Griffith Observatory Gets *The Big Picture*

When Los Angeles' Griffith Observatory reopens to the public on November 3 after a $93-million and nearly five-year renovation, it will feature the biggest astronomical image ever seen. Twenty feet tall and 152 feet long, *The Big Picture*, a true-color panorama of the core of the Virgo cluster of galaxies, covers an entire wall of the Richard and Lois Gunther "Depths of Space" Exhibit Hall. Data for the image—from a patch of sky roughly the size of your index finger held a foot away from your face—were taken by a team headed by Caltech Professor of Astronomy George Djorgovski using the Samuel Oschin Telescope as part of the Palomar-Quest digital sky survey, a collaboration between Caltech and Yale.

This view of "Markarian's Chain" of galaxies, with the giant ellipticals M 84 and M 86 on the right, and the merging pair of galaxies NGC 4435 and NGC 4438 near the center, occupies 16.7 by 10 feet of wall space.

The full story of this pharaonic undertaking—the enameled porcelain panels will far outlast their creators—will be told in the next issue of *E&S*. □—*DS*

The Breadth of Light

"No, Mr. Bond. I expect you to die," said Auric Goldfinger as a steel-melting laser inched closer to 007's favorite anatomical region. This secret-agent-slicing beam would probably only need to be a few thousand watts of continuous power, according to Martin Centurion (PhD '05), a postdoc in Caltech's Center for the Physics of Information, but the femtosecond lasers he works with routinely put out an unimaginable 10 gigawatts of pulsed power. (For Dr. Evil's benefit, that's ten BILL-ion watts.) It's not that the lasers have gotten bigger—in fact, they're quite a bit smaller these days—but power equals energy divided by time, and a femtosecond is 10^{-15}, or one quadrillionth, of a second.

These ultrafast pulses might be ideal for communications and switching systems, and even optoelectronic computers, but for one serious drawback—the sheer intensity of the light induces a nonlinear phenomenon called the "Kerr effect" that alters the refractive index of the material the beam is passing through. The lasers used in fiber-optic systems are way too weak to be subject to this, but once you cross a certain threshold, the brighter the beam, the more the refractive index changes. The light consequently focuses inside the glass, heating the atoms along its path to a plasma—a fog of free electrons and ionized silicon and oxygen atoms. This might actually be a good thing, in that the plasma's refractive index is negative and prevents further self-focusing, but forming the plasma drains the beam's energy. And, of course, there's the unfortunate side effect of eventually vaporizing the fiber.

A theoretical fix, called "nonlinearity management," has been around for a decade, and now Centurion; fellow postdoc Mason Porter (BS '98); Demetri Psaltis, the Myers Professor of Electrical Engineering; and mathematics professor Panayotis Kevrekidis of the University of Massachusetts at Amherst have actually demonstrated it. The basic idea is to alternate stretches of a material that focuses light of the given intensity with one that causes

Still Going. . .

Voyager 1, humanity's most well-traveled explorer, left the sun 100 astronomical units behind on August 15, meaning it is 100 times farther away than the earth is—9.3 billion miles. The spacecraft has been on the road for 29 years and, moving at a speed of about one million miles per day, could cross the boundary into interstellar space within a decade. It is now in the heliosheath—the outer skin of a bubble of gas called the heliosphere, which is formed by the solar wind—and returns data from these uncharted domains almost daily. □—*DS* it to spread at that same intensity. As the beam passes through this "Kerr sandwich," it alternately expands and contracts—it "breathes," if you will—and the beam size remains relatively constant overall.

"Basically, the smaller the beam is, the faster it will expand in the air," says Centurion, "and the higher the power, the faster it will focus in the glass, so you can play with these parameters to reach a balance. In our case, the beam diameter doubles after about four millimeters in air."

The sandwich consisted of nine ordinary microscope slides, each about one millimeter thick, placed parallel to one another at one-millimeter intervals. The slides were used not only because they were handy, says Porter, but because "we also wanted to indicate that it didn't need any special materials or circumstances to work." The laser, focused to a beam less than 50 microns (millionths of a meter) in diameter, was shot in pulses of 160 femtoseconds each. If these pulses had gone through solid glass, plasma formation would have kicked in after about two millimeters. Instead, it emerged from the sandwich with essentially the diameter it had when it entered, with no plasma formation. It did lose more than half its power, however, due to internal reflections at each air-glass interface; further studies using slides with a nonreflective coating are already showing better results.

The work was published in the July 21 issue of *Physical Review Letters*. □—*DS*

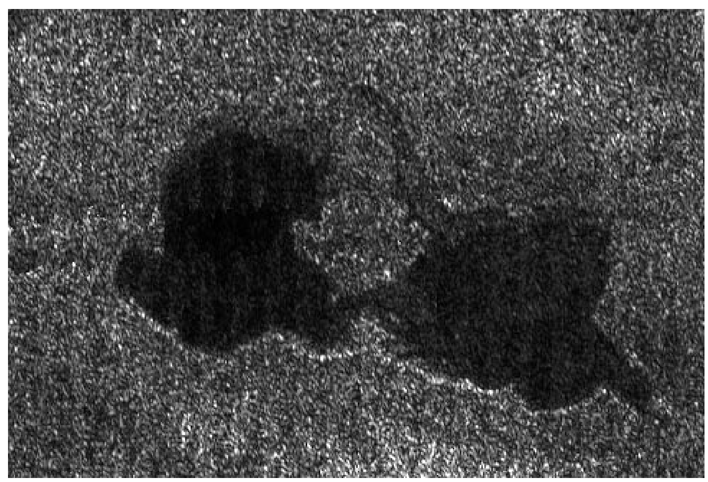
Rockin' with Richter

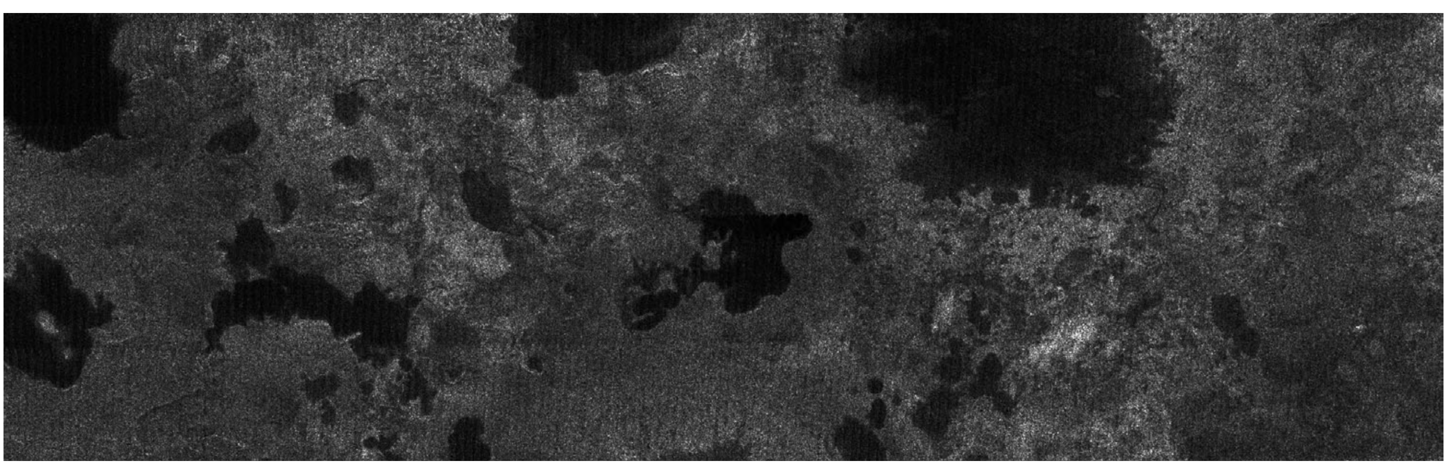
The Caltech Archives' virtual exhibit in honor of the centennial of the great San Francisco earthquake continues. Module 2 was released on June 22. "The Beginnings of Seismology at Caltech, 1920–1930" chronicles the early work of geologist Harry Wood, instrument builders John Anderson and Hugo Benioff, geophysicist Beno Gutenberg, and the first household name in earthquakes, Charles Richter (PhD '28). Module 3, "Charles Richter and the Earthquake Magnitude Scale," came out on October 4. New features to this module include excerpts of Richter's account of the development of the scale from the taping sessions of his oral history, and an MP3 file of Professor of Literature, Emeritus, J. Kent Clark and Dave Elliot's "The Richter Scale," as performed by the Caltech Stock Company.

