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Caltech News

Volume 38, Number 2
2004

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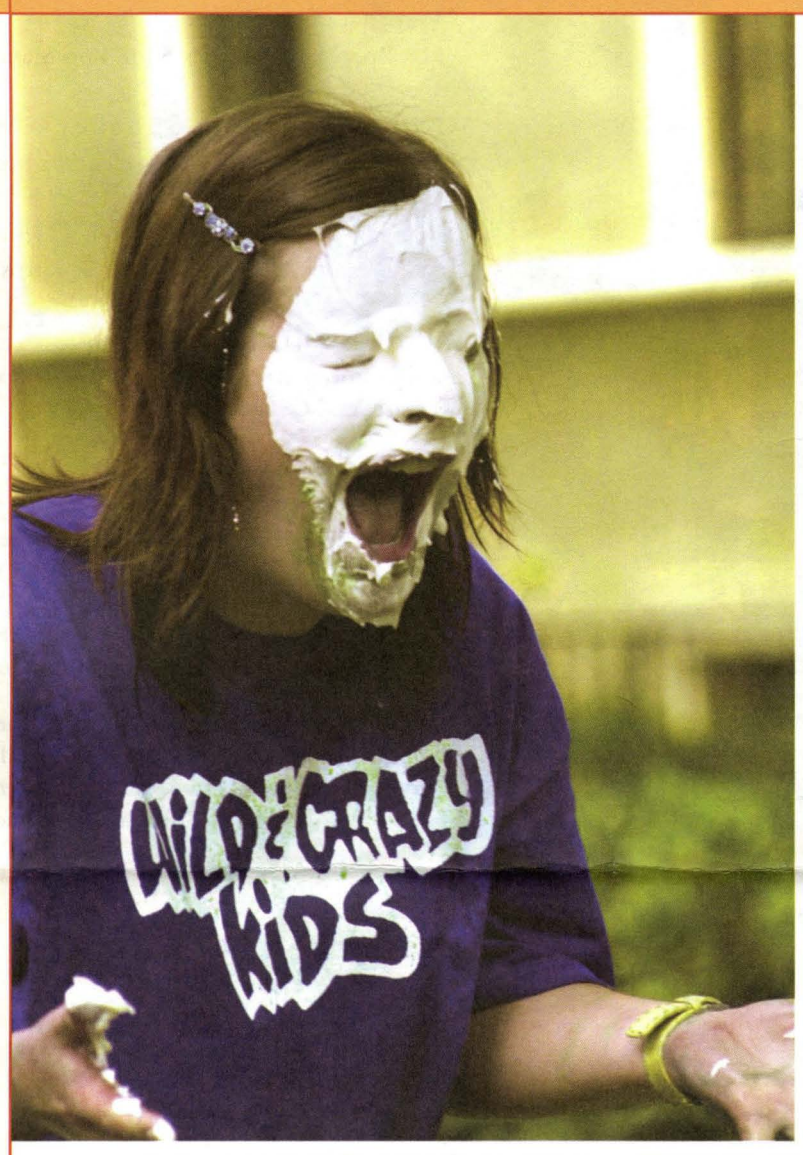

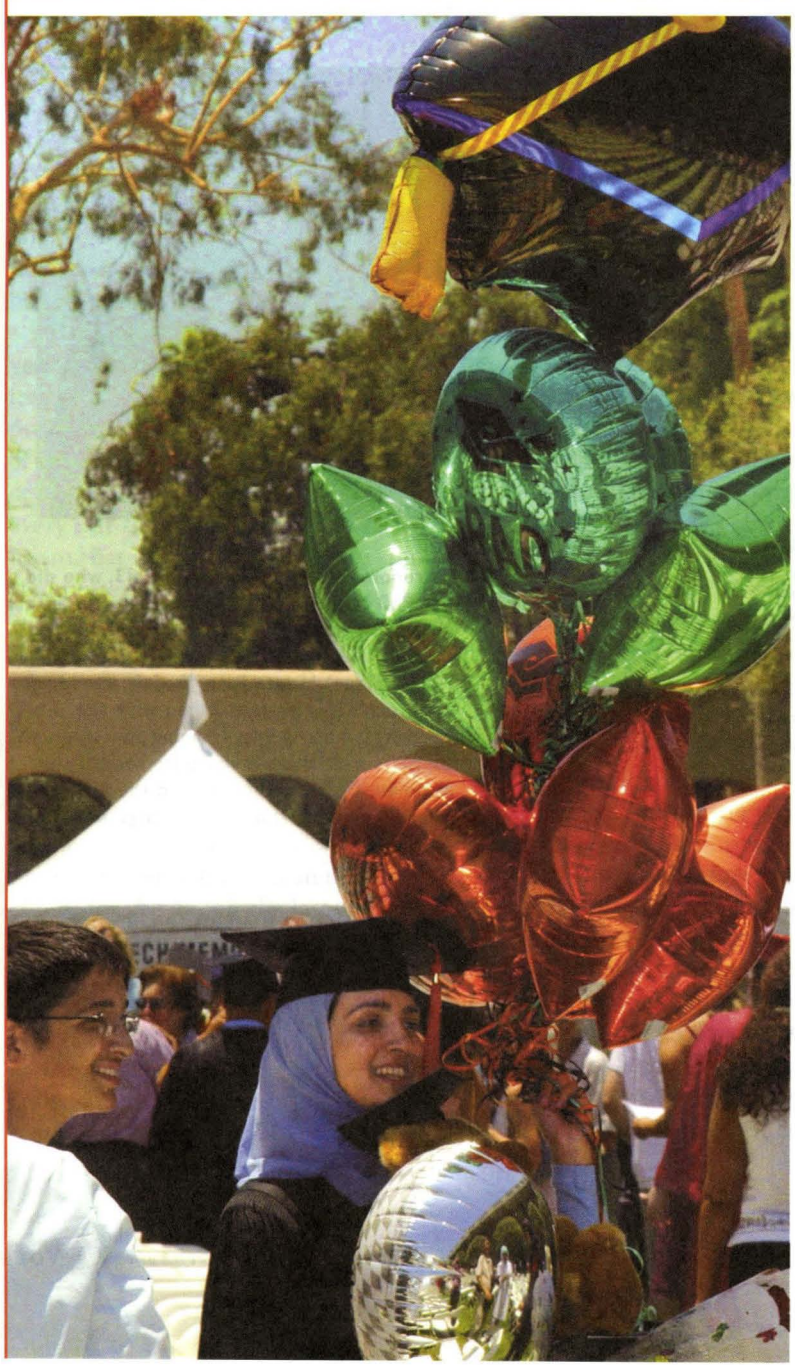

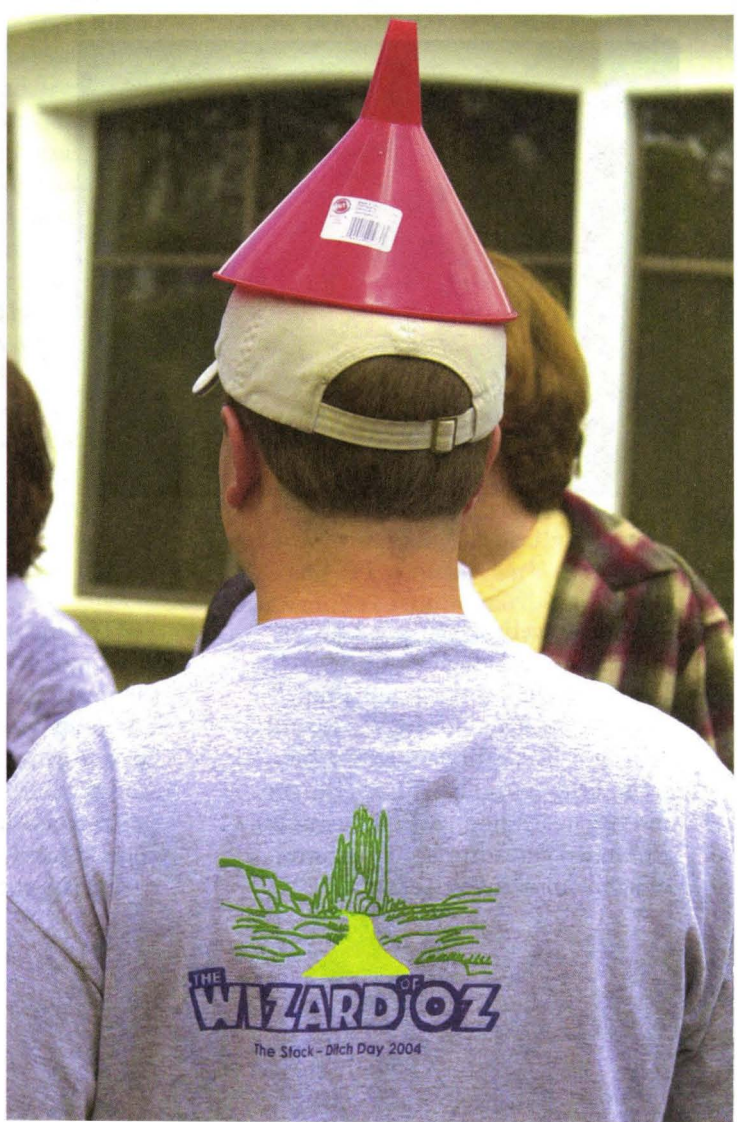

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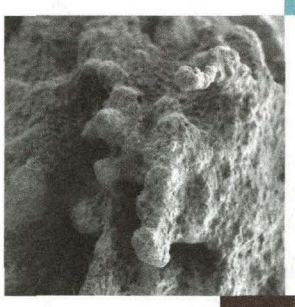

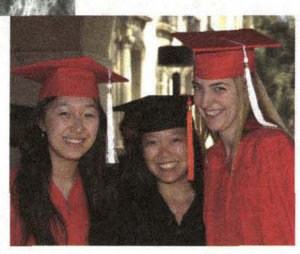

ON THE COVER
Caltech students enjoy their annual rites of passage—the far-out pranks of Ditch Day (top left, bottom right) and the festivities and felines of commencement (top right, bottom left). Read more about this year's graduation ceremony on page 4.

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Up Front

Rings around Cassini

Astronomer Carolyn Porco, PhD '83, who did her PhD research at Caltech on Saturn and its rings, now heads the imaging team for Cassini, which went into orbit around the ringed planet in late June. At left, the image of Saturn's ring system, taken with the spacecraft's Ultraviolet Imaging Spectrograph, suggests that there is more ice toward the outer part of the rings than in the inner part, offering possible clues to the rings' origins and evolution.

After traveling nearly 2.2 billion miles since its launch on October 15, 1997, the Cassini spacecraft slipped through the F and G rings of Saturn on June 30, successfully entered orbit around the sixth planet from the sun, and began sending back pictures that astounded and surprised an international team of investigators.

"The images are mind-blowing," said Carolyn Porco, PhD '83, who leads the imaging team from NASA, the European Space Agency, and the Italian Space Agency, which joined forces to send the bus-sized spacecraft to the sun's second-largest planet at a cost of approximately $3.3 billion. At a press conference at the Jet Propulsion Laboratory, which is managing the mission, Porco said that the level of detail and clarity in the images of the rings was better than she expected.

"Even though we had a long time to plan, I'm surprised at how surprised I am at the images," said Porco, who analyzed images of Saturn and its rings taken by Voyager 1 in 1980 while she was a Caltech graduate student. The Cassini images were so shockingly clear, Porco said, "that I thought the team was showing me simulations of the rings and not the actual rings themselves."

Porco said that she was particularly surprised by a close-up that showed an unexpected straw-like pattern in one region and another image that revealed startlingly detailed structure on the edge of a gap. "We're seeing structures that have never been imaged before," said Porco, an adjunct professor at the University of Arizona in Tucson and the University of Colorado in Boulder, and director of the Cassini Imaging Central Laboratory for Operations (CICLOPS). "These images will help us determine the properties of the rings and the particles in them, and will vastly improve our theories of how they behave."

The last time that spacecraft took pictures of Saturn was more than 20 years ago during the Voyager 1 and Voyager 2 flybys in 1980 and 1981, respectively. Porco said that Cassini's imaging instrument provides "inher-

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Rob Manning points out rover features in the sandbox, aka JPL's Mars-on-Earth testbed, whose walls are covered in camouflage to add visual complexity to the test environment.

Man on a Mission

Fueled by lack of sleep and loads of challenges, JPL engineer Rob Manning rides the Red Eye to the Red Planet

By Rhonda Hillbery

When Rob Manning '82 ebulliently proclaimed January 24, 2004, "a great night for the solar system," just after shepherding the Mars Exploration Rover (MER) Opportunity to a happy landing on the Red Planet, his beard looked a lot grayer than the last time he starred in a Mars mission.

It's not just because it's been six years since Manning helped design and lead the hugely successful Pathfinder project. He can also point to the stress of the MER mission's daunting development timetable, one that called on every last reserve of energy and optimism that this veteran of Mars exploration possesses.

A self-declared JPL lifer, Manning began working at the Pasadena lab while he was still a Caltech undergraduate, majoring in engineering. Since then, he's spent most of his career on Red Planet missions, managing to dodge the disasters while riding the winners. His success as chief engineer on Pathfinder made him an obvious choice for the job on the larger, more ambitious MER project. As systems engineering manager for the Opportunity and Spirit mission rovers, Manning oversaw the design, development, and testing of all aspects of the spacecraft, and also managed the entry, descent, and landing (EDL) operations.

Fast forward to MER mission control, nearly five months after the Opportunity landing. It's a beautiful May morning on Earth, and sol (day) 129 for the rover Spirit, which is now approaching the Martian Columbia Hills. As JPL drivers direct Spirit and Opportunity to their latest destinations, geoscientists in shorts and sandals cluster around images of rocks. Surrounding them are tables strewn with examples of RATs (rock-abrasion tools) and brushes, as well as thermal inertia maps whose riotous hues bring to mind Georgia O'Keefe's abstract flower paintings. The brilliant false-color spectrum, ranging from red to fuchsia, and lilac to turquoise, indicates how much heat is being retained by diverse rocks and sand layers on the Martian surface, a place known to plunge to -199 degrees F on its coldest nights.

Manning stops to don a pair of 3-D goggles—the better to monitor Spirit's progress on a computer screen—and chats with a colleague monitoring the rover, which has now been driven a distance of nearly 1.5 miles from its landing site. "If you had told me we could go this far I wouldn't have believed it," Manning enthuses as he heads down the hall past an empty ice-cream freezer, once filled with Dove bars that helped MER personnel—at least symbolically—ward off stress meltdowns. With many months of hard work now safely behind him, he talks about some of the mission's highlights, tensest moments, and what it all means to him now that he's almost caught up on his sleep.

An improbable timetable

It was the dawn of a new millennium, and NASA and JPL needed a Mars win after the embarrassing mishaps that had doomed Mars Climate Orbiter and Mars Polar Lander in 1999. The next realistic mission window would arrive in four years, when a 2003 launch followed by a 2004 landing would take advantage of an alignment that placed Mars closer to Earth than it had been in 60,000 years. Two years or even four years after that, conditions wouldn't be nearly as good.

Could JPL come up with a project that wouldn't require starting from scratch, one that would build upon earlier missions?

Manning's fellow Caltech alum, Mark Adler, PhD '90, had the job of Mars Exploration Program architect, overseeing a series of Mars missions. After considering several ideas, Adler

Continued on page 6 . . .

Commencement speaker urges Caltech graduates to reach out

Any chief executive of a Fortune 500 company should know the value of authoritative market research. So perhaps it is not surprising that prior to giving the commencement address at Caltech's 110th graduation ceremony, Carly Fiorina, the chairman and CEO of computing giant HP, recruited Caltech's graduating seniors to help her craft a message.

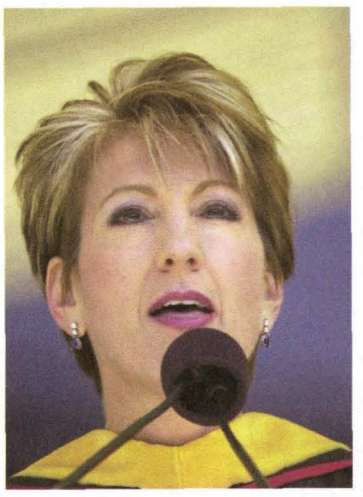
On a sunny June 11 on Caltech's Beckman Mall, Fiorina told the crowd of Institute students, alumni, faculty, family members, and friends that back in May she had sent an e-mail message to members of the class of 2004, asking how they imagined that greatness would be defined for their generation.

Reporting on the results of that informal survey in her commencement speech, Fiorina said that many students thought that solving environmental problems would be a task worthy of high praise. Other definitions of greatness included teaching people to consume less, building bridges between cultures, and using science to improve the human condition. But Fiorina's point wasn't expressly to highlight the ways in which Caltech's newest graduates are poised to change the world. It was about convincing them that if they really want to be productive citizens of that world, they must find ways to use their Caltech training to help others to understand how science works and why it is beneficial.

There are "too many public debates about too many issues having to do with science and technology in which politicians have a voice, lawyers have a voice, lobbyists have a voice, journalists have a voice, religious leaders have a voice, but the people most responsible for making change—the scientists and technologists—don't have a voice, because they have chosen not to represent their views in a public forum," she said.

"In part, I think it stems from the 'why bother' school of public discourse, which states that most people don't have a very deep interest in or knowledge of science and technology and so why bother taking the time to explain or make understandable the most difficult science."

On a day when Caltech awarded 166 PhD degrees, two engineer's degrees, 156 MS degrees, and 208 BS degrees, there was a particular timeliness to Fiorina's message about communication. Caltech's commencement exercises took place as the country marked the funeral of former president Ronald Reagan with a national day of mourning. The media had spent much of the week commenting on Reagan's ability to connect with people from all walks of life—even those who didn't support his policies. Caltech's commencement crowd paid tribute to Reagan with a moment of silence, after which Board of Trustees Chair Ben Rosen '54 also requested a moment of silence to honor the memory of one of Caltech's most distinguished and devoted alumni, Arnold Beckman, PhD '28, who had died in May.



Carly Fiorina, CEO of HP, addresses the Institute's graduates at Caltech's 110th commencement ceremony on June 11.

Rosen, one could say, has a vested interest in commencement speaker Fiorina. For 18 years, he served as chairman of Compaq Computer Corporation, retiring in October 2000. Less than a year later, HP and Compaq announced a merger agreement.

In her remarks, Fiorina said that while science and technology never stop advancing, the public's understanding of these developments is not keeping pace with progress. "Every year that science and technology cross another divide, is another year that the gap between what scientists know and what the public knows grows wider. In some ways, the Silicon Valley of the 20th century has given way to the scientific canyon of the 21st century, with scientists on one side, the general public on the other, and too few guides who can bring us safely across from one side to the other."

While Fiorina acknowledged that it would be easy for Caltech's latest group of alumni to spend their lives doing innovative research in a community of scientists and engineers who all speak the same language, she urged them to also reach out to educate the nonscientific world. "We need you to help be [our] guides, because we will not be able to create the future we all want if the size of that canyon continues to grow wider."

There are "practical, ethical, and aspirational" reasons why the world needs scientists to explain science to the public, she said. The practical reason is that "before things get discovered, they need to get funded," and what gets funded will depend on scientists' "ability to help people see the benefits of scientific exploration." The ethical reason "is that our sense of right and wrong doesn't evolve as fast as our science and technology." Controversial science issues like cloning and stem-cell research "deserve to be considered on the basis of fact, and not fear. Unless the battle is joined by people who know the science, the debate will be controlled by the people who don't, and that will not serve any of us in the end."

The third reason why future scientists need to develop a public voice, said Fiorina, "is that scientists and inventors today possess a quality that is in short supply in this world, and that is the quality of unbounded optimism in the future and the belief that tomorrow can be better than today. After all, what other profession goes to work every day, trying to imagine something that has never been created before, works day and night to see that vision through from the conception to completion, fails 99 times out of 100, but never sees those attempts as failures, but as learning experiences to build upon and grow? That is exactly the kind of bold, persistent experimentation that built this nation, and ultimately it is this kind of creativity that will keep us strong in the 21st century.

"So what will define greatness for your generation?" she asked. "I believe it is to use the knowledge that you have earned here to find ways not only to connect computers but to connect people. Not only to bridge gaps in science but to bridge gaps between cultures. Not only to use numbers and formulas to create, but to use words to lead, and in the process to close that canyon between ignorance and understanding."

Communicating science was also on the mind of Caltech president David Baltimore. In his concluding remarks, he urged the graduates "to be true to what you have discovered" and "not allow political preconceptions to dominate over established knowledge. We must maintain the principle that the search for knowledge is a search for a factual basis on which to make decisions about public life. We must recognize that those decisions may be difficult ones and may present us with unpleasant alternatives. But to deny the truths of scientists to build a society on myths is to abdicate the responsibility that we have to generations that will come after us.

"Your training positions you to do more than make your own distinctive mark in your chosen field," he told the graduates. "Your special understanding of the role of science and technology in

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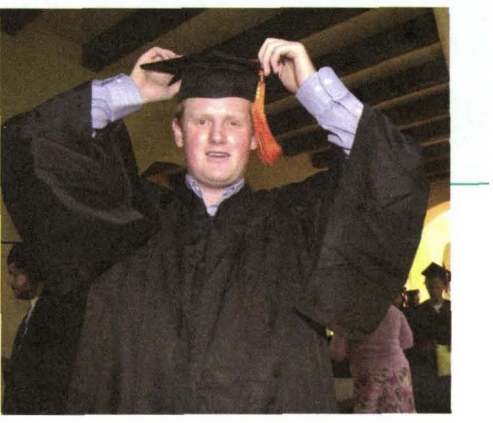
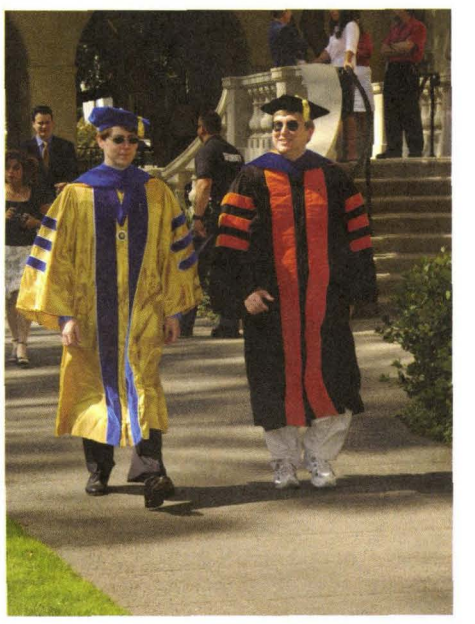
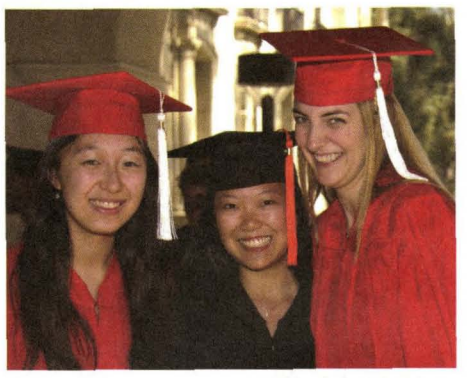
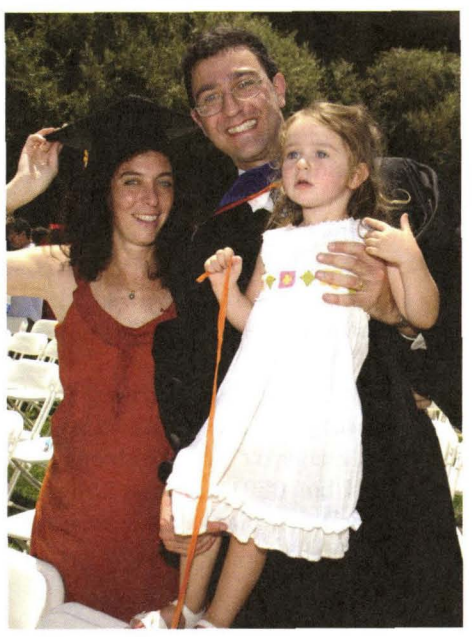








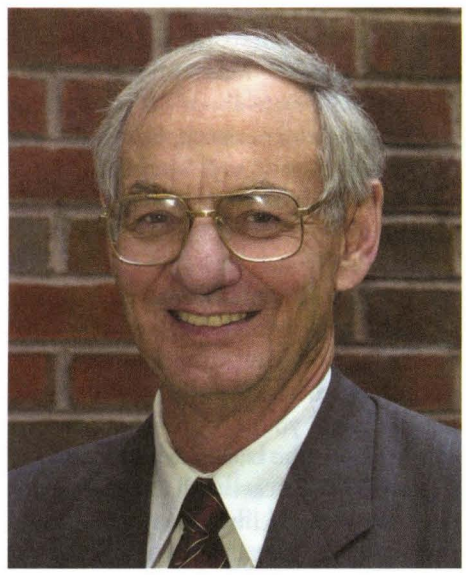
Now the trumpet summons Paul again

It would seem a safe bet to say that Caltech's recently appointed eighth provost, Paul Jennings, PhD '63, will pattern himself after the Institute's sixth provost—Paul Jennings, PhD '63. The emeritus professor of civil engineering and applied mechanics served as vice president and provost from 1989 through 1995. His return to Caltech's second highest administrative post follows the departure earlier this year of Steve Koonin '72, who took over from Jennings in 1995 and stepped down as provost earlier this year to become chief scientist of BP, formerly called British Petroleum, in London. Edward Stolper, chair of the Division of Geological and Planetary Sciences, served as acting provost from February through July.

Jennings, who resumed his duties as provost on August 1, said that he is excited to have his old job back, even though he acknowledged that it will likely cut into the extra time that he had recently enjoyed spending with his wife, Missy, as well as on his research, and on fishing—one of his favorite pastimes. "The call for Institute service tipped the balance," he said.

"Paul is an exciting choice," said Caltech president David Baltimore, who offered Jennings the job in late June. "At a time when so many things are happening on campus—the $1.4 billion capital campaign is in midstream, there are a number of building and renovation projects projected, there are budgetary challenges to be met—he brings a wealth of knowledge and experience to the office. He is an effective administrator, a great leader, and an eloquent spokesman. I personally enjoyed very much working with Paul when he filled in as acting vice president for business and finance a few years ago, and I look forward to having the opportunity to work closely with him again."

Jennings has spent 44 years of his life on the Caltech campus—as a student, professor, and administrator. After earning a BS from Colorado State University in 1958, he received both his MS and PhD from Caltech, in 1960 and 1963, respectively. He then taught at the U.S. Air Force Academy before returning to Caltech in 1965 as a research fellow in civil engineering, quickly moving up the academic ladder to become a full professor in 1972. Executive officer for civil engineering and applied mechanics from 1975 to 1980, Jennings was chair of the Division of Engineering and Applied Science from 1985 to 1989. He then served as provost before becoming acting vice president for business and finance in 1995 and for several months in 1998 and 1999. He has been an emeritus professor since 2002.



Paul Jennings, PhD '63, is moving back to his old office in Parsons-Gates Hall of Administration.

Besides his achievements as an administrator, Jennings is internationally renowned in the seismology and engineering fields as an expert on earthquake engineering, strong ground-motion studies, and seismic design of structures.

A member of the National Academy of Engineering and recipient of many other honors, he has served as president of both the Seismological Society of America (1980) and the Earthquake Engineering Research Institute (1981–1983). He also chaired the California Council on Science and Technology (1999–2002).

He currently chairs the National Research Council's Committee on Criteria for Management of Los Alamos and Lawrence Livermore National Laboratories, as well as the Pasadena City Hall Retrofit Oversight Committee, which monitors the seismic safety rehabilitation of Pasadena City Hall.

Jennings said that he was surprised when the provost search committee asked him in May if he would consider being a candidate. "I figured they'd want only active faculty members," he said, speaking by phone in early July from his vacation home in Colorado before heading to Japan for an earthquake engineering conference.

After meeting with the committee and then the president, he agreed to take the job, even though he knew it would mean turning his life around.

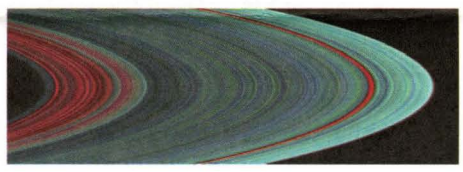
"I'm not the kind of guy who sits around and has nothing to do for six months," he said. "But I always felt that Caltech has been a special place, and I was willing to come out of retirement to help."

One of the main jobs of a provost is to recruit new faculty, and Jennings said that this will occupy much of his time. And even though he's been a fixture on campus for two generations, he said that he looks forward to spending time getting to know new faculty and reacquainting himself with the other members of the faculty. "I want to meet the new faculty and establish new communications among faculty and staff." The provost's job is practically a round-the-clock occupation, since it often involves entertaining faculty and others at home, which Jennings said that both he and Missy enjoyed during his previous tenure.

Jennings said that he expects to serve as provost a few years this time around. "I won't speculate about the exact time involved."

He said that he's more concerned now with getting started on the job than with getting back to retirement.

"There are many new exciting developments in research, including some in the biosciences and information technology programs, plus things in many other areas. In addition, Caltech is going through a period of transition, with many new projects happening because of the campaign. There's a new astrophysics building coming in, the rehab of Dabney Hall, and other capital projects. We have to absorb these changes and make them work."



Cassini . . . from page 2

ently 30 percent greater resolution," can photograph larger areas from the same distance, and can discriminate finer contrasts than the Voyager cameras. "And because Cassini is very much closer to the rings than spacecraft have ever been before, overall Cassini ring images are five times more detailed than those returned by Voyager."

The beauty of Saturn's rings—which are actually particles of ice contaminated by bits of rock—has captivated the human imagination since the 17th-century Dutch astronomer Christiaan Huygens first saw them, along with Saturn's enigmatic moon, Titan, through his telescope in the mid-1650s. (Galileo had actually glimpsed the rings roughly 50 years earlier when he was the first to look at Saturn through a telescope, but because of inferior optics he had been unable to determine exactly what he was seeing.) Today, astronomers and planetary scientists believe that the dynamics of Saturn and its ring system may serve as a model for the pre-planetary nebula—the disc of gas and dust around the young sun that ultimately formed the planets.

By studying the new pictures of the rings and comparing these with the images taken by the Voyagers, scientists "hope to study the processes that cause all the observable structure, and to see how the rings have changed, if at all, with an eye towards figuring out their rate of evolution and their age," Porco said. "The mission may help us understand the processes that occurred in the solar nebula before planets were formed, which may have aided in the formation of planets."

During its four-year mission, Cassini will circle Saturn approximately once every one to four months, in all snapping about 300,000 pictures of the planet, its moons, and rings. The mission is named after the French-Italian astronomer Jean-Dominique Cassini (1625–1712), who discovered four moons around Saturn, as well as a gap in the planet's ring system.

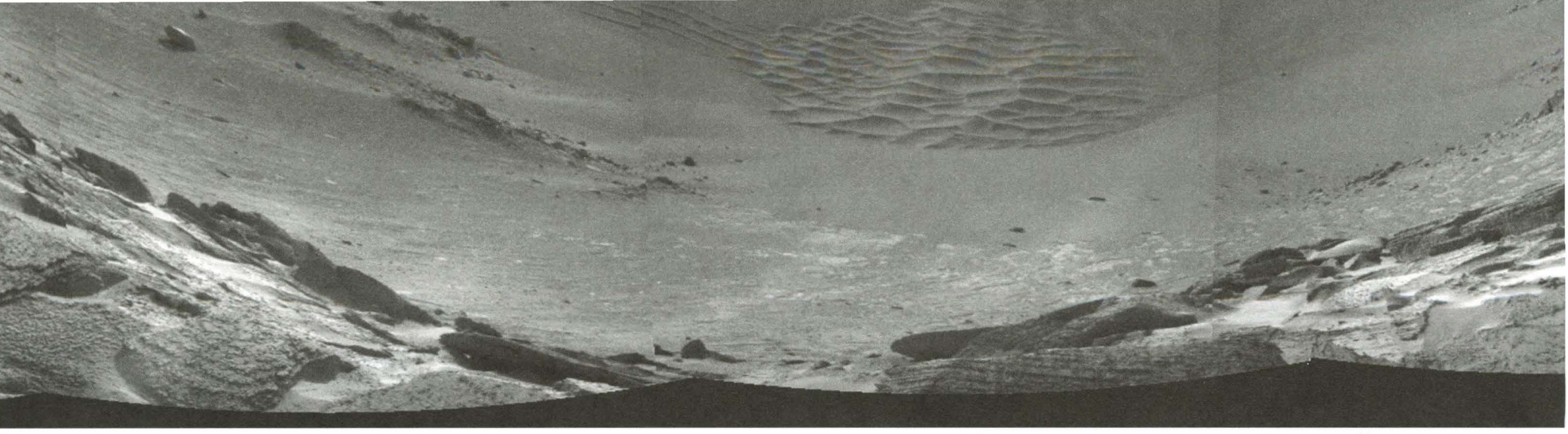
Although Saturn's rings have always fascinated amateur and professional sky watchers alike, many consider the real prize of the Cassini mission to be Titan—the largest of Saturn's 31 known moons—which has an atmosphere rich in organic material. Cassini is carrying along a probe, named for Huygens, which will be released in December before heading down to Titan in January.

Titan appears to be the only moon in the solar system with a significant atmosphere, but its surface remains largely shrouded in orange haze. As Huygens parachutes in, it will analyze the moon's weather and its clouds, and will look for lightning. Special instruments will examine Titan's surface after Huygens lands, assuming it survives the landing.

One scientist anxiously awaiting the Titan rendezvous is JPL director Charles Elachi, PhD '71, an imaging radar expert who heads the Cassini Titan radar team.

"I'm really interested in the surface of Titan," said Elachi. "Smaller than Mars but bigger than Mercury, it's a world in itself. This mission will give us a look through the haze for the first time. Some people think we'll see oceans of methane and methane rain." Elachi, who has been in charge of the Cassini Titan radar team since 1990, said, "I've moved on to other things since then, but with Cassini, I kept the fun part."

Mike Rogers



Manning . . . from page 3

proposed to Manning and a handful of others that he and Rob dust off an old idea bandied about years earlier. It piggybacked off Pathfinder, whose rover was the tiny but tenacious Sojourner.

A few weeks later, Adler, who would go on to become the Spirit mission manager, presented the MER proposal to NASA. Unlike Sojourner, the scenario called for converting the inside of the lander into a rover that could stand up, drive off, and roam free beyond the confines of the lander to operate as a robotic geologist. Less than two months later, NASA Administrator Dan Goldin suggested launching not one but two rovers.

The cruise, as well as the entry, descent, and landing design scheme borrowed from Pathfinder, called for encasing each golf-cart-sized rover in a cocoon of air bags inside a folded-up lander. Entering Martian gravity after a seven-month journey through space, each craft would jettison the bottom half of its protective aeroshell and ride a parachute to the surface. Meanwhile, deployment of the air bags would protect the landers from destruction on impact. It was essentially the same idea that Manning and the Pathfinder team had originated and implemented for Pathfinder, the last mission to successfully land on Mars, in 1997.

According to the plan, the rovers would spend at least three months probing the planet's surface, looking for signs that the planet at one time had possessed an environment capable of supporting life.

Manning's first instinct told him that despite the appeal of the Mars-Earth alignment timing, it was too late to pull off a 2003 launch. "But management really liked the idea," he recalls, and everyone figured that at least half of the design work was already completed.

At least that was the idea. By the time MER was green-lighted, the calendar read July 2000. That gave a team that had now grown to a little more than 100 engineers and scientists a window of less than three years to prepare for launch. The operation would be headed by yet another Caltecher, MER project manager Pete Theisinger '67. It was Theisinger, says Manning, who argued that the inspired notion of launching twin rovers would enable the mission to achieve economies of scale and time while also expanding research opportunities. Landing on opposite sides of Mars, the two rovers could go on to explore contrasting regions of the planet. Spirit's destination, Gusev Crater, stood halfway around the planet from Opportunity's target, Meridiani Planum, a smooth plain rich in hematite, an iron oxide mineral usually formed in association with liquid water.

It was an ingenious and appealing scheme. But as things turned out, MER ended up being far more complex than Pathfinder, which was developed over a comparatively leisurely four years.

The first months of work revealed the devil hidden in the details. "It was when we did the detailed engineering studies that we learned that although the mission looked like Pathfinder, almost everything had to change," Manning says. "We had little tweaks here and there to the point where we were basically redesigning every detail from scratch."

The MER team was also going through a growth spurt that would eventually top out at around 800 personnel. Rob's job was to directly supervise the 30 to 40 systems engineers who would make sure that all of the spacecraft pieces, once designed, worked together as they should.

Among the problems: The rovers rapidly grew too heavy for the air bags—as originally designed—to support them. So the air bags had to get bigger too. And as they consumed more space inside the spacecraft, that forced a redesign of some of the science instruments. It also called for larger lander petals and additional motors to enable the solar panels to unfold. Meanwhile, during a drop test with a heavier lander meant to simulate a successful Martian landing, the air bags were torn to shreds. Analyzing that disaster, Manning and his engineering colleagues concluded that the air bags had to be redesigned.

"It became what I call an origami spacecraft," Manning says. "It was a mess. The team had to work longer and longer hours." At the same time, because of planetary alignments, the launch date couldn't be pushed back. That eliminated any cushion of time to fully test technical and logistical alternatives one by one.

So the engineers resorted to the simultaneous development and testing of multiple designs. This approach was used to test fuel tanks, built of both titanium and composite material, and the air bag design. "By building four air bag designs in parallel and testing them all in parallel, we were able to come up with a new air bag design that was strong enough."

As launch dates approached, the two-day weekend became a quaint and distant memory for Manning and his colleagues. They needed more help. Fortunately, when Theisinger made the case that JPL needed more money to pull off the mission (whose cost would ultimately grow from $650 million to $820 million), NASA came through. The MER team used some of that funding to hire dozens of recent grads from Caltech and the universities of Colorado, Texas, and Washington, among other places. Naturally, these bright-eyed newcomers were thrilled to work long hours on a Mars mission. "I seemed to get the most mileage out of the ones who were about 30 years old and had some experience, but didn't have families yet," says Manning.

