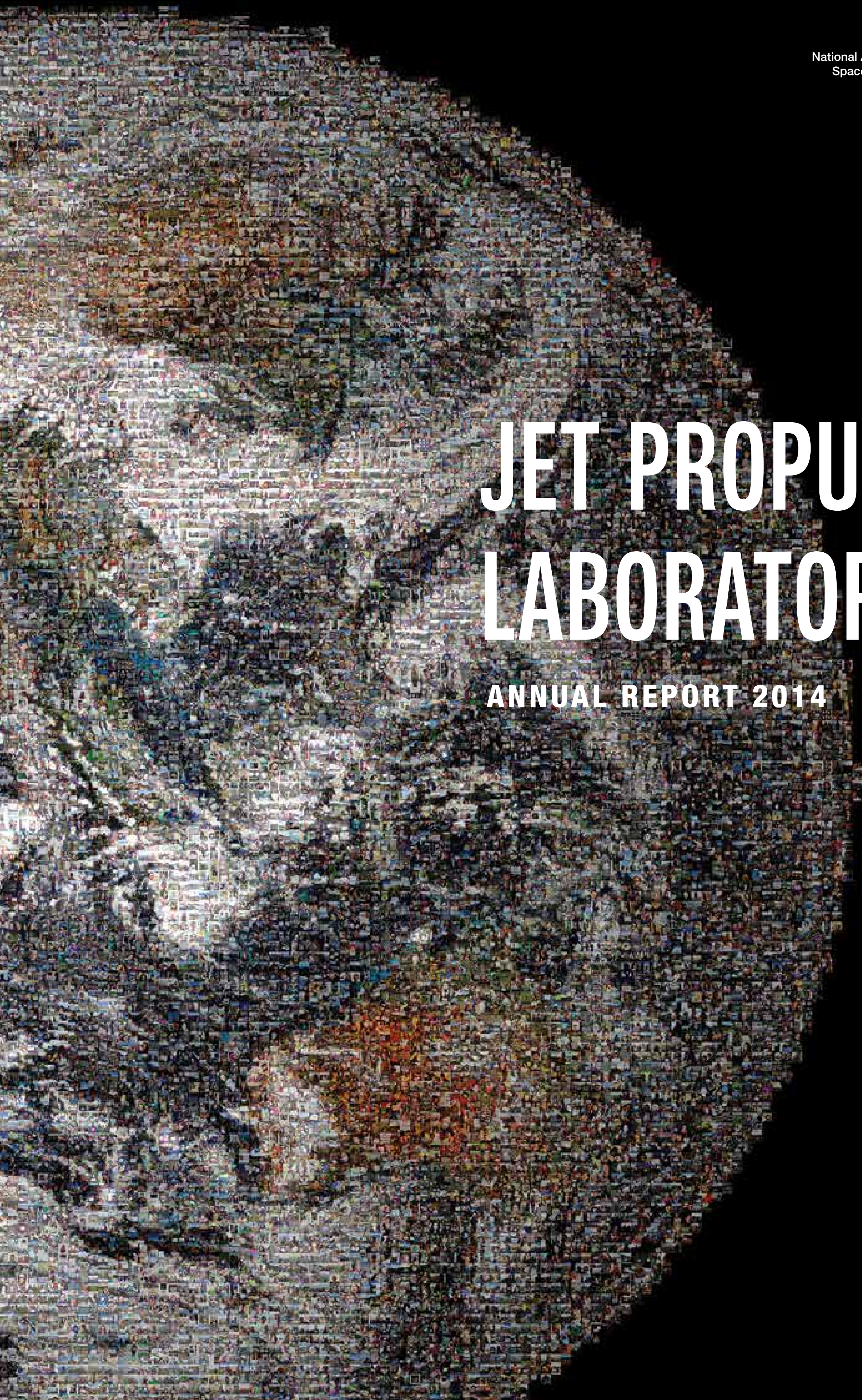
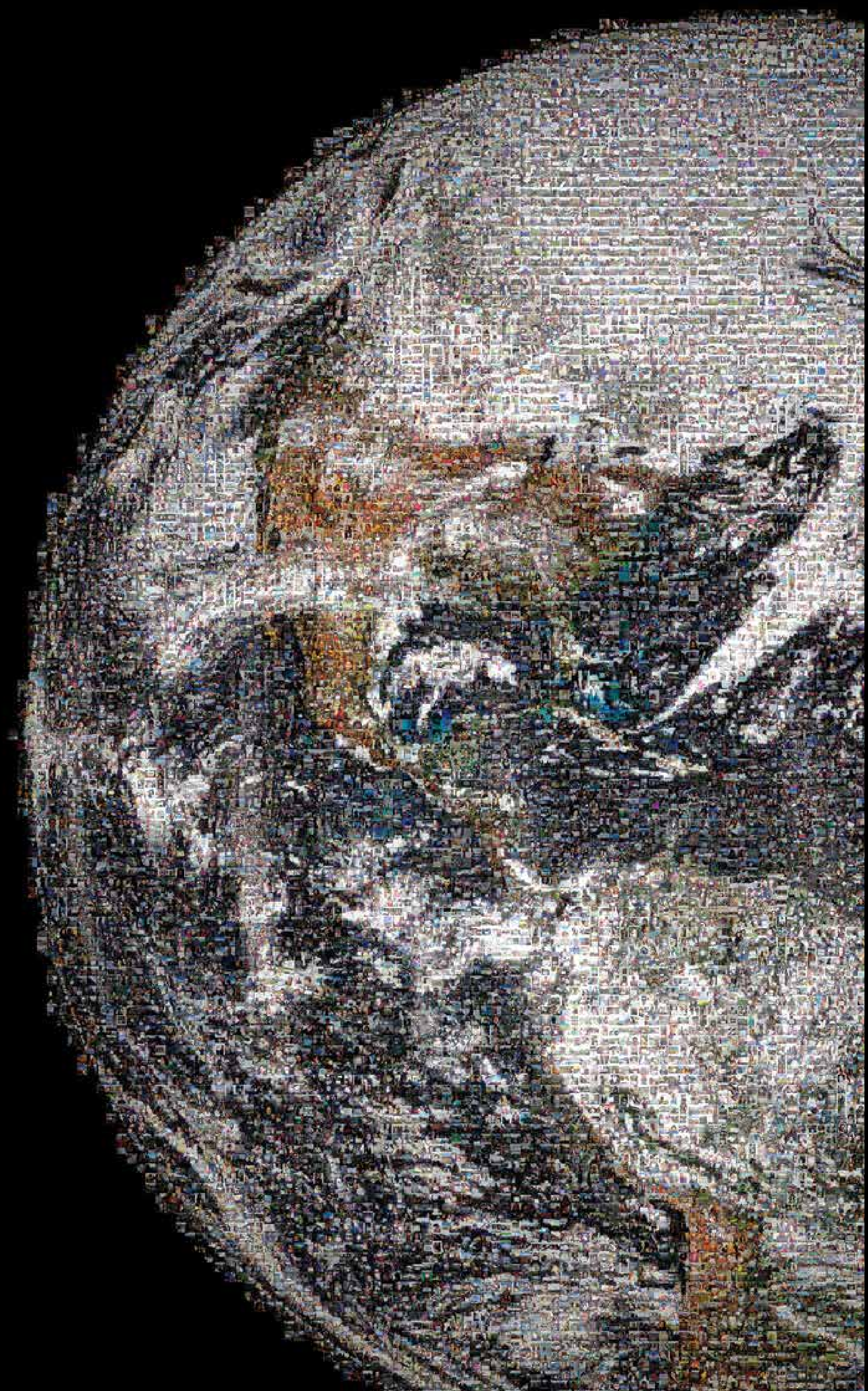


National Aeronautics and
Space Administration

# JET PROPULSION LABORATORY

## ANNUAL REPORT 2014





# CONTENTS

◁ *Cover and left: The "Global Selfie" created from nearly 40,000 photos sent to NASA and JPL by members of the public to mark Earth Day.*

CHARLES ELACHI

# DIRECTOR’S MESSAGE

**One of the things that makes working at JPL so exciting is to see the peaks from year to year in our various programs. One year, a Mars landing takes center stage. Another year, the launch of a space telescope attracts the headlines. 2014 was definitely a year in which Earth science was big news.**

We sent into space Orbiting Carbon Observatory 2, a satellite that is measuring the greenhouse gas carbon dioxide. That was soon followed by RapidScat, an instrument that is tracking ocean winds from the vantage point of the International Space Station. And there’s more still to come. In early 2015 we will launch Soil Moisture Active Passive, or SMAP, a satellite that will study Earth’s water in one of its most important, but least recognized forms — soil moisture. It will be joined in space by Jason 3, the latest in a long series of satellites monitoring sea level heights.

Of course there was plenty of exciting news with other JPL projects. In technology development, a flying saucer–like test vehicle conducted a dramatic test in the skies over Hawaii. On Mars, the Curiosity rover arrived at the base of Mount Sharp, the final destination for the mission. A JPL instrument aboard Europe’s Rosetta spacecraft helped shape its arrival at a comet and release of its lander to descend to the nucleus. The Spitzer Space Telescope continued to deliver high-quality science a decade after its launch. Our recent hires developed and flew a laser telecommunications payload on the International Space Station leading to a breakthrough in high-speed video transmission from space to Earth. And JPL applied its capabilities and talents to issues of national importance beyond NASA.

As you will see, 2014 was another productive year of close collaboration with our parent organization, Caltech. I’m fond of saying that we are privileged to be part of two of the great organizations in the world — NASA and Caltech — and a variety of initiatives demonstrate how we benefit from this identity.

Most of all, I’m extremely proud of the imagination and talent of all of the 5,000 engineers, scientists and support personnel who are the great secret of all of JPL’s successes. Inside this report you’ll find profiles of just a few of them, but they represent the imagination and dedication to be found all across the lab.


**Earth's environment continues to change under the pressure of natural and human sources, and NASA is marshaling significant resources to better understand our home planet. In 2014, NASA began a period of launching more Earth missions than it had in more than a decade, and much of the effort is coming from JPL.**

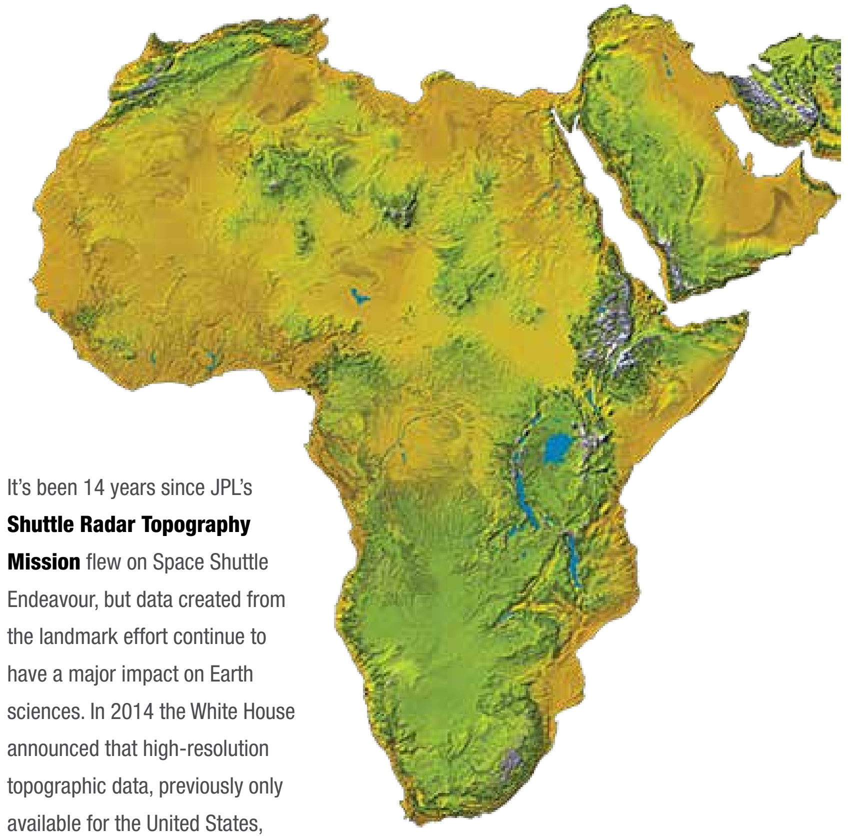
The laboratory's first Earth mission of the year, Orbiting Carbon Observatory 2, was sent into orbit in July from California's Vandenberg Air Force Base. The satellite is making global measures of carbon dioxide, the greenhouse gas that is the largest human-generated contributor to global warming.

Climate research, weather and marine forecasting are benefiting from the ocean wind observations of RapidScat, an instrument sent on a supply rocket to the International Space Station in September. Built and launched at the fraction of the cost of a free-flying satellite, RapidScat will also aid the tracking of storms and hurricanes.

Two more JPL Earth missions were readied for launches in early 2015. The Soil Moisture Active Passive, or SMAP, satellite will help improve flood predictions and drought monitoring. Jason 3 is the latest in a long-running collaboration between JPL and France's space agency, and will monitor sea surface heights following its launch on a NASA rocket.

◁ *JPL's Orbiting Carbon Observatory 2 awaiting launch at Vandenberg Air Force Base.*

# TO BETTER UNDERSTAND OUR HOME PLANET



It's been 14 years since JPL's **Shuttle Radar Topography Mission** flew on Space Shuttle Endeavour, but data created from the landmark effort continue to have a major impact on Earth sciences. In 2014 the White House announced that high-resolution topographic data, previously only available for the United States, will be released globally over the next year.

△ *A relief image of Africa created from Shuttle Radar Topography Mission data.*

Cities and their power plants are the largest human contributors to climate change, and JPL is partnering in a new initiative to understand how that is taking place. The **Megacities Carbon Project** is an international, multi-agency effort to develop and test ways to monitor greenhouse gas emissions in megacities — metropolitan areas of at least 10 million people. JPL is in charge of the project's segment studying the Los Angeles Basin, which will monitor greenhouse gas releases with instruments at 15 stations around the region.

*Major cities targeted for greenhouse gas reduction by the Megacities Carbon Project.* ▷

Other JPL scientists found that while sea level edges upward, the cold waters of Earth's deep ocean have not warmed overall across the past decade. Scientists became interested in **the deep ocean** because they thought it might contain "missing heat" to explain lapses in how air, surface and ocean temperatures sync up as climate change occurs. The new finding, however, rules out the deep ocean as a hiding place for heat they are trying to account for. Meanwhile, warming in the top half of the ocean has continued unabated.

In California, JPL is partnering with the state to bring new technologies to bear on its demanding **water management** needs. The lab's researchers are working with state offices to quantify winter snowpack and groundwater resources, improve forecasts of extreme precipitation events, and monitor impacts from groundwater extraction.





In perhaps the most significant climate news of the year, JPL scientists announced that the rapid melting of much of the **West Antarctic Ice Sheet** appears to be unstoppable. Linking observations from radar satellites and other sources, they conclude that the glaciers there have passed a point of no return. The likely cause is higher ocean temperatures where the ice sheets meet the sea. They contain enough ice to raise global sea level by 1.2 meters (4 feet).

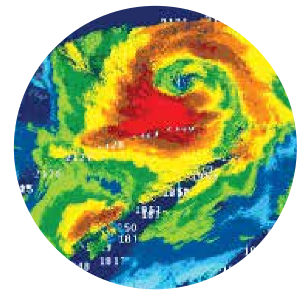
△ *Antarctica's Thwaites Glacier.*

Scientists also reported that canyons underneath the glaciers of Greenland are deeper and more expansive than previously thought. That means they contain more ice that can feed future sea level rise as the glaciers melt.

A tiny region at the Four Corners intersection of Arizona, Colorado, New Mexico and Utah is putting out a huge amount of the **greenhouse gas methane**, scientists found. While hydraulic fracturing, or fracking, is practiced in the area, the methane emissions started years earlier — meaning they are likely due to leaks from natural gas harvesting in New Mexico's San Juan Basin, the most active coal-bed methane production area in the United States.



# DRAGANA PERKOVIC-MARTIN



One of the harsh realities that Dragana Perkovic-Martin faced as she made her way toward her eventual career as a radar engineer was what is evidently a uniquely American institution: college homework.

“Where I grew up, there is homework in high school but not at university — so there are exams, but no homework or tests,” says Dragana, who was born in Serbia and went to college in Malta. “When I came to the States for graduate school, that was one of the biggest cultural shocks.”

She not only survived, but thrived in a stimulating remote-sensing program at the University of Massachusetts at Amherst. Those who complete the program typically end up in academia or industry. “I didn’t want to go into academia, and as a foreign national I couldn’t do defense work in industry, so here I am happily at JPL.”

Two years ago, Dragana joined the RapidScat team as an instrument system engineer; the recent mother considers the project as one of her two babies. “To do system engineering you have to know at least a little about a lot of very different things,” says Dragana, who is now also working on the descent radar for the Mars 2020 rover. “My graduate school gave me good training for that. We built radars, put them together, took them out to the field, processed data. JPL to me feels just like that graduate school experience — just on a very large scale.”

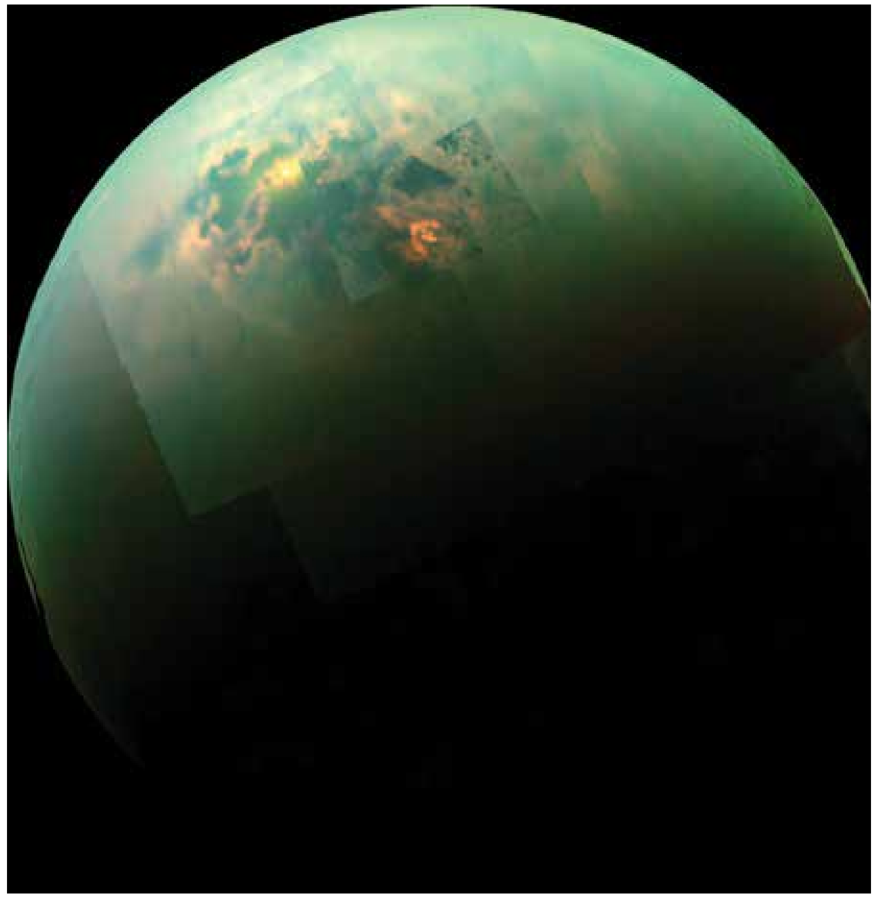
**Beautiful at a distance yet unprepossessing in size, comets are risky to visit — the particles they throw off could mean sudden death for a spacecraft.** That makes Europe's Rosetta mission all the more ambitious — and challenging. Launched in 2004, Rosetta spent a decade in transit before rendezvousing beyond the asteroid belt with Comet 67P/Churyumov–Gerasimenko, a peanut-shaped icy body named for a pair of Ukrainian astronomers who found it while inspecting photographic film in the late 1960s. As the spacecraft closed in on the comet in spring 2014, scientists activated the Microwave Instrument for the Rosetta Orbiter, or MIRO, an instrument contributed by JPL. Designed to measure volatile gases like water, ammonia and carbon monoxide around the comet, and to measure the subsurface temperatures of its nucleus, MIRO provided data that helped pick the target spot for Rosetta's lander, Philae, which settled down on the comet's nucleus in November 2014. Rosetta thus became the first mission ever to land successfully on a comet. If all goes well, MIRO will continue monitoring the comet as it heats up and goes into a more frenetic state as it approaches the sun in 2015.

*Rosetta's Philae lander captured this view of the orbiter spacecraft with Comet 67P/Churyumov–Gerasimenko in the background before it descended to the comet's surface. ▷*



SOLAR SYSTEM

# ACROSS THE PLANETS



It's easy to lose count of how many flybys the **Cassini spacecraft** has made of Saturn's moons during its decade orbiting the stately planet, but scientists are always surprised by what's new. In 2014 that meant gravity data showing Saturn's geyser-spouting moon Enceladus harbors a large underground ocean of liquid water, making it a potential home to extraterrestrial microbes. Images from Cassini's cameras, meanwhile, revealed the birth of what looks like a new moonlet formed from the stuff of the planet's rings.

◁ *Sun glints off the north polar seas of Saturn's moon Titan in this mosaic image from the Cassini spacecraft.*

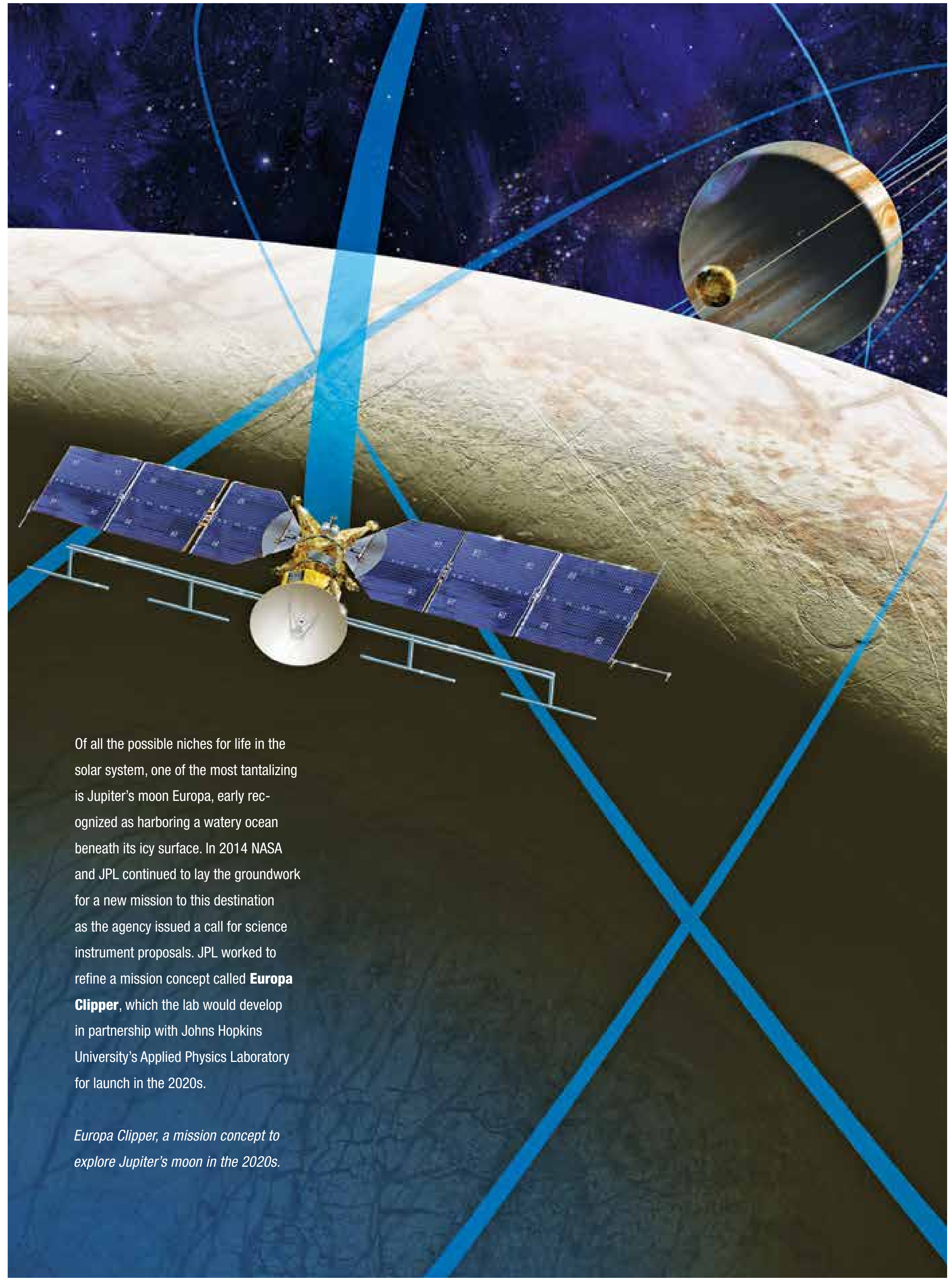
# BEAUTIFUL AT A DISTANCE

Are we there yet? Not just yet. The **Dawn spacecraft,** which orbited the protoplanet Vesta for more than a year, spent 2014 firing its ion engines to send it farther into the asteroid belt toward the dwarf planet Ceres. By year's end it was within 350,000 miles of its target, less than one and a half times the distance between Earth and its moon; Dawn is expected to reach Ceres by March 2015. The Jupiter-bound **Juno** spacecraft, meanwhile, was still on the long leg of its voyage. In 2014 it made it past the asteroid belt, and by year's end had about 18 months remaining to reach the solar system's largest planet.

So many rocks and so little time. In five years NASA plans to launch a mission to snag a small asteroid and pull it into orbit around Earth's moon where it can be visited by astronauts. One key step is to pick out just what space rock that would be. **NASA's Near-Earth Object** office at JPL has been busy sifting through possibilities. One candidate: A school bus–sized rock called 2011 MD discovered three years ago by robotic telescopes in New Mexico.







Of all the possible niches for life in the solar system, one of the most tantalizing is Jupiter's moon Europa, early recognized as harboring a watery ocean beneath its icy surface. In 2014 NASA and JPL continued to lay the groundwork for a new mission to this destination as the agency issued a call for science instrument proposals. JPL worked to refine a mission concept called **Europa Clipper**, which the lab would develop in partnership with Johns Hopkins University's Applied Physics Laboratory for launch in the 2020s.

*Europa Clipper, a mission concept to explore Jupiter's moon in the 2020s.*

# BRENT BUFFINGTON

Sports and math may seem like an odd couple as talents go, but they were what Brent Buffington was especially good at growing up. Despite a dream of a career in the major leagues, he eventually opted for the latter — and baseball's loss was space exploration's gain.

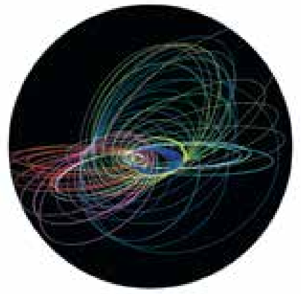
After majoring in physics (math minor) and picking up a master's in aerospace engineering, Brent was hired by JPL to do trajectory design and navigation for the Cassini mission, which was then nearing arrival at the ringed planet Saturn. "My third day on the job was Saturn orbit insertion," Brent recalls with a smile. "I knew that if it didn't go well, it would definitely be career-limiting."

Happily, Cassini's arrival was a smashing success. Brent went on to tweak Cassini's prime mission, and played a major role in designing both of Cassini's extended missions. The second of those will culminate with 22 highly inclined orbits passing inside Saturn's ring system and just above its cloud tops in excess of 76,000 mph before impacting Saturn in 2017.

"Having a technical aptitude in astrodynamics is essential to what we do," says Brent, "but creativity is very important. If you give a complex trajectory design problem to 10 people, they will design 10 different trajectories."

And though a sports career may be a long-ago dream, Brent keeps in shape playing softball and is an avid skier, recently travelling to a set of remote Norwegian islands above the Arctic Circle to mountaineer and backcountry ski.

Now Brent is leading a team to concoct trajectory designs for Europa Clipper, a proposed expedition to Jupiter's moon Europa in the 2020s. "Europa resides in a very harsh radiation environment, which makes the mission particularly challenging," says Brent. "Our job is to maximize science return while mitigating risk and cost."



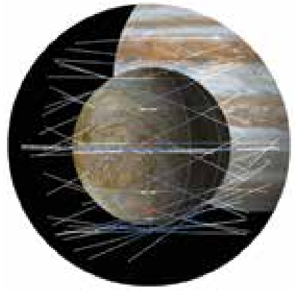


Photo by Walt Mancini/Pasadena Star-News

RESEARCH

# THE CAMPUS-LAB CONNECTION

**JPL's culture thrives not only on the accomplishments of the laboratory itself, but is enriched as well by its unique role as a NASA-funded facility staffed and managed by Caltech. This university parentage goes far beyond a formal identity — JPL strongly benefits from the intellectual infusion from a campus whose faculty and alumni have garnered 31 Nobel Prizes, 53 National Medals of Science and 12 National Medals of Technology.**

JPL staff and Caltech faculty work alongside each other in a diverse array of collaborations. Many of those are enabled by the President's and Director's Fund, established to support research that takes advantage of the lab's and institute's strengths.

Flight project leaders such as the project scientist for Mars Science Laboratory's Curiosity rover and the principal investigator for the NuSTAR space telescope are Caltech faculty. The campus serves as home for science analysis centers supporting such astronomy missions as the Spitzer and Herschel space telescopes.

Technological advancement is at the core of many campus–lab collaborations. Research includes efforts in advanced spectrometers for use on space missions; photonics to improve the measure of stars' wobble to seek new exoplanets; "Big Data" initiatives to tame the processing of huge data sets; and detectors for ground-based observatories and balloon-borne flights.

Joint appointments are blossoming, as individuals take on roles both at campus and at JPL in areas such as robotics, atmospheric chemistry and GPS technologies. The President's and Director's Fund supports many of the collaborations.

Caltech's Keck Institute for Space Science has played a distinctive role in incubating new ideas for exploration missions. The institute originated the concept for the Asteroid Retrieval Mission planned by NASA to snag a small asteroid and bring it into orbit around Earth's moon where it can be visited by astronauts.

◁ *JPL's role at Caltech is so key that the institute's new president, Thomas Rosenbaum (at right in photo, with JPL's Charles Elachi), chose the lab to start his day of inauguration activities.*

# MARTIAN CHRONICLES

**Sometimes the trip is about the journey, but sometimes it really is about the destination.** That must have been how the minders of the Curiosity rover felt when the one-ton robotic explorer rolled up to the base of Mount Sharp, the five-kilometer-high mountain at the center of Gale Crater where the robot landed in 2012. In the two years since, Curiosity sent home proof that the vast crater held a freshwater lake billions of years ago with all of the ingredients required for simple life. But Mount Sharp was always the ultimate physical destination — by ascending its slopes, layer by layer, the rover would turn the pages of the planet's geological history.

Not that getting there was without its perils. The most significant: as Curiosity rolled toward the mountain, the team discovered that unexpectedly sharp rocks were punching holes in four of its six aluminum wheels. (Why weren't the wheels more rugged? All an engineering tradeoff having to do with the perils of entry, descent and landing.) Curiosity's drivers quickly learned to adapt, picking and choosing terrains to minimize risks and driving in reverse during many stretches.

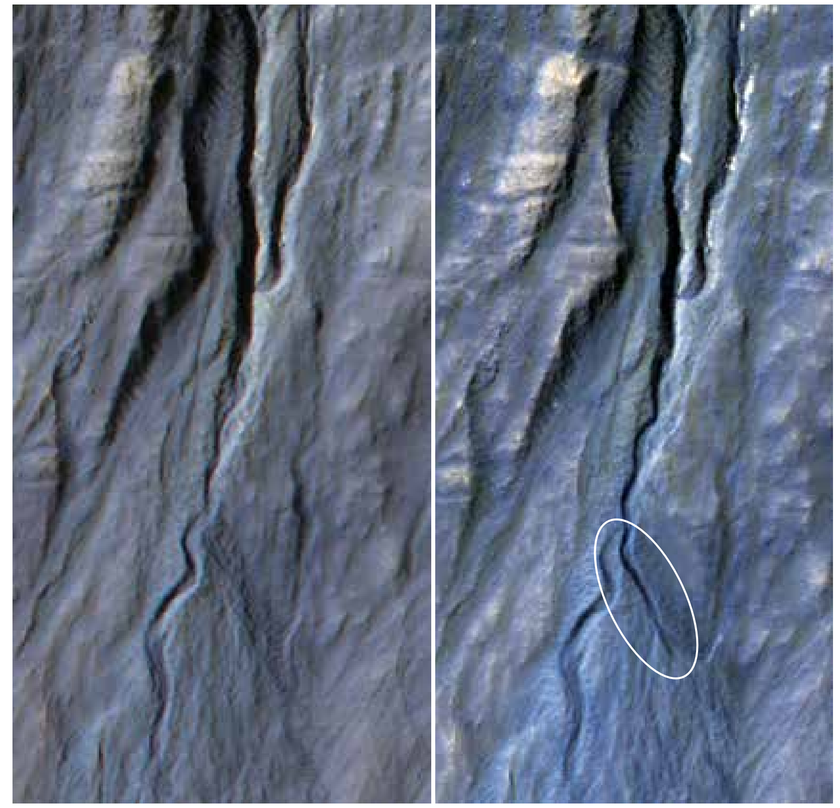
As the year ended, Curiosity's science team announced that the rover made a potentially stunning find — a surge in methane in the atmosphere that lasted at least two months. One possible explanation is that the methane was created by microbes alive on Mars today, though the methane could also be produced with no life present.

◁ *The first holes drilled by the Curiosity rover after arriving at Mount Sharp.*

As wake-up calls go, this got everyone's attention: A newly discovered comet tossed inward toward the sun from the frozen zones beyond the planets was due to pass unusually close to Mars, possibly pelting the planet with dust from the edge of the comet's tail. That in turn could put at risk the fleet of five orbiters stationed at the planet; impacts from cometary dust particles moving at hypersonic speeds could be mission-ending if any of the spacecraft were in harm's way. NASA took the cautious tack of directing its three orbiters to the far side of Mars during the time of greatest danger. All were relieved to see no harm done as the comet — called **Siding Spring** for the Australian observatory at which it was discovered — sailed past, the closest near-miss by a comet and planet in recorded history.

*Comet Siding Spring en route to its close pass by Mars.*

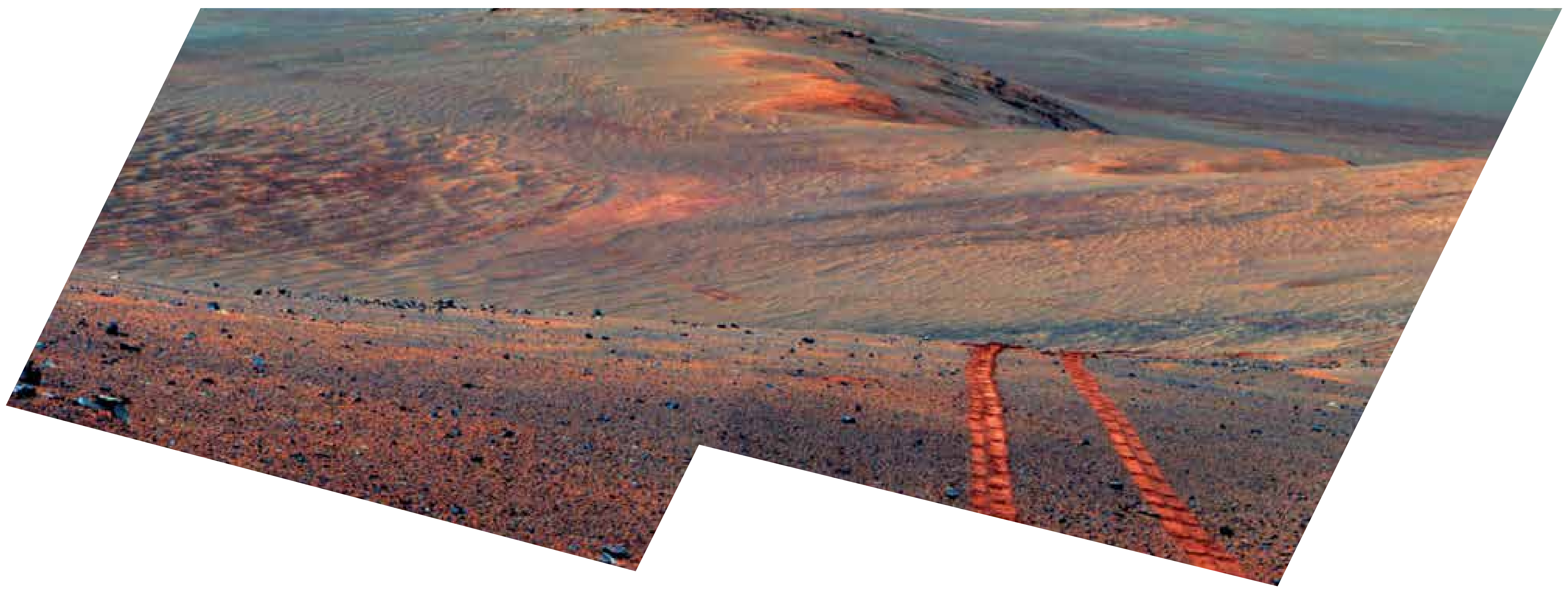
MARS EXPLORATION



Flowing water is not plentiful on today's Mars, but there's now more evidence suggesting possibly limited flows, thanks to the **Mars Reconnaissance Orbiter**. The craft detected lines appearing and darkening down the steep walls of craters that scientists think could be briny water of some kind released in warmer seasons. First spotted in mid-latitudes, the markings were later found near the equator on the walls of Mars' enormous valley, Valles Marineris. If proven, flowing water on the planet today would be a major finding.

*Before and after pictures from Mars Reconnaissance Orbiter reveal a new gully formed on a mid-latitude slope.*

# HARSH THOUGH THE ENVIRONMENT MAY BE



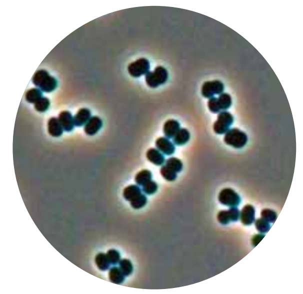
Harsh though the environment may be, a decade at Mars has been a great adventure for the Opportunity rover. In 2014 JPL celebrated the **10th anniversary of Opportunity's landing**. While Spirit went silent in 2010, Opportunity has rolled on, racking up the record for the longest-distance travel by any vehicle on another world — 40 kilometers, or 25 miles. Opportunity continued its multi-year exploration of the rim of Endeavour Crater near Mars' equator, finding multiple layers of clay minerals before heading to a new area called Marathon Valley.

If any more show up, will they have to start assigning parking spaces? Unlikely, but the orbital space above Mars has been attracting plenty of company with the arrival of two new orbiters in 2014. JPL assisted with navigation for **NASA's MAVEN**, which will focus on investigating the Red Planet's upper atmosphere. The lab also helped with navigation and communication for India's first interplanetary mission, the orbiter Mangalyaan.

*The Opportunity rover's view back toward the rim of Mars' Endeavour Crater where it has spent the year exploring.*



# ABBY ALLWOOD



The first thing Abby Allwood noticed when she started college in Australia in physics was that the Earth science classes had all the good field trips. Before long, she swapped majors: “I loved the fact,” she says, “that you could go into the outdoors and look at rocks and read something about the deep past.”

Most young geologists in Australia end up in the oil or mining businesses, but Abby had her heart set on more fundamental science. Traipsing across reefs on the continent’s western edge, she took up the study of stromatolites: structures formed in rock in shallow water that might or might not be the signature of bacteria billions of years old, depending on what scientist you talk to.

One of the world’s experts on stromatolites coincidentally had become the project scientist for JPL’s Mars Science Laboratory, and Abby ended up at JPL as a postdoc eight years ago. Soon she started developing a new instrument that would beam X-rays at rocks to read the signatures of the elements they contain.

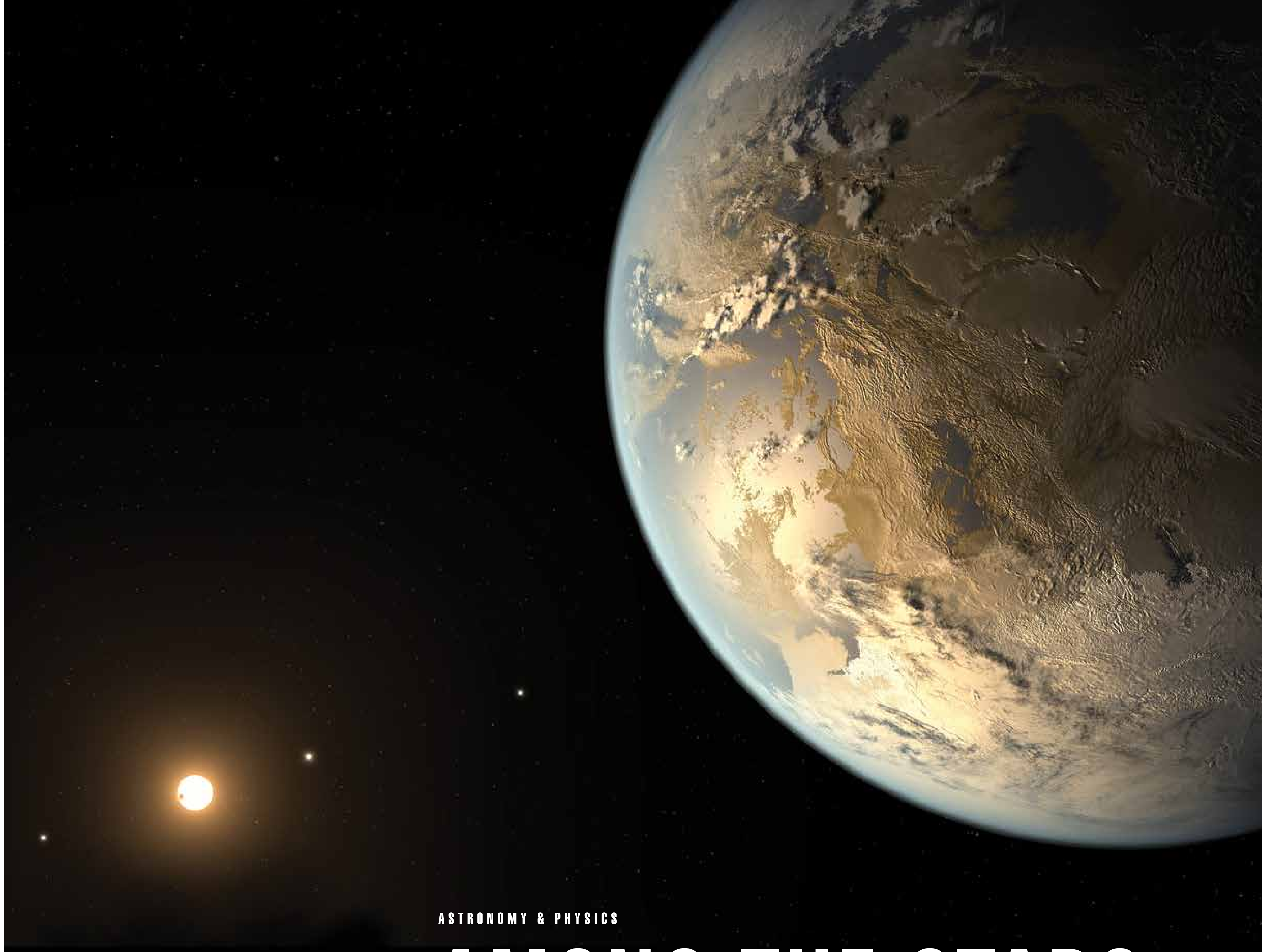
This year Allwood learned that her instrument was picked by NASA to fly on the next rover, Mars 2020. Suddenly she was heading a team of 10 scientists and dozens of engineers.

“This is very different,” she says of her leadership role. “I like that it’s a combination of pure research and project management. It’s a different realm working with a team.”

**In the interstellar search for planets like our own, Goldilocks is getting ever closer to home.** Like the story in the classic fairy tale, a Goldilocks planet is "just right" — not too big or small, and the right distance from its star to host liquid water on its surface. Sifting through 150,000 stars, the Kepler Space Telescope found precisely that — the first planet just the right size and just the right distance from its star to be similar to Earth.

Not that Kepler 186f, as the newfound world is called, is precisely like our own. First, its sun — nearly 500 light-years away, in the constellation Cygnus — is a red dwarf, smaller and cooler than ours, about as bright in the middle of the day as ours is an hour before it sets. Then there are the world's four sister planets — they whiz around their star every four, seven, 13 and 22 days, surely too scorching for life. Scientists thus call Kepler 186f an Earth cousin, not a twin. There is also much left to know about it. Some of that will have to wait for future exoplanet missions, but in the meantime Kepler will continue looking for even more Goldilocks worlds.

*Artist's concept of what newly discovered exoplanet Kepler 186f might look like at close range.* ▷

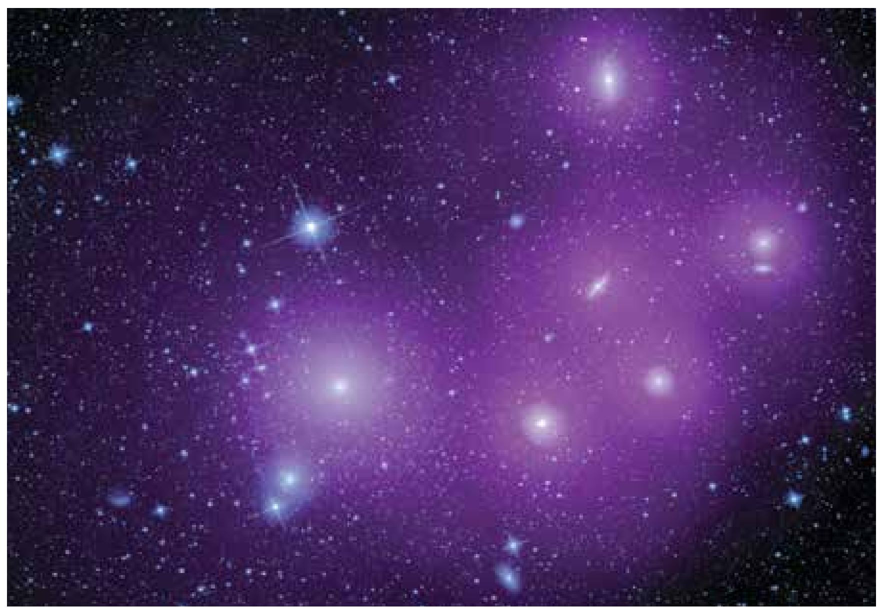


ASTRONOMY & PHYSICS

# AMONG THE STARS

You could call it a galactic selfie — and a monster one at that. During its decade-plus aloft, the **Spitzer Space Telescope** has snapped more than 2 million pictures of stars around all 360 degrees of our Milky Way Galaxy. Now astronomers have mashed them together into an enormous mosaic so big that printing it out would require a billboard as big as the Rose Bowl. The public can browse and zoom in on stars in the 20-gigapixel panorama at Spitzer's website.

# THANK GOODNESS FOR EXPLODING STARS



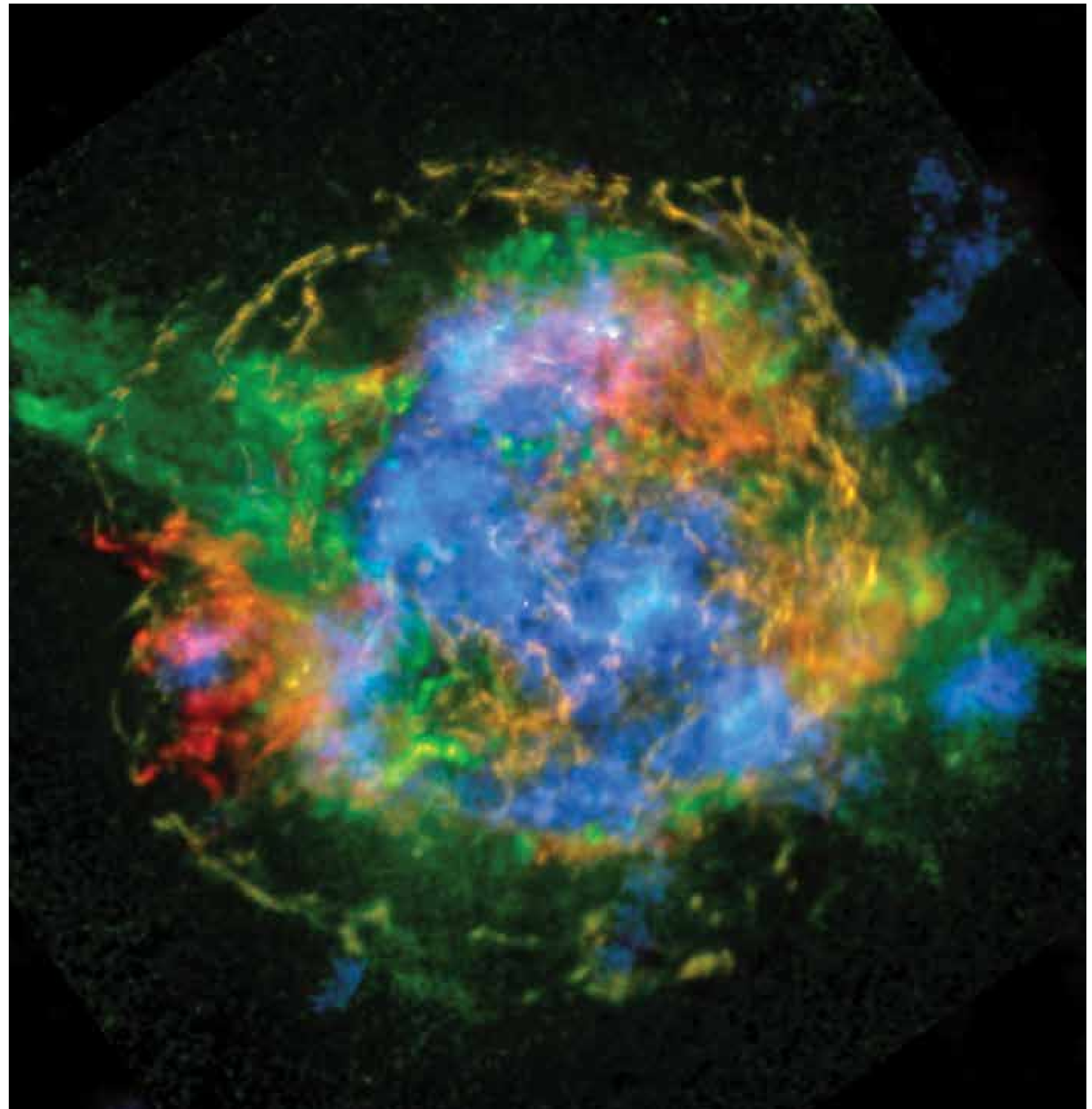
△ *The Fornax cluster of galaxies viewed by the Wide-field Infrared Survey Explorer, with an artist's impression of dark matter overlaid.*

Multiple passes over the sky by the **Wide-field Infrared Survey Explorer** enabled the best search yet for a "Planet X" — any previously unknown object the size of Saturn or larger that might be lurking in the far reaches of the solar system. The conclusion? No sign of any such world.

When that spacecraft was reactivated at the end of 2013 to search for possibly hazardous near-Earth objects, it didn't waste any time. A mere two weeks after starting its survey following nearly three years in hibernation, the space telescope — renamed "NEOWISE" — discovered its first near-Earth object, a coal-dark rock half a mile in diameter. It spent the rest of 2014 logging still more, detecting 10,252 objects including 228 near-Earth asteroids by year's end. That will help protect Earth against potentially dangerous objects, as well as provide possible targets for NASA's planned mission to an asteroid.







Thank goodness for exploding stars — as Joni Mitchell observed, we are the stuff of stars, and the elements that make our life possible wouldn't exist if ancient generations of stars hadn't concocted bigger atoms as they went nuclear. Thanks to the **NuSTAR mission**, astronomers now understand that process better. Eying the remnants of a supernova called Cassiopeia A, the space telescope revealed that such stars literally slosh around before they detonate, helping to keep their explosions from fizzling out. That in turn aids scientists in understanding how supernovas helped create the world in which we live.

*NuSTAR's image of remnants from exploded supernova Cassiopeia A.*



# FARISA MORALES

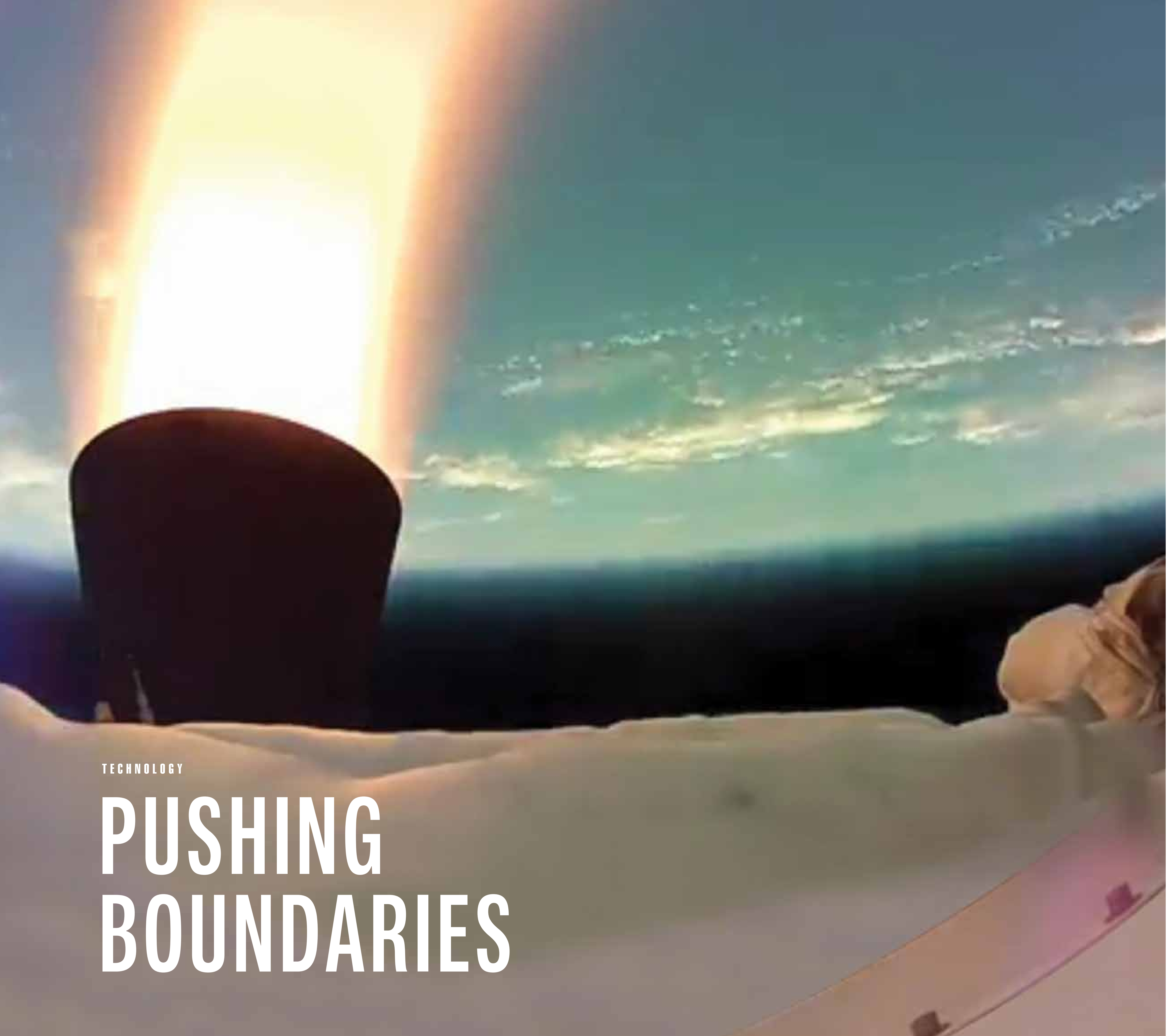
By Farisa Morales' account, she has taken the scenic route to her career as an astronomer on NASA space telescopes. Marrying young with two children soon to follow, Farisa went back to community college at age 23. Before transferring to UCLA, she won a summer internship at JPL in an engineering group.

"After I got here, I looked over at what the scientists did, and I was inspired to become one of those troublemakers who ask all the questions," she recalls. "My supervisor said, 'No, no, no, you're an engineer.' But things worked out differently."

Thanks to a mentorship by the Spitzer Space Telescope's project scientist, Farisa changed to a science track shortly before Spitzer was getting launched. Working her way through school, Farisa ended up with a doctorate in physics from USC.

"I wasn't one of those kids who knew what I wanted to do when I grew up," says Farisa, who spent time in both California and Mexico during her youth. "It was fun when I was in college and my children were in school. We all did homework together in the afternoon."

Now Farisa uses Spitzer as well as the Herschel Space Telescope to scrutinize debris around sun-like stars to understand how planetary systems form. "The more we look, the more we find they aren't too different from what we think our solar system looked like when it was young," says Morales. "This is nature talking to us."



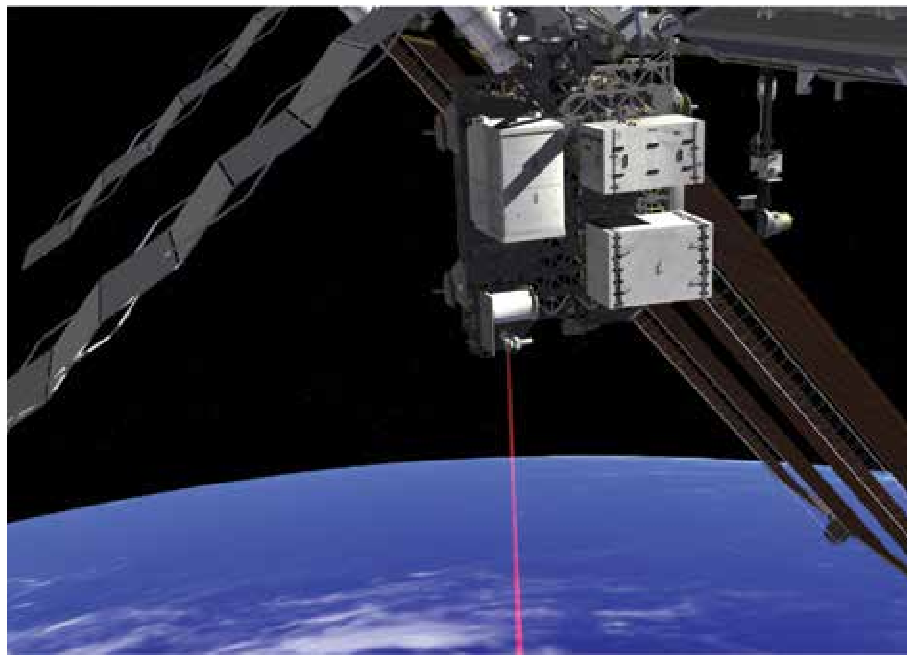
TECHNOLOGY

# PUSHING BOUNDARIES

**Flying saucers over Hawaii? In a word, yes, but no need to call the Men in Black. When a large spinning disc fired its rocket engine in the skies near Kauai last summer, it was in the service of delivering bigger and heavier payloads to other planets.** Soaring to 120,000 feet, the vehicle — called the Low-Density Supersonic Decelerator — then dropped Earthward to simulate a spacecraft arriving at a planet like Mars. As it fell, it deployed an inflatable, doughnut-shaped skirt designed to slow its descent, along with a next-generation parachute. The first worked swimmingly, while the parachute shredded — but then, reasoned the engineers, that is precisely what tests are for, and the team collected reams of data to shape their next go-around of the design. In the fall they went to California's desert for further parachute tests on a rocket sled. Another flight test at Hawaii is planned for 2015.

*The Low-Density Supersonic Decelerator fires its solid-fuel rocket motor during its test over Hawaii.*

Space missions of the future may be able to beam home vastly greater amounts of information, thanks to a technology demo that JPL flew on the International Space Station in 2014. Called the Optical Payload for Lasercomm Science, or **OPALS**, the experiment used a laser to beam a video down to a ground station on a mountaintop outside Los Angeles. In 3-1/2 seconds, it was able to send as much data as a planetary spacecraft can transmit in 10 minutes using today's radio technologies. The project employed the talents of 20 newly hired JPL employees who are early in their careers.



*Artist's concept of the OPALS experiment using a laser to beam video from the International Space Station.* ▷

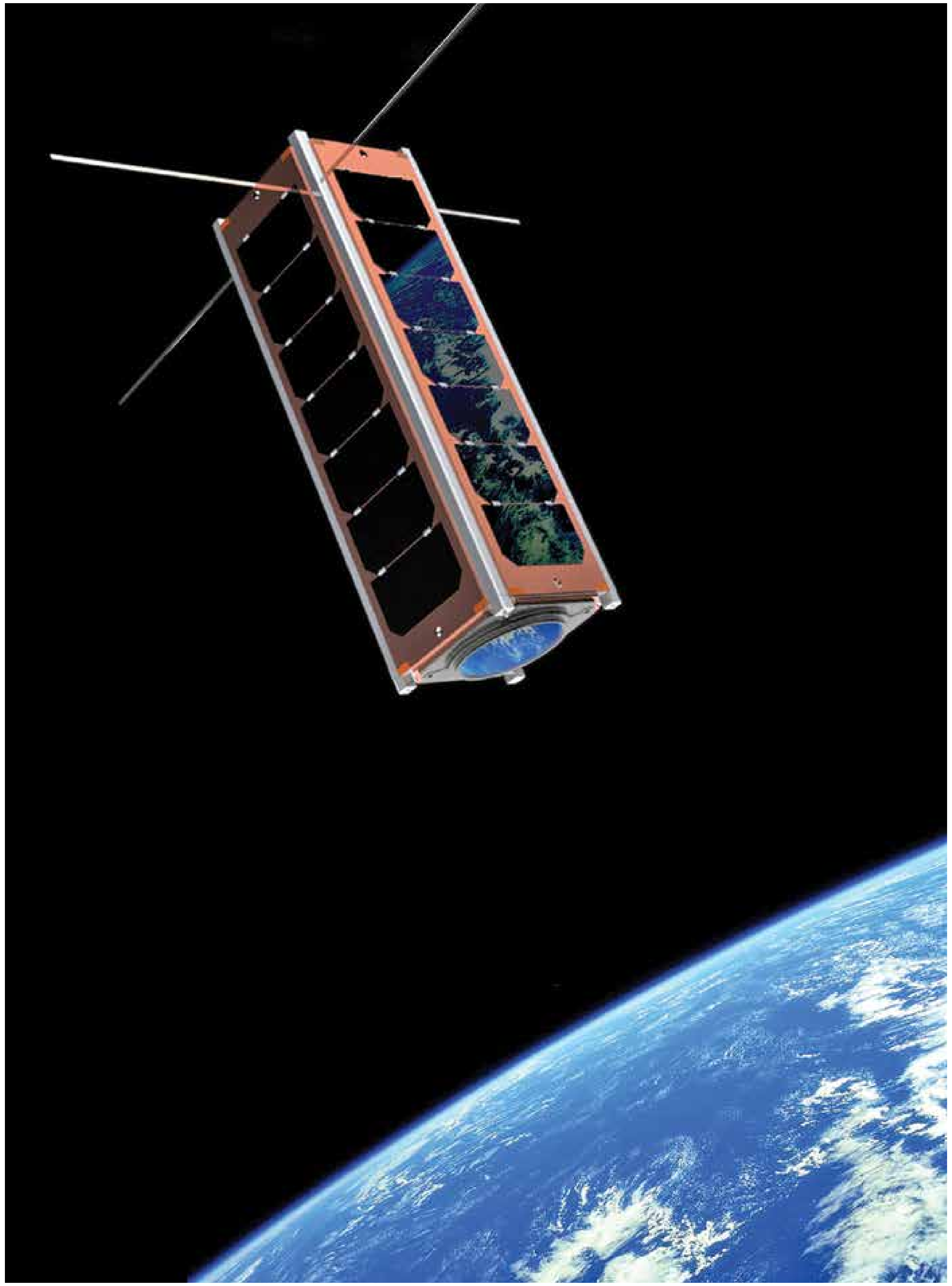
# THAT IS PRECISELY WHAT TESTS ARE FOR

Small is getting very big. "**Cubesats**," satellites about the size of a Rubik's Cube often built by students at universities, are increasingly being used by JPL to achieve science at low cost and risk. A cubesat called RACE was developed by JPL early career hires and students in Texas to test new designs for Earth science instruments, but it was lost in a launch vehicle accident in October. JPL also worked on plans for a pair of cubesats, called MarCo, that could fly along with the InSight spacecraft to Mars in 2016 to help relay data during its fiery descent. In addition, the lab provided seed funding to 10 universities to define concepts for cubesats to fly along with a mission to Jupiter's moon Europa in the 2020s.

The most precise clock ever sent into space? That's the idea behind the **Deep Space Atomic Clock**, a device created at JPL that is 50 times more accurate than the best timekeeping devices on today's spacecraft. The clock is scheduled to launch in 2016.

*Artist's rendering of a cubesat orbiting Earth.* ▷





PUBLIC ENGAGEMENT

# SELFIES GO GLOBAL


**Space has always fascinated the public at large, yet in 2014 the planet that beckoned the most was right at home — our own world, Earth.** During the year, NASA embarked on its most sustained campaign ever of Earth science launches. JPL played a vital role in leadership of the agency's "Earth Right Now" public engagement campaign, developed at the laboratory.

Tens of thousands of people in 115 countries on all continents responded to a call from NASA and JPL to share "selfie" pictures of themselves to commemorate Earth Day in April. Image processing software turned nearly 40,000 of those pictures into a "Global Selfie" mosaic in which the shots became pixels in a massive image of Earth.

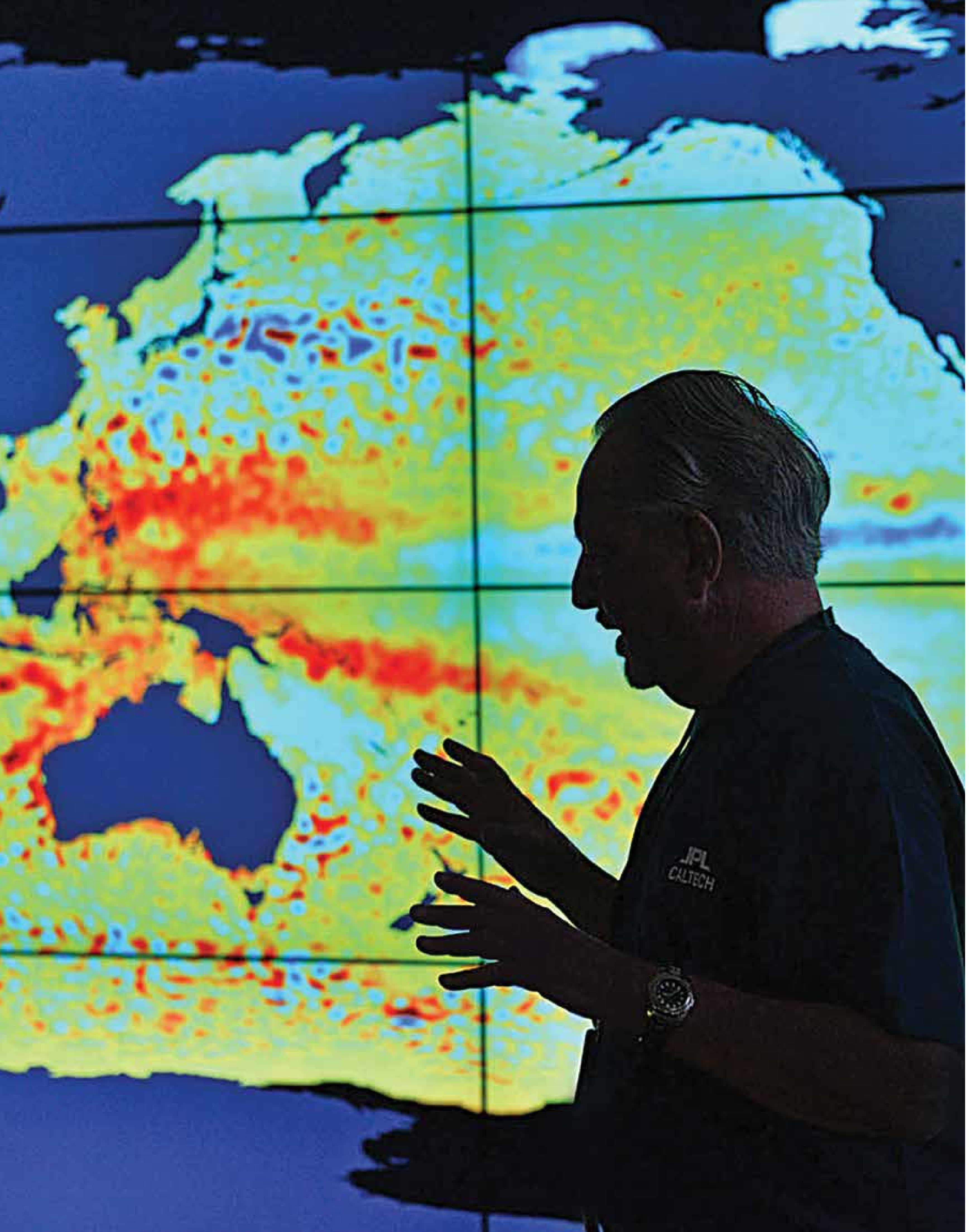
But that was only one of many communications successes for JPL, where the public avidly followed exploration missions in realms from solar system exploration to space-based astronomy. Another sign of strong interest on the local level was JPL's Open House, which returned in 2014 after a two-year hiatus due to budget constraints. Crowds came out in droves, with the laboratory tallying an all-time attendance record of more than 45,000 visitors.

◁ *Just four of the nearly 40,000 public self-portraits that went into the making of the Global Selfie (background image).*

# IF THEY CAN LAND A SPACECRAFT ON MARS...

If they can land a spacecraft on Mars, can't they fix the parking? That was the question for decades among JPL employees as they coped with tight parking at the laboratory and on adjacent leased land. A parking structure was in JPL's master plan since the 1960s, but budget constraints for decades prevented it from being realized. But In 2014, longstanding hopes were fulfilled as JPL opened a new structure to house nearly 1,500 cars.

The development also paid environmental dividends. After the structure opened, JPL relinquished its long-used lot east of the laboratory back to the City of Pasadena, which planned to remove the asphalt and restore it to a natural state as part of the Arroyo Seco watershed. That will allow the city to capture groundwater in new spreading basins.




# MAJOR EXTERNAL AWARDS

**Blaine Baggett**
Engineers' Council
Distinguished Achievement Award

**Douglas Bernard**
Engineers' Council
Distinguished Engineering Award

**Nacer Chahat**
Airbus Group Foundation
Best Thesis Award

**Goutam Chattopadhyay**
Institution of Electronics and Telecommunication Engineers
Mitra Memorial Award

**Max Coleman**
Geological Society of London
Prestwich Medal

**Dariush Divsalar**
Institute of Electrical and Electronics Engineers
Alexander Graham Bell Medal

**James Donaldson**
Engineers' Council
Distinguished Engineering Award

**Ryan Endres**
Aviation Week
Tomorrow's Engineering Leaders: The Twenty20s Award

**Christian Frankenberg**
American Geophysical Union
James B. Macelwane Medal

**Carl Guernsey**
Engineers' Council
Distinguished Engineering Award

**Jet Propulsion Laboratory**
Computerworld
Top 100 Places To Work in Information Technology

**Steven Lee**
Engineers' Council
Outstanding Engineering Achievement Merit Award

**Robert Manning**
Engineers' Council
Outstanding Engineering Achievement Merit Award

**Son Nghiem**
Institute of Electrical and Electronics Engineers
Elected Fellow

**Shouleh Nikzad**
American Physical Society
Elected Fellow
Society for Brain Mapping and Therapeutics
Pioneer in Medicine Award

**Magalene Powell-Meeks**
Federal Computer Week
The 2014 Federal 100

**Michael Sierchio**
Engineers' Council
Outstanding Engineering Achievement Merit Award

**Kentaroh Suzuki**
Japanese Meteorology Society
Society Award

**Jeffrey Umlan**
Engineers' Council
Outstanding Engineering Achievement Merit Award
University at Buffalo
Clifford C. Furnas Memorial Award

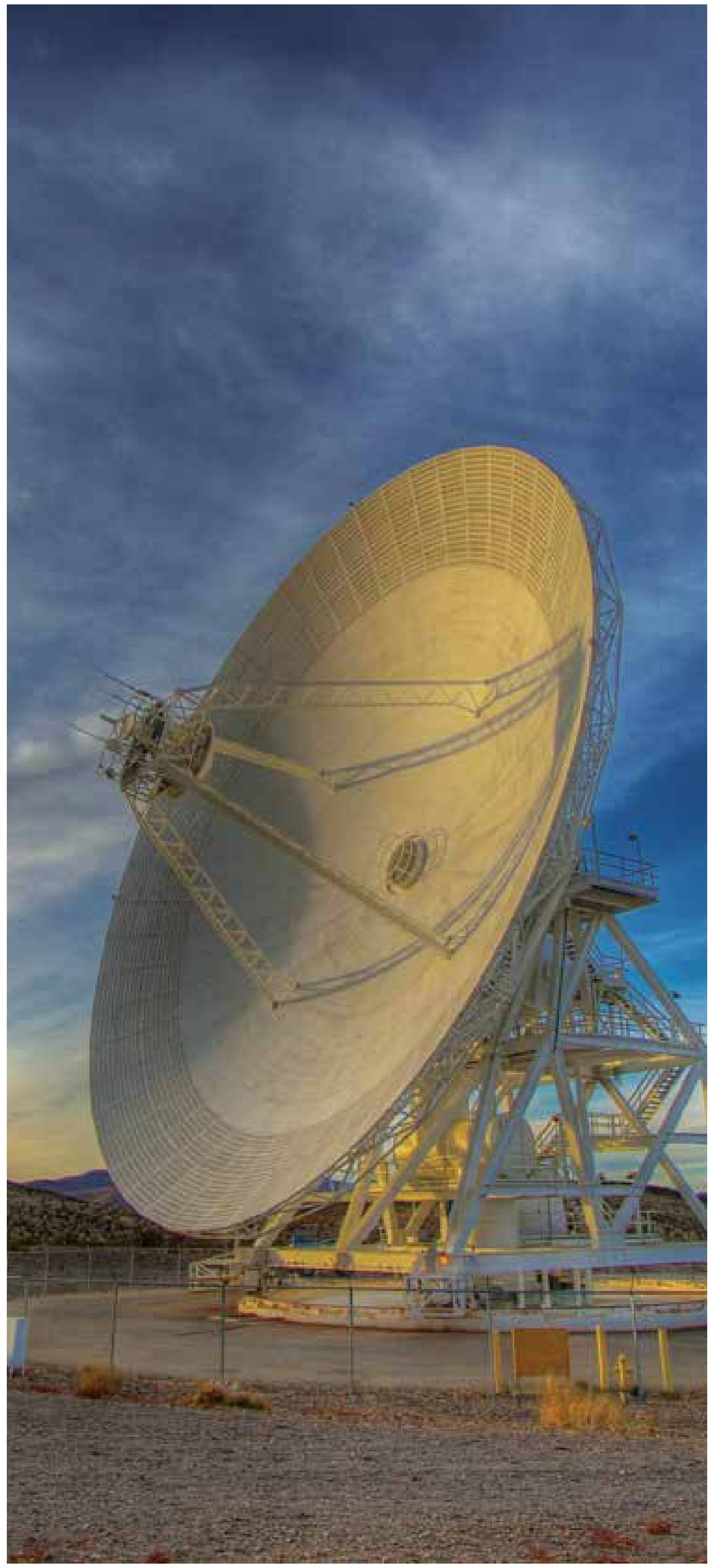
**Marco Velli**
American Geophysical Union
Elected Fellow

**Voyager Team**
Engineers' Council
Distinguished Engineering Project Achievement Award

**Sander Weinreb**
American Astronomical Society
Joseph Weber Award for Astronomical Instrumentation

**Michael Werner**
American Institute of Aeronautics and Astronautics
Space Science Award

◁ *Data from JPL satellites illustrate water warming trends in the western Pacific Ocean.*



# MAJOR CONTRACTOR PARTNERS

**Lockheed Martin Corporation**

Desktop Institutional Computing, InSight, Juno, Mars 2020, Mars Odyssey, Mars Reconnaissance Orbiter, Mars Science Laboratory, Rosetta, Spitzer Space Telescope

**Northrop Grumman Systems Corporation**

Atmospheric Infrared Sounder, James Webb Space Telescope Mid-Infrared Instrument, Soil Moisture Active Passive

**Exelis Incorporated**

Deep Space Network Operations

**Raytheon**

Data Systems Implementation and Operations, Sensor 2/Scorpio

**Orbital Sciences Corporation**

Active Cavity Radiometer Irradiance Monitor, Dawn, Orbiting Carbon Observatory 2

**EMCOR Government Services Incorporated**

Facilities Maintenance and Operations

**Swinerton Builders**

Arroyo Parking Structure Design/Build

**G4S**

Security and Fire Services

**MORI Associates**

Information Technology Infrastructure Support

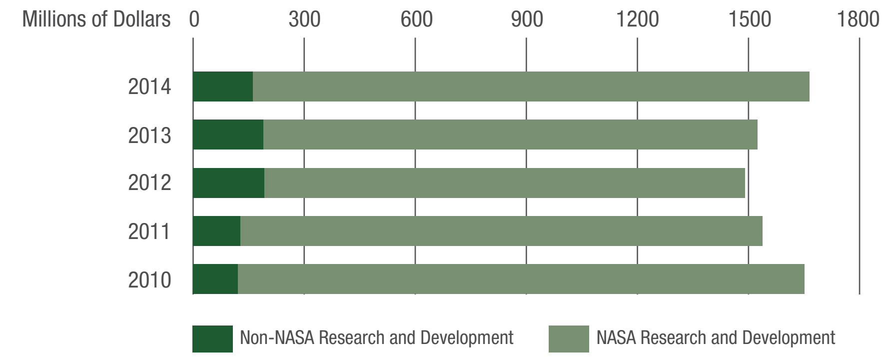
**ATK Space Systems**

Active Cavity Radiometer Irradiance Monitor, Jason 2, Low-Density Supersonic Decelerator, Mechanical and Thermal Engineering Services, Mars 2020, Near-Earth Object Wide-field Infrared Survey Explorer, Ocean Surface Topography Mission, Seawinds

