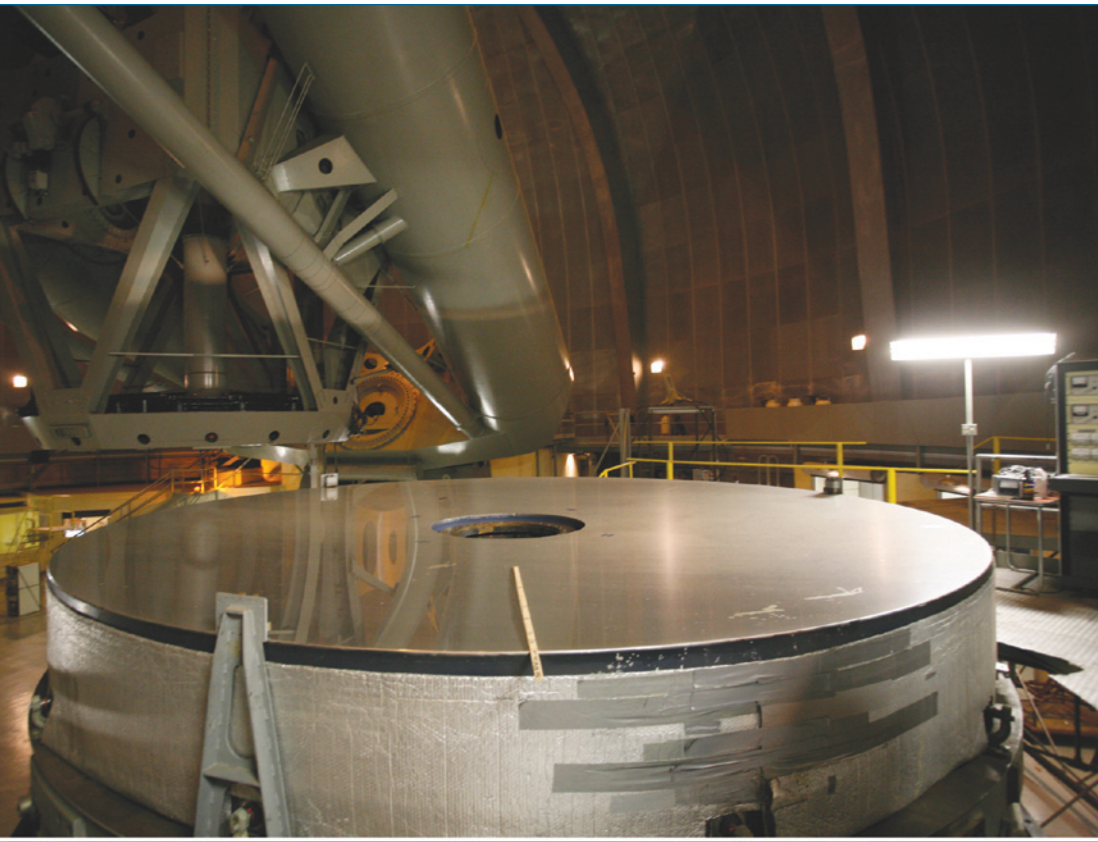


THE SHINING

There's a fresh gleam in the eye of the Hale telescope. In November, the 200-inch mirror at the Palomar Observatory was treated with a good scrub and a shiny new coat of aluminum.

After staring into space for nearly 300 days out of the year, the mirror accumulates dirt and dust that even weekly cleanings can't get rid of. So, every year or two, the mirror is unmounted, washed, and given a new reflective surface.

First, the staff uses a cart to lower the 14.5-ton piece of glass from the scope. They then clean the mirror with soap and water, keeping the surface wet at all times to prevent spots. Next, an acid wash called "Green River" strips away the old aluminum. After some more cleaning, drying (with paper towels), and inspection, the mirror's ready for its new shine.

A 17.5-ton bell jar is lowered over the mirror. It takes a day to suck out enough air to make the vacuum the mirror needs to be recoated. Inside the chamber, hundreds of tungsten coils covered in aluminum are heated to more than 500° C. The heat vaporizes the metal, and the aluminum deposits onto the mirror, forming a layer less than eight millionths of a centimeter thick.—*MW* e&s

After a spa treatment and a fresh coat of aluminum, the Hale telescope's 200-inch mirror boasts a new shine. The butt end of the telescope, from whence the mirror came, looms in the background of the "before" picture (top).

GET YOUR BLOOD SCANNED ON A BARCODE CHIP

Some day when you put a pinprick's worth of blood into a lab-on-a-chip developed at Caltech, you'll be able to tell within 10 minutes if you're at risk for heart disease or cancer. The device, known as the Integrated Blood-Barcode Chip, or IBBC, measures the concentrations of dozens of proteins in your blood serum at once. It was developed by a group led by James Heath, Caltech's Gilloon Professor and professor of chemistry, along with postdoc Rong Fan and grad student Ophir Vermesh, and by Leroy Hood (BS '60, PhD '68), president of the Institute for Systems Biology in Seattle, Washington.

An IBBC is essentially a microscope slide coated with silicone rubber. The rubber's underside is molded into a system of microscopic channels. As a pinprick of blood flows through the channels, the protein-rich plasma is separated out, and protein biomarkers are measured in the plasma.

Nowadays, blood tests take hours, not counting the time needed to draw a vial of blood from your arm and deliver it to the lab. There, the blood is centrifuged to separate the plasma, which is analyzed for each specific protein separately. "The process is labor intensive, and even if the person doing the testing hurries, the tests will still take a few hours to complete," says Heath. "We wanted to lower the cost of such measurements by orders of magnitude. We measure many proteins for the cost of one. Furthermore, if you reduce the time it takes for the test, the test is cheaper, since time is money." A test kit for a single protein currently costs about $50. Says Heath, "We are optimistic that our platform, when fully developed, will reduce this cost to pennies per biomarker."

A single chip can simultaneously test the blood from eight patients, and each test measures many proteins at once. "We're aiming to measure 100 proteins per fingerprick within a year or so. It's a pretty enabling technology," Heath says.

The IBBC analyzes a blood drop by gently pumping it through a relatively wide channel. Smaller channels branching from the main one skim off some of the plasma and direct it along a "barcode"—one per channel. Each line in the barcode is 20 millionths of a meter wide and covered with an antibody that allows it to capture a specific protein from the plasma passing over. When the barcode is "developed," the individual bars emit a red fluorescent glow, whose brightness depends upon the amount of each protein captured.

In the paper announcing this work in the December issue of *Nature Biotechnology*, the researchers measured human chorionic gonadotropin, a hormone produced during pregnancy. "The concentration of this protein increases by about 100,000-fold as a woman goes through the pregnancy cycle, and we wanted to show that we could capture that whole concentration range through a single test," Heath says. The scientists also analyzed the blood of breast- and prostate-cancer patients for a number of biomarkers. These proteins vary in type and concentration—a woman with breast cancer, for example, will produce a different suite of biomarkers than a man with prostate cancer, and a woman with an aggressive breast cancer may produce proteins that are different from a woman with a less-deadly cancer. After the diagnosis, biomarkers may change as treatment progresses, so an IBBC could also be used much as a diabetic tests his or her blood sugar.

The barcode chip is now in human clinical trials on patients with

A test kit for a single protein currently costs about $50. Says Heath, "We are optimistic that our platform, when fully developed, will reduce this cost to pennies per biomarker."

glioblastoma, a common, aggressive brain tumor. The researchers are also using the chips to determine how diet and exercise change the composition of the proteins in the blood of healthy people.

Currently, the barcoded information is "read" with a common laboratory scanner that is also used for gene- and protein-expression studies. "But it should be very easy to design something like a supermarket UPC scanner to read the information," making the process even more user-friendly, says postdoc Rong Fan, the first author on the paper.

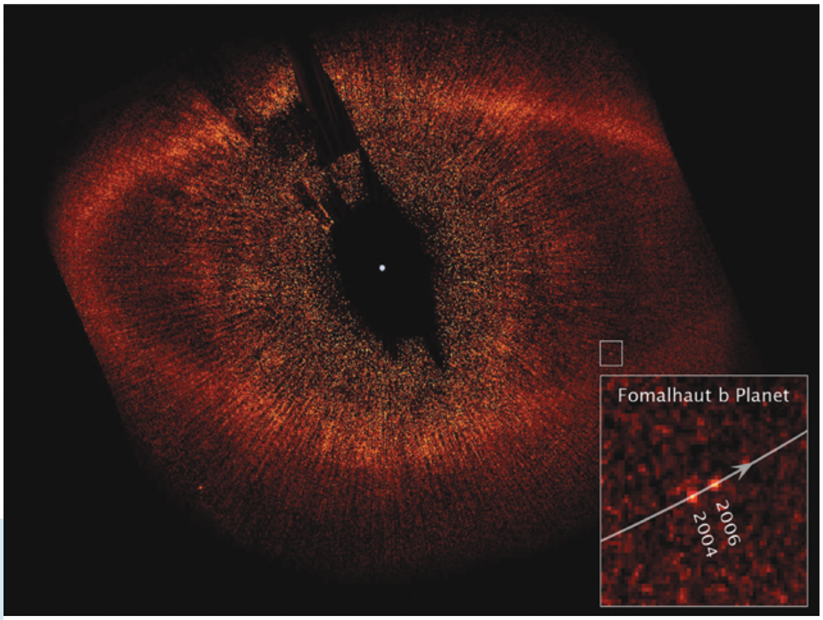
The paper's other authors are Alok Srivastava, a postdoc at the Institute for Systems Biology; Brian Yen, then a Caltech postdoc; postdoc Lidong Qin; grad students Habib Ahmad and Gabriel Kwong; and undergrads Chao Chao Liu and Julianne Gould. The work was funded by the National Cancer Institute and by the Institute for Collaborative Biotechnologies through a grant from the United States Army Research Office.

—KS e&s

PLANET, HO!

A team of scientists including two Caltech alumni and a brace of JPL staffers have used the Hubble Space Telescope to take the first-ever visible-light photo of a planet orbiting another star—Fomalhaut, a bright star about 25 light-years from Earth. The planet, estimated to be no more than three times Jupiter's mass, was found by comparing pictures of the debris ring around Fomalhaut taken two years apart. The first picture revealed several bright points in the ring that might have been planets; the second one showed one of them had moved.

The team includes UC Berkeley professors Paul Kalas, James Graham, and Eugene Chiang (PhD '00), Berkeley grad student Edwin Kite, Mark Clampin of NASA's Goddard Space Flight Center, Michael Fitzgerald of Lawrence Livermore National Laboratory, and JPL's Karl Stapelfeldt (PhD '91) and John Krist. *—DS* e&s



Fomalhaut has been a prime target for planet hunters ever since JPL's Infrared Astronomy Satellite (IRAS) found a region of excessive dust around it in the early '80s. This image was taken using the coronagraph in Hubble's Advanced Camera for Surveys, which blocks out the bright light of the central star (here represented by the white dot). The radial streaks in the image are glare from the star, but the bright ring is real dust, and its off-center shape suggested to Kalas that a planet might be "shepherding" it. That planet, Fomalhaut b, is about one billion times fainter than its star, has a calculated orbital period of 872 years, and is roughly 18 billion kilometers from its star, or 10 times the distance from Saturn to the sun.

Opposite, left to right: Ripples on an atomically smooth graphite surface. These images were taken 200 nanoseconds (billionths of a second), 500 nanoseconds, 10 microseconds (millionths of a second), and 30 microseconds after a laser set the atoms in motion.

PASS THE POPCORN

More than a century ago, movies brought still photographs to life. Now the same thing has been done at Caltech on the atomic scale—the first real-time, real-space views of fleeting changes on a tract of crystalline real estate barely a billionth of a meter on edge. The making of such "movies" starring gold and graphite is described in the November 21 issue of *Science*. (The movies themselves can be found at http://ust.caltech.edu/movie_gallery/.) The new technique, dubbed four-dimensional (4D) electron microscopy, was developed at Caltech's Physical Biology Center for Ultrafast Science and Technology, directed by Ahmed Zewail, the Pauling Professor of Chemistry and professor of physics, and winner of the 1999 Nobel Prize in Chemistry.

Zewail was awarded the Nobel Prize for pioneering the science of femtochemistry, the use of ultrashort laser flashes to observe fundamental chemical reactions—atoms uniting into molecules, or breaking apart back into atoms—occurring at femtosecond timescales. (A femtosecond, or 10^{-15} seconds, is one millionth of a billionth of a second. To grasp how incredibly evanescent this is, consider that it takes a beam of light one second to travel from Earth to the moon. In a femtosecond, light goes one one-hundredth the thickness of your eyelash.) The work "captured atoms and molecules in motion," Zewail says, akin to the freeze-frame sequences snapped by 19th-century photographer Eadweard Muybridge of a trotting horse that proved for the first time that it does indeed lift all four hooves off the ground as it trots.

Snapshots of molecules in motion "gave us the time dimension," Zewail says, "but what we didn't have was the dimensions of space, the structure. We didn't know what the horse looked like. Did it have a long tail? Beautiful eyes? My dream since 1999 was to come up with a way to look not just at time but also at the spatial domain."

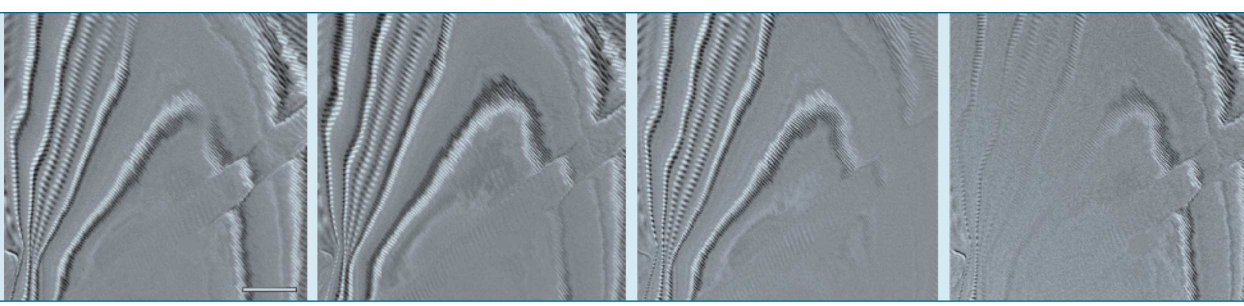
The system uses a high-resolution transmission electron microscope, which "illuminates" the specimen with a stream of electrons to produce an image. In order to be "seen," a feature on the specimen must be significantly larger than the wavelength of the "light"—in this case, the electron beam—illuminating it. Because the wavelength of an electron shrinks as its velocity increases, very tiny things indeed can be seen with electrons that have been accelerated to dizzying speeds.

But this isn't enough—the electrons have to be carefully doled out so that they arrive at the sample at specific times. This is achieved by precisely timed laser pulses that individually control every electron's trajectory through time and space.

The image produced by each electron represents a femtosecond still photo. Like the frames in a film, many millions of such images can be assembled into a digital movie of atomic-scale motion.

Zewail and colleagues applied the technique to superthin sheets of gold and graphite, the form of carbon in pencil lead. They would zap the specimen with a femtosecond laser pulse that caused heat-induced stress in the material, and then watch as the atoms moved in response.

Graphite is particularly interesting because its atoms are locked into sheet-like arrays. These sheets remain highly crystalline even when not much thicker than a single atom, making them a potentially very important item in the nanoengineer's toolkit—for example, as ultrathin resonators. These experiments were done on samples some 200 atoms thick and a few



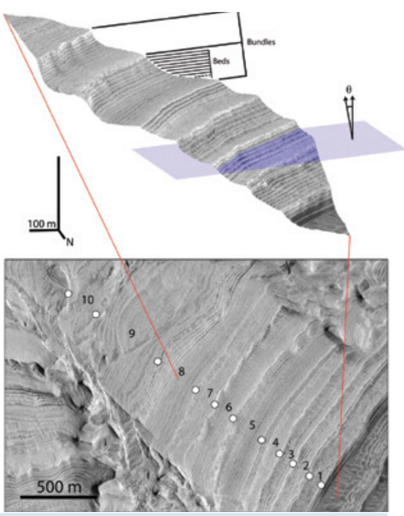
From Oh Hoon Kwon, et al., *Nano Letters*, Vol. 8, No. 11, pp. 3557–62, November 2008. © Copyright 2008, American Chemical Society.

millionths of a meter wide. Three different behaviors were found, on three different timescales. "The behavior evolves with time," says postdoc Brett Barwick, the lead author of the *Science* paper. "If you could keep watching the same sample, you'd see it do all three things, one after the other."

When the atoms first get blasted by the laser, the heat sets them into random individual vibrations. But neighboring atoms begin to synchronize with each other on femtosecond timescales, and in picoseconds (a picosecond is 10^{-12} seconds, or one thousandth of a billionth of a second), sound waves begin to reverberate back and forth through the sample's thickness. Each little patch of the sample's surface vibrates at its own frequency, but a companion paper by postdoc Oh Hoon Kwon in the November 2008 issue of *Nano Letters* describes how, as the picoseconds drag into microseconds (millionths of a second), the patches slowly lock into phase with one another, and the oscillations travel the width of the sample, going back and forth across the surface in a heartbeat-like "drumming." The papers were co-authored with J. Spencer Baskin (PhD '90), senior scientist; Hyun Soon Park, senior postdoctoral scholar; and Zewail.

"With this 4D imaging technique the atomic-scale motions that lead to structural, morphological, and nanomechanical phenomena, can now be visualized directly, and hopefully understood," says Zewail, who is now expanding the research to biological imaging within cells in collaboration with Associate Professor of Biology Grant Jensen. (See *E&S* 2006, No. 2.) The researchers are looking at things such as proteins and ribosomes—the cellular machinery that makes proteins—trying to track their component parts as they move. —*KS/DS* e&s

From K. Lewis, et al., *Science*, Vol. 322, pp. 1532–5, December 5, 2008. © 2008, AAAS.



Stereographic analysis of photos from the HiRISE camera on the Mars Reconnaissance Orbiter allowed the topography of Becquerel crater (8° W, 22° N) to be reconstructed. Ten "bundles" of layered beds can be seen here. The individual beds are 3.6 ± 1 meters thick, and the bundles are 36 ± 9 meters thick.

ICE AGES ON MARS?

Some layered deposits on Mars may have been caused by regular variations in the planet's tilt. On Earth, similar "astronomical forcing" drives ice-age cycles. Grad student Kevin Lewis and Oded Aharonson, associate professor of planetary science, along with John Grotzinger, the Jones Professor of Geology, examined outcrops in four craters in the Arabia Terra region and found that each set of layers have similar thicknesses and similar features.

The scientists propose that each layer was formed over a period of about 100,000 years, corresponding to a change in the tilt of Mars's axis by tens of degrees analogous to the (smaller) Milankovitch cycles on Earth. When the axis is near vertical, the sun hovers over the equator and the poles stay cold. This would cause volatiles in the atmosphere, like water and carbon dioxide, to migrate poleward, where they'd be locked up as ice.

As the axis tilts, the poles get relatively more sunlight, and those materials would migrate away. "If you move carbon dioxide away from the poles, the atmospheric pressure would increase, which may cause a difference in the ability of winds to transport and deposit sand," explaining the layering, Aharonson says.

Groups of 10 layers are bundled into larger units that were laid down over approximately million-year periods. This corresponds to a known modulation in the tilt cycle caused by solar-system dynamics.

Lewis is the lead author on the paper, which appeared in the December 5 issue of *Science*. Other authors include Randolph Kirk (MS '84, PhD '87), of the U.S. Geological Survey; Alfred McEwen of the University of Arizona, and Caltech staff member Terry-Ann Suer. —*KS* e&s

The Friday morning crew. Putnam, in a brown baseball cap, is seated in the foreground. Kelzenberg is standing second from right, wearing a cowboy hat.

STUDENTS GO SOLAR

Even as the Caltech administration launches big-ticket sustainability projects, there are grassroots endeavors as well. The roof of the Watson Laboratories of Applied Physics sprouted a 72-panel solar array the week before Thanksgiving, thanks to the newly formed Caltech Student Solar Initiative (CSSI). About 80 undergrads, grad students, and postdocs laid out solar panels, bolted them to their supports, wired them up, and schlepped cinder blocks between November 19 and 21—"We had as many people as we could manage," says Morgan Putnam (MS '08), the project leader.

Putnam and Michael Kelzenberg (MS '06), the lead project engineer, are keenly interested in solar power. When not clambering around on rooftops, they're grad students in the lab of Harry Atwater, the Hughes Professor and professor of applied physics and materials science, and work on developing silicon microwires that could be used as solar cells. (The Atwater group, coincidentally, lives in the Watson Labs.)

The project was student-designed and executed as much as possible. Kelzenberg handled the array layout and wiring, while Putnam worked out the details of the cinderblock ballasting system that keeps the arrays in place without having to drill holes in the roof. Says Kelzenberg, "Students contacted suppliers, designed the array, and [junior] Daryl Coleman filed the application for the rebate" with Pasadena Water & Power that will pay back about half of the $118,000 materials and installation cost.

Grad student Amy Hofmann (MS '08) organized and submitted the CSSI's application to the Moore-Hufstedler Fund for Student Life, which will cover another $32,000 of the initial installation costs. Says Putnam, "This was a large task, and Amy did a great job of assembling information from a large number of sources to produce a final product." Caltech's Facilities Department will cover the rest of the cost, while the Graduate Student Council chipped in $1,000 to feed the volunteers during the installation.

Facilities, particularly Mike Anchondo, the head of Caltech's electrical shop, donated a lot of help and expertise, says Kelzenberg. For example, Narinder "Nick" Grewal, the electrical engineer for physical plant, double-checked the rebate application. Adds Putnam, "CSSI offers its sincere thanks for the generous support of Caltech Facilities. Nick Grewal and Mike Anchondo helped field electrical questions. Don Thomas helped with roofing concerns. Kalman 'Lee' Benuska handled seismic and wind-loading concerns. Bill Irwin and Kenneth Hargreaves helped with long-term planning and project planning. Most importantly, Jim Cowell [Associate VP, Facilities] and John Onderdonk [Sustainability Program manager] fielded questions across a spectrum of topics. Their offices were always open."

"This is the only Caltech-owned solar array on campus," says Kelzenberg. "There are larger, more expensive arrays, such as the one on the roof of the Holliston parking structure, but Caltech actually leases these roof areas to outside companies, who own the solar panels. Caltech then buys the power. Here, Caltech owns the panels, and all the power they produce."

The array will put out an estimated 13.7 kilowatts at peak—that is, at noon on a sunny day. Year round, this is expected to amount to about 23,000 kilowatt-hours of juice. The CSSI plans to sell this green energy in the form of 150 Renewable Energy Credits for 150 kilowatts each—

Atwater postdocs Dierdre O'Carroll and Marina Leite install the support structure on the back of a solar panel.

"enough to run your laptop for one year," says Putnam—which students can buy for $20. The proceeds will go into a student sustainability account to fund future projects.

Including the Holliston parking structure array, which went online November 4, Caltech Facilities plans to install 1.4 megawatts of solar power over the next 12 months. These arrays will be atop the two Wilson Avenue parking structures, the Braun Athletic Center, the Infrared Processing and Analysis Center, Baxter Hall of the Humanities and Social Sciences, and the new Cahill Center for Astronomy and Astrophysics.

The CSSI hopes to add to the total, using the roofs of smaller, more oddly shaped buildings. Says Putnam, "These small projects are very labor-intensive, and therefore amenable to student activity. And with the group we have now trained, we could do a lot more very easily." Kelzenberg agrees, "We could do it again with half of the effort, if we get more funding. There are lots of smaller roofs all over campus that students could do this way." —*DS* e&s

NEW ENERGY FOR MECHANICAL ENGINEERING

Author Tom Friedman leveled his gaze at a lunchtime assemblage of Caltech faculty, students, and friends and threw down the gauntlet: "Only Caltechs are going to get us out of this problem," he said. He was talking about three problems, really, that he views as one giant Gordian knot: climate change, the global economic crisis, and America's dented world leadership. During his most recent campus visit, the writer of the best sellers *Hot, Flat, and Crowded* and *The World Is Flat*, not to mention innumerable "most e-mailed" articles in the *New York Times*, joined Argyros Professor and professor of chemistry Nate Lewis (BS, MS '77)—a principal investigator in the Caltech Center for Sustainable Energy Research (CCSER)—in a conversation about these problems. Friedman commented that America's research universities could help lead the way out of all three with one bold stroke. He's calling the solution ET—not the alien darling of the '80s, but energy technology, the challenge of the Aughts. "The motto for America," he quipped, "should be 'Invent, Baby, Invent.'"

Invent we will. Caltech already boasts programs like CCSER, which focuses on solar energy, and the Linde Center for Global Environmental Science. These have now been joined by an Energy Engineering Initiative, which was funded as part of a $10 million gift from the Gates Frontiers Fund this September that established the Charles C. Gates Center for Mechanical Engineering.

"One is tempted to say that energy is *the* technological challenge facing engineering," says Kaushik Bhattacharya, professor of mechanics and materials science and executive officer for mechanical engineering. "The scale and magnitude of the numbers involved make the problem very hard to grapple with—the amount of energy used, the time horizons on which investments are made. Decisions we're making today will tie our hands in the future. The challenges we're facing are such that we have to invest in completely new technologies, but at the same time, we have to address

The solar array atop the Holliston parking structure, installed and operated by El Solutions, will crank out some 320,000 kilowatt-hours (kWh) per year, earning a $0.632/kWh rebate from Pasadena Water & Power—and it provides shaded rooftop parking.

the intermediate time scale."

Solving these problems requires expertise in many disciplines, but that only whets the appetite of Caltech's ME faculty, which has a staggering intellectual diversity. Fourteen of the 19 professors have joint appointments in other fields, from geophysics to materials science.

The initiative will attract new faculty, students, and postdoctoral scholars with their own ideas and research emphases. It will also expand existing ME interests in areas such as fuel cells and nuclear energy.

Professor of Mechanical Engineering and Applied Physics Dave Goodwin's group models and develops materials for advanced fuel cells, which can be used for stationary power generation and for automotive power. Goodwin's models—created with a widely used software package called Cantera that he developed to model chemically reacting flows—predict that solid-oxide fuel cells (SOFCs) could be vastly improved by engineering their structures at micrometer and nanometer scales. In SOFCs, oxygen ions flow through a ceramic electrolyte to oxidize hydrogen in the fuel. The cells make electricity from a variety of fuels already well established in the market, including methanol, ethanol, methane, propane, coal-derived syngas, or even diesel reformate. To maximize the amount of electricity produced from these fuels at the power-plant scale, Goodwin's group is engineering the architecture of the electrodes using nanowires and nanoparticles to build a three-dimensional, ion-conducting lattice framework that provides easy ion flow and allows rapid gas transport through the electrode. Through their efforts, in combination with those of researchers in CCSER and other Caltech programs, ME researchers hope that fuel cells will become an ideal source of electricity: superefficient, fuel-flexible, and, eventually, powered by clean, renewable fuels such as hydrogen electrolyzed from water by sunlight (see *E&S* No. 2, 2008).

Several faculty members are addressing what Bhattacharya calls the "show-stopping problems" associated with nuclear energy. With Michael Ortiz, the Hayman Professor of Aeronautics and Mechanical Engineering, Bhattacharya is working to make reactor vessels last longer in the face of bombardment by high-energy neutrons. This would remove a bottleneck in building reactors that reprocess spent uranium to generate their own fuel. Meanwhile, Hayman Professor of Mechanical Engineering Chris Brennen's work improves several energy technologies, including nuclear reactors. He wrote the book (the two key books, actually) on cavitating flows, whose tiny bubbles collapse with trip-hammer force to chew through valve, propeller, engine, turbine, and pump blades. And Joe Shepherd (PhD '81), the Johnson Professor of Aeronautics and professor of mechanical engineering, studies what happens when things go seriously wrong—from deflagrations, ordinary fires that spread at subsonic speed through heat transfer, to detonations, their supersonic kin that spread through shock waves.

The initiative will also support research not yet under way. For instance, engineers will be able to collaborate with geophysicists and atmospheric scientists on carbon sequestration—keeping carbon out of the atmosphere by storing it underground—and with information science and technology experts on designing smart power grids, which use digital technology such as sensors and two-way communication to improve the transmission and distribution of electricity from myriad decentralized sources, bypassing traffic jams and cable breaks. Graduate students and undergraduates interested in wind power, solar-thermal energy, and other technologies will be able to design research projects based in ME that draw on talent and resources across several academic divisions.

The Gates Frontiers Fund gift will help support a planned renovation of the postwar Franklin Thomas Laboratory into a state-of-the-art research and teaching facility. Taking a leaf from the successful renovation of GALCIT's home (see *E&S* No. 1, 2008), Caltech plans to rehabilitate the landmark building rather than build a new lab. Still, another $10 million will be needed to recruit key people and complete the renovation.

The late Charles C. Gates, a Caltech trustee for 25 years, felt that Caltech excelled at solving complex problems and getting the solutions to market, and he relished the faculty's disregard for disciplinary boundaries. His daughter, Diane G. Wallach, remembers that he kept up with every aspect of science at Caltech, reading each issue of this magazine cover to cover. A conservationist who loved the outdoors, Gates would have appreciated the environmental aims of the Energy Engineering Initiative. Even more, though, he would have liked its multifaceted approach. "My father felt that Caltech did things differently than other prominent universities. He liked the concentration of energy going into science and technology, and loved Caltech's focus on the hard sciences. He was an engineer himself, and believed that mechanical engineering should cut across all the disciplines, that we have to get people from all these areas into the same room, get them talking to each other to solve problems. This gift will help make that happen." —*AW* e&s

BECALMED?

The solar wind has apparently become just a solar breeze. New data from the Ulysses spacecraft shows that the solar wind has lost power, which has exposed the solar system to more cosmic rays. The data also reveals that the wind and the sun's magnetic field are more intimately related than previously thought, shedding light on how the wind is produced. "Ulysses has provided a new constraint on the origin of the solar wind," says JPL's Ed Smith, project scientist for the mission. "The data provides us with a new view of what's going on at the source."

Made of charged particles gushing from the sun's outer atmosphere—called the corona—at hundreds of kilometers per second, the solar wind reaches billions of kilometers away. The sun's magnetic field, however, keeps the particles trapped within the corona at first, preventing the wind from escaping. Scientists used to think that the pressure of the wind would grow until it broke free from the magnetic field, like a flock of sheep escaping by pushing open the gate to their pen.

But Ulysses is finding that the solar-wind flux—that is, how many particles spew out per second—is proportional to the strength of the sun's magnetic field. This relationship suggests a different understanding of how the wind blows. "The magnetic field plays not only an important role, but a dominant role," Smith explains. Magnetic field lines emanate from the sun and curve back toward it, forming loops that hold in the wind's charged

FOUR FOR TWENTY

This year's Discover 50, an annual list of the "best brains in science" published by *Discover* magazine, features four Caltech "young visionaries" in the article titled "20 Under 40"—Assistant Professor of Biology and Applied Physics Michael Elowitz; Assistant Professor of Biology Sarkis Mazmanian; Associate Professor of Environmental Science and Engineering Tapio Schneider; and Assistant Professor of Electrical Engineering and Bioengineering Changhuei Yang.

Elowitz designs and builds cellular "circuits," as described in *E&S* No. 1, 2008. Mazmanian studies the "good" bacteria that live in our guts and symbiotically help our immune systems keep us healthy. Schneider makes computer models of the complex effects of atmospheric turbulence and heat transfer on global climate change. And Yang has built a lensless microscope-on-a-chip that could be incorporated into a pocket-sized device for analyzing blood samples or potable water supplies in the developing world.

UCLA, Harvard, and MIT were the only other institutions having more than one person on the list, with two each.—*DS* e&s

particles. The sun's field is irregular and dynamic, however, and sometimes those loops break. When they do, they release the wind into space. In other words, the gate opens by itself to let the sheep roam free. The solar-wind flux is analogous to the number of sheep, and the strength of the magnetic field is analogous to how wide the gate opens. The correlation between the wind and magnetic field must now be taken into account in future computer models, Smith says.

Once released, the wind reaches far beyond the edge of the solar system, where it slams into particles from other stars—the interstellar wind—forming the boundary of a huge bubble called the heliosphere. Because it's kept inflated by the solar wind, the heliosphere shields the solar system from cosmic rays.

In September, Ulysses scientists announced that the pressure of the solar wind has waned 20 percent since the mid-1990s. The wind hasn't slowed down much, losing only 3 percent of its speed, but it's 13 percent cooler and 20 percent less dense. The lack of pressure causes the heliosphere to deflate and weaken, allowing more cosmic rays to pass through. The sun's magnetic field has also diminished by 30 percent, further crippling the heliosphere.

We're protected by Earth's atmosphere and magnetic field, so those of us on the ground don't have anything to worry about. But a surge in cosmic rays could pose a threat to astronauts, who would need more protection against the damaging radiation, as would spacecraft and satellites in high-Earth orbit.

A shrunken heliosphere also explains Voyager 2's findings. In the beginning of September 2007, the spacecraft crossed the heliosphere boundary, called the termination shock, earlier than researchers had anticipated.

It's unclear what a quieter solar wind means. After all, scientists have only been studying the wind since the dawn of the space age a mere 50 years ago. Launched in 1990 and operated from JPL by NASA and ESA, Ulysses circles the sun, studying how solar activity changes along different solar latitudes, from pole to pole.
—*MW*

The Ulysses spacecraft is in a polar orbit around the sun, allowing complete three-dimensional observations of the solar wind and the near-solar region to be made. An instrument called Solar Wind Observations Over the Poles of the Sun (SWOOPS) records the solar wind's "dynamic pressure," a measure of its kinetic energy. The outer white circle around the sun represents a pressure of five nanopascals, or billionths of a pascal; the inner one is one nanopascal. (A pascal, of course, is a force of one newton per square meter. But you knew that.) The colored lines trace the dynamic pressures observed.
The background images of the sun are from NASA's Solar and Heliospheric Observatory (SOHO).