Meanwhile, Theisinger had the job of informing JPL and NASA management of every step and stumble along the way. As Manning describes it, "They'd say over and over, we're really amazed at how well you guys have done, how you have pulled through, how amazing your progress has been." Every pat on the back was invariably followed by the caveat that if the next challenge proved insurmountable, the project would be canceled.

Although setbacks became the norm in this high-stakes environment, "eventually we found that we were getting good at standing back up again. What if this breaks? Well it did break. On the one hand, you start thinking eventually that there are very few things that will really stop us. On the other hand, there is the feeling that you won't be able to solve all of the problems before the clock stops ticking."

Amid the tumult, Manning, as systems engineering manager, had to continuously wear his game face. "In my position, you can't let stress show, because if I looked excessively stressed or depressed about not being able to pull it off, then my team would feel that way, and that would trickle down to everyone. So I had to keep a measure of buoyancy, to keep smiling and saying we can do it."

He says a sort of left-brain–right-brain duet integrated his engineering and people skills. "Some of the best moments came when I would have gotten a germ of an idea or other people's ideas and we could cultivate it. It's a real thrill seeing a skeleton of an idea bloom in front of you. And I've seen that happen many, many times.

"I can't take credit for this," Manning adds before reeling off a long list of names that includes, along with Adler and Theisinger, Richard Cook, the flight system manager; Jennifer Trosper, Spirit surface mission manager; Matt Wallace, MS '91, Opportunity mission manager; Wayne Lee, chief engineer for EDL; and, says Manning, "so many others."

For an engineer who clearly enjoys interacting with colleagues and coworkers, one of the hardest day-to-day realities was that there simply wasn't time for chitchat.

"It was so impersonal," he recalls. "The first thing you'd do when you saw somebody is think about this little list of things in your head that you needed to ask them about, and it's all technical. It's all related to the job."

There wasn't even time to acknowledge the stress—much less alleviate it. "We are such left-brain people here at the lab. It's like Caltech. This place just sucks you up, and you become really immersed in the minutiae of the problem-solving world and all the things you need to do. And it's amazing how noisy your brain gets." So noisy that he would often wake up and jot down stray thoughts that came to him in the middle of the night.

The tensest moments

The hectic period just before Spirit's launch in June 2003 proved to be one of those "moments of absolute intensity" that came to characterize the mission. The cables that course between the rover and the rest of the craft they control are separated during the landing process using small cable cutters that work like guillotines. As Manning made a few final calculations one evening, the numbers revealed that in the unlikely event that two wires touched at a pivotal moment during the cable cuts, MER would be disabled during landing.

(Above) This image mosaic, taken by the navigation camera on the Mars rover Opportunity, offers a panoramic view of the "Endurance" crater. Below, MER Project Manager Pete Theisinger (right) congratulates a beaming Rob Manning moments after Opportunity safely touched down on Mars on the night of January 24.

The timing couldn't have been worse. "This was only three days after we had told everybody that it was okay to launch." Key players including Theisinger and Cook were in Washington, D.C., for a final NASA briefing. By midnight that day Rob had discovered two more such problems. "We are in deep trouble," he recalls thinking. "By now I'm very stressed. I'm shaking." At 3 a.m. EDT, he awakened spacecraft manager Cook with the bad news. Springing into action, Cook then alerted colleagues in Florida, who worked on the dilemma throughout the night and into the next morning.

Meanwhile, Theisinger had apprised NASA of the snag, which was finally resolved by midday, once again allowing MER to resume its routine schedule of merely high rather than frantic anxiety.

For Manning and many of his colleagues it all meant yet another night without sleep. He admits that after 24 hours or so of wakefulness, he would lose his ability to think. So he'd drive to his nearby home and collapse. But some of the relative youngsters brought in to help bulk up staffing logged hours worthy of an ER resident. "There were people here who would stay for as many hours as they could stay conscious, and they did. And we would kind of forcibly have to kick them out," or send them to a cot for a mandatory rest.

Knowing that the likelihood of mistakes multiplies under conditions of sleep deprivation, the MER team built in a safety net that required review teams to confirm every critical calculation. Weighing on JPL was the memory of how a failure to convert navigation information from English to metric units had led to the loss of the Mars Climate Orbiter in 1999.

"The crime is not in making a mistake. It is in not catching it," Manning says. "We made thousands, maybe millions of mistakes on this project. Because we're human beings after all. But we caught them."

As people glued to January's news reports now know, problems didn't end with Spirit's successful Mars landing on January 4. After a terrific couple of weeks, the rover went buggy, staying up all night like a disobedient teenager and refusing to follow instructions. At JPL, its appalled handlers realized that the robotic rock hound had gone into a mode where it was continually rebooting itself and sending messages of gibberish.

To Manning, the now-AWOL Spirit offered a maddening example of the razor-thin margin separating success from failure. "I was getting very nervous that we might have lost Spirit. Then if the Opportunity entry, descent, and landing didn't work, we would have had a tantalizing glimpse of Mars for just 18 days, and then, nothing. I was very worried."

January 23, the night before Opportunity was set to land, Manning didn't sleep well. "I should have slept in, because it was going to be a late night." Instead, he got out of bed at dawn and drove to JPL. Walking in to MER mission control before 7 a.m., he was greeted by Cook and Trosper both wearing smiles of incredible relief. "They had just gotten word that we were able to get Spirit to reboot properly and that Spirit was going to be fine."

Fourteen hours later came Opportunity's flawless touchdown in a crater on Meridiani Planum, and Manning's announcement, "We're on Mars, everybody," before he finally broke into tears of joy and relief. After joining the first postlanding press conference to field questions from a throng of reporters, he quietly took his leave.

"After the Opportunity landing, I was emotionally exhausted. Instead of staying up here and looking at pictures come down like the rest of the team, I went home. I grabbed a glass of wine, got into bed with my wife, and we watched pictures on the cable feed from NASA TV."

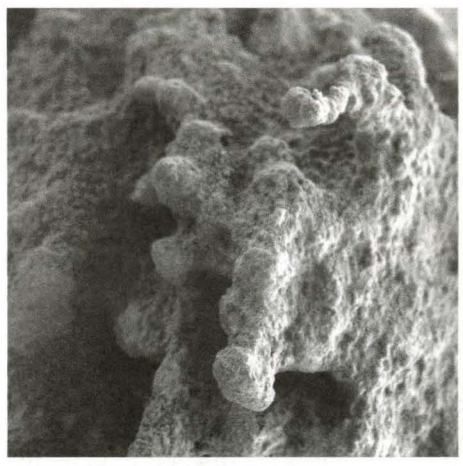
All that pressure was gone, and Manning saw the wonder and excitement on the faces of team members. "They were seeing these pictures streaming down from Mars from a vehicle that they had built and helped put there. So everything that's happened since then with these wonderfully exciting surface missions and wonderful science headlines from Mars, it's just gravy. It's wonderful."

Scientists' field day

Engineers aren't generally known to wax poetic, but Manning seems eager to talk philosophically about why Mars is fascinating and important to life on Earth.

"This is a real step in understanding scientifically our place in our solar system. Mars and Earth formed as siblings. They had a common birth and a shared growth experience. Yet at some point in the distant past, they diverged. How is it that Earth evolved to become a place that is conducive to life, while Mars became a harsh, forbidding environment?

"It's almost impossible for us to fathom the age of those Mars rocks. They are 3.5 billion years old. They vastly predate the evolution of complex multicellular life forms on Earth. In a very real sense, Mars is a museum. This mission has allowed us to unlock the museum door and explore our solar system's geologic and maybe biologic history in an incredibly preserved state of antiquity."



The false-color composite panoramic Spirit image (left) shows sparkly, dusty material revealed in the "Hank's Hollow" region, while a close-up (above) reveals nodular nuggets on the rock dubbed "Pot of Gold."

The Martian rocks and surface layers that the rovers are now investigating open a window onto that almost unimaginable deep time, says Manning, adding that he enjoys following the science updates almost as much as the scientists do.

"By learning about Mars we learn a lot about what we were and what we could be, and how life itself evolves on Earth and may evolve elsewhere in our universe. I think that's very exciting. This is about the common biology of our universe."

In late June, just before starting a long vacation, Manning attended a MER press conference, to catch up with the latest on Spirit and Opportunity. After more than half a year on Mars, the two rovers had vastly exceeded their expected operating lifetimes.

At the JPL press briefing, the big story was that Spirit had discovered a rock formation—dubbed "Pot of Gold"—in the Columbia Hills, two miles from its landing site. Principal investigator and Cornell astronomer Steve Squyres described Spirit's latest find as containing "nuggets on the end of stalks." He quipped, "I don't know how these things formed, and it's driving me nuts."

Meanwhile, Opportunity had entered "Endurance," a crater the size of a football stadium, and RATted (using Rock Abrasion Tools) into the enticing layers that open an invaluable window onto Martian geologic history. For scientists eager to learn more about these latest findings, the MER project had entered a fresh, new phase. "It has felt to us in the last few weeks that the mission has started all over again," Squyres said with a smile.

"This is a real step in understanding scientifically our place in our solar system . . . . How is it that Earth evolved to become a place that is conducive to life, while Mars became a harsh, forbidding environment?"

Back on Earth, Manning was looking forward to the eight weeks he planned to spend with his wife and daughter, traveling to his home state of Washington, and tackling home-improvement projects likely to be less demanding than engineering two picture-perfect landings on Mars. He planned to spend some of his free time weighing future options, including signing on for a 2009 Mars mission, described as the Mars Science Laboratory. But he vows that he won't volunteer for any more warp-speed missions that require carrying out four to five years' work in essentially half that time.

"I wouldn't do it again, because it's just too hard. It's too hard on my family. It's not healthy. It's really hard."

That doesn't mean he's not hungry for a new challenge. Throughout his participation in the Mars program, he says the best part has been knowing that "knowledge is a different kind of food. I work for JPL and NASA because I get to be part of this quintessentially human enterprise of nurturing our spirit. I think that's something you don't get a chance to do very much in this world."

Follow the MER mission at http://www.jpl.nasa.gov/missions/mer.

The End of the Age of Oil

By David Goodstein

This article is adapted from a talk that Caltech vice provost and professor of physics and applied physics David Goodstein presented at an April 29 program of the Institute support group, the Caltech Associates. Goodstein's new book, Out of Gas: The End of the Age of Oil, *was published in February by W. W. Norton.*

In the 1950s, it was not Saudi Arabia but the United States that was the world's greatest producer of oil. Much of our military and industrial might grew out of our giant oil industry, and most people in the oil business thought that this bonanza would go on forever. But there was one gentleman who knew better. He was an oil exploration geologist named Marion King Hubbert.

In about 1950, Hubbert realized that the trajectory of oil discovery in the continental United States was going to be a classic bell-shaped curve, for the decades from 1910 to 1970, in billions of barrels per year (see figure 1, facing page). He also saw that there would be a second bell-shaped curve that would represent production, or consumption, or extraction. The oil industry likes to call it "production," but the industry doesn't really produce any oil at all. It does, however, reflect the rate at which we use the oil up. Perhaps you could call it supply.

Hubbert realized that using what he knew in 1950 about the history of discoveries, along with what was already known about consumption, and a little mathematics, he should be able to predict that second bell-shaped curve. And so he did (see figure 2, facing page). The red, bell-shaped curve is the kind of curve he predicted. The black points are the actual historical data, and the uppermost point represents what has come to be known as Hubbert's Peak. Obviously, he was doing something right.

The situation worldwide is a little less well-determined. A third graphic provided by the energy conglomerate BP, shows what the world's known crude oil reserves are (see figure 3, left-hand graph, facing page). The amount that we have now is a trillion barrels of oil. So people in the industry might say, we have a trillion barrels just sitting there waiting to be pumped out of the ground; we're using it up at a rate of about 25 billion barrels a year, and so we have 40 more years to go—there's nothing to worry about. But as Hubbert has shown us, that's the wrong way of looking at it

Before we leave that curve, though, I want to point out that a sudden jump of 300–400 billion barrels of oil in OPEC (the Organization of the Petroleum Exporting Countries) reserves occurs in the late 1980s (see figure 3, left-hand graph, facing page). But there were no significant discoveries of oil in OPEC countries during that period. What happened instead is that OPEC changed its quota for how much each country could pump on the basis of what it claimed in reserves, and politicians discovered 400 billion barrels of oil without ever drilling a hole in the ground! This helps us to understand how undependable these numbers are for worldwide proven oil reserves.

As you can see, the curve that traces the historic record of oil discovery peaks around 1960. In other words, Hubbert's peak for oil discovery came and went 40 years ago.

The curve for oil usage, as you can see, is a rising curve and will become a bell-shaped curve eventually. Note that for the last quarter century, we've been using oil faster than we have been discovering it. World reserves should have decreased during that time by about 200 billion barrels. Instead, as we've seen, they've increased by 400 billion barrels. In any case, it should be possible, given this much information, to make a prediction similar to the one that Hubbert made for the continental United States for worldwide oil production.

One such estimate was published in 1998 in *Scientific American.* It predicts that we will have a worldwide maximum in oil production just about now—around the middle of the decade 2000–2010. What will happen when we reach that peak we don't really know. But we had a foretaste in 1973 and '79 when the OPEC countries took advantage of the supply shortage in the United States and shut down the valve a bit. What happened, as you may recall, is that we had instant panic and despair for the future of our way of life, and mile-long lines at gas stations.

We don't know what's going to happen at the next peak, but we do know that those past peaks were artificial and temporary. The next one will not be artificial and it will not be temporary.

However, we have to use caution in evaluating these types of predictions. One crucial quantity that goes into making such an estimate is knowing how much oil Mother Nature originally made for us—that is, how much oil was in the ground before we ever started pumping it. The *Scientific American* estimate used 1.8 trillion barrels of oil as the baseline number. Today it looks like 2.1–2.2 trillion barrels might be more accurate. That number—the total amount of oil that ever existed—tends to increase with time for a variety of reasons.

First, new technology and new discoveries have exactly the same effect—they both make more oil available. Secondly, as oil becomes scarcer and the price goes up, more oil becomes available at the increased price, because you can invest more capital into pulling it out of the ground. And finally, these estimates depend to some extent on those proven reserve numbers and, as we've already seen, those numbers are not very reliable. Nevertheless, the central idea of the Hubbert Curve is certainly correct: the supply of any natural resource invariably rises from zero to a maximum point, and then it falls forever. Oil will behave in the same way.

In 1997, Kenneth Deffeyes, a former Shell Oil geologist who's now an emeritus professor of geosciences at Princeton, published a book he entitled *Hubbert's Peak—The Impending World Oil Shortage.* In it, Deffeyes said he knew that Hubbert had been right and that the peak for domestic production had been reached when he saw this sentence in 1971 in the *San Francisco Chronicle*: "The Texas Railroad Commission announced a 100% allowable for next month."

To demystify that sentence, the Texas Railroad Commission was the quaintly named cartel that controlled the U.S. oil industry by making strategic use of the excess capacity for pumping in Texas. When the commission said, "100% allowable for next month," it meant that there was no longer any excess capacity. They were pumping flat-out, and therefore Hubbert's Peak had been reached.

Ever since reading this, I've thought that the signal that the worldwide peak had been reached would be when we found out that Saudi Arabian production had peaked. For the last few decades, the Saudis have been using excess pumping capacity to manipulate the world oil market in exactly the same way the Texans once did.

Well, on February 24 of this year, a story appeared on the front page of the *New York Times* entitled "Forecast of Rising Oil Demand Challenges Tired Saudi Fields." Among other things, the article said that Saudi Arabia's oil fields are in decline, prompting industry and government officials to raise serious questions about whether the kingdom will be able to satisfy the world's thirst for oil in the coming years.

This is a *New York Times* story, so it's very long, as many *Times* stories are, and it's written in a style in which each successive paragraph is contradicted by the next paragraph. This is called "balanced reporting." Sure enough, much farther down in the article, we find these words: "Some economists are optimistic that if oil prices rise high enough, advanced recovery techniques will be applied, averting supply problems." But here comes the contradiction in the next paragraph, "But, privately, some Saudi oil officials are less sanguine."

I don't know whether we will look back years from now and say that this was the beginning of the end of the age of oil. We're much too close to it to tell, and our figures are, overall, much too uncertain. But, to those people who are aware of the Hubbert's Peak predictions, as the writer of this article apparently was not, this was a chilling report.

Economists tell us that there can never be a gap between supply and

Continued on page 10

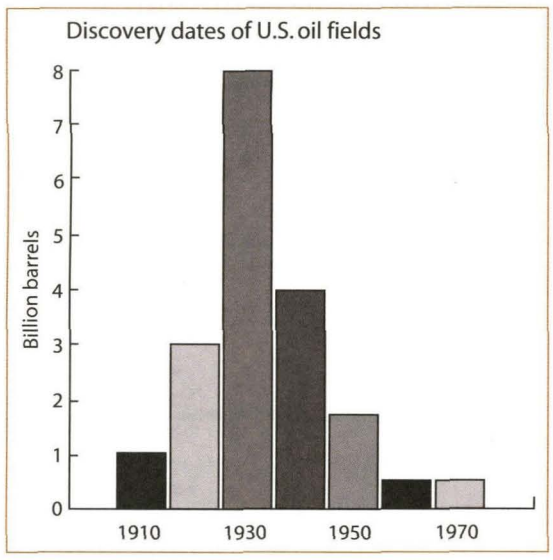


Figure 1

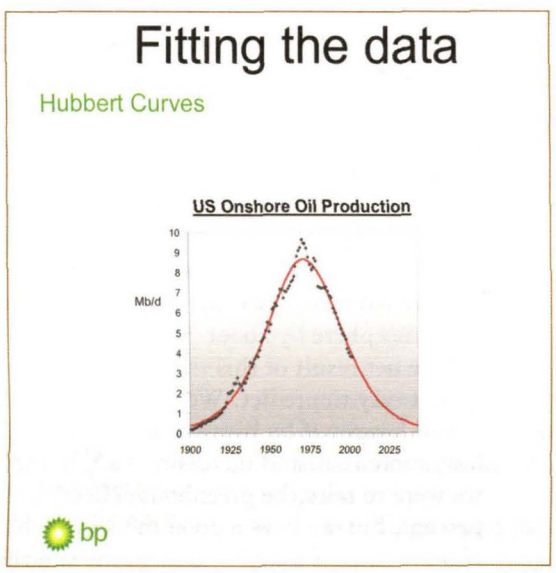


Figure 2

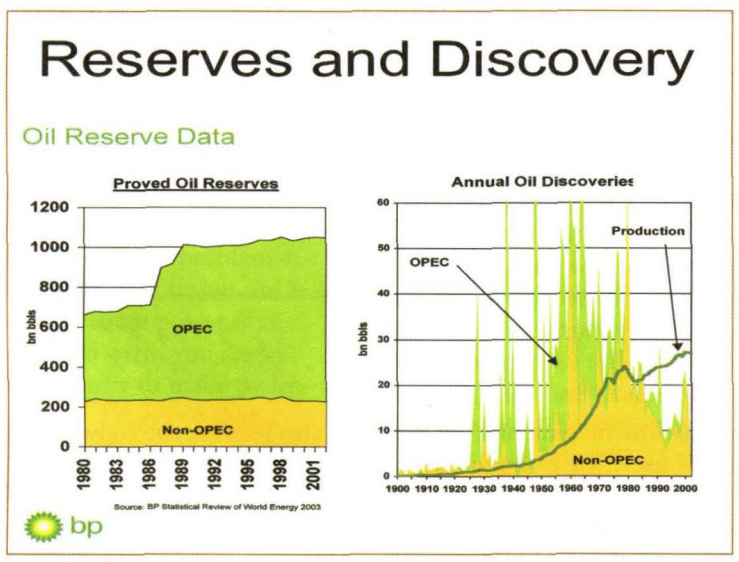


Figure 3

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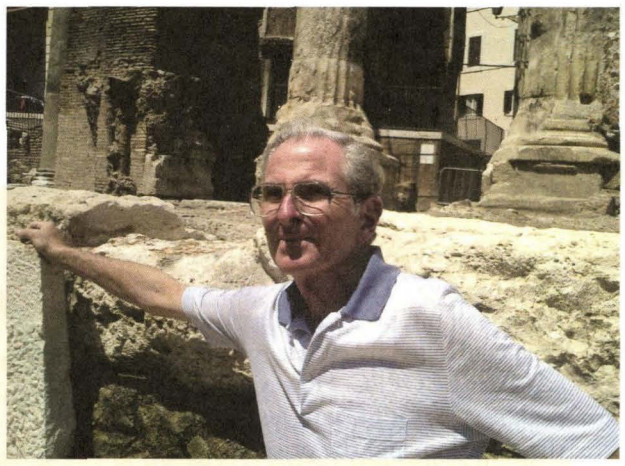
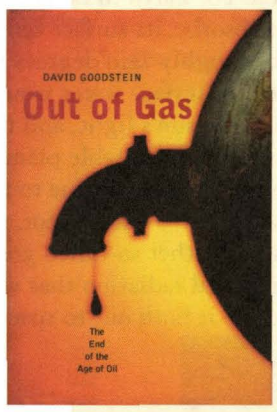


David Goodstein contemplates the fragile nature of civilization on a recent visit to Rome.

THE SAGE OF THE END OF OIL

Caltech's vice provost David Goodstein remembers very well when he got the idea for *Out of Gas* because the date was June 11, 2001, exactly three months before an event that would further crystallize his thinking about America's dependence on oil. What caught his eye that June morning was an illustration in the *Los Angeles Times*. The graphic depicted a type of bell curve that had originally been plotted out in the 1950s by a contrarian-minded Shell Oil geophysicist, Marion King Hubbert. Hubbert had predicted that oil production in the continental United States would peak within 20 years, and, although he had plenty of detractors at the time, he turned out to be right. The Hubbert's Peak bell curve pictured in the newspaper cast a wider net—it applied Hubbert's calculations to oil resources worldwide and projected that supplies would peak within a decade, followed by, as Goodstein puts it, "an inexorable decline."

The Caltech professor of physics and applied physics, who remembered all too well the upheaval caused by short-term oil crises in 1973 and 1979, immediately began to wonder how an ill-prepared world would cope with an irreversible fuel shortage in the near future. The self-evident answer: Not very well. "I thought, 'I'd better find out what this is about, because it's a prediction for worldwide calamity in approximately 2007.' And, as I read up more on it, I began to think, 'What can I do? I'm a physicist—I don't really do anything that helps anybody,'" says Goodstein, who is also the Institute's Gilloon Distinguished Teaching and Service Professor. "Then I realized—I can write a book."



Out of Gas was published February 2, 2004, Groundhog Day—an auspicious date (or not) for a book whose opening lines bluntly predict heavy weather ahead. "The world will soon start to run out of conventionally produced, cheap oil. If we manage . . . [to shift] the burden to coal and natural gas . . . life may go on more or less as it has been—until we start to run out of all fossil fuels by the end of this century . . . . Civilization as we know it will not survive unless we can find a way to live without fossil fuels."

Goodstein says he really didn't know what sort of reception these ominous pronouncements would get, but before the week was out, the *New York Times Book Review* had published an enthusiastic review, calling *Out of Gas* "a book that is more powerful for being brief, [written] with the clarity and gentle touch of a master teacher," and virtually guaranteeing that the publisher, W. W. Norton, would sell out its modest first run of 15,000 copies. Now in its 4th printing, *Out of Gas* will be published in paperback in February 2005.

This year's steep run-up in gasoline prices has also boosted interest and sales. "We really caught a wave," says Goodstein, who has since been swept up in a variety of media interviews and appearances around the country, including write-ups in *Newsweek*, *Forbes*, and *Fortune*, and broadcasts on CNN, Fox-TV, NPR, and the new Air America radio network, where his fellow panelists—an oil company consultant and an environmental activist—promptly got into a round of verbal fisticuffs. Recalls Goodstein, "I was able to pretty much stay out of that one."

Although Caltech's vice provost is pleased with the widespread interest *Out of Gas* has evoked, he says he is disappointed, if hardly surprised, that he has yet to hear from anyone who is actually in a position to influence national or global energy policy. "This issue is the third rail of politics," he says. "Nobody wants to touch it."

Out of Gas is Goodstein's third book and the first to deal explicitly with science and public policy, although he has addressed the issue at length in articles and lectures. His previous books include *States of Matter* and *Feynman's Lost Lecture*, coauthored with his wife, Judith Goodstein, Caltech archivist and faculty associate in history. There are no plans at the moment to write another book. "When you write a book about the end of civilization as we know it, there's not much left to cover."

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End of the Age . . . from page 8

demand because the process is regulated by price. That's never been true in the case of oil, because it has always been controlled by cartels, first in Texas and later by OPEC. However, once the peak occurs, OPEC will lose control of the situation, and the price mechanism will kick in with a vengeance. But the supply can keep up with the price only if there is something to supply.

I'm sometimes asked, what about replenishing our oil reserves through deep-ocean exploration? I'm already factoring in close-to-shore oil production, but the deep oceans are essentially unexplored and, it's true, we don't know whether there's any oil out there. Over the last hundreds of millions of years, oil typically has been manufactured in places that are rich in life, which deep oceans are not. But the landmasses have moved around over geologic time, so there may be deep-ocean oil reserves.

Even so, deep oceans are technically extremely difficult places to drill for oil. That leaves us with only two remaining reservoirs—the South China Sea, which currently has seven countries claiming mineral rights to it; and Siberia, which has very bad access problems. And those resources, of course, are finite also. So let's see what else there is to use, aside from oil.

The word "oil" covers more than just the conventional light crude that we've been pumping up to now. It also covers heavy oil, oil sands, and tar sands. Heavy oil is essentially what's left behind in the field after you pump the light crude away. And, of course, if you put more money in—that's the price mechanism—you can usually squeeze a little more oil out of any field. But it's both more costly and more time-consuming to get that oil out. And the more you pump out, the heavier it gets.

Natural gas could be a very good substitute for oil. Cars that are not very different from those we drive today can run on compressed natural gas, and it's a particularly clean-burning fuel. But if we turn to natural gas in a major way to replace diminishing supplies of oil, it will only be a temporary solution. The Hubbert Peak for natural gas is only a decade or so behind Hubbert's Peak for oil.

Oil was created when so-called source rock, full of organic inclusions, sank deep within the earth. The inside of the earth is heated by natural radioactivity, and the deeper you go, the hotter it gets. This source rock sank just deep enough into the heated interior for the organic matter to get cooked into oil. Rock that sank deeper got overcooked and became natural gas. Rock that sank to a more shallow level became shale oil, which is essentially unborn oil that can be made into a fuel by strip-mining, crushing, and heating the rocks until you generate a usable liquid. People who have invested many millions of dollars into trying to exploit this resource have come to the conclusion that it will probably always be energy-negative, meaning that you will always have to put more energy into acquiring and processing it than you will ever get out of it.

Methane hydrate is a solid that looks like ice, but that burns if you ignite it. It consists of methane trapped in a sort of cage of water molecules and it gets created when methane comes into contact with water under very high pressure at very low temperatures close to the freezing point of water. Nobody has any idea of where all it is, how much there is, whether it can be mined, or how it could be used—all we know is that this stuff exists.

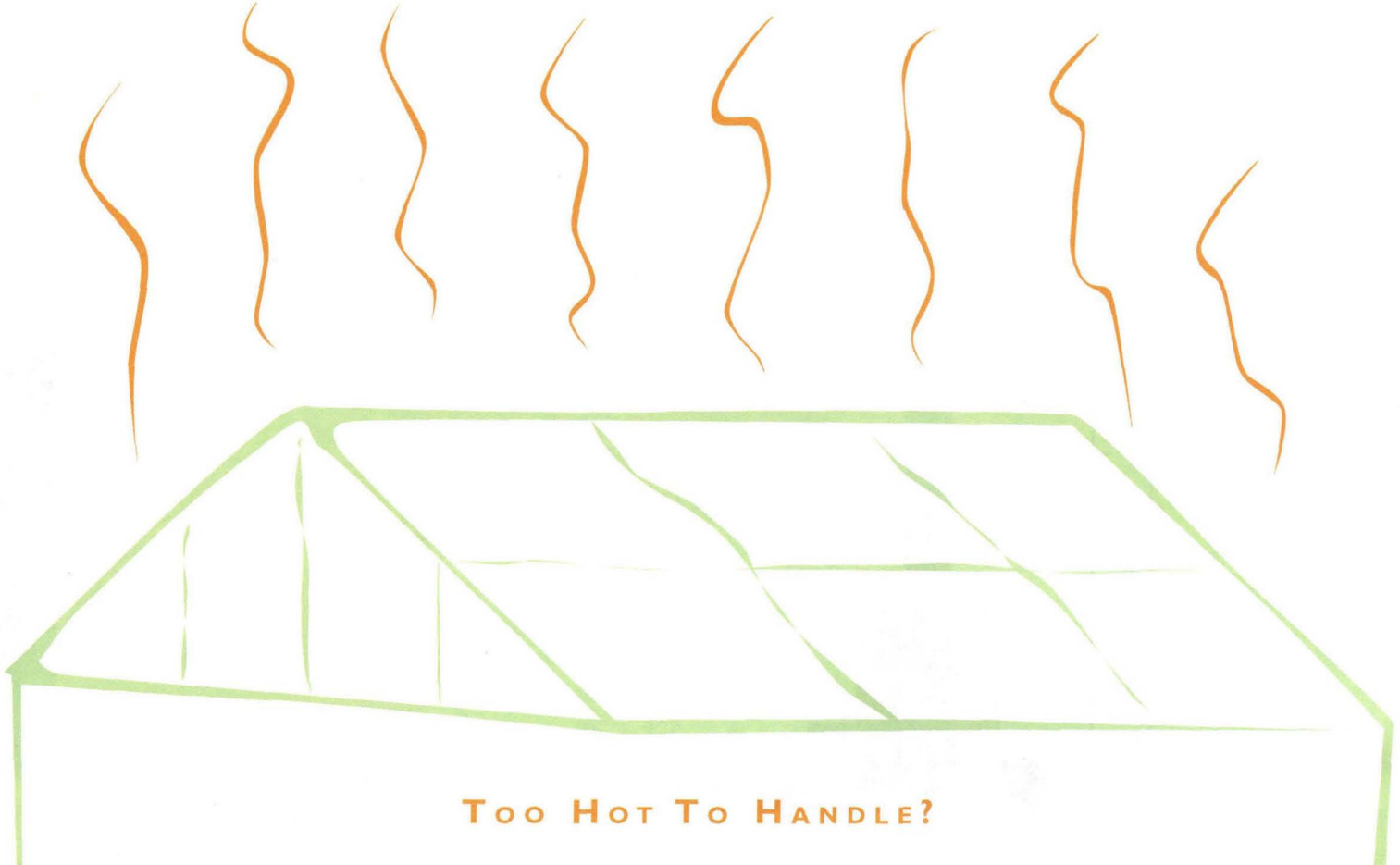
Finally, there is coal. We are told that there is enough coal in the ground for hundreds, maybe even thousands of years, at the present rate of use. The fact that these estimates range over a factor of ten tells you immediately that nobody has the foggiest notion of how much coal is actually available. But even those projections might be considered reliable, compared to the second part of that optimistic sentence: "at the present rate of use"! We'll get to that in a moment.

The largest coal deposits are in the United States, and China and Russia have very large reserves as well. Coal can be liquefied and made into a substitute for oil. That was done in Nazi Germany during World War II, and in South Africa under apartheid. That alone should tell you that you have to be fairly desperate to do it, but it can be done.

But, coal is a dirty, dirty fuel. It often comes with nasty impurities, including mercury, arsenic, and sulfur. The mercury that accumulates in the bodies of tuna or swordfish—and which has led to FDA warnings to limit our consumption of these fish—originates in coal-fired power plants in the United States. We use now about twice as much energy from oil as we do from coal, so if you wanted to mine enough coal to replace the missing oil, you'd have to mine it at a much higher rate, not only to replace the oil, but also because the conversion process to oil is extremely inefficient. You'd have to mine it at levels at least five times beyond those we mine now—a coal-mining industry on an absolutely unimaginable scale.

And even that doesn't take into account the world's increasing population, or the fact that nations like China and India want to have a higher standard of living, which means burning more energy. Finally, it doesn't take into account the Hubbert's Peak effect, which is just as valid for coal as it is for oil. Long before we have mined the last ton, we will have started to deplete our ability to get the stuff out of the ground. So, it's a very good bet that the governing "rate of use" number I mentioned earlier is not hundreds or thousands of years, and that no more than one-tenth of that timeframe represents a realistic estimate.

What all this suggests is that if we accept the economists' solution and just let the marketplace do its thing as we



Too Hot To Handle?

As prices at the pump have risen this year, so has the intensity of the debate over the relative abundance of Earth's remaining oil (an issue, David Goodstein notes, on which reasonable people can and do differ). However heated that discussion ultimately becomes, it has some way to go before it reaches the level of commentary and vitriol that is routinely generated over the related question of what impact fossil fuels are having on the greenhouse effect, the atmospheric phenomenon that for eons has kept Planet Earth—like Baby Bear's cereal—neither too hot nor too cold.

In *Out of Gas,* Goodstein takes on the seemingly thankless job of distilling the innumerable position papers, research studies, and policy debates on this issue down to a few immutable physical facts: At 93 million miles from the sun, Earth receives a flux of solar energy that, averaged over the face of the planet at the top of the atmosphere, comes to 343 watts per square meter. A portion of this energy is reflected, and the rest is absorbed and radiated back into space as infrared radiation. For Earth to radiate back energy equal to what it absorbs, its surface temperature would have to be roughly zero degrees Fahrenheit. At that temperature, its surface water would freeze, reflecting more of the sun's light, and making Earth an even colder and less hospitable planet.

That this hasn't happened is due to the fact that atmospheric trace gases—water vapor, methane, carbon dioxide, and the other so-called greenhouse gases—absorb infrared radiation that would otherwise escape and reradiate it both out to space and back to Earth, warming the planet's surface overall to, in Goodstein's words, a relatively "balmy, comfortable 57 degrees Fahrenheit, as a mean surface temperature. At that temperature we evolved, climbed down from the trees and started building steam engines."

In the preindustrial era, Earth's atmosphere absorbed 88 percent of the infrared radiation that would otherwise have been radiated away. In the last 150 years, however, that balance has been significantly altered by humans' ever-growing reliance on fossil fuels. Says Goodstein, "Since the beginning of the industrial age, we have increased the amount of carbon dioxide in the atmosphere by about 30 percent."

The net result of this tinkering, observes Goodstein "is not easy to predict. We don't know exactly what would happen if by burning more fossil fuel, particularly more coal, and increasing CO_2 in the atmosphere, we were to raise the greenhouse effect, let's say, to 100 percent, but we have a good model to look at. The planet Venus is a little closer to the sun than Earth is, but the physics should permit Venus to be very earthlike in temperature. But it's not.Venus has a runaway greenhouse effect and a surface temperature hotter than molten lead. As we have seen, distance from the sun is only one of several variables that determine habitability on Earth. At 93 million miles from the sun, our planet could be a frozen wasteland, or it could be a Venusian inferno. The fact is that it is neither. Instead it has this delicately balanced partial greenhouse effect that is ideal for creatures like us. We mess with that greenhouse effect at our peril."

H.A.

make use of all the fossil fuel we can, we'll start running out of *all* fossil fuels by the end of this century.

So, what does the future hold? Well, for one thing, there will be an oil crisis very soon. Whether that means it has already begun or won't happen until later in this decade or sometime in the next decade, I don't know. In my view, the numbers are not dependable enough for us to say. However, while the difference between those estimates may be very important to us, it's of no importance at all on the timescale of human history. Either we, our children, or perhaps our grandchildren, are in for some very, very bad times. If we turn to all the other fossil fuels and burn them up as fast as we can, they will all probably start to run out by the end of the 21st century. Assuming that our planet remains habitable after such a vast consumption binge, we will have to invent a way to live without fossil fuels. (See sidebar "Too Hot To Handle?" on facing page.)

How about hydrogen? Both President Bush and California governor Schwarzenegger have publicly embraced hydrogen as a solution to our fuel problems. But there are only two commercially viable ways of making hydrogen. One is to make it out of methane, which is a fossil fuel. The other is to use fossil fuel to generate the electricity that you need to electrolyze water and get hydrogen. The economics of doing that are such that you end up using the equivalent of six gallons of gasoline to make enough hydrogen to replace one gallon of gasoline. So this solution is not a winner in the short run. In the long run, if the problem of harnessing thermonuclear fusion can be solved and we have more power than we know what to do with, you could use that form of energy to make hydrogen for mobile fuel. I'll get to that a little later.

There is also wind power, which many now see as a viable energy alternative. And it is, but only to a limited extent. In regions like northern Europe, where fossil fuels are very expensive and the wind is really strong, wind power will someday come to rival hydroelectric power as a source of energy. But there are relatively few places on earth where the wind blows strongly and steadily enough for it to be a dependable energy source, and people don't really like wind farms—they're ugly and they're noisy. Wind power will always be a part of the solution. But it's not a magic bullet. It's not going to save us.

In recent years, the debate over nuclear power has revived, with proponents maintaining that we can find environmentally sound and politically acceptable ways to deal with the waste and security hazards. But even assuming that to be true, the potential is limited. To produce enough nuclear power to equal the power we currently get from fossil fuels, you would have to build 10,000 of the largest possible nuclear power plants. That's a huge, probably nonviable initiative, and at that burn rate, our known reserves of uranium would last only for 10 or 20 years.

The ultimate solution to our energy problem would be to master the power of controlled thermonuclear fusion. The solution has been 25 years away for the past 50 years, and it is still 25 years away.

As things stand today, the only possible substitutes for our fossil-fuel dependency are light from the sun and nuclear energy. Developing a way of running a civilization like ours on those resources is an enormous challenge. A great deal of it is social and political—we're in the midst of a presidential election, and have you heard either party say a word about this extremely important subject? But there are also huge technical problems to be solved. So, you might well ask, what can Caltech do to help?

The ultimate solution to our energy problem would be to master the power of controlled thermonuclear fusion, which we've been talking about doing for more than half a century. The solution has been 25 years away for the past 50 years, and it is still 25 years away. Beyond those sobering statistics, there are at least five or six schemes for harnessing fusion energy that I know of. One of them, called the spheromak, is studied here at Caltech in an experimental program run by Professor of Applied Physics Paul Bellan and his research group.

In the spheromak, electric currents flowing in a hot ionized gas—otherwise known as a plasma—interact with magnetic fields embedded in the plasma. As these fields and currents push the plasma around, new fields and currents are created. There's a sort of self-organizing interaction occurring. You can see in this sequence of snapshots at the right, starting from the top, that the plasma is organizing itself into a jet and then a kink develops in the jet. This is something that happens all by itself, and it's not something that happens only occasionally—the gas always self-organizes like that. After the kink develops, it breaks away from the body of the jet as a doughnut. If you can find a way to maintain that doughnut and keep it going—that is to pump in enough energy to keep it from decaying—the doughnut has the perfect geometry required for containing a hot plasma undergoing thermonuclear fusion.

But attaining this objective is far off. The existing apparatus is much too small to reach the hundred million degree temperatures needed to generate power. The Bellan team is studying the fundamental physics of the self-organizing process in the hope it can be used to create and sustain the desired fusion plasma confinement geometry in a reliable, controlled manner.

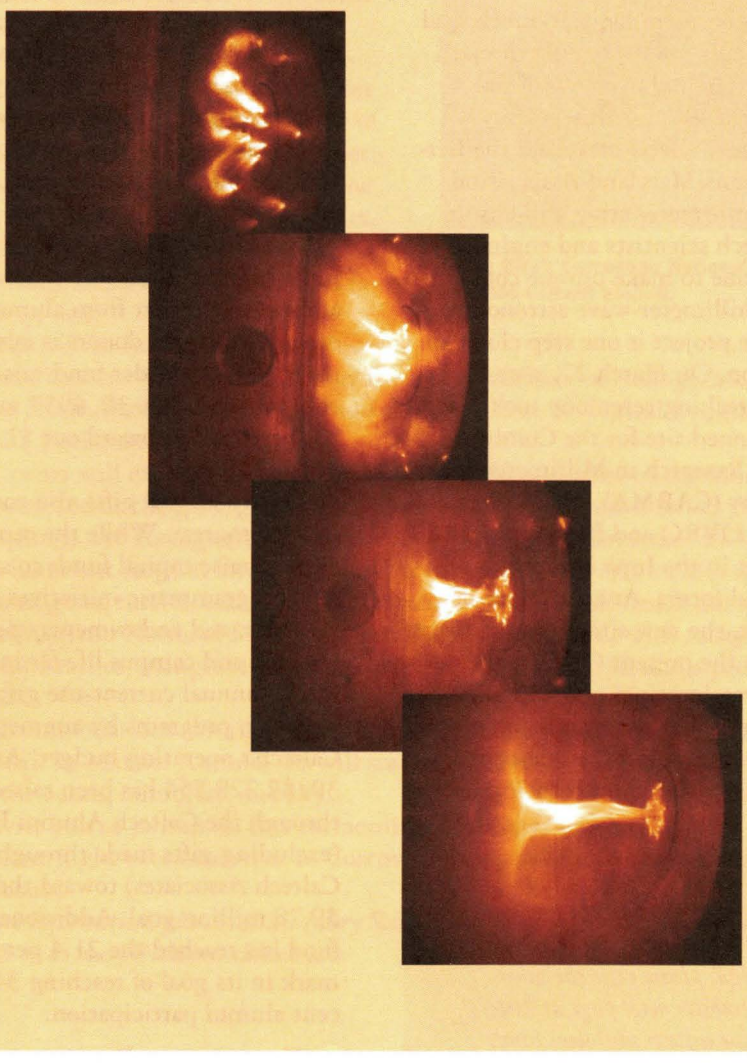
There's another group at Caltech whose efforts are aimed largely at the other alternative—solar energy. Their program is called Power the Planet: Caltech Center for Sustainable Energy Research. Members include applied physicist Harry Atwater, chemists Harry Gray, Nathan Lewis, and Jonas Peters, and materials scientist Sossina Haile.

Furthermore, our former provost Steve Koonin recently stepped down from the provostship and took a leave of absence from the Caltech physics faculty to become chief scientist at BP. BP, formerly British Petroleum, is one of the largest energy companies in the world, and so he now has one of the most important energy positions in the world.

The fact that these and similar scientific and technical efforts are under way at Caltech and elsewhere are encouraging, but they are not enough. What we really need is leadership with the courage and vision to talk to us as John F. Kennedy did in 1960, when he pledged to put a man on the moon by the end of the decade. It's the same kind of problem. We understand the basic underlying scientific principles, but we have huge technical problems to overcome.

If our leaders were to say to the scientific and technical community, "We will give you the resources, and you—right now, even before it becomes imperative—will find a way to kick the fossil-fuel habit," I think that it could be done. But we have to have the political leadership to make it work.

Fusion Research at Caltech



there's only **one.caltech**

THE CAMPAIGN

Campaign Highlights

From its earliest days, Caltech has had a meaningful and global impact. Faculty and alumni have contributed to a broad range of fields and successfully undertaken projects of stunning size and scope. The Caltech community continues this tradition of excellence today, and the funds raised through the Institute's "There's only one. Caltech" campaign will enable Caltech faculty, research staff, and students to push the frontiers of science even further.

The Gordon and Betty Moore Foundation has approved a $25.4 million grant for Caltech's nanoscale systems initiative. These resources will complement the Fred Kavli and Kavli Foundation gifts to create the Kavli Nanoscience Institute at Caltech. The Moore Foundation grant will help fund a variety of programmatic components, as well as laboratory equipment, research facilities, and research and administrative staff associated with the Kavli Nanoscience Initiative. The combined support provides almost $33 million to produce new research opportunities and attract more of the world's best researchers to the Institute, thus placing Caltech at the leading edge of nanoscale science and engineering.

Innovative astronomy and technical developments made possible through the relocation and merging of the Owens Valley Radio Observatory (OVRO) millimeter array and the Berkeley-Illinois-Maryland Association (BIMA) millimeter array will ensure that Caltech scientists and engineers can continue to make unique contributions to millimeter-wave astronomy. Today, the project is one step closer to completion. On March 27, a small ground-breaking ceremony took place at the planned site for the Combined Array for Research in Millimeter-Wave Astronomy (CARMA). The project will move the OVRO and BIMA arrays to Cedar Flat in the Inyo Mountains of eastern California. At an altitude of 7,300 feet, the new site is almost twice as high as the present OVRO and BIMA array locations and will allow for better atmospheric transmission of the radio waves reaching the telescope dishes from a variety of cosmic phenomena. When it is completed, CARMA will consist of 15 telescopes, making it a frontline instrument for investigating the formation of planets, stars, and galaxies, as well as the large-scale structure of the universe. Early funding toward Caltech's $5 million portion of the $15 million project cost was provided by the Kenneth T. and Eileen L. Norris Foundation.

Caltech received from the Henry Luce Foundation, Inc., the fourth installment of its five-year, $700,000 grant supporting research and educational activities for environmental science and engineering in Kerckhoff Marine Laboratory in Corona Del Mar, California. This funding has helped Jess Adkins establish a new undergraduate laboratory course in estuarine and ocean chemistry. (Adkins joined the Institute in 2000 as assistant professor of geochemistry and global environmental science.) In early 2000, the Luce Foundation launched a five-year, $30 million environmental initiative as a part of its program in public policy. Caltech was among the 55 leading American colleges and universities invited to apply for grants as part of the foundation's entry into supporting the field of environmental science.

New science and technology initiated from projects like these will play an important role in our ability to further understand and interact with our world. Moreover, the lead gifts to such initiatives allow the Institute to jump-start research activities while additional support from alumni and other friends and donors is raised through our broader fund-raising efforts. As of June 30, $957 million has been raised toward our $1.4 billion goal.

Finally, annual gifts also contribute to our progress. While the campaign aims to raise capital funds to support new programmatic initiatives and facilities, and endowments to sustain research and campus life far into the future, annual current-use gifts help maintain programs by augmenting Caltech's operating budget. As of June 30, $2,228,554 has been raised through the Caltech Alumni Fund (excluding gifts made through the Caltech Associates) toward the fund's $2.78 million goal. Additionally, the fund has reached the 21.4 percent mark in its goal of reaching 34.7 percent alumni participation.

Vannessa Dodson

For more news on the progress of the "There's only one. Caltech" campaign, please visit the campaign website news page at http://www.one.caltech.edu/news.html.

As Rosen Professor of Astronomy and CARMA director Anneila Sargent looks on, the groundbreaking ceremony for the Combined Array for Research in Millimeter-Wave Astronomy gets under way. From left are CARMA Board members Richard Barvainis of the National Science Foundation, R. James Kirkpatrick of the University of Illinois, Tom Tombrello of Caltech, Stephen Halperin of the University of Maryland, Mark Richards of UC Berkeley, and son; and Jesse Delia, also of the University of Illinois.

Associates Activities

All events will be held at the Athenaeum unless otherwise noted. Individual invitations for each event will be sent monthly.

***September** 12, President's Circle Garden Party at the home of President David Baltimore and Faculty Associate in Biology Alice Huang.*

***September** 18, Northern California Dinner and Program, Fairmont Hotel, San Jose*—"Nanosystems, Biology, and Cancer," with James Heath, Elizabeth W. Gilloon Professor and professor of chemistry.

***October** 2, Associates Tours, Luncheon, and Program*—Einstein Exhibit at the Skirball Museum, Los Angeles, with Kip Thorne '62, Feynman Professor of Theoretical Physics, and Tilman Sauer, scientific editor, Einstein Papers Project.

***October** 10–14, President's Circle Bryce and Zion Travel Program*, with Joe Kirschvink '75, MS '75, Van Wingen Professor of Geobiology.

***October** 21, Associates Dinner and Program*—"The Neurobiology of Conscience," with John Allman, Hixon Professor of Neurobiology.

***November** 8, President's Circle Dinner and Program*, with Ares Rosakis, von Kármán Professor of Aeronautics and Mechanical Engineering—"Seeing the World through Shockwaves."

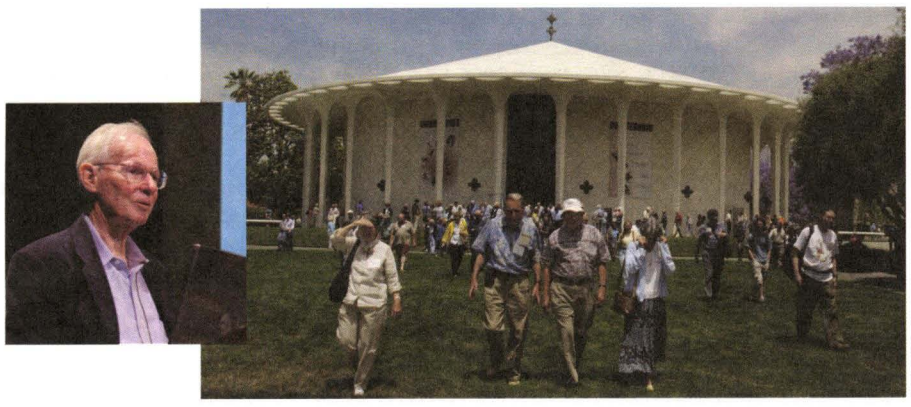
***November** 10, East Coast Associates Dinner and Program, New York City*—"Out of Gas: The Scientific and Political Challenges in Sustainable Energy Technology," with Nate Lewis '77, MS '77, Argyros Professor and Professor of Chemistry.

***November** 18, Associates Dinner and Program*—"Good CARMA and the Origins of Everything," with Anneila Sargent, PhD '77, Rosen Professor of Astronomy and director, Owens Valley Radio Observatory. (CARMA is the Combined Array for Research in Millimeter-Wave Astronomy.)

***December** 2, Associates Luncheon and Program*—"The Snowflake: Winter's Secret Beauty," with Ken Libbrecht '80, professor of and executive officer for physics.

***January** 1, 2005, Rose Parade Event*—Continental Breakfast at the Athenaeum, followed by Rose Parade Viewing.

For further information about the Caltech Associates, please contact Carrie Stubstad at 626/395-3919, or via e-mail at associates@caltech.edu. Visit our website at http://giving.caltech.edu/CA/.



CELEBRATING SEMINAR DAY 2004

On campus May 15 for the Alumni Association's 67th Annual Seminar Day, alumni stream out of Beckman Auditorium, where (top left) Caltech graduate and AeroVironment founder Paul MacCready, PhD '52, spoke on the highly topical subject of alternative energy technologies, and Caltech president David Baltimore presented six Caltech graduates with the Institute's Distinguished Alumni Award. Above, Baltimore (center) poses with the six honorees. From left: Blouke Carus '49 is chairman of Carus Corporation, whose operations include providing chemicals and services for water and wastewater treatment, air purification, and other environmental applications, and he is also chairman of Carus Publishing Company, which produces educational materials, including a research-based K–6 reading and writing program that has been credited with revitalizing elementary-school language arts education in a number of states, among them California. Kenneth Kellermann, PhD '63, senior scientist at the National Radio Astronomy Observatory (NRAO), research professor at the University of Virginia, member of the National Academy of Sciences, and an outside scientific member of the Max Planck Society, has carried out pioneering research into radio galaxies and quasars and the development of new instrumentation for radio astronomy. A graduate of the Indian Institute of Technology, Narendra (Naren) Gupta, MS '70, is cofounder of Integrated Systems Inc., which later merged with another company to form Wind River, the dominant maker of software for such diverse computing devices as airplane radar systems and DVD players, and of which he is now vice chairman. Gerhard Parker '65, PhD '70, served as vice president and director of technology development at Intel from 1977 to 1988, when he became senior vice president in charge of manufacturing, technology development, purchasing, construction, quality, and planning, overseeing Intel's worldwide expansion of production capacity in the early 1990s. From 1998 to his retirement in 2001, he served as executive vice president for the company's new business group, guiding numerous internal start-ups. Henry Schwartz, PhD '66, is senior professor of civil and environmental engineering at Washington University in St. Louis, and has had a long career with the Sverdrup Corporation, where his work was instrumental in developing and expanding Sverdrup into a national leader in construction management. A member of the National Academy of Engineering, Schwartz was named president and chairman of Jacobs/Sverdrup Civil Inc. in 1993, and was president of the American Society of Civil Engineers from 2001 to 2002. Robert Kirshner, PhD '75, the Clowes Professor of Science at Harvard, and president of the American Astronomical Society, has made major research contributions in such areas as galactic distribution and the large-scale structure of the universe, and he is author of *The Extravagant Universe: Exploding Stars, Dark Energy, and the Accelerating Cosmos*, which received the 2002 AAP Award for Best Professional/Scholarly Book in Physics and Astronomy.

GET CONNECTED! CHECK OUT NEW ASSOCIATION WEBSITE AND UPDATE YOUR INFO

A new edition of the *Caltech Alumni Directory* is in preparation, and to make it a success we need your help! Please take a moment to visit the Caltech Alumni Association's new website alumni.caltech.edu/network to log in and update your personal profile. By doing this now, you'll ensure that your listing in the forthcoming Alumni Directory will be complete, accurate, and up to date. For questions about logging in or using the site, contact information@alumni.caltech.edu or call 626/395-8365.

After you've updated your listing, have a look around the Association's new online home. The site has been completely redesigned for easy navigation, and it's brimming with news and activities for and about Caltech's worldwide alumni community. There's the versatile, searchable Alumni Network, where you can find old friends and make new networking contacts; a calendar of upcoming alumni events; online Class Notes (see page 14 for more on this); and job postings for exclusive viewing by Caltech alumni.

Alumni Activities

***September** 13–22,* "From Newton to Crick: England and the History of Science," led by professors of history Jed Buchwald and Diana Kormos-Buchwald.

***January 1, 2005,** New Year's Day Parade, followed by lunch at the Caltech Athenaeum.*

Alumni Association Board of Directors Meeting Dates— Sept 10–11 2004; Jan 21–22, 2005; April 8–9; June 10–11. All meetings will be held in the Millikan Board Room.

For details about these and other Association activities, please contact the Caltech Alumni Association office at 626/395-6592 or visit the Association website at http://www.alumni.caltech.edu and click on "Events."

ALUMNI TO EXPLORE COSTA RICA
FEBRUARY 24–MARCH 7, 2005

Costa Rica's Corcovado National Park beckons Caltech alumni.

Explore the wonderful national parks and reserves of Costa Rica on an extraordinary 12-day journey. Renowned for its farsighted leadership in establishing national parks and reserves that protect over 25 percent of its land, Costa Rica is one of the great treasuries of nature in the Americas, home to 850 species of birds, pristine beaches, tropical rainforests, cloud forests, waterfalls, and an array of animals that includes white-faced monkeys, sloths, macaws, and iguanas.

Our trip will be led by the faculty team of Marianne Bronner-Fraser, the Billings Ruddock Professor of Biology, and Scott Fraser, the Rosen Professor of Biology and director of the Biological Imaging Center in Caltech's Beckman Institute.

Participants will experience Costa Rica's bounty during hikes in the Monteverde Cloud Forest and at the geologically active Arenal volcano, known for its therapeutic thermal springs. At Tortuguero National Park on the Caribbean coast, we will explore a luxuriant tropical forest and canal system alive with howler and spider monkeys, trogons, turtles, and flocks of foraging birds. We will finish our adventure at Manuel Antonio National Park, a pristine Pacific Coast gem, with rocky headlands, great beaches, mangrove-lined estuaries, squirrel monkeys, and a profusion of bird life.

Our accommodations throughout our stay will be lodges that keep us comfortable and well fed. In Manuel Antonio we will stay at a deluxe hotel with spectacular views of the ocean, rainforest, and sky.

We invite you to join us on this extraordinary journey, which also offers an optional four-night extension visit to Corcovado National Park, located in the remote Osa Peninsula.

For more information, please contact Mary Said in the Alumni Association office at 626/395-8363 or at mary@alumni.caltech.edu.

Class Notes

Letter from the Association President

Love letters . . . . I was wrapping up my year as president and feeling good about some of the things we had accomplished when I received a couple of notes from my fellow alumni—and worse yet, one of these alumni was from my student house!

"I suggest the Alumni Association have a reduced membership fee for those of us out of the area. All I would ever use of the alumni benefits are the e-mail address and the [*Engineering & Science*] magazine, so I find it hard to justify $45. Think about it. No reply expected," read the first.

"I paid $500 to be an alumni member primarily for the prestigious-sounding permanent e-mail address. However, the last time I was looking for a job, many of my resumes were silently and indefinitely queued . . ." purred the second.

This was definitely *not* a good week.

Not to put too fine a point on it, both these alums are touching an important issue: Why be a Caltech Alumni Association member, and can we deliver the services our alumni members expect?

Well, let's go from the specific to the general—from the good news to the hard truths and the great opportunity.

"Indefinite queues"—fortunately, very few of you experienced them—in our e-mail system are a thing of the past. By the end of September, perhaps even by the time you read this, the CAA will have installed a completely new e-mail system that is professionally maintained around-the-clock. Hopefully this new system will be a seamless transfer for all us users.

Arranged by the CAA in June, the Institute is building and will maintain for us this new, dedicated system, using the same proven technology with which it provides e-mail services to faculty, researchers, staff, and students. The system will be robust, comprehensive, and will possess sufficient capacity to support all our members. There will continue to be no charge to members for normal e-mail account usage. The Institute has been very supportive of the Association in this effort.

Last May the Association went live with a new website (www.alumni.caltech.edu) featuring a vastly improved online alumni directory. Like any remodel, the plumbing and wiring don't show but represent a significant fraction of the investment. It's an investment that will continue to pay off in the future, in the form of added new features. But even now, work and job history information may be displayed at the alum's discretion, and fields are searchable so that alumni with common experience (and in the future, common interests) can connect. (*Please* visit your own entry to make sure it is correct and displays what you wish.)

The website already makes it possible for any prospective employer to post jobs potentially of interest to alumni and is searchable only by alumni. Additional job-search, counseling, and support information is also available through the site and will be enhanced in the years ahead. In the near future, Caltech students will have access to this information as well.

All these new developments are an important aspect of networking among all alumni, working together to support one another in career, family, personal, and community interests.

But what about the more general complaint that the E&S magazine, website, e-mail, jobs page, and alumni directory "aren't worth" $45 a year (at current rates) or a present value (discounted at 5 percent) of $560 for 20 years of membership? What is it that would make Alumni Association membership worth $45 per year or worth *any* number greater than the perceived value of tangible benefits?

The short answer: *the maintenance and support of the alumni community for the benefit of all its members, the Institute, and the world at large*. Your Association—more important, *your* involvement—helps find and educate the best and the brightest (just as you were, and are). You received your education and your opportunities in part through *the efforts and support of the 80+ years of alumni who preceded you.* Your Association helps *all* 20,000 Caltech alumni worldwide through education, information, jobs and connections, friendship, and the support of the Institute. Your Association membership dues finance activities that leverage thousands of hours of alumni volunteer support for these objectives.

What is that worth? It's priceless.

Newly elected Alumni Association president Stephanie Charles '73 will take over this column in the next issue of Caltech News.

1942
John McClain
JANDEMCC@aol.com

It seems that my plea for more input did bear a little fruit, because I did get some replies! **Al Albrecht** sent greetings and said "still surviving and consulting at 83 in beautiful Bellingham, Washington. Glad to be out of the D.C. rat race now."

I also got a great letter from **Bill Turner**, whose grandkids had gotten him to write an autobiography. What he sent me was only the first chapter, which deals with his undergraduate years at Caltech and brought back memories of my own time at Tech. Bill's goal at Tech was to put out a high-grade *California Tech*, and during his two years as editor, the *Tech* achieved "All-American" honors both years. Bill also earned an honor key, but says that he darn near flunked out because of the time spent on the paper.

Russell Rhyne wrote that he no longer enjoys reunions, and that is a shame because he misses out on the great Half Century luncheons and the enjoyable chance to get together with old (and I do mean old!) friends. This year, he also missed hearing the excellent presentation by the first female vice president at Tech—Margo Marshak, who is vice president for student affairs. Her talk on past and present student activity was indeed outstanding!

In my calls for the Alumni Fund I talked to **Web Beckstead**, and his wife, Helen, and came up with a "can you top this?": 4 children, 19 grandchildren, and 25 great-grandchildren.

I had a great call from **"Zeke" Davis**. He and Betty are still in Spokane, doing what he's done since Tech days, hunting, fishing, and duck-hunting.

Several years ago when the surgeon put my wife's pacemaker in, I told him that I had had bypass surgery in 1978 and his comment was, "Hmmm they don't usually last that long." Well, he was right (give or take a few years), and so I went in on February 27 for a second time. It was a bit harder on me this time, but now—minus 30 pounds—I'm pretty much back to full-charge now. Hope all you octogenarians are enjoying what you are doing as much as I am.

1944
Paul Winter
Paul.Winter@caltech.edu

William (Bill) Harland writes to say that he is sorry to have missed our reunion, but he is still active in the design of "small run-of-river, green, sustainable producers of sustainable energy" in Canada and Asia. He is currently working on a 7 MW hydro project in Laos, and on a 25 MW hydro project in British Columbia. The company Bill is working with is also heavily into wind power, and their general objective is to develop power sources without burning fossil fuels. Bill's e-mail address is engranbarx@telus.net; and he would like to hear from any of his classmates. In addition to engineering, he maintains his interest in ranching.

1965
Ted Jenkins
rtjenk@aol.com

Stanley Christman writes from Houston, "I retired last year, after 38 great years with Exxon (Exxon Mobil) doing exploration and production. As some of you may know, I lost my wife, Hannelore, to lung cancer in 2001, and that had delayed my decision while healing. Many friends and family members helped enormously to get 'good' again. For now, I am splitting time between Houston and a home in the North Carolina mountains at Flat Rock (Asheville/Hendersonville). While I pondered going back to California, the beauty and climate of NC won out. Perhaps, as Thomas Wolfe mused, 'You can't go home again.' I am on a list of old, new, and resurrected interests: cooking, photography (includes the PC now), gardening, learning piano, meeting new people, travel, and for aggravation, golf. Life is good."

Alumni Notes Update

Starting with its next issue, *Caltech News* will introduce a comprehensive Alumni Notes section that will publish news and notes from all undergraduate and graduate alumni, replacing both the Class Notes and the Personals. The impetus is the new Alumni Association website at *www.alumni.caltech.edu/* (see story on page 13). Its searchable Alumni Network link enables alumni to post and read notes directly online. In the wake of this change, the Association will no longer use a class agent system for collecting and publishing undergraduate Class Notes.

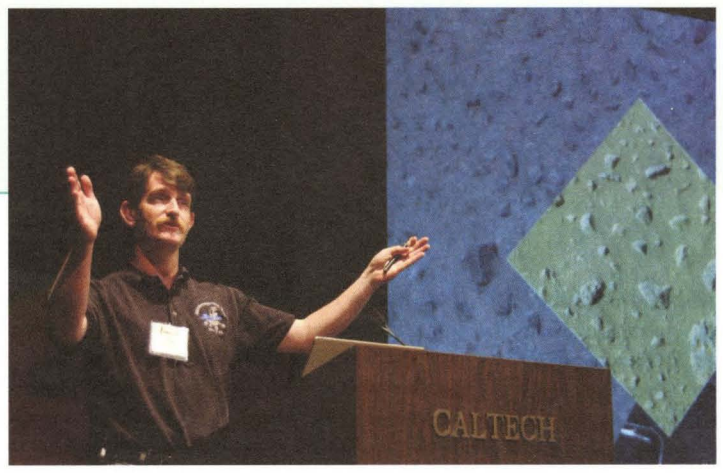
Alumni who post electronic notes online can also direct them simultaneously to *Caltech News* by clicking a second button at the same site to make sure that they will be published in a subsequent issue. We hope many alumni will use this opportunity to have their notes published both online and in print. As always *Caltech News* reserves the right to edit for length and content prior to publication.

Alumni may also continue to submit personal updates and any related material directly to *Caltech News* by utilizing the mail-in coupon that appears in each issue of the paper (see page 16) or via e-mail. These submissions will be subsequently posted at the online Class Notes site unless specifically requested otherwise.

We look forward to hearing from you online and in print!

Caltech News *and the Alumni Association would also like to acknowledge the undergraduate class agents for their commitment over the years to the Class Notes and for their contributions to* Caltech News.

Personals



At Caltech's Alumni College in June, Albert Haldeman, PhD '97, deputy project scientist for the Mars Exploration Rover mission, spoke to an enthusiastic capacity crowd in Ramo Auditorium about the latest scientific findings on Mars.

1941

Ralph W. Spitzer, PhD, of Vancouver, British Columbia, writes that he was saddened to read in *Caltech News* the obituary of Henri Levy, who was a postdoc in Linus Pauling's group when Spitzer arrived as a fresh graduate student. "All of us looked forward—not only to the help Henri gave us in calculating molecular and crystal structures—but also to the annual barbecue in Oxnard," replete with "three-star" 16-ounce T-bone steaks. Spitzer adds that, after leaving Caltech, he worked for the National Advisory Committee for Aeronautics (NACA—NASA's predecessor), taught chemistry at Oregon State College and the University of Kansas, did research in underwater explosives at the Woods Hole Oceanographic Institution, and did an additional postdoc with Ken Pitzer in Berkeley. Adding an MD (University of Manitoba, 1957) to his PhD, he practiced as a chemical pathologist and professor of pathology at the University of British Columbia until his retirement 15 years ago. "My wife of 59 years, who was with me at Caltech, died some 6 years ago. Since then I have been happily remarried to Hisako Kurotaki. We cook, garden, attend concerts, and travel together. We celebrated my 86th birthday a month ago in Hawaii."

1948

William S. Johnson, MS, of Montgomery, Alabama, recently presented his paper "'Pick's Pike': That 'Impossible' World War II Military Highway from Ledo, India to Kunming, China" at the 57th annual meeting of the Alabama Historical Association, May 7–8 in Birmingham. Johnson is a retired lieutenant colonel, U.S. Air Force, and spent two years in the China-Burma-India theater as an Air Transport Command aircraft maintenance officer.

Benoit B. Mandelbrot, MS, Eng '49, has been elected to the American Philosophical Society, the oldest learned society in the United States. Founded in 1743 by Benjamin Franklin for the purpose of "promoting useful knowledge," the society's early members included George Washington, Thomas Jefferson, and Thomas Paine. Later members included Charles Darwin, Thomas Edison, Louis Pasteur, Albert Einstein, and Robert Frost.

1958

Allen Klinger, MS, was the guest of Zhejiang and Ningbo Universities in China, giving six presentations to the Workshop on Image Processing and Related Mathematical Problems, under the auspices of the Institute of Imaging and Computer Graphics at Zhejiang University, in Hangzhou, and giving two general talks on computer research, one in Ningbo and the other at a new campus of Zhejiang University. A professor emeritus at UCLA since 1994, Klinger began his teaching and research career at UCLA in 1967, after working in the Rand Corporation's mathematics department and receiving his PhD from UC Berkeley in 1966.

1959

Norman J. Zabusky, PhD, has received the 2003 Otto LaPorte Award from the American Physical Society, Division of Fluid Dynamics, "for pioneering and enduring contributions in nonlinear and vortex physics and computational fluid dynamics." The State of New Jersey Professor of Computational Fluid Dynamics at Rutgers University since 1989, he is organizer for ScArt4, the Fourth International Symposium on Science and Art, to be held in New Brunswick, New Jersey, June 9–12, 2005 (for information, see http://www.mechanical.rutgers.edu/scart4). Zabusky will spend December 2004–March 2005 at the Weizmann Institute of Science in Rehovot, Israel.

1960

Leroy Hood, PhD '68, became the sixth recipient of the annual Biotechnology Heritage Award at the BIO 2004 Annual International Convention, held June 6–9 in San Francisco. During his acceptance speech, he called for scientists to play more of a leadership role, saying that scientists have "been remiss in taking to the public what science is," particularly in regard to communicating the benefits of biotechnology. The cofounder and president of the Institute for Systems Biology in Seattle, Hood is also the cofounder of Amgen, Applied Biosystems, and other biotechnology companies. A former professor and division chair at Caltech, he is currently a visiting associate in biology.

1962

C. Roland Haden, MS, of College Station, Texas, writes that he has recently retired from the post of vice chancellor and dean of engineering of the Texas A&M University System. During his career he also served as provost at Louisiana State University and at Arizona State University, where he also served as dean of engineering. "My good fortune included being named a Fellow of the IEEE and ASEE," he adds. "I am now serving on the Texas Board of Professional Engineers, the licensing board of the state, and on two corporate boards. My wife, Joyce, keeps me busy the rest of the time!"

1964

George M. Whitesides, PhD, Mallinckrodt Professor of Chemistry at Harvard, has been named Harvard's first Woodford L. and Ann A. Flowers University Professor, effective July 1. According to Harvard president Lawrence H. Summers, "George Whitesides is a scientist of extraordinary imagination and scope, and his long record of cross-disciplinary innovation, most recently in nanotechnology, exemplifies the excitement and promise of modern science." His other honors include the National Medal of Science in 1998. A faculty member at Harvard since 1982, Whitesides has served as chair of Harvard's chemistry department and as an associate dean of the Faculty of Arts and Sciences.

1967

Robert Parker, of Rancho Palos Verdes, California, has retired from Hughes Aircraft, which he joined after earning his PhD at USC in 1972. At Hughes, he worked on the development of specialized electronic components, radar design and production, communications and weather satellite design, and satellite design and marketing in Asia. After Boeing purchased Hughes's spacecraft business, Parker moved within Boeing into classified programs. In the late 1990s he began teaching graduate-level courses at USC on satellite systems engineering, and presenting university seminars on business development for high-value products in Asia. He adds that, as a recent survivor of emergency surgery himself, he volunteers on a website designed to help survivors of aortic aneurysms and their relatives, and, with his wife, Kathleen, does volunteer work for his church, St. Peter's By the Sea. He plans to spend the next few years continuing to teach, consulting on satellite design and marketing, raising Golden Retrievers, and developing his craft of writing and photography.

1970

Ronald W. Davis, PhD, of the Stanford University School of Medicine, has received the Herbert A. Sober Lectureship Award, presented during the annual meeting of the American Society for Biochemistry and Molecular Biology International Union of Biochemistry and Molecular Biology, in Boston, June 12–16. The award recognizes his "outstanding contributions to biochemical and molecular biological research, with particular emphasis on development of methods and techniques to aid in research." His current focus is on whole-genome analysis and the development of new technology for constructing genetic maps and high-throughput DNA sequencing.

1972

Neil J. Risch, professor of genetics, statistics and health research and policy at Stanford University, has been named director of the new Center for Human Genetics at UC San Francisco. He will also serve as the first Lamond Distinguished Professor in Human Genetics at UCSF. The center, which is in the UCSF School of Medicine, with participation and support from the School of Pharmacy, will bring together scientists from a broad spectrum of studies related to human genetics—from basic and behavioral research to medical science, and from psychiatry to cardiovascular research—to identify genes that contribute to human diseases and variation in response to drugs. Known for his innovative genetics research on a range of diseases and the author of more than 200 scientific papers, Risch is the winner of the American Mental Health Fund Research Award. He received his MS in mathematics from the University of Illinois in 1973 and his PhD in biomathematics from UCLA in 1979, then served on the faculties of Columbia and Yale before joining the Stanford genetics faculty in 1995.

1975

Suzanne Ostrand-Rosenberg, PhD, professor of biological sciences at the University of Maryland, Baltimore County, has been elected to the Johns Hopkins University Society of Scholars. She and 14 other scientists and clinicians were honored during the society's 35th induction ceremony on May 19, and again at the university's commencement ceremony on May 20. Created on the recommendation of former Johns Hopkins president Milton S. Eisenhower and approved by the university board of trustees in 1967, the society—the first of its kind in the nation—inducts former postdocs and junior or visiting faculty at Johns Hopkins "who have gained marked distinction in their fields of physical, biological, medical, social, or engineering sciences or in the humanities." Ostrand-Rosenberg, who holds the Robert and Jane Meyerhoff Chair of Biochemistry at UMBC, is cited for having "achieved a fruitful balance between excellence in research and clarity and quality in teaching."

1978

Charles Alcock, PhD, the Reese W. Flower Professor of Astronomy and Astrophysics at the University of Pennsylvania, has been appointed director of the Harvard-Smithsonian Center for Astrophysics, effective August 1. Headquartered in Cambridge, Massachusetts, the center is a collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. As director, Alcock will manage a staff of more than 900 employees—including more than 300 scientists—and an annual budget of about $110 million. A member of the National Academy of Sciences, Alcock received the 1996 E. O. Lawrence Award in physics and the American Astronomical Society's 2000 Beatrice M. Tinsley Prize. He is the principal investigator for the Taiwan-America Occultation Survey—a project for taking a census of the solar system's population of Kuiper Belt objects—and chairs the Observatories Council of the Association of Universities for Research in Astronomy.

Nils Petersen, PhD, vice president for research at the University of Western Ontario, has been appointed director general of the National Institute for Nanotechnology in Edmonton, Alberta. In addition to being vice president for research at Western, Petersen is chair of the board of SHARCNET (Shared Hierarchical Academic Research Computing Network), a network of high-performance computer clusters in Southwestern Ontario; a member of the College of Reviewers for the Canada Research Chair Program; and a former member of the board of trustees for the Canadian Institute of Synchrotron Radiation. A fellow of the Chemical Institute of Canada, Petersen has received the Faculty Association Alumni Award, the Edward G. Pleva Award for Excellence in Teaching, the Lieutenant Governor's Laurel Award for Teaching, and a Distinguished Research Professorship from Western's Faculty of Science, among other honors. His research focuses on intermolecular interactions in biological membranes, spanning a range of disciplines from theoretical mathematics to biology.

1980

William Newsome, PhD, has received the Dan David Prize, which annually awards three prizes of $1 million each for "achievements having an outstanding scientific, technological, cultural or social impact on our world." The prize, which is presented in Tel Aviv, Israel, recognizes Newsome's development with two colleagues of a new level of understanding regarding how the visual system works: specifically, how neurons help the eye, whether human or animal, detect prey. An investigator with the Howard Hughes Medical Institute, Newsome has worked for the past 15 years in the Stanford School of Medicine's department of neurobiology. Prior to that, he worked as a professor at the State University of New York at Stony Brook and at the National Eye Institute in Bethesda, Maryland. He received the Distinguished Scientific Contribution Award from the American Psychological Association in 2002.

1981

Murray S. Daw, the R. A. Bowen Professor of Physics at Clemson University, has been elected a fellow of the American Academy of Arts and

Sciences. Founded in 1780, the academy brings together scholars and leaders in every field of the arts and sciences, in a structure conducive of "interdisciplinary studies on international security, social policy, education, and the humanities that draw on the range of academic and intellectual disciplines of its members." Among its 4,500 members are 150 Nobel laureates and 50 Pulitzer Prize winners. Daw's work—funded by NASA, the Department of Energy, and the National Science Foundation—uses theoretical physics to investigate what makes metals strong, with the goal of finding new alloys capable of enduring extreme stress and temperatures.

1982
Cathryn A. Manduca, MS, PhD '88, has been selected to receive the American Geophysical Union's Excellence in Geophysical Education Award for 2004. Established in 1996 to acknowledge "a sustained commitment to excellence in geophysical education," the award is given annually to "educators who have had a major impact on geophysical education at any level," or "who have been outstanding teachers and trainers for a number of years; or who have made a long-lasting, positive impact on geophysical education through professional service.

1989
Andrea Ghez, MS, PhD '93, professor of physics and astronomy at UCLA, has been awarded the 2004 Gold Shield Faculty Prize for Academic Excellence. Presented to a UCLA faculty member every second year, the prize recognizes "extraordinary accomplishment" in research, as well as "outstanding teaching and distinguished university service." Named in *Discover* magazine's 20th-anniversary issue as one of the top 20 scientists in the country under 40, Ghez has been working since 1995 with the W. M. Keck Observatory's 10-meter Keck I Telescope atop Mauna Kea in Hawaii to study the movement of 200 stars close to the galactic center, and has demonstrated the existence there of a monstrous black hole with a mass 2.6 million times that of our sun. The recipient of many honors and awards, Ghez was earlier this year elected to both the National Academy of Sciences and the American Academy of Arts and Sciences, and received the Sackler Prize, an international award intended for young scientists who have made outstanding and fundamental contributions in their fields.

1994
Wayne Chen writes that he will have completed his geriatric medicine fellowship at USC in August, and that he will be joining the faculty of USC's department of geriatric and general internal medicine as an associate professor of clinical medicine.

1998
Tina Salmassi, MS, PhD '01, assistant professor of biological sciences at Cal State L.A., has been chosen from 762 candidates to be a faculty fellow in the 2004 NASA Faculty Fellowship Program at the Jet Propulsion Laboratory. "The fellowships are awarded to faculty, mainly in engineering and science, based on their work on research projects of interest to both the faculty member and the NASA center." Salmassi will work in the aeronautics and space program and on basic research problems. A microbial ecologist who studies bacteria in various environments, she teaches microbiology courses.

2001
Adam Lawton writes, "I'm leaving the Southern California sunshine and will be enrolling at Harvard Law School in the fall. I'm looking forward to joining the Cambridge/Boston alum crowd."

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Obituaries

1933
Samuel Y. Johnson, MS '34, of Rancho Santa Fe, California, on August 6, 2003; he was 91. He received an MBA from Harvard in 1938. He served for several years as budget director for the Freeport Sulphur Company in Louisiana, then returned to Harvard Business School as an instructor. He joined the U.S. Navy in 1942 and served four years, principally based at the Aviation Supply Office in Philadelphia, before retiring in 1946 as a lieutenant commander. After the war he joined Consolidated-Vultee Aircraft Corporation (later General Dynamics), eventually transferring to the San Diego area. He held various executive positions, including budget director, assistant to the president, and director of facilities planning. After retiring in 1976, he was active in the Golf Club, the Garden Club, and the Rancho Santa Fe Historical Society. An avid gardener, he was particularly interested in the California Native Plant Society and the cultivation of native plants. He also enjoyed hiking and backpacking, including alumni trips led by former classmate Robert Sharp. He is survived by Frances, his wife of 58 years; two daughters, Sally Koblinsky and Deborah Richmond; a son, Samuel Y. Jr., and five grandchildren.

1934
Horace W. Babcock, of Santa Barbara, California, on August 29, 2003; he was 90. An astronomer and a former director of the Pasadena-based Carnegie Observatories, he joined the Mount Wilson and Palomar observatories after World War II. He and his father, engineer and astronomical observer Harold Delos Babcock, built the first solar magnetograph, which they used to measure the sun's magnetic field. Babcock later invented a device of his own for measuring the magnetic fields of stars other than the sun, and he developed a so-called seeing monitor, for evaluating mountaintops as possible telescope sites. In 1953 he proposed the system of "adaptive optics," which permits real-time adjustments of telescope mirrors in order to compensate for the atmospheric distortion of celestial images. Director of the Mount Wilson and Palomar observatories from 1964 to 1978, he was a strong advocate for constructing an observatory in the Andes; and the Carnegie telescopes at Las Campanas, in Chile, have provided outstanding views of the Southern Hemisphere's sky, including the center of our galaxy. His awards include the Henry Draper, the Eddington, the Gold, and the Bruce medals, as well as the Hale Prize. He is survived by two sons, Ken and Bruce; a daughter, Ann; and a granddaughter.

1936
John I. Gates, on February 3, 2003.

Dick Wallman, MS, of Nashville, Tennessee, on December 20, 2002; he was 90. Wallman owned the Leonard Melton Sporting Goods Company. Predeceased by his wife, Dorothy, he is survived by a daughter, Lynne, and a son, Richard.

1938
William Carl Brenner, of Pittsburgh, Pennsylvania, on August 26, 2003; he was 86. An electrical engineer, he worked for Westinghouse for 44 years. He is survived by his wife, Ina-Marie; three daughters, Christine Holtshopple, Annemarie Little, and Marie-Luise Caster; and seven grandchildren.

Clay Smith, MS '40, PhD '43, in Socorro, New Mexico, on November 10, 2003; he was 86. He spent 40 years at the New Mexico Institute of Mining and Technology, beginning in 1947 as assistant professor of engineering and acting head of the department of engineering. He held various positions thereafter, including head of the department of geology, dean of students, and director of admissions, eventually retiring as professor of geology, emeritus, in 1987. Active in his community, Smith was a charter member of the Socorro Lions Club (serving as secretary and two-time president) as well as heavily involved in the Socorro First Presbyterian Church, including as a choir soloist. He also served as treasurer for the Friends of the Bosque Del Apache National Wildlife Reserve. His love of athletics led him into several coaching positions while at Caltech, and later into high-school football and basketball officiating in New Mexico, which resulted in his induction into New Mexico's hall of fame for sports officials. Instrumental in expanding the study of geology and other earth sciences throughout New Mexico, Smith served twice as director of the State Science and Engineering Fair and participated in several productions for educational television. After retiring, he continued to work as a consultant, and for the past 13 years he served as the regional director of alumni relations for Caltech, covering the western states. A fellow of the Geological Society of America, the Society of Economic Geologists, and the American Association for the Advancement of Science, an honorary member of the New Mexico Geological Society, and a member of the National Association of Geoscience Teachers, Smith was a charter/emeritus member of the American Institute of Professional Geologists, a life member of the New Mexico Academy of Science, and a member of Sigma Xi, New Mexico Chapter. He is survived by Sallie, his wife of 63 years; two sons, Dean and Stan; and four grandchildren.

1940
Frederick C. Brunner, MS '41, on September 17, 2003. He is survived by his wife, Celeste.

Ellery Stowell, of Huntington Beach, California, on August 22, 2003; he was 84. After receiving his PhD in biochemistry in 1947 from UC Berkeley, he did research for three years on a National Cancer Institute Grant at the University of Washington, then moved to USC for seven years, where he taught in the biochemistry department and performed research in cardiology, cancer, tuberculosis, and related fields. In 1957 he joined the Veterans Hospital in Long Beach, where he engaged in medical and dental research, particularly in regard to the causes of mouth cancer, and was instrumental in the development of fluoride. After retiring in 1980, he continued to teach at Newport Christian High and helped home-schoolers, and he was elder emeritus at Westminster Orthodox Presbyterian Church. He is survived by Helen, his wife of 62 years, and by a sister, Isabel Mavity.

1943
Stanley A. Dunn, of Madison, Wisconsin, on November 23, 2002; he was 81. After graduating he served as an officer on a wooden mine sweeper—one of the most dangerous U.S. Navy vessels during World War II—and specialized in highly classified radar detection technology. After the war he did graduate studies at Johns Hopkins University, MIT, and Harvard, then

obtained a fellowship at DuPont. He worked at Rhodia, an international perfumer, then in 1959 moved to Wisconsin and began a long career at Bjorksten Research Laboratories, where he oversaw research projects for both government and industry. Resigning from Bjorksten, Dunn started SEDUN, a research and development company, and also took a position in the University of Wisconsin's department of chemical engineering, so that he could continue his development of a superior fiber, using his own method. Upon retiring from the university, he went to work for Evco Plastics. A "Renaissance man," Dunn enjoyed intellectual activities, music, travel, skiing, tennis, woodworking, problem solving, and his family. He is survived by his wife, Ethel; four children, Mark, Randy, Elizabeth, and Stanley Jr.; two stepdaughters, Lydia Stephens and Andrea Poulos; and seven grandchildren.

1944

Leon Green Jr., MS '47, PhD '50, in Laguna Hills, California, on December 5, 2003; he was 81. He worked for North American Aviation, Aerojet-General, and the Aeronautic Division of the Ford Motor Company. In 1962 he became chief scientist of Lockheed Propulsion Company, and in 1964 he moved to Washington, D. C., to become director of the Research and Technology Division of the Air Force Systems Command. Later he became the executive secretary of the Defense Department's Defense Science Board and a consultant to the Atomic Energy Commission. In the late 1970s he left the government for private consulting work promoting clean coal technology. Predeceased in 1995 by his wife of 44 years, Eleanor, he is survived by three children, John, Emily, and Charles, and by four grandchildren.

Howard E. Johnson, CAVU, MS '52, of Boise, Idaho, on August 7, 2003. One of a number of students who during World War II received certification after completing an accelerated training program in meteorology, and who referred to themselves as Ceiling and Visibility Unlimited, he was later awarded a master's degree in meteorology, dated 1952. He taught physics and chemistry at Brentwood High School, in California, and he worked in research and development at Rockwell International. Predeceased by his wife, Betty, he is survived by his daughters, in whom he instilled "enthusiasm, passion and a love of learning."

John C. "Jack" Warren, of Glendora, California, on December 4, 2003; he was 81. He is survived by Helen, his wife of 56 years; a daughter, Marlys; a son, David; a sister, Barbara; and three grandchildren.

1945

Bill Perkins, of Sherman Oaks, California, on August 9, 2003; he was 79. A noted West Coast jazz saxophonist for more than 40 years, Perkins began his professional career in 1950 at the relatively late age of 26. After serving in the U.S. Navy at the end of World War II, he earned a degree in music from UC Santa Barbara, and then worked for the band of Jerry Wald. Through the 1950s he was a popular soloist with the Stan Kenton and Woody Herman big bands, and then in the 1960s did studio work as both a performer and a recording engineer. He also played with the *Tonight Show* band, earning a reputation for versatility by playing flutes and clarinets as well as saxophones. He continued playing with bands through the '70s and '80s, as well as with pianist Frank Strazzeri in the '80s and '90s. He most recently played with Bill Holman's band. Applying to music his knowledge of electrical engineering, Perkins held patents on a number of electronic instrument components, including a synthesized trumpet and synthesized saxophone. He is survived by his wife, Charlene; two daughters, Kimberly and Penny; two sons, Ernest and Thomas; and six grandchildren.

1946

Dansy T. Williams, MS, of Macon, Georgia, on September 20, 2003; he was 85. He served with the U.S. Army Air Forces from 1941 to 1946, mostly as a weather officer in Alaska and northwestern Canada, and after the war took a position with the former U.S. Weather Bureau, serving as a research meteorologist on projects in Florida and Ohio. Over the years his assignments with the bureau took him to many locations, and in 1965 he moved to Macon, where he had accepted a transfer as a research meteorologist with the U.S. Forest Service's Southern Forest Fire Laboratory, a position he retired from in 1978. A member of the United Methodist Church, the Young at Heart and Pacesetters organizations for senior citizens, and the Golden K Kiwanis Club of Macon, of which he was a past president, Williams hosted a weekly interview program with "mature" citizens on a local TV station and worked as an enumerator for the U.S. Census Bureau and as a volunteer for the American Red Cross Bloodmobile, the Macon/Bibb County Meals on Wheels, and the Ocmulgee National Monument. He is survived by Marie, his wife of 54 years; two daughters, Jeanne McLain and Mary Horton; a son, Edwin; and six grandchildren and one great-grandchild.

1947

Stanford Grant Stiles, of Houston, Texas, on September 16, 2003; he was 78. He served as an officer in the U.S. Navy during World War II and the Korean War, and he joined the Shell Oil Company in 1947. During his long career with Shell, he worked in 25 locations both in the United States and abroad, including Indonesia, Trinidad, the Netherlands, and England, ultimately rising to vice president and for many years supervising the construction of a city in Saudi Arabia. He retired in 1986. His particular passion was persuading and helping young people to go to college. He is survived by his wife, Roddie, and by two sons, Michael and Mark.

Donald B. Wheeler, PhD, of Bethlehem, Pennsylvania, on April 15, 2002; he was 84. A physics professor at Lehigh University for 37 years, he had retired in 1984. He was a member of Phi Beta Kappa, Tau Beta Pi, Beethoven Mannerchor, and the American Philatelic Society. He is survived by Mary, his wife of 47 years; three sons, David, Daniel, and Mark; a daughter, Anne; and three grandchildren.

1948

William E. Botts, of Long Beach, California, on August 2, 2002. He had pursued a career as a civil engineer in Southern California, working for many years at Douglas Aircraft (later McDonnell Douglas) in Long Beach, from which he retired some time after being diagnosed with Parkinson's disease. A gifted photographer and avid bicyclist and hiker, he greatly enjoyed traveling and exploring in other countries, particularly tropical, exotic, out-of-the-way locales. Botts's travels took him to Thailand, Indonesia, and other regions of southeast Asia, among other places. Despite his illness, "he biked almost to the end." Botts is survived by his sister.

1949

Alan H. Green, MS, of Williamstown, Massachusetts, on October 13, 2003; he was 81. An aeronautical engineer who worked for various companies during his career, Green served as copy editor for *The Advocate* after moving to Williamstown in 1972. He is survived by Alcenith, his wife of 41 years; a daughter, Nancy Smith; a brother, Ira; and four grandchildren.

1953

John S. Saxon, Eng, of Bryan, Texas, on August 22, 2003; he was 81. A U.S. Navy fighter pilot who flew hundreds of missions, he worked for Texas Instruments, where he played a key role in developing FLIR, or Forward-Looking Infrared, the night-vision video still used by police and military aircraft all over the world. After retiring, Saxon returned to his ranching roots in the Navasota River region, to smoke cigars and raise Chianina cattle on his parents' land. He is survived by his wife, Katherine, and by four children, Jean, Rose, John II, and Mary Lou.

1954

Garson P. Shulman, on June 11, 2003.

1957

Robert Baxter Kohlmeyer, MS, of Los Angeles, on June 18, 2003; he was 71. He is survived by Zanette, his wife of 44 years; a daughter, Corrine O'Neill; and two grandchildren.

1958

Dick Wright Thurston, Eng, of La Jolla, California, on September 17, 2003; he was 74. A U.S. Navy officer and aviator inspired by his brother, Wright, who was killed in a plane crash during World War II, Thurston flew missions worldwide during his career. After retiring from the Navy, he became assistant dean of engineering at Brigham Young University, and he served in both the Rotary Club and in many positions for the Mormon Church. He spent the last 20 years of his life struggling with hereditary emphysema. He is survived by Mary Lou, his wife of 52 years; two sons, Wright and Rob; a daughter, Elizabeth; and 15 grandchildren and six great-grandchildren.

1961

Malcolm L. Kinter, of Scottsdale, Arizona, on August 2, 2003; he was 64. A materials-science engineer, he had retired as director of manufacturing for Siemens 11 years ago. He is survived by MaryAnn, his wife of 14 years, and by a sister, Chris.

1965

Gordon E. Keller, PhD, of Charlottsville, New York, on July 5, 2003.

1969

Denny R. Ko, PhD, of Palos Verdes Estates, California, on September 25, 2003; he was 64. Founder and chair of Dynamics Technology Inc. since its formation in 1976, and founding general partner of DynaFund Ventures, which was formed in 1997, Ko played a leading role for over 25 years in the formation and growth of high-tech companies in both the United States and Taiwan. He is survived by Starla, his wife of 41 years; a daughter, Grace; a son, James; four sisters, Rulin, Lucy, Ruchiung, and Grace; and a brother, Rusan.

1970

James H. Starnes Jr., PhD, of Yorktown, Virginia, on October 27, 2003; he was 64. Chief engineer for structures and materials at NASA's Langley Research Center, where he spent 33 years, he was internationally recognized as an expert in the field of aerospace structures. Regarded by many as the nation's preeminent expert in composite structures technology, his contributions can be found on every aircraft flying today. He participated in the design of the International Space Station, the NASA investigations into the *Challenger* and *Columbia* disasters, and NASA's efforts during the National Transportation Safety Board's failure investigation of American Airlines Flight 587; provided technical advice to other government agencies as well as to industry and universities; and represented NASA in NATO's Research and Technology Organization. Awarded NASA's Exceptional Engineering Achievement Medal, he was a fellow of the American Institute for Aeronautics and Astronautics, the American Society for Composites, and the American Society of Mechanical Engineers, and he was a member of the Georgia Tech Academy of Distinguished Engineering Alumni. He is survived by his wife, Sue; a daughter, Susan; a son, James H. III; a sister, Ruth Ann Rodgers Lumpkin; and a brother, Joseph.

Commencement . . . from page 4

society offers you an opportunity and even imposes a duty to help your countrymen recognize this value and act on it. It is not institutional pride or parochialism but patriotism that forces us to ask how we can get more of America to do what Caltech does so well. Play your part in those debates. Help your fellow citizens who may have absolutely no idea how their television or their car or their phone or their medicine actually works. Help them to appreciate what science and engineering is and does. Make them a constituency for maintaining our technical strength."

Video of Fiorina's address can be seen at http://pr.caltech.edu/commencement/04/broadcast/bb/bb.html, and the speech can be read at http://www.hp.com/hpinfo/execteam/speeches/fiorina/caltech04.html.

Arnold Beckman, 1900–2004

Arnold Orville Beckman, chair emeritus of the Caltech board of trustees, died May 18 at Scripps Hospital in La Jolla, California, after a long illness. The founder and president of Beckman Instruments Inc., and for many years a nationally recognized inventor, scientist, philanthropist, and business leader, Beckman was 104.

Caltech president emeritus Thomas Everhart, who came to know Beckman well when he headed the Institute from 1977 to 1987, said, "Arnold Beckman was a great man. His inventions transformed chemical measurements—and more. I first met him at the University of Illinois and learned to know him much better at Caltech. He showed his appreciation for his education by generously supporting Caltech with his leadership as a trustee, and with his gifts, which have enriched the campus. He was admired by all and loved by many.

"Everyone associated with the Institute is richer for having had him among us."

Beckman Professor of Chemistry Harry Gray, a longtime friend and associate of Beckman's and founding director of Caltech's Beckman Institute, said, "Arnold Beckman started an instrumentation revolution that completely changed the course of chemistry and biology not only at Caltech, but all over the world."

And Peter Dervan, Bren Professor of Chemistry, said that the country has "lost one of the truly great visionaries of the 20th century. Arnold Beckman had a huge impact regarding the quality of our lives."

Born in 1900 in Cullom, Illinois, Beckman, the son of a blacksmith, played piano for silent movies before embarking on his work as an inventor and scientist. After earning a bachelor's degree in chemical engineering in 1922 and a master's degree in physical chemistry in 1923 at the University of Illinois, he entered Caltech as a graduate student, initiating what would become a lifetime association with the Institute, first as a chemistry student, later as a professor, and finally as a major benefactor.

Beckman earned his PhD in photochemistry in 1928, and six years later invented the pH meter, which became the foundation of his career as an industrialist and philanthropist. He started Beckman Instruments in 1935, and in 1940 resigned his Caltech faculty appointment to devote his full efforts to his rapidly expanding company. That same year he introduced a number of other inventions, including the Beckman DU spectrophotometer and a helical potentiometer—known as the Helipot—which went on to become an essential component in World War II–era radar. For his invention of the pH meter he was named to the National Inventors Hall of Fame in 1987.

Beckman was a committed and generous benefactor of Caltech and other teaching and research institutions. At Caltech, he provided funding for the Beckman Institute, the Beckman Laboratories for Behavioral Biology, Beckman Auditorium, and the Arnold and Mabel Beckman Laboratory of Chemical Synthesis, among other contributions.

He also gave $40 million to fund an interdisciplinary research institute at the University of Illinois, $20 million to create a conference center in Irvine, California, for the National Academy of Sciences, $14.5 million in 1998 to improve K-6 science education in Orange County, and many other gifts in support of basic research and public education. By his 100th birthday, in 2000, he had provided more than $270 million for the direct support of research.

Against the backdrop of Beckman Auditorium, Arnold Beckman (left), then-Caltech president Harold Brown (center), and Mabel Beckman take part in a construction site ceremony for the Arnold and Mabel Beckman Laboratories for Behavioral Biology in 1972.

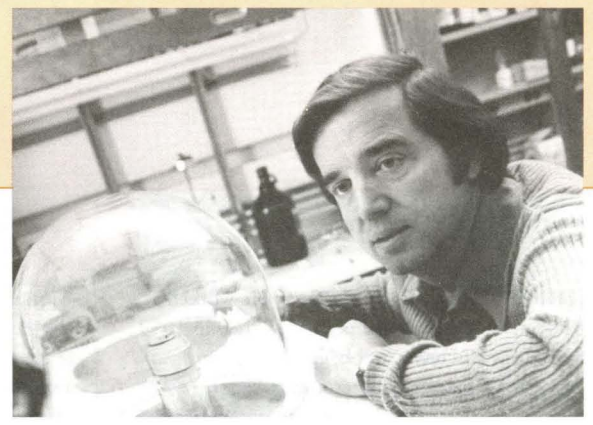
Air pollution was a long-standing concern of Beckman's. He provided early support of the scientific investigations that revealed the sources and mechanisms of photochemical smog. Later he helped develop pollution control regulations and smog-warning procedures for Los Angeles County.

A recipient of both the National Medal of Science and the National Medal of Technology, Beckman also received the 1997 Treasures of Los Angeles Award from Mayor Richard Riordan.

Beckman lived for more than 40 years in the Shore Cliffs seaside development in Corona del Mar. Last year, neighbors dedicated the Arnold and Mabel Beckman Park, named for him and his wife, Mabel, who died in 1989.

Beckman is survived by his daughter, G. Patricia Beckman of Corona del Mar, and a son, Arnold S. Beckman of Asotin, Washington, two grandchildren, and three great-grandchildren.

William Dreyer 1928–2004



William Dreyer in his lab, in the 1970s.

William Dreyer, a professor of biology at Caltech since 1963, died April 23, 2004, after a long illness. He was 75.

A native of Kalamazoo, Michigan, Dreyer earned his bachelor's degree at Reed College and his doctorate in biochemistry at the University of Washington in 1956. He then worked for six years as a research biochemist at the National Heart Institute and National Institute of Arthritis and Metabolic Disease before joining the faculty at Caltech, where he remained the rest of his life.

Dreyer was perhaps best known for his suggestion in the 1960s that genes could be "reshuffled" to provide additional information for the formation of proteins. At first a controversial idea, the theory later came into prominence after it was experimentally demonstrated by others, including Lee Hood '60, PhD '68, who at one time was Dreyer's student.

At a Society for Biomolecular Screening conference held in 2003, Hood credited Dreyer for mentoring his early career, teaching him the art of conceptual thinking, and providing him with "a wonderful introduction to the exhilaration of rapidly paced molecular immunology." Hood added that Dryer consistently emphasized two principles: "Always practice biology at the leading edge," and "If you really want to change biology, develop a new technology for pushing back the frontiers of biological knowledge."

Dreyer also carried out fundamental research into the mechanisms of embryonic development, and he made major contributions to the field of biological instrumentation. He was the author of a number of journal articles and also held a number of patents, including one for an immunological reagent and radioimmunoassay, and two for polyacrylate beads that he developed with two colleagues.

Dreyer is remembered by former students as an original thinker, who taught them to look at data with a fresh eye, rather than through the filter of conventional scientific dogma, and for having instilled in them his love of science.

An avid pilot for many years, Dreyer often flew to Baja California, various archaeological sites in the western United States, and to remote regions in British Columbia. He once said that his taste for flying his Cessna P210 at altitudes of 15,000 feet—high for a small privately-owned prop plane but low for commercial aircraft—was "an allegory for my tastes in scientific research. I like to work where research isn't too competitive and crowded—to move beyond the current mob scene, even if the place where I end up is lonely."

The Caltech professor is survived by his wife and colleague, Dr. Janet Roman, and three daughters.

As Caltech News *went to press, the Caltech community was deeply saddened to learn of the death of Edward Lewis, PhD '42. The Morgan Professor of Biology, Emeritus, died on July 21 at age 86, following a long battle with cancer.*

A modest man and profoundly original scientist, Lewis shared the 1995 Nobel Prize in physiology or medicine for his groundbreaking studies of how genes govern the order in which body parts are patterned and laid down during embryonic development. A Caltech faculty member since 1946, he spent his life investigating the relationship of genes to embyronic development in the drosophila fly—research that yielded key insights into the mechanisms of development in animals ranging from flies to humans, as well as shedding light on how and why these processes can go seriously awry. On both the Caltech campus and in the larger biomedical community, Lewis was renowned for his dedication to his fly research, and until recently he maintained an active schedule in his campus laboratory. A full obituary will appear in the next issue of Caltech News.

A memorial service is planned for Monday, October 25, at 2 p.m. in Ramo Auditorium on the Caltech campus.

Robert Sharp 1911–2004

Robert Sharp '34, MS '35, a leading authority on the surfaces of Earth and Mars and longtime chairman of Caltech's Division of Geology, died May 25 at his home in Santa Barbara at 92.

An internationally recognized geologist and a recipient of America's top scientific honor, the National Medal of Science, Sharp was also widely known for the originality and breadth of vision he brought to modernizing and diversifying Caltech's earth sciences program at a crucial juncture in the history of both the Institute and post-World War II science. In his more than 15 years as division chair, he demonstrated a remarkable talent for hiring gifted people and a keen interest in fostering new interdisciplinary approaches to take advantage of the dawning age of planetary exploration.

Particularly noteworthy was his support of planetary science as a vehicle for extending geological research to the other planets, especially Mars, and his contributions to creating the field of geochemistry and building the Institute into a world-class center for geochemistry research. The discipline was especially important in the interpretation of lunar samples, research that began at Caltech in 1970. Sharp was also closely involved with NASA during the 1960s as an interpreter of the Mariner imagery from Mars.

Sharp's many research activities included investigations of basin and range structure, continental basin deposits, mountain glaciation, continental glaciation, glacial-lake shorelines, frozen ground, erosion surfaces, desert sand dunes, glaciers, oxygen and hydrogen isotopes in snow and glacier ice, and surface forms and processes on Mars.

Elected to the National Academy of Sciences in 1973, Sharp received the National Medal of Science in 1989 for having "illuminated the nature and origin of the forms and formation processes of planetary surfaces, and for teaching two generations of scientists and laymen to appreciate them."

His many other awards and honors included the Kirk Bryan Award from the Geological Society of America (1964); NASA's Exceptional Scientific Achievement Award Medal (1971); the Penrose Award from the Geological Society of America (1977); and the Charles P. Daly Medal from the American Geographical Society (1991). He was named one of ten outstanding U.S. college teachers by *Life* magazine in 1950, and, in an unprecedented move by Caltech, honored with a professorship in his own name—the Robert P. Sharp Professorship in Geology—in 1978. (Geologist Kerry Sieh is the current holder of the chair.)

Sharp's geology colleagues are fond of recalling how warmly Sharp embraced the idea of getting the geology division its first named chair and enthusiastically participated in fundraising efforts to endow it, including a trio of rafting "trips of a lifetime" down the Colorado River at $50,000 a head. The name of the Sharp Professorship and the selection of Sharp as its first occupant came as a complete shock to Sharp, who later said, "On the third trip, I was dumb-struck when [then Caltech president] Murph Goldberger announced it was to be named . . . for me, and said, 'If I had known this, I wouldn't have worked so hard.'"

A native of Oxnard, California, Sharp first came to Caltech as an undergraduate in 1930. He became a standout quarterback on the Caltech football team and many years later told an interviewer from *Sports Illustrated* magazine that his gridiron experience served to show a scientist that he needed "to be determined as hell and that there is a certain poise and aggressiveness that is desirable."

In a 1990 interview with the Caltech newspaper *On Campus*, Sharp described himself as something of an accidental geologist, who stumbled into the field as the result of a course requirement. "In my sophomore year [when] we all had to take geology, [we all] laughed and said, 'what's that?' I knew nothing about geology before that class . . . . After a week or two, I was really excited . . . . [When] we had to pick an option at the end of our sophomore year, it was during the Depression, and I wondered if I could earn a living doing geology. I took a chance and signed up . . ."

After earning his PhD from Harvard in 1938, Sharp spent several years in the geology department at the University of Illinois, and then served in the U.S. Army Air Forces from 1943 to 1945, attaining the rank of captain. He then spent two years on the University of Minnesota faculty, returning to Caltech in 1947 as a geology professor. He was division chairman from 1952 to 1968, retiring as the Sharp Professor Emeritus in 1979.

Even before his retirement, Sharp had taken on the job of planning, organizing, and leading a wide range of geology-themed travel/study programs for Caltech community members, particularly geology students and Institute alumni. Arlana Silver, who currently heads the Caltech Associates and worked with Sharp on these programs for many years as associate and then deputy director of the Alumni Association, recalls that "Bob was the one who came up with the idea that Caltech should be offering these travel programs to alumni. Once he got the program started, he went on leading these trips right into his eighties. He touched every person who ever traveled with him."

Robert Sharp in the field, in the 1970s.

Sharp's excursions included trips he led to Canada, Alaska, Hawaii, Yellowstone National Park, Montana's Glacier National Park, and the American Southwest. Every trip drew new travelers, as well as an ever-growing contingent of returnees. "Once you went somewhere with Bob," says Silver, "you always wanted to be on his next trip."

Sharp wrote or coauthored several popular-geology books, including *Field Guide to Southern California*, as well as *Geology Underfoot in Southern California* and *Geology Underfoot in Death Valley and Owens Valley* (both written with Allen Glazner and now in their fourth printings). He had almost finished another "Geology Underfoot" book on Idaho, which will be completed by his coauthors.

Sharp, whose wife of 62 years, Jean Todd Sharp, predeceased him, is survived by his children, Kristin and Bruce.

A memorial service is planned for the fall.

Those wishing to make a contribution to Caltech in Sharp's memory are asked to write to the Robert P. Sharp Ventures in Earth Sciences Fund, GPS Division, attention Marcia Hudson, Mail Code 170-25, Pasadena, CA 91125, making checks payable to Caltech with a notation earmarking the gift for the memorial fund.

Readers who would like to share their memories of the late Caltech faculty commemorated here are invited to write to Caltech News, Caltech 1-71, Pasadena 91125, or to e-mail hja@caltech.edu. Caltech News *reserves the right to select and edit letters for publication.*

Rings to Rule Them All

If the Cassini spacecraft could phone home about its current visit to Saturn, it would probably be speechless. That's because it has come up against some jaw-dropping views of the planet and its moons over the last few months. During its approach, Cassini, which went into orbit around Saturn June 30, took advantage of some amazing photo-ops—a sampling of which are depicted in the photo montage on the back-page poster. They include the central photo of the ringed planet taken by two narrow-angle cameras on May 7, a mosaic of two images taken on June 11 of Saturn's pock-marked moon Phoebe (upper right), and combined images taken with a narrow-angle camera on June 10 of the planet's large, haze-shrouded moon Titan (lower left). It should be noted that for purely aesthetic reasons these images are not to scale, nor are the objects accurately positioned around Saturn. And the picture of Cassini itself (upper left) was extracted from an image of the spacecraft taken while it was being built. For more on the mission, see *UpFront,* page 2.

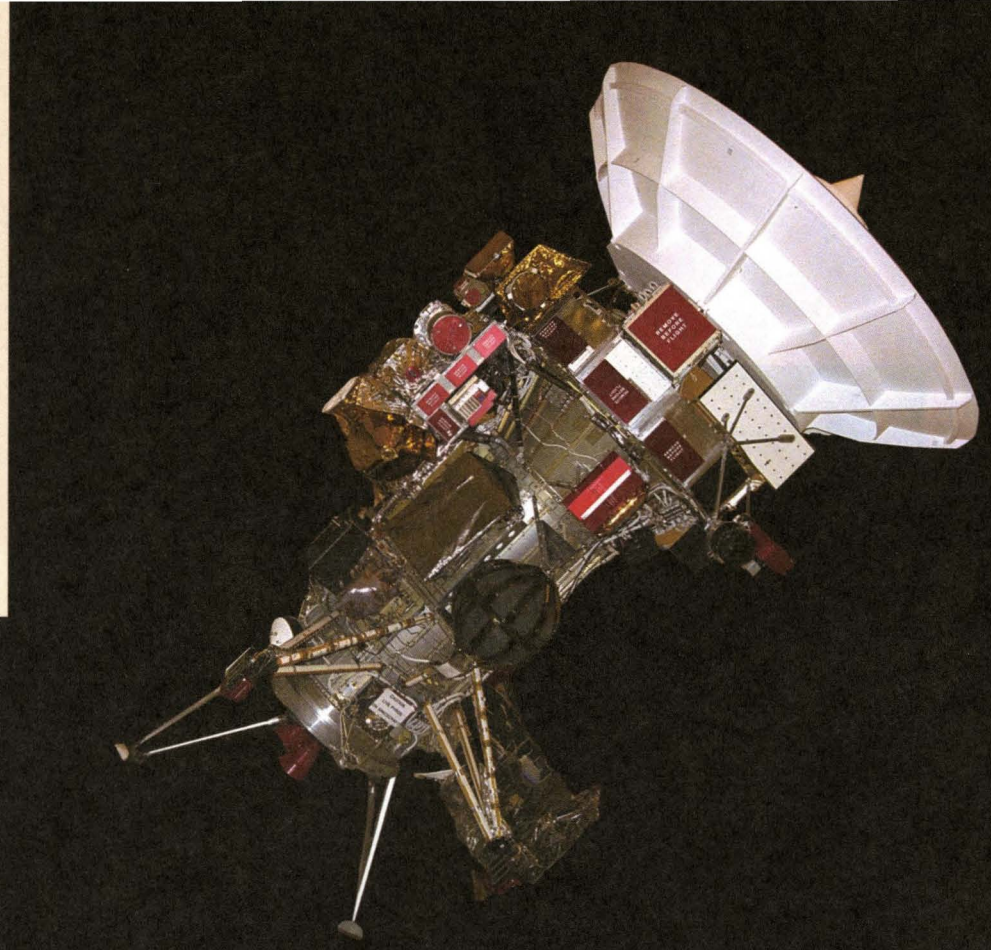
For the Record—Man and the Moon

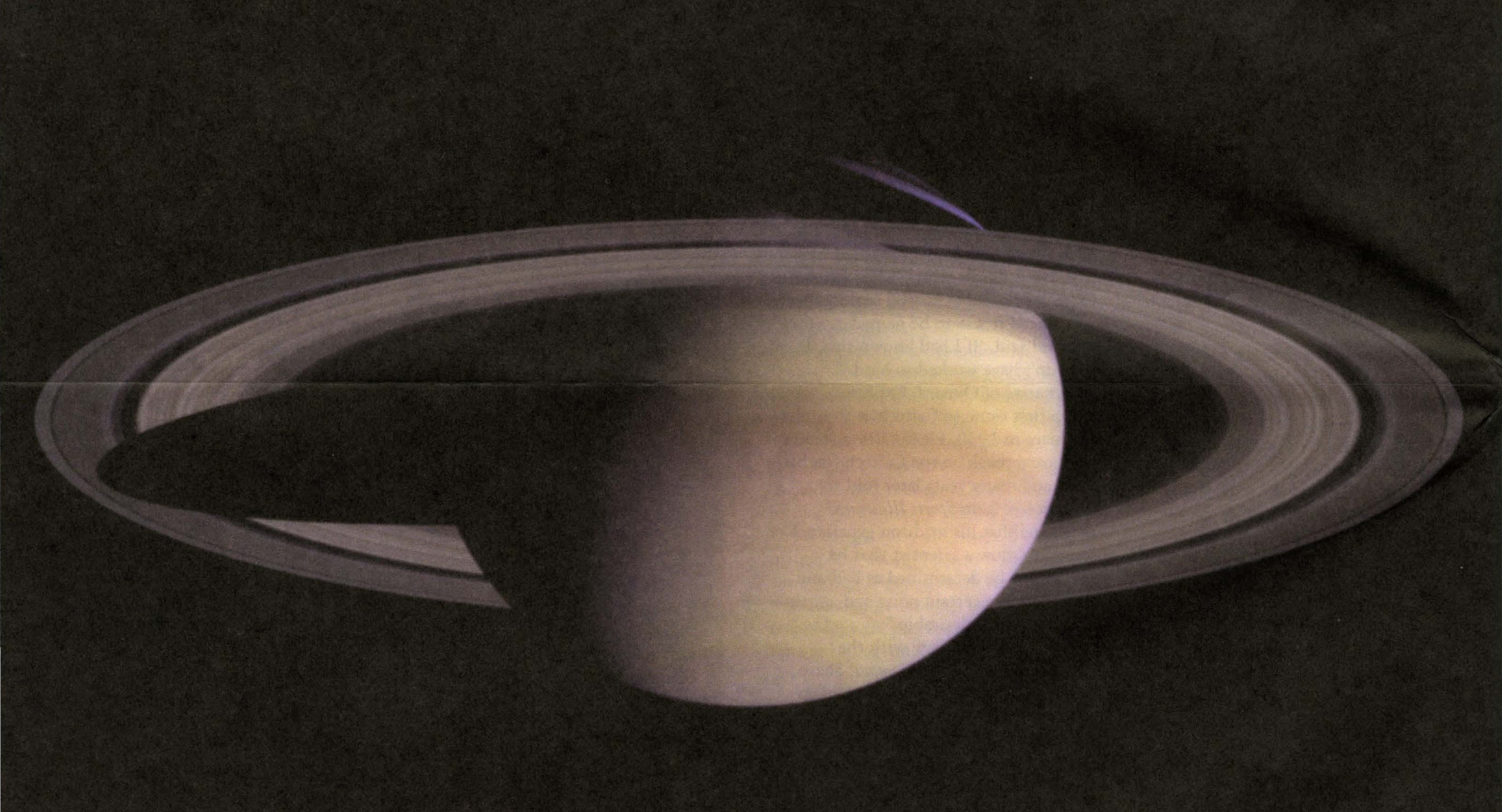
Is a miscaptioned picture worth a thousand letters? Could be, according to Al Bersbach '67. After seeing the picture (above) that we published to accompany the obituary of former JPL director William Pickering in the last *Caltech News*, Bersbach wrote us from the University of Maine: "I guess a thousand people must have pointed out that the photo of William Pickering on page 19 of *Caltech News* V. 38, No.1, has a map of the moon in the background, not Mars."

Well, no, not a thousand, but we did also hear from Sue Kieffer, PhD '71, at the University of Illinois at Urbana-Champaign. "Has anyone told you that the photo of Pickering in your recent issue is not 'a map of Mars,' but rather is a photo-mosaic of the Moon!

"I have an identical one here that was given to me when I was an intern at Goddard Space Flight Center in 1963. I have cherished it, and moved it with me everywhere," says Kieffer, who is now the Walgreen Chair and professor of geology at UIUC. "It is quite a collector's item. It was made up from terrestrial photos taken as the terminator moved across the Moon."

Okay, the planet's not red. Now, as for our faces . . .





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