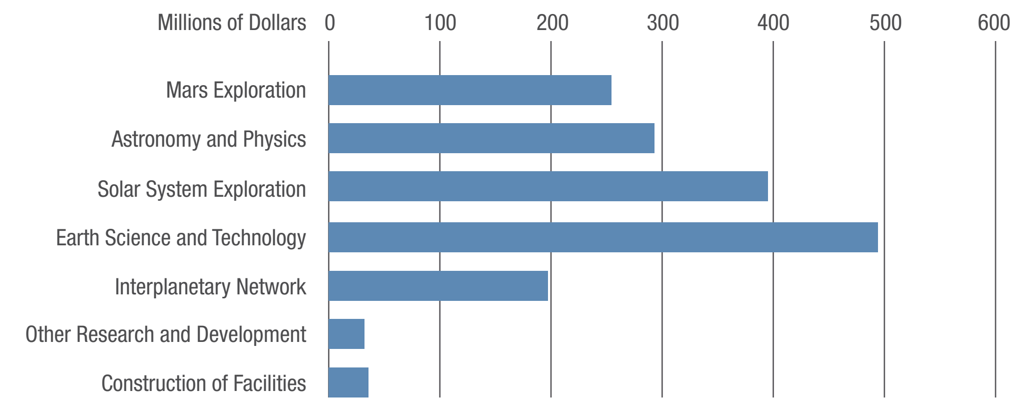
*A Deep Space Network antenna at Goldstone, California.*

# BUDGET AND WORKFORCE

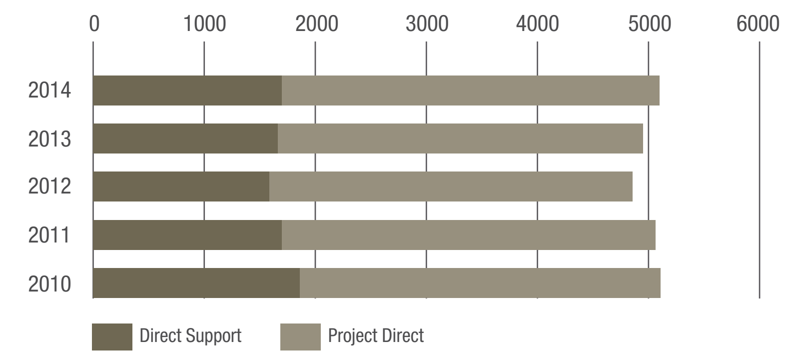
**Total Costs**




**2014 Total Costs by Program**




**Total Personnel**




2013 and 2014 totals include early career hires

# CALTECH BOARD OF TRUSTEES COMMITTEE ON JPL



## Ex Officio Members



## Consulting Participants



## Standing Attendees



# JPL ADVISORY COUNCIL

# JPL Executive Council

**Charles Elachi**
Director

**Larry D. James**
Deputy Director

**Chris P. Jones**
Associate Director
Flight Projects and Mission Success

**Jakob van Zyl**
Associate Director
Project Formulation and Strategy

**Blaine Baggett**
Director for Communications and Education

**Janis L. Chodas**
Director for Safety and Mission Success

**Diane L. Evans**
Director for Earth Science and Technology

**Dave Gallagher**
Director for Astronomy,
Physics and Space Technology

**Cozette M. Hart**
Director for Human Resources

**Fuk K. Li**
Director for Mars Exploration

**Leslie Livesay**
Director for Engineering and Science

**Daniel McCleese**
Chief Scientist

**Brian Muirhead**
Chief Engineer

**Firouz M. Naderi**
Director for Solar System Exploration

**Richard P. O'Toole**
Executive Manager
Office of Legislative Affairs

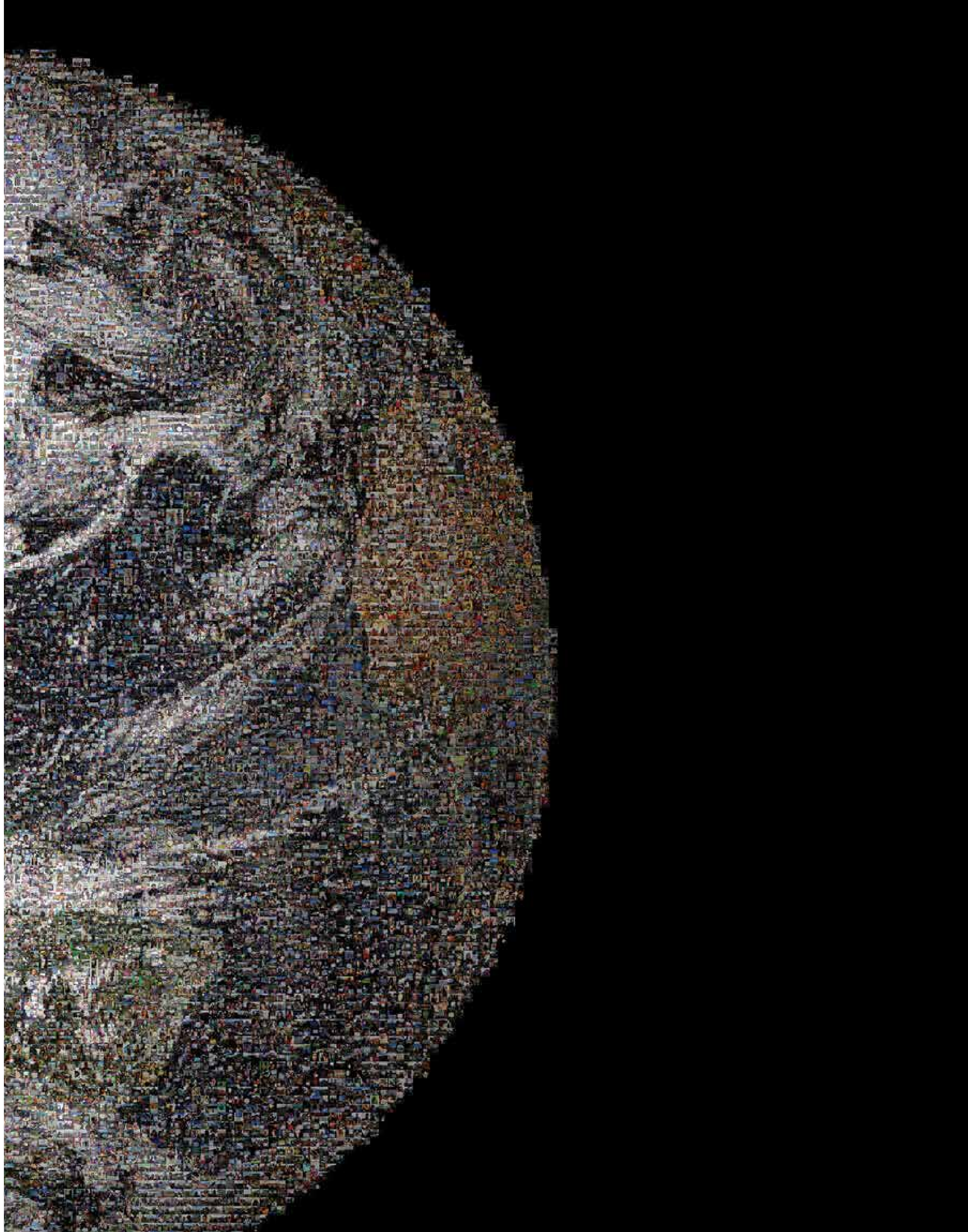
**Keyur C. Patel**
Director for Interplanetary Network

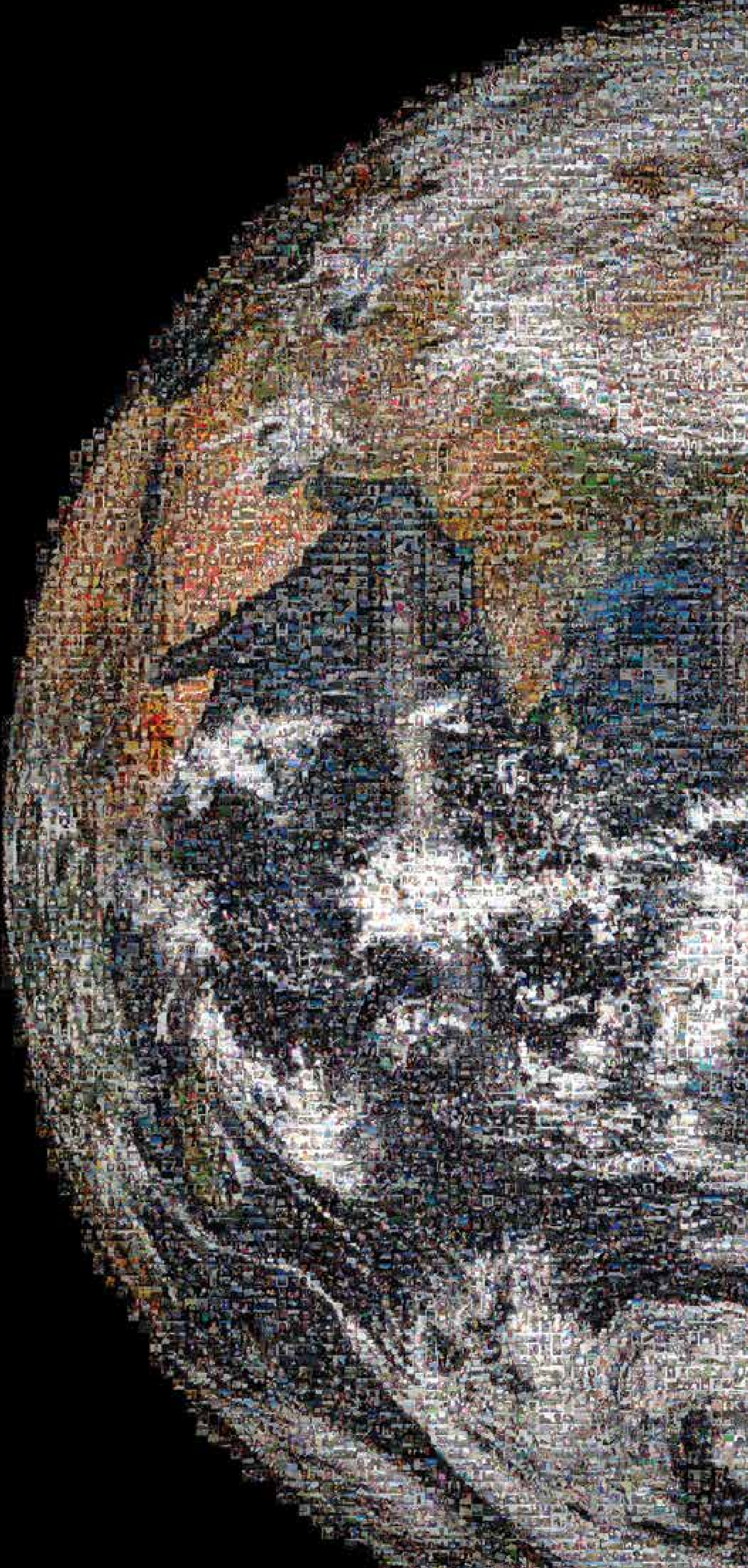
**Steve Proia**
Chief Financial Officer
Director for Business Operations

**James Rinaldi**
Chief Information Officer
Director for Information Technology

**Victoria Stratman**
General Counsel, Caltech

**Jonas Zmuidzinas**
Chief Technologist





National Aeronautics and Space Administration

**Jet Propulsion Laboratory**
California Institute of Technology
Pasadena, California

**www.nasa.gov**

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