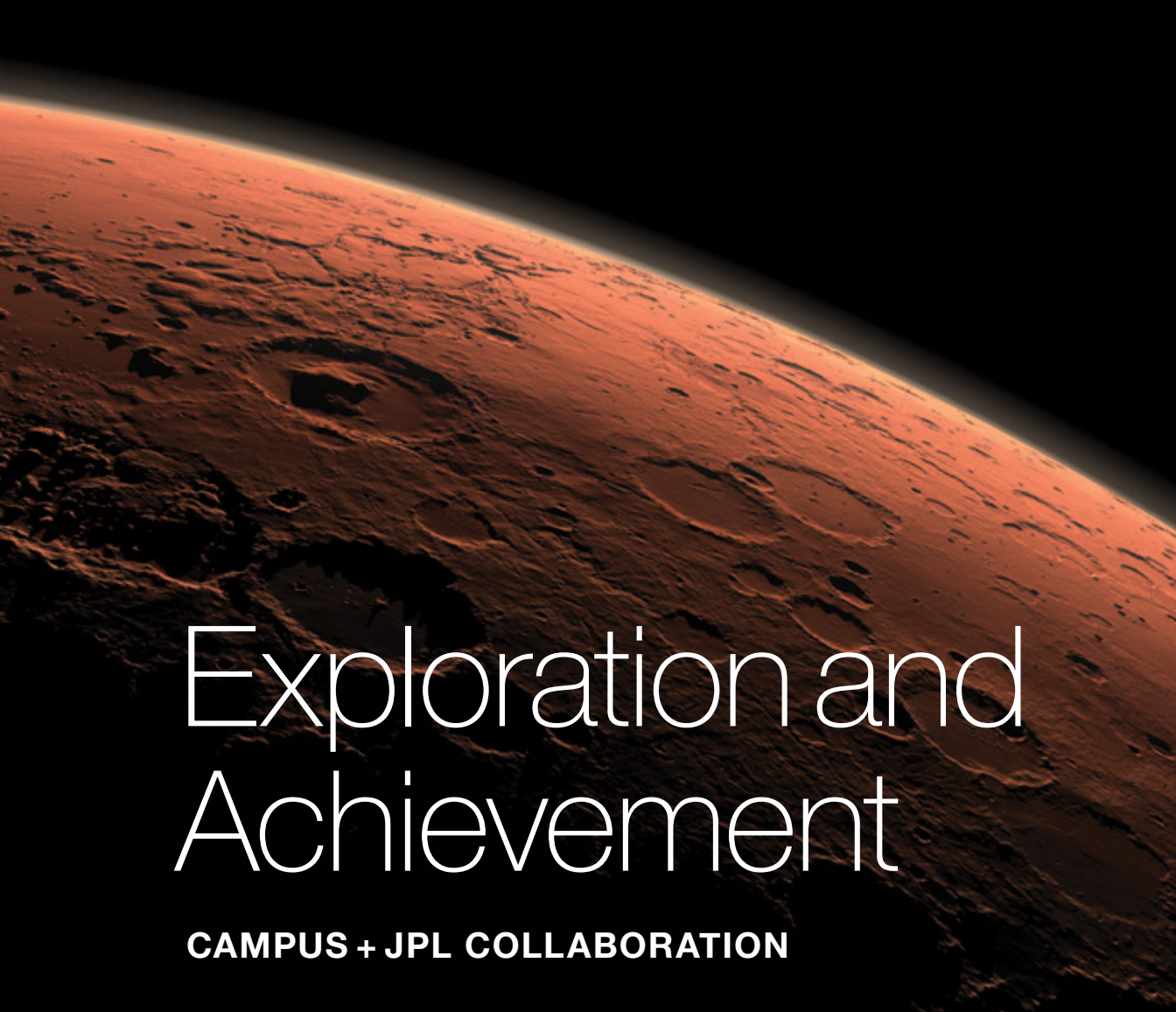
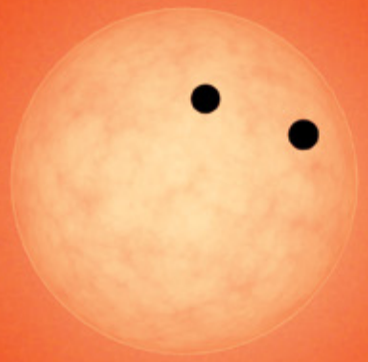


Exploration and Achievement

CAMPUS + JPL COLLABORATION

Caltech



Exploration and Achievement

More than eight decades ago, faculty at Caltech established the Jet Propulsion Laboratory. Since 1958, Caltech has worked alongside NASA to keep the United States at the vanguard of space exploration and planetary science. Today, campus and Lab researchers collaborate across a variety of missions and disciplines to advance understanding of Earth and the universe.

Artist's concept of the TRAPPIST-1 solar system.

"The spirit and ambition of JPL helps define the character of Caltech. Together, we unlock the secrets of the universe, trace the changes on our planet, capture the imagination of our fellow citizens, and inspire the next generation of scholars. We are able to think big because the separation between our campuses remains small."

—**THOMAS F. ROSENBAUM**
Caltech President
Sonja and William Davidow Presidential Chair
Professor of Physics

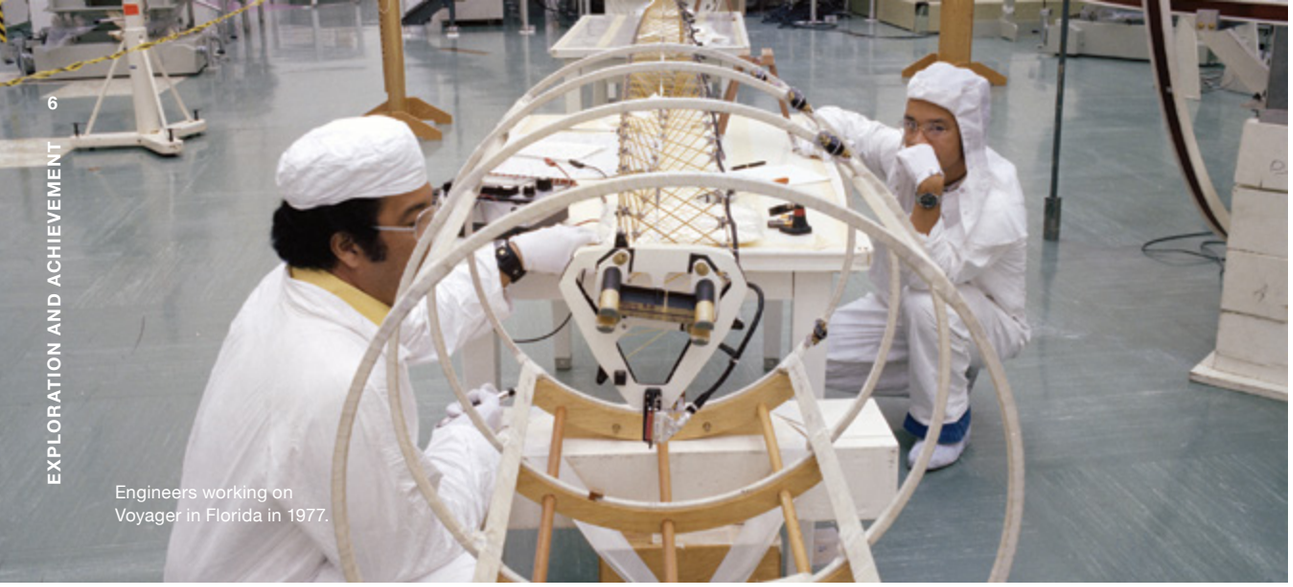
"When our spacecraft venture to Mars or Saturn on journeys of discovery, they carry a handful of instruments but also the imaginations of millions of people. Working with colleagues on campus and across NASA, we continue to forge new directions toward even greater discoveries."

—**MICHAEL M. WATKINS**
Caltech Vice President
Director of the Jet Propulsion Laboratory
Professor of Aerospace and Geophysics

EXPLORING THE Solar System

Former JPL director William Pickering (BS ’32, MS ’33, PhD ’36) launched the first U.S. satellite, Explorer I, into orbit in 1958. Since then, campus and Lab have continued to lead the world in robotic exploration of the solar system with spacecraft that study Earth’s planetary neighbors and traverse beyond the frontiers of interstellar space.

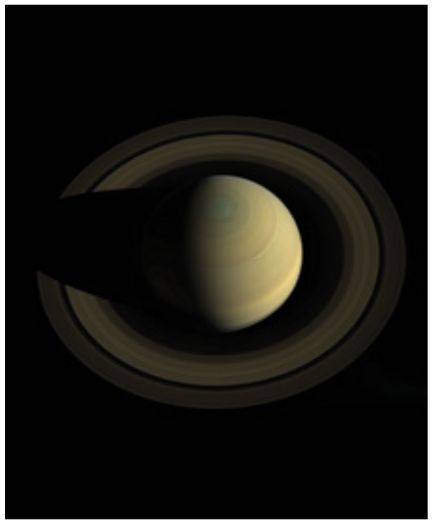
An image taken by Cassini of Saturn’s icy moon Enceladus.



Engineers working on Voyager in Florida in 1977.

Voyager

The twin Voyager spacecraft, launched in 1977, are each more than 10 billion miles from Earth. Their pioneering mission, led by project scientist and Caltech physicist Ed Stone, has contributed extraordinary discoveries in planetary science, including that of an Earth-like atmosphere on Saturn's moon Titan and active volcanoes on Jupiter's moon Io. Voyager 2 is the only spacecraft to have flown by all four outer planets—Jupiter, Saturn, Uranus, and Neptune—while Voyager 1 is the first to have entered interstellar space.



An image of Saturn taken by Cassini.

Cassini

Before taking its final, fiery dive into Saturn's atmosphere in September 2017, the Cassini spacecraft—designed, developed, and assembled at JPL—spent 13 years orbiting the planet. During that time, Cassini made dramatic discoveries, including that of a liquid-water ocean underneath the icy shell of the moon Enceladus. Caltech faculty and alumni on the Cassini team included electrical engineer, planetary scientist, and former JPL director Charles Elachi; planetary scientist Duane Muhleman; planetary scientist Andrew Ingersoll; Torrence Johnson (PhD '70); Carolyn Porco (PhD '83); and Dennis Matson (PhD '72).

Juno

After five years and 1.8 billion miles of space travel, the Juno spacecraft arrived at Jupiter in July 2016. The mission, whose science team includes Caltech planetary scientists Andrew Ingersoll and Dave Stevenson and physicist Ed Stone, investigates the giant planet's formation. Understanding Jupiter's past could hold clues about the origin of water on Earth.

The swirling cloud patterns of Jupiter.

Mars Science Laboratory

In August 2012, the Mars Science Laboratory mission's Curiosity rover landed in Gale Crater. The largest and most advanced vehicle ever sent to Mars, Curiosity, which functions as a mobile lab, has found evidence that water once flowed on the ancient Martian surface. Caltech faculty members have played key roles on the mission: geologists Edward Stolper and John Grotzinger have served as project scientists, while planetary scientist Bethany Ehlmann and geochemist Ken Farley are members of the science team. Ashwin Vasavada, project scientist for the Mars Science Laboratory since 2015, earned his PhD at Caltech in 1998.

LOOKING AHEAD TO MARS 2020

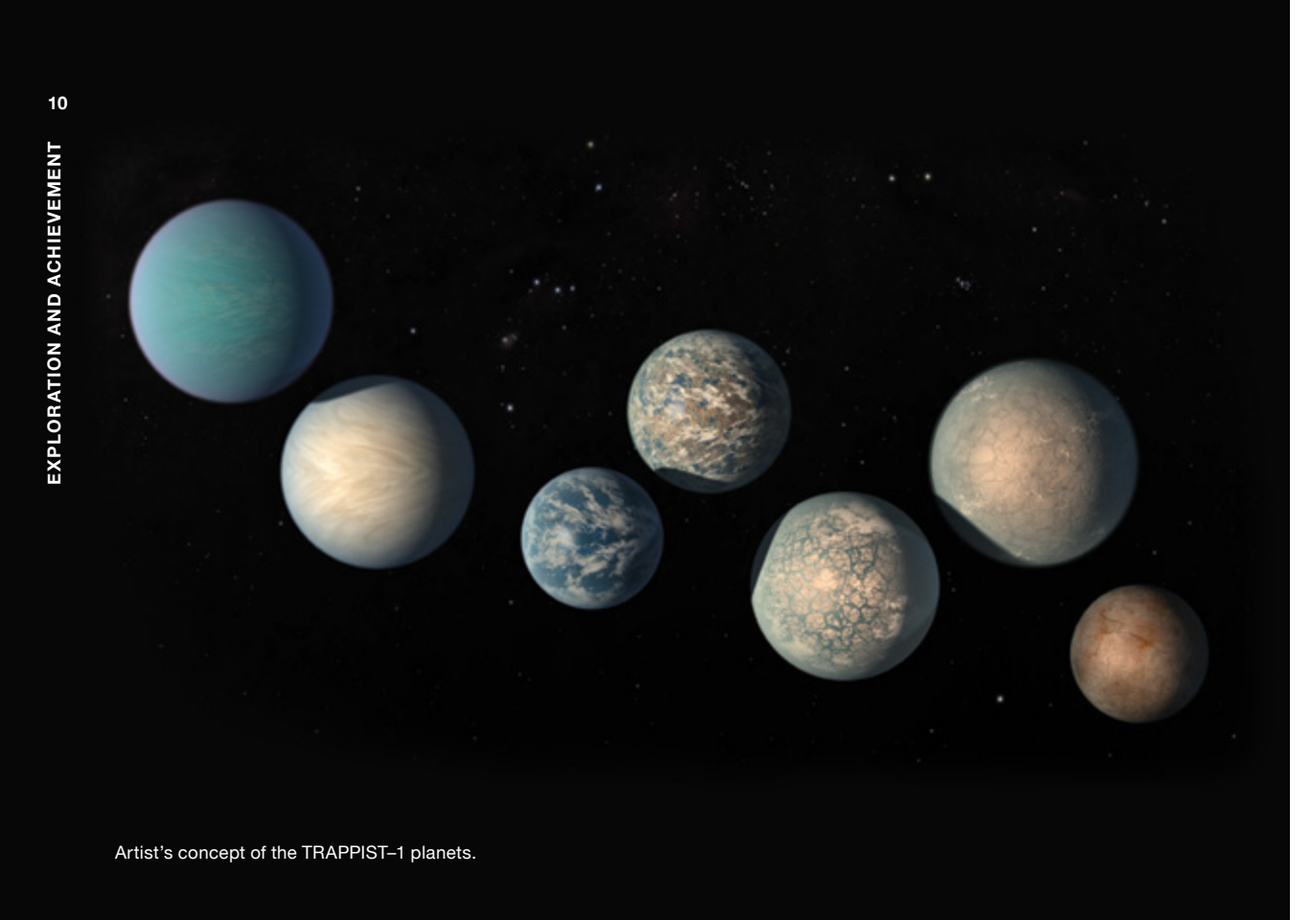
Ken Farley, Caltech's W. M. Keck Foundation Professor of Geochemistry and former chair of the Division of Geological and Planetary Sciences (GPS), is project scientist for the Mars 2020 mission, which is scheduled to send a new rover to the Red Planet in 2020. In a bold step forward in Mars exploration, Curiosity's successor will collect and store samples that might one day be returned to Earth. Meanwhile, the Bruce Murray Laboratory for Planetary Visualization, a state-of-the-art image processing and data visualization lab within GPS, has helped determine the best landing site for the upcoming mission.

PROBING THE

Cosmos

With advanced telescopes that open unprecedented windows onto the cosmos, JPL and campus researchers explore the origins of the universe and investigate planets far beyond our galaxy, including some that may be hospitable to life.

The W. M. Keck Observatory in Maunakea, Hawaii.



Artist's concept of the TRAPPIST–1 planets.

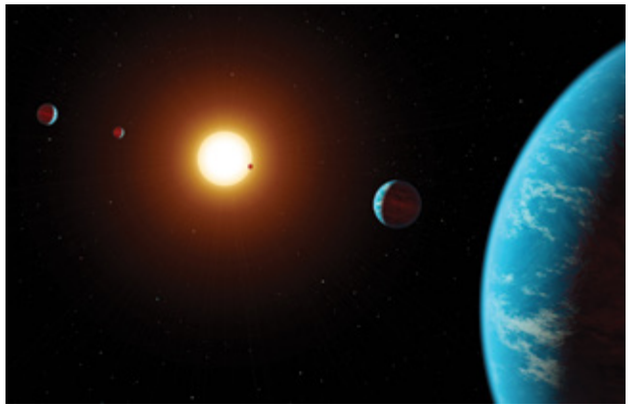
Launch of the Spitzer Space Telescope.

Spitzer Space Telescope

The Spitzer Space Telescope detects infrared energy emitted by distant stars and galaxies that otherwise would be invisible to researchers. The campus-based IPAC data processing and analysis center manages science operations for the JPL-led mission, whose compelling discoveries include TRAPPIST-1, a system of seven Earth-sized planets around a single star. Three of those planets are located in the habitable zone, the region around a star where liquid water—and thus life—could exist.

Kepler Space Telescope

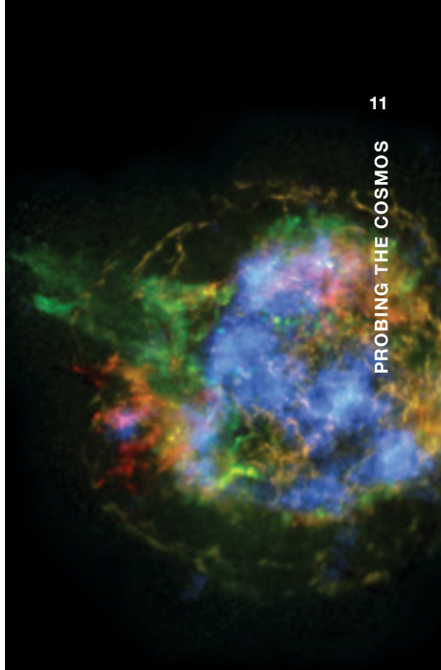
In its search for exoplanets—planets outside our solar system—NASA's Kepler Space Telescope detects the subtle dimming of a star that occurs when a planet crosses in front of it. To date, Kepler's primary and extended missions have detected more than 2,500 exoplanets and more than 2,800 additional exoplanet candidates. More than two dozen of those confirmed planets are roughly Earth-sized and potentially habitable. Mission development for the Kepler Space Telescope was managed at JPL, while the NASA Exoplanet Science Institute (part of IPAC, on the Caltech campus) cataloged planets discovered by the telescope.



K2-138, illustrated in this artist's concept, is the first multi-planet system discovered by citizen scientists.

Tools for Detecting Life

While astronomers have discovered dozens of potentially habitable planets in recent years, it remains a challenge to determine whether those planets in fact host life. Caltech's Dimitri Mawet, also a senior research scientist at the Lab, works with colleagues in the Exoplanet Technology Laboratory to develop a strategy for scanning exoplanets for signs of life such as oxygen molecules and methane.



MARSHALING TALENT

Since its beginnings in the 1930s, JPL has drawn on the intellectual strength and depth of Caltech's faculty. For example, as principal investigator for the Nuclear Spectroscopic Telescope Array (NuSTAR), Fiona Harrison—Caltech's Benjamin M. Rosen Professor of Physics and the Kent and Joyce Kresa Leadership Chair of the Division of Physics, Mathematics and Astronomy—worked with the Lab to conceive, develop, construct, and launch the mission. One of the most powerful high-energy X-ray telescopes ever built, NuSTAR provides an extraordinary new perspective on black holes, neutron stars, and the remnants of supernovas.

UNDERSTANDING

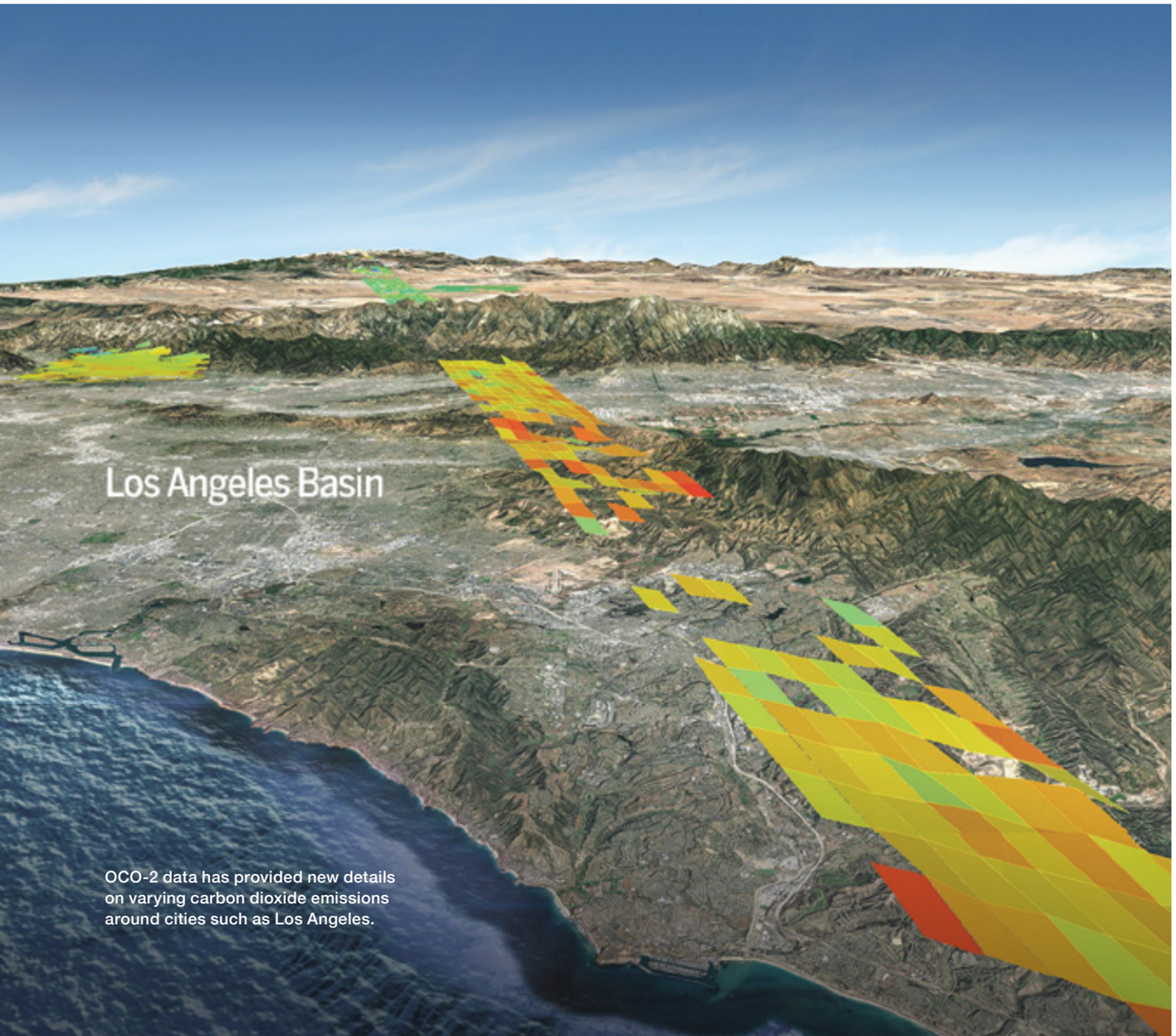
Our Planet

Caltech's strength in Earth and atmospheric science allows campus and Lab researchers to tackle some of humanity's most urgent challenges, from climate change to natural disasters such as earthquakes and volcanoes.

An image of the sun setting over the Gulf of Mexico captured from the International Space Station.

Orbiting Carbon Observatory-2

Data from the Orbiting Carbon Observatory-2 (OCO-2) mission help scientists precisely measure the amount of carbon dioxide in Earth's atmosphere and better understand its sources and effects. The JPL-built satellite has also enabled researchers—including Caltech environmental scientist and engineer Christian Frankenberg, who is also a research scientist at the Lab—to analyze plant productivity, which could one day help determine the best regional farming practices and identify early signs of drought.



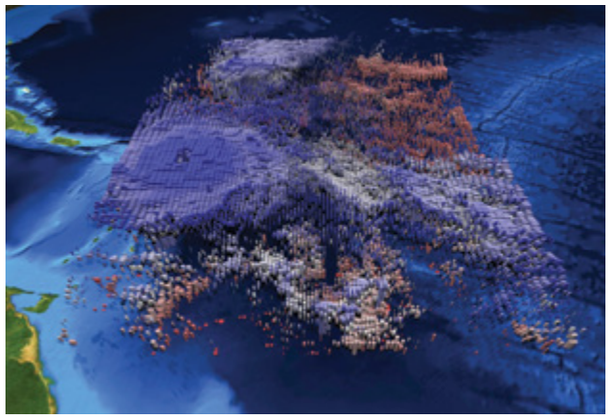
OCO-2 data has provided new details on varying carbon dioxide emissions around cities such as Los Angeles.

Advanced Rapid Imaging and Analysis

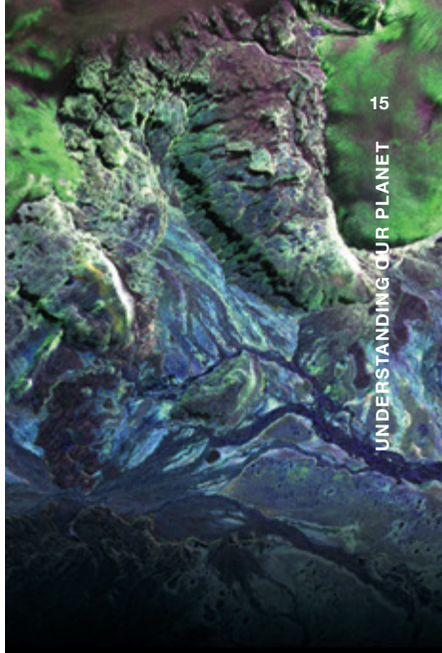
Using a combination of satellite data and seismic observations from instruments around the world, the Advanced Rapid Imaging and Analysis (ARIA) collaboration between campus and Lab has delivered precise measurements of ground movement and block-by-block maps of damage in the wake of recent natural disasters. Following earthquakes in Nepal and Mexico City and Hurricane Maria in Puerto Rico, for instance, ARIA scientists provided first responders and government officials with information that helped guide recovery efforts.

Atmospheric Infrared Sounder

Launched into orbit in 2002 aboard NASA's Aqua satellite, the Atmospheric Infrared Sounder (AIRS) was designed to support climate research and improve weather forecasting. The instrument uses infrared technology to create 3-D images of air and surface temperatures, water vapor, and cloud properties. AIRS can also measure trace greenhouse gases, and researchers, including Caltech planetary scientist Yuk L. Yung, who is also a senior research scientist at the Lab, have used it to study atmospheric carbon dioxide.



An image of Hurricane Irma's clouds created with data from AIRS.



GLACIER DYNAMICS

Using a JPL-designed radar instrument mounted to the underbelly of a Gulfstream III jet, Mark Simons, Caltech's John W. and Herberta M. Miles Professor of Geophysics and chief scientist at JPL, has measured and imaged Iceland's glaciers, in part to study how glaciers react to climate change. Researchers have used the same technique to measure motion above restless volcanoes.

NAVIGATING

Autonomous Systems

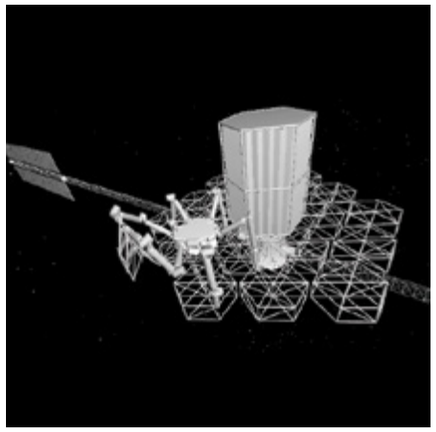
Compelling developments in autonomous technologies, from next-generation drones to walking robots to self-driving vehicles, build on the engineering prowess of campus and Lab and could, in turn, transform the future of space exploration.

Inside the Center for Autonomous Systems and Technologies (CAST), which opened in October 2017.

JPL engineers lower a submersible into Alaska's Matanuska Glacier.

A Robot-Assembled Space Telescope

Space telescopes provide some of the clearest images of the universe—the larger the telescope, the sharper the image. Yet space telescopes are typically limited in size due to the difficulty and expense of launching them. Now, Sergio Pellegrino, a Caltech aerospace and civil engineering professor and senior research scientist at the Lab, and Joel Burdick, a Caltech mechanical engineering and bioengineering professor who is also a Lab research scientist, have developed a strategy to circumvent the challenge: they have proposed a large telescope that would be sent to space in pieces and there assembled by robots.



Robotic Submersibles

Researchers from campus, Lab, and other institutions are developing artificial intelligence for robotic submersibles that can study marine environments in ways satellites cannot. The artificial intelligence that enables a submersible to plunge beneath the ocean surface, plot its own course, and make its own decisions could someday be used to explore the ice-covered oceans of Jupiter's moon Europa.

CAST

At the Center for Autonomous Systems and Technologies (CAST), researchers from JPL and the divisions of Engineering and Applied Science and Geological and Planetary Sciences collaborate to build the hardware and artificial intelligence that will drive autonomous systems for exploration, medicine, and everyday life. Among the goals ("moonshots") of CAST scientists and engineers, including director Mory Gharib, Caltech's Hans W. Liepmann Professor of Aeronautics and Bioinspired Engineering, is to develop an autonomous flying ambulance that could rise above urban gridlock and deliver a patient to safety.

FUELING

Innovation

Every year, campus and Lab innovations are transformed into commercially available technologies that amplify the impact of space and planetary research and strengthen the nation’s competitive advantage.

Technology developed at JPL helped put cameras in cell phones.

FINDER

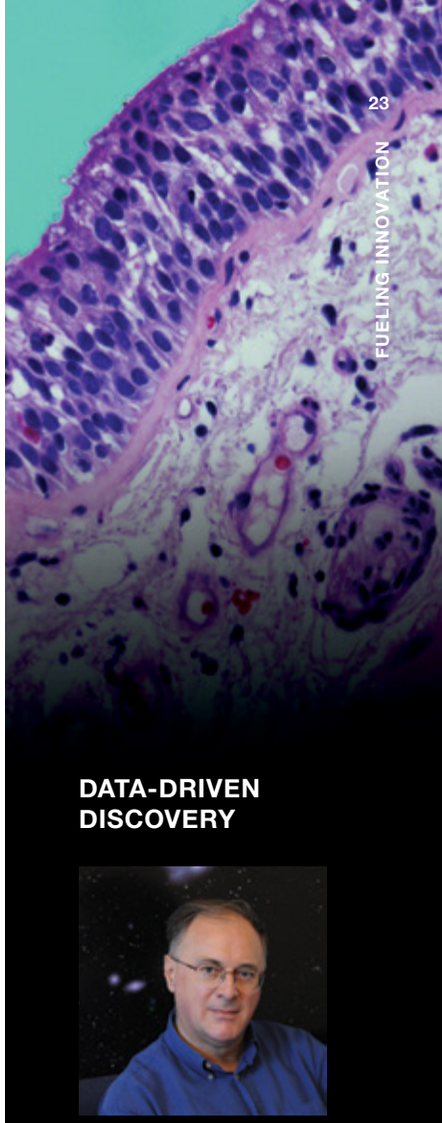
FINDER (Finding Individuals for Disaster and Emergency Response) is a suitcase-sized device that uses a low-powered microwave signal to detect movement as subtle as a human pulse beneath rubble. The technology evolved from the Lab's efforts to develop small, low-cost instruments that measure minor changes in spacecraft motion. After a magnitude 7.8 earthquake struck Nepal in April 2015, rescue workers used FINDER to locate victims trapped under collapsed buildings. The technology has been licensed to two private companies and deployed in the aftermath of subsequent disasters including the Mexico City earthquake in September 2017.

Cameras for Space and Cell Phones

Asked to miniaturize cameras for future spacecraft, a team at the Lab led by physicist Eric Fossum invented a new kind of image sensor that functions as a camera on a chip. That technology, the Complementary Metal Oxide Semiconductor (CMOS), also made it possible to put cameras in cell phones. On campus, scientists are pursuing innovations in CMOS technology in fields from astronomy to medical engineering.

A Wireless Reflector Chip

If the power needed to send and receive data from a wearable device (such as a personal fitness tracker) to a computer, cellular, or Wi-Fi network were reduced, users could recharge those devices less often. This challenge led researchers, including the Lab's Adrian Tang, to develop microchips for wearable devices that reflect wireless signals instead of relying on transmitters and receivers to relay information. The technology transmits data using 1,000 times less power than a regular Wi-Fi link and could one day be used to transmit images from robotic spacecraft.



DATA-DRIVEN DISCOVERY

Astronomer George Djorgovski directs the Center for Data-Driven Discovery, which applies the data-processing and analysis techniques pioneered by campus and Lab scientists to new disciplines. For example, the National Cancer Institute has used data science that originated with space exploration to create the Early Detection Research Network, a consortium of biomedical investigators whose findings on cancer biomarkers are collected in a single searchable network.

INSPIRING

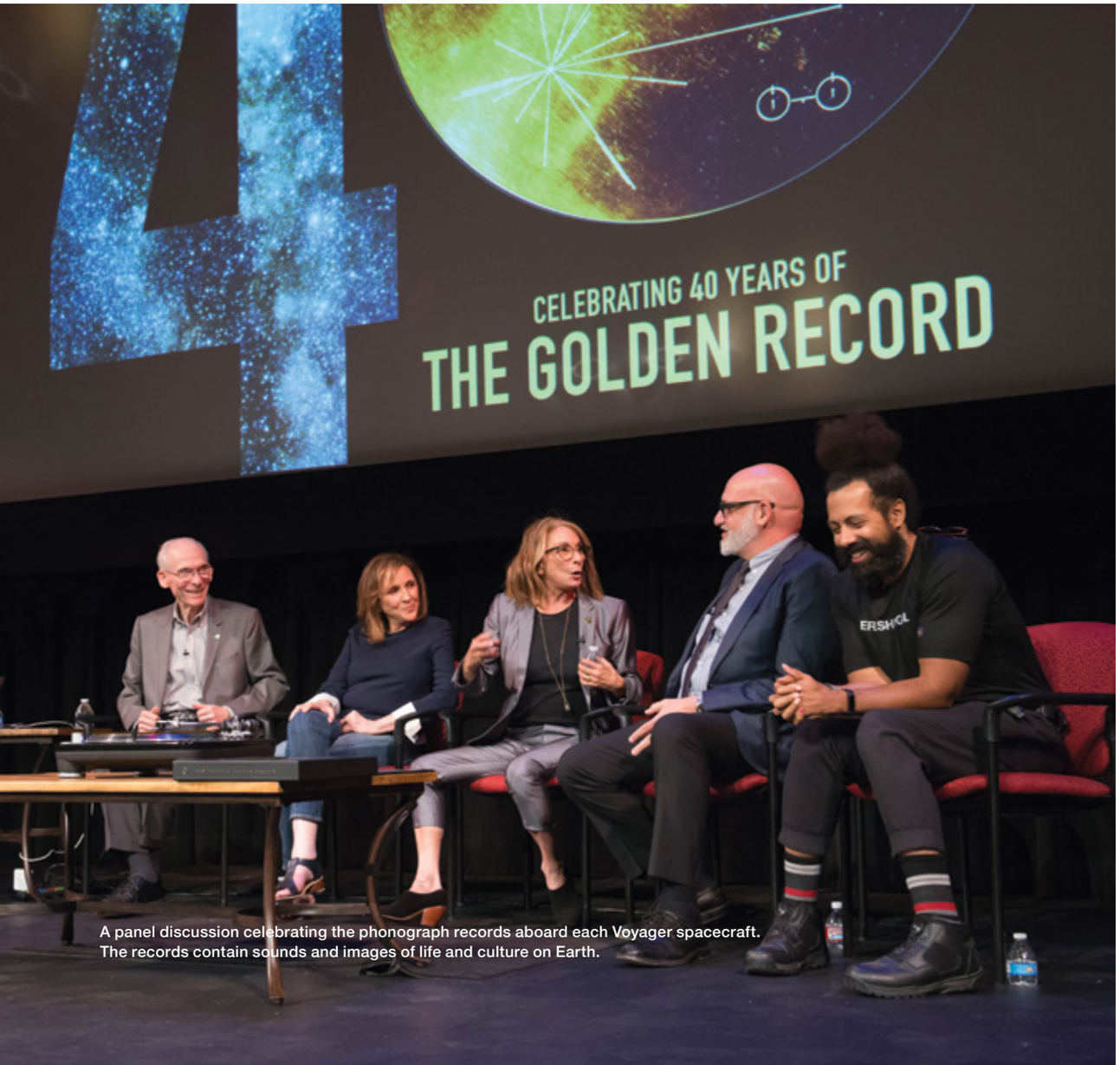
Scientific Curiosity

Public outreach and education initiatives, along with unparalleled opportunities for undergraduate and graduate student research on campus and at the Lab, contribute significantly to a robust space-science pipeline.

Employees and visitors at JPL observe the 2017 solar eclipse.

Public Events and Science Education

Through public events such as A Ticket to Explore JPL, weekday tours, and the Theodore von Kármán Lecture Series, members of the public can explore interactive demonstrations and engage with campus and Lab researchers.



A panel discussion celebrating the phonograph records aboard each Voyager spacecraft. The records contain sounds and images of life and culture on Earth.

Caltech Space Challenge

As part of the biennial Caltech Space Challenge, teams of students from around the world develop strategies to address challenges in space exploration. During the weeklong competition, campus and Lab engineers and industry experts mentor participants.

Summer Research

Summer programs offer graduate and undergraduate students opportunities to engage in space and planetary science research alongside campus and Lab investigators.

Undergraduate researchers work in the Mars Yard at JPL.

KECK INSTITUTE FOR SPACE STUDIES

Established in 2008 with a grant from the W. M. Keck Foundation, the Keck Institute for Space Studies (KISS) brings together expertise from campus, Lab, and the wider scientific and technical community to inspire, develop, and begin to implement ideas with the potential to revolutionize space science. KISS—led by Tom Prince, Caltech's Ira S. Bowen Professor of Physics and senior research scientist at JPL—also invites graduate students and postdoctoral fellows to engage in space mission research and contributes to public outreach through open lectures.

A History of Collaboration

1936

A small group of graduate students and assistants of physicist and aerospace engineer Theodore von Kármán start testing handmade rocket engines in Pasadena's Arroyo Seco. Their first rocket launch takes place there on October 31, 1936.

Early history in the Arroyo Seco

1943

The Caltech team refers to its organization for the first time as "the Jet Propulsion Laboratory."

The future site of JPL

1957

Soon after the Soviet Union launches Sputnik on October 4, 1957, the U.S. Army commissions JPL to develop America's response: Explorer 1.

Explorer 1

1958

Explorer 1, America's first satellite—built by JPL—is launched on January 31, 1958. This pivotal space flight leads to the creation of NASA.

The launch of Explorer 1

1964

Mariner 4 launches. The Mariner missions mark the beginning of planetary geology, led by researchers at Caltech including Bruce Murray and Robert Sharp.

Launch of Mariner 4

1977

Voyager 2 (August 20) and Voyager 1 (September 5) are launched. The Voyager spacecraft go on to visit more planets than any other single mission. Caltech's Ed Stone has served as project scientist for the Voyager program from 1972 to the present.

Voyager 1

1985

The IPAC data processing and analysis center is established on the Caltech campus.

Infrared image of the star-forming region NGC 2174

1989

NASA's space shuttle launches the first of three JPL-managed solar system exploration missions: the Magellan mission to Venus; the Galileo mission to Jupiter; and the Ulysses mission to study the sun's poles.

Magellan at Kennedy Space Center

1997

Mars Pathfinder lands on the Red Planet on July 4. Pathfinder marks the start of 20-plus years of ongoing Mars exploration, continuing today with Curiosity.

Artist's concept of Pathfinder

2004

Cassini arrives at Saturn and begins an intensive study of its rings, moons, and magnetosphere.

Saturn

2008

KISS (the Keck Institute for Space Studies) is established on the Caltech campus.

KISS facilities

2012

NuSTAR, a powerful high-energy X-ray telescope, is launched into orbit. Caltech physicist Fiona Harrison serves as its principal investigator.

Was 49a galaxy merging with Was 49b galaxy

2016

The Juno spacecraft arrives at Jupiter.

Jupiter

2017

The Center for Autonomous Systems and Technologies (CAST) opens on campus.

CAST facilities

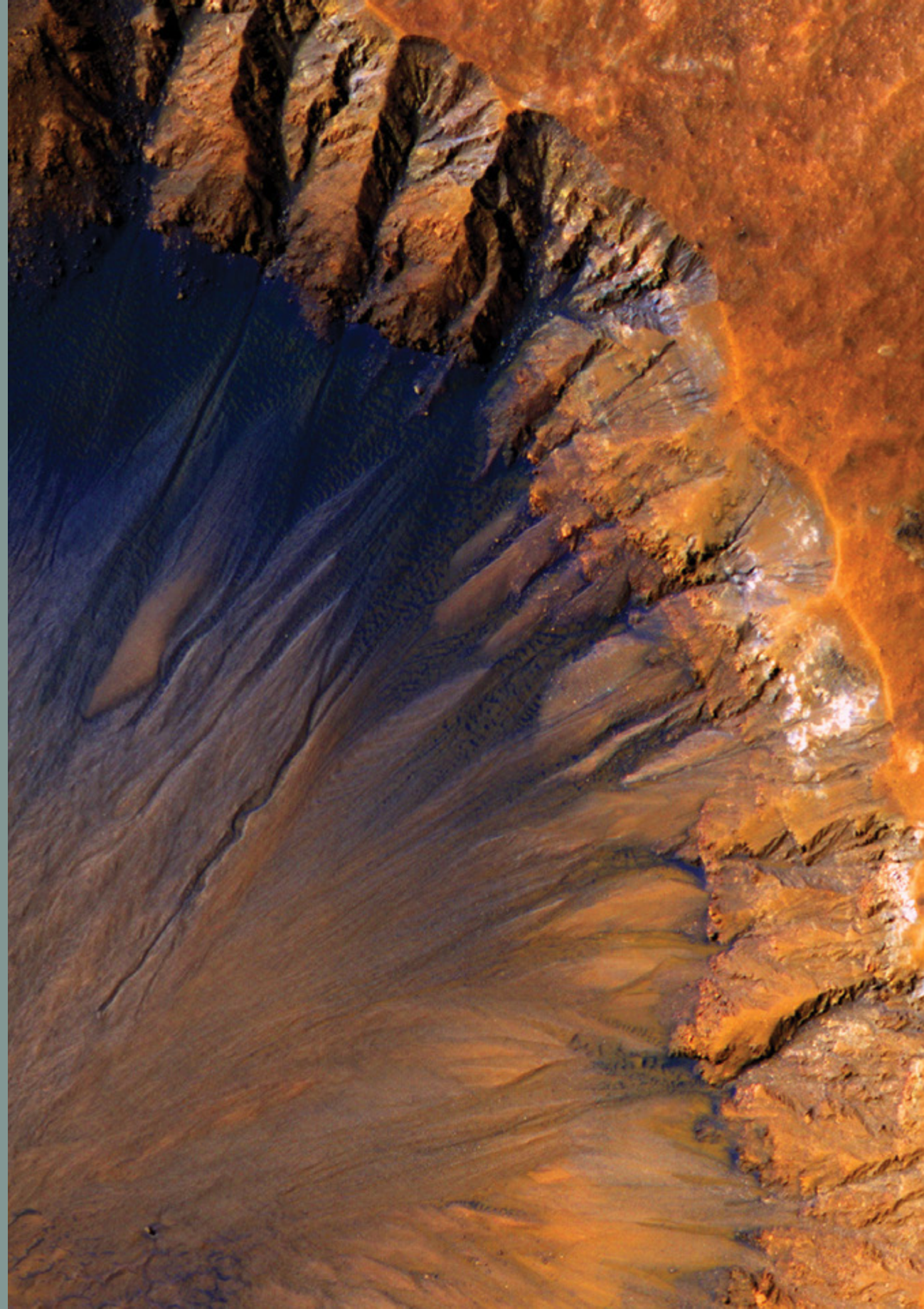
Cassini completes its tour of Saturn with a dive into the giant planet's atmosphere.

2020

The Mars 2020 mission is scheduled to send a new rover to the Red Planet in 2020.

Artist's concept of the Mars 2020 rover

All images provided by NASA/JPL-Caltech



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