The exhibit may be accessed at http://archives.caltech.edu/exhibits/earthquake/index.html. □—*DS*

Cassini's radar may have found lakes of liquid methane or ethane all over the north polar region of Titan, Saturn's largest moon. The patches resemble Earth's lakes in shape, and the black ones reflect essentially no radar signal, meaning they are extremely smooth. The dark gray ones have a slightly rougher surface, possibly due to winds—finding their textures to vary in future passes would strongly support their liquid nature. The image below is centered near 80° N and 92° W and measures about 420 kilometers by 150 kilometers; its smallest visible details are about 500 meters in size. The image at right was taken near 73° N and 46° W and shows two lakes some 20 to 25 kilometers across, or a bit smaller than Lake Tahoe, joined by a relatively narrow channel. The lighter patches in the lake on the right indicate that it may be slowly drying out as summer approaches.

JPL built the Cassini orbiter and manages the mission, which is a joint effort of NASA, the European Space Agency, and the Italian Space Agency.





And Speaking of Large Earthquakes. . .

How will Southern California's steel-frame, earthquake-resistant high-rises fare when the Big One hits? That's a very complicated question that a team led by Caltech postdoc Swaminathan Krishnan (PhD '04) has answered with unprecedented specificity using a supercomputer model—the first to combine 3-D seismological simulations with 3-D nonlinear analyses of building motions.

The model "ruptured" a 290-kilometer section of the San Andreas fault between Parkfield, located in the Central Valley, and Southern California. Two magnitude-7.9 earthquakes were simulated—one rupturing southward and the other northward. The model calculated the resulting motions for a grid of 636 points spaced 3.5 kilometers apart and covering the Los Angeles basin, which includes the San Gabriel Valley and Orange County, and the San Fernando basin, which is a geologically separate entity, and applied them to two structures: an actual 18-story building that was designed according to 1982 building code standards and suffered significant damage in the 1994 Northridge earthquake when welds failed, and the same building designed to the stricter 1997 standards. The model predicted each building's "peak interstory drift," which measures the structure's distortion as it sways—for example, for a 10-foot-high story, a drift of 0.10 means that the ceiling is displaced one foot in relation to its floor. Zero-point-one is also approximately the threshold of collapse, while anything over 0.06 indicates severe damage.

Not surprisingly, L.A. fared worse in the south-propagating rupture, where peak drifts for the 1982 building far exceeded 0.10 in the San Fernando Valley, Santa Monica, and West Los Angeles, as well as the areas around Baldwin Park, Compton, and Seal Beach. Peak drifts were in the 0.06–0.08 range in the Huntington Beach, Santa Ana, and Anaheim areas, and in the 0.04–0.06 range everywhere else, including downtown Los Angeles. The 1997 version did better—although peak drifts in some parts of the San Fernando Valley still exceeded 0.10, they were in the range of 0.04–0.06 for most of the Los Angeles basin. In the south-to-north rupture, both buildings scored in the 0.02–0.04 range, suggesting damage enough to close the building but little danger of collapse.

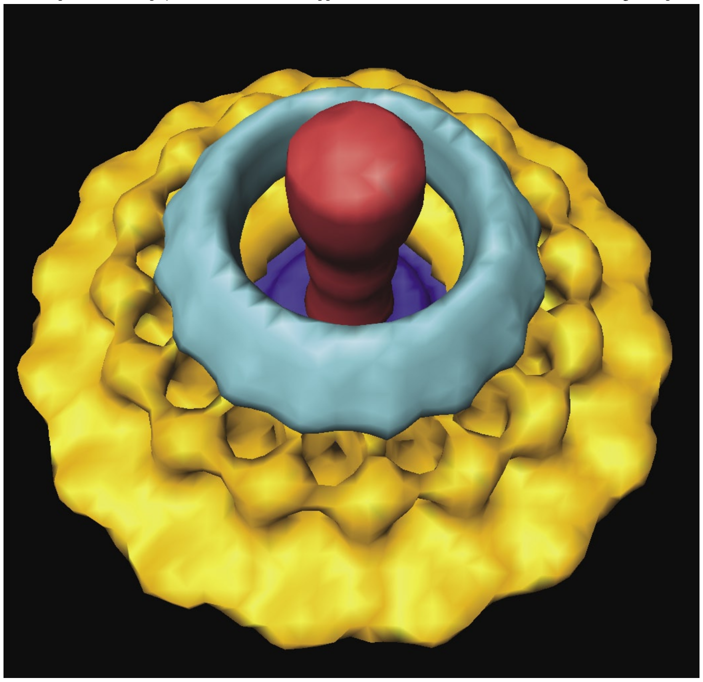
Such hazard analyses could be performed on specific existing and proposed buildings for a range of earthquakes, providing detailed information for developers, building owners, city planners, and emergency managers. "We have shown that these questions can be answered, and they can be answered in a very quantitative way," Krishnan says.

A southward-propagating 7.9 earthquake hit the San Andreas in 1857, and seismologists think an event of that size—propagating in either or both directions—could happen every 200 to 300 years. To put this in context, the Northridge earthquake was a mere magnitude 6.7, yet caused 57 deaths and economic losses of more than $40 billion.

The results were published in October issue of the *Bulletin of the Seismological Society of America*. The other authors are Chen Ji (MS '99, PhD '02), now at UC Santa Barbara, Dimitiri Komatitsch of the University of Pau in France, and Jeroen Tromp, Caltech's McMillan Professor of Geophysics and director of the Seismological Laboratory. Online movies of the earthquakes and building-damage simulations can be viewed at http://www.ce.caltech.edu/krishnan. □—*JP*

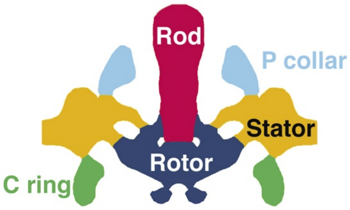
Four stamps featuring snowflake photographs taken by Professor of Physics Ken Libbrecht (BS '80) have been issued by the post office just in time for all your holiday-card needs. Libbrecht attended a dedication ceremony for the stamps on October 5 at a major stamp-collecting convention at Madison Square Garden in New York. The snowflake photos are an outgrowth of Libbrecht's work on the physics of pattern formation during crystal growth (see *E&S*, 2001, No. 1). His latest, pocket-sized book on the subject, *Ken Libbrecht's Field Guide to Snowflakes*, just came out as well. Ho, Ho, Ho!

Now They Can Be Shown



We couldn't run these images in last issue's electron cryotomography article ("Cellular CAT Scans") because of an embargo by *Nature*. At right is the first-ever high-resolution, 3-D view of a working molecular motor. As coauthor Grant Jensen, assistant professor of biology, remarked in *E&S*, "If he [grad student Gavin Murphy, the *Nature* paper's lead author] thawed the cells out, they'd swim away." The cells in question are a bacterium known as *Treponema primitia*, and the motor spins at about 300 revolutions per second to drive a flagellum that propels the cell.

A marvel of complexity, the motor is assembled from molecules of about 25 different proteins. Other researchers had isolated and purified some of them to determine their structures, or had pulled the motor out of the cell to examine it, losing pieces in the process. Seen here for the first time is the ring-shaped torque generator, called the stator (yellow), which is embedded in the inner cell membrane. Nested inside the stator is the moving part, the rotor (dark blue), which is attached to a rod (red) that turns the flagellum. A cross section through the stator (below right) shows that each of its 16 symmetric units grabs the rotor in two places, like a person's two hands gripping the rail of a playground merry-go-round in order to spin it. Also revealed are the stator's connections to the P collar (light blue), which is basically a bushing, and the C ring (green), which acts like a transmission to select clockwise or counterclockwise rotation. The paper, whose third author is Associate Professor of Environmental Microbiology Jared Leadbetter, ran in *Nature*'s August 31 issue. □—*DS*



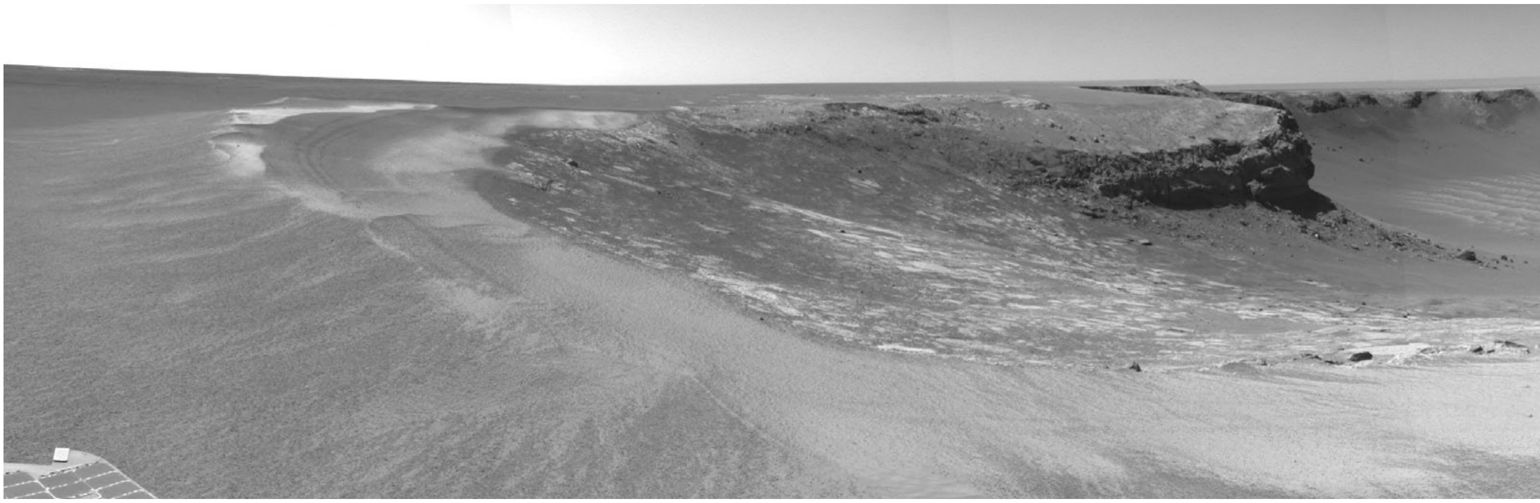
Opportunity snapped th

frames from the navigati

far side is about 800 meters away, and its rim towers approximately 70 meters above its floor. Victoria's exposures of layered bedrock are 20–30 meters

thick—compared to

Eagle Crater, where Opportunity landed—and should reveal a proportionately longer span of local Martian history.



Mike Brown and the Five Dwarfs

As you've no doubt heard by now, in August the body formerly known as "Xena" was denied planetary status by the International Astronomical Union (IAU), which then, for good measure, booted Pluto out of the club as well. These objects, plus the other ones discovered by Professor of Planetary Astronomy Mike Brown and colleagues—Quaoar, Sedna, "Santa," and "Easterbunny"—will henceforth be termed "dwarf planets." The IAU also formally named "Xena" Eris, the Greek goddess of discord; its moon "Gabrielle" is now Dysnomia, Eris's daughter and the goddess of lawlessness. But fans of TV's warrior princess need not despair—Brown notes that Xena was played by Lucy Lawless, and Eris appeared on the show as a recurring character under her Latin name, Discordia. □—*DS*

O'Donovan's Giant Planet

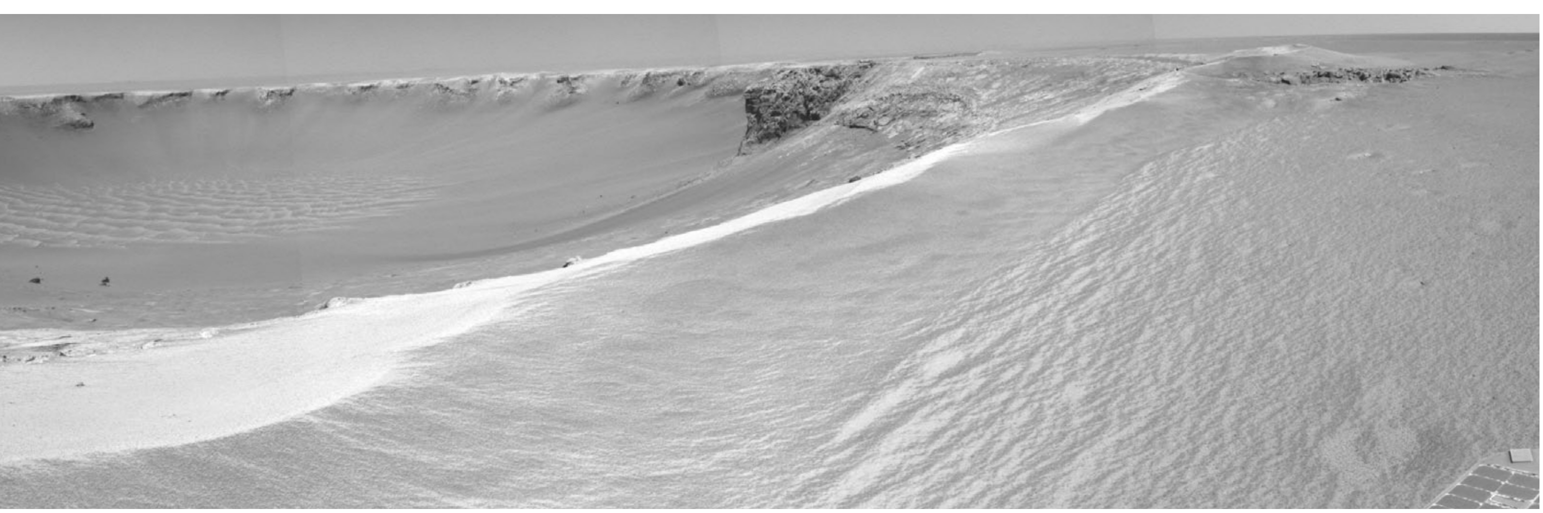
We may be down a planet with the recent demotion of Pluto (see box), but the number of giant planets discovered in orbit around other stars continues to grow steadily—around 200, at last count. Now, an international team of astronomers led by Caltech grad student Francis O'Donovan has detected a planet slightly larger than Jupiter that orbits a star 500 light-years from Earth in the constellation Draco. The planet, known as "TrES-2" (pronounced Trace-2) passes in front of a star called GSC 03549-02811 every two and a half days, causing a dimming of its light by about 1.5 percent.

TrES-2 is the first transiting planet—or planet that passes directly between its star and Earth—to be found in an area of the sky known as the "Kepler field," a piece of celestial real estate about the size of your two hands held together at arm's length, or twice the bowl of the Big Dipper. NASA's Kepler mission, set to launch in October 2008, will stare at this patch of sky for four years, and should discover hundreds of planets, both giant and Earth-like. Discovering TrES-2 beforehand allows Kepler's astronomers to plan additional observations of it, such as searching for moons.

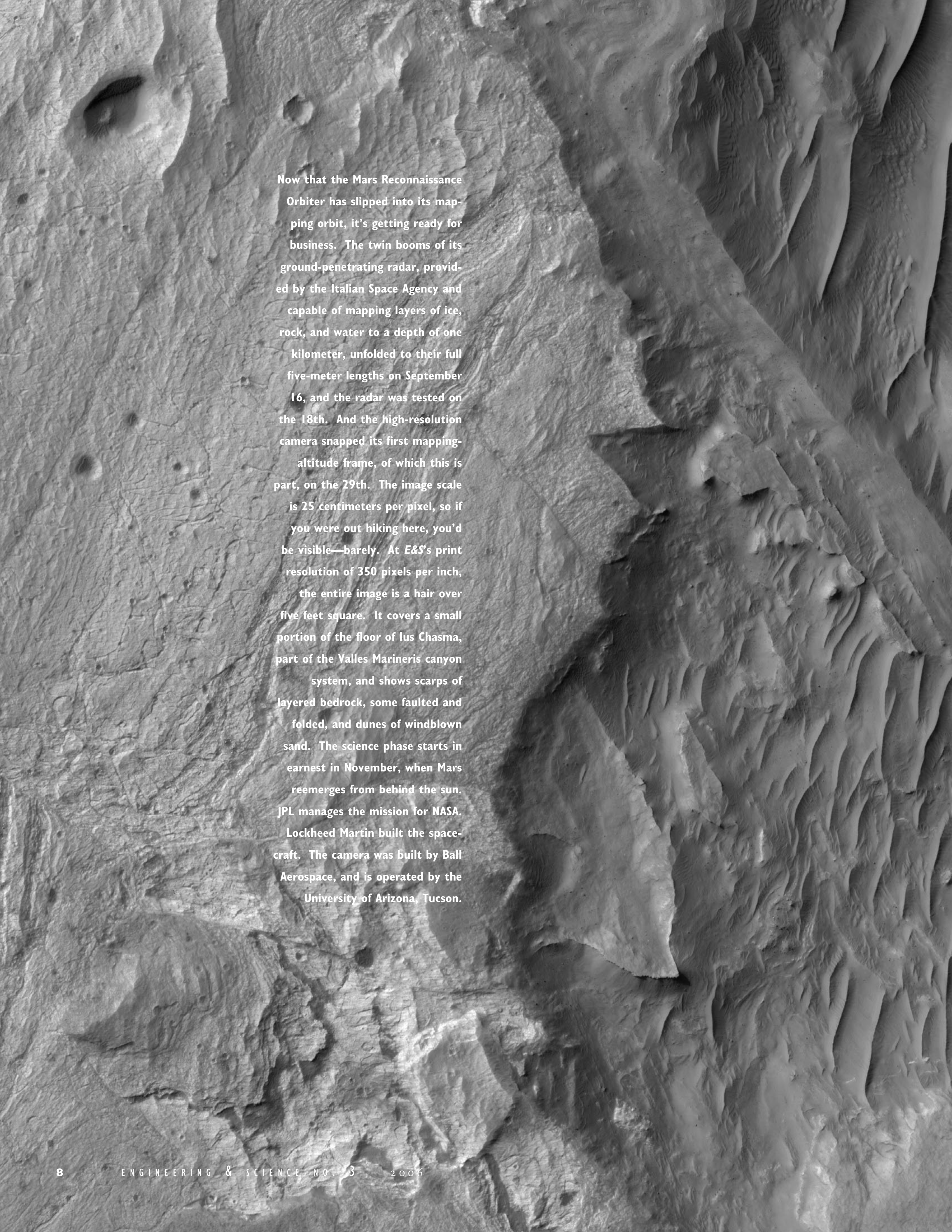
TrES stands for Trans-Atlantic Exoplanet Survey, an effort involving the Sleuth telescope at Caltech's Palomar Observatory, the Planet Search Survey Telescope (PSST) at Lowell Observatory near Flagstaff, Arizona, and the STellar Astrophysics and Research on Exoplanets (STARE) telescope in the Canary Islands—all three of which were built with off-the-shelf camera lenses and mostly from amateur-astronomy components. TrES-2, the second planet to be found by the survey, was first spotted by Sleuth, which was set up by Caltech postdoc David Charbonneau, now at the Harvard-Smithsonian Center for Astrophysics and a coauthor of the paper. The PSST, which is operated by coauthors Georgi Mandushev and Edward Dunham, corroborated the initial detection.

These small, automated telescopes took wide-field, timed exposures covering thousands of stars at a time over a period of about two months per field. When the software detected regular variations in the light from an individual star, it alerted the astronomers. In order to confirm that the dimming was due to an orbiting planet, and not, say, a small, faint companion star, O'Donovan and his colleagues switched to one of the 10-meter telescopes at the W. M. Keck Observatory on the summit of Mauna Kea, Hawaii, to do detailed spectroscopic observations. Says O'Donovan, "All our hard work was made worthwhile when we saw the results from our first night's observations, and realized we had found our second transiting planet."

The paper announcing the discovery will appear in an upcoming issue of the *Astrophysical Journal*. The 15 other authors include JPL's John Trauger and Associate Professor of Astronomy Lynne Hillenbrand. □—*RT*



PICTURE CREDITS: 2-3—Palomar-Quest team/Caltech; 4, 6-7—NASA/JPL; 5—United States Postal Service; 8-9—NASA/JPL/U. of Arizona



Now that the Mars Reconnaissance Orbiter has slipped into its mapping orbit, it's getting ready for business. The twin booms of its ground-penetrating radar, provided by the Italian Space Agency and capable of mapping layers of ice, rock, and water to a depth of one kilometer, unfolded to their full five-meter lengths on September 16, and the radar was tested on the 18th. And the high-resolution camera snapped its first mapping-altitude frame, of which this is part, on the 29th. The image scale is 25 centimeters per pixel, so if you were out hiking here, you'd be visible—barely. At *E&S*'s print resolution of 350 pixels per inch, the entire image is a hair over five feet square. It covers a small portion of the floor of Ius Chasma, part of the Valles Marineris canyon system, and shows scarps of layered bedrock, some faulted and folded, and dunes of windblown sand. The science phase starts in earnest in November, when Mars reemerges from behind the sun. JPL manages the mission for NASA. Lockheed Martin built the spacecraft. The camera was built by Ball Aerospace, and is operated by the University of Arizona, Tucson.