Elachi (left) and Stone at the press conference.

## The Lab Names One of Its Own

Charles Elachi (MS '69, PhD '71) has been named the new director of the Jet Propulsion Laboratory (JPL), which Caltech manages for NASA, effective May 1. President David Baltimore made the announcement at a press conference on January 31, where Elachi and Baltimore were joined by retiring JPL director Edward Stone, the Morrisroe Professor of Physics; and NASA administrator Daniel Goldin. Elachi has served in a variety of research and management positions at JPL since 1971. Most recently, he has been head of the Space and Earth Science Programs; other positions include manager for radar development and leader of the radar remote-sensing team.

Elachi "knows JPL better than anyone and will be best able to lead the Laboratory in the coming years," Baltimore said. "Charles has an extraordinary record of accomplishment in his 30 years at JPL. He is an alumnus of Caltech, and so knows the school well. He is an expert in remote sensing, and in recognition of his work, he was one of the youngest members ever elected to the National Academy of Engineering. He has long been a leader of planetary exploration at JPL and is widely respected at the Laboratory. I look forward to having a close working relationship with him."

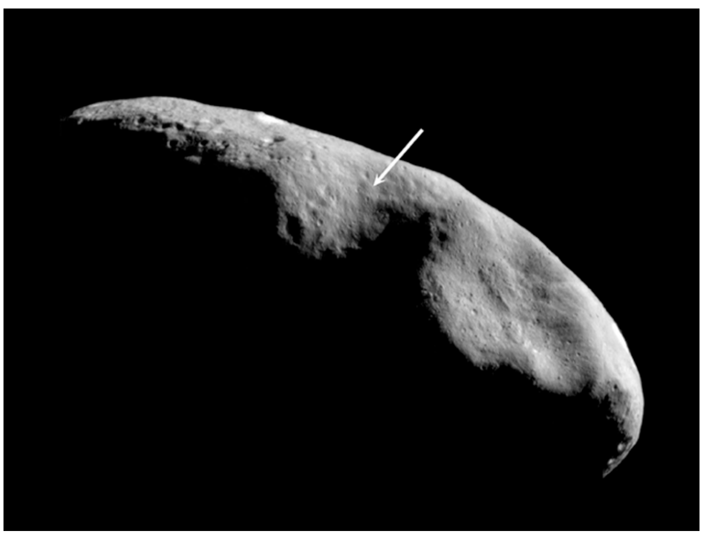
"Charles Elachi brings formidable talents to his new job, as both a scientist and a leader," said Goldin. "In addition to already being responsible for many of JPL's missions in solar system exploration, Earth sciences, and astrophysics, he has led efforts to create road maps of our exploration strategies decades into the future. He is both an effective administrator and a visionary."

Elachi said he was honored to be entrusted with the leadership of JPL. "For the last 40 years JPL has enjoyed a tradition of excellence as a NASA center and division of Caltech, and I intend to continue that tradition. My commitment is to continue the tradition of excellence and boldness in exploring our solar system, understanding the origin of galaxies, and applying that knowledge to better understand the changes on our own planet." The new post brings Elachi full circle, as he recalled being inspired as an 11-year-old in Lebanon by JPL's launching of Explorer 1—43 years ago to the day, he noted. "Maybe that's a good omen for me," he joked. He grew up to receive a BSc in physics from the University of Grenoble, France, and the Dipl.Ing. in engineering from the Polytechnic Institute, Grenoble, both in 1968, and then earned his Caltech MS and PhD in electrical engineering. He also earned an MBA from USC in 1978, and an MS in geology from UCLA in 1983.

Elachi is perhaps best known for his role in the development of a series of imaging radar systems for the Space Shuttle that have allowed scientists to see through the clouds that blanket Earth. (The technology also penetrates the top layer of soil in arid regions, revealing hints of what lies below.) He has participated in a number of archaeological expeditions in the Egyptian desert, the Arabian peninsula, and the Western Chinese desert, using satellite data to search for old trading routes and buried cities. Some of these expeditions have been featured in *National Geographic*, on PBS, and in *Caltech News* ("The Road to Ubar," April, 1992). He has also served as principal investigator on numerous NASA research and development studies and flight projects. He is currently the team leader of the Cassini Titan radar experiment and a coinvestigator on the Rosetta Comet Nucleus Sounder Experiment. He is the author of more than 200 publications on space and planetary exploration, Earth observation from space, active microwave remote sensing, wave propagation and scattering, electromagnetic theory, lasers, and integrated optics, and he holds several patents in those fields. He has written three textbooks on remote sensing and has taught EE/Ge 157, Introduction to the Physics of Remote Sensing, since 1982.

In 1988, the *Los Angeles Times* selected him as one of "Southern California's rising stars who will make a difference in L.A." In 1989, Asteroid 1982 SU was renamed 4116 Elachi in recognition of his contributions to planetary exploration.

Elachi is the second Caltech alumnus to be named director of JPL. The first, William Pickering (BS '32, PhD '36), headed the lab from 1954 to 1976. □—*JP*



**On February 12, NEAR Shoemaker became the first spacecraft to land on an asteroid—all the more impressive when you consider that this legless orbiter was never designed to land on anything. NASA's Near Earth Asteroid Rendezvous mission, which was renamed in honor of the late Eugene Shoemaker (BS '47), the father of planetary geology, had been in close orbit around the 21-mile long Eros for a year. The craft touched down at a gentle four miles an hour and in an orientation that allowed its solar panels to continue to function, so jubilant scientists turned its gamma-ray spectrometer back on to get a close-up analysis of Eros's surface mineralogy. In this image mosaic, taken from an orbital altitude of 200 kilometers, the arrow points to the landing site. Gene's gotta be happy....**

## Sniff Me a Tune

When Hamlet told the courtiers they would eventually "nose out" the hidden corpse of Polonius, he was perhaps a better neurobiologist than he realized. According to research by Caltech neuroscientists, the brain creates subtle temporal codes to identify odors. Some neural signals change over the duration of a sniff, giving first a general notion of the type of odor, then a more subtle discrimination that leads to precise recognition of the smell. In the February 2 issue of the journal *Science*, Gilles Laurent, associate professor of biology and computation and neural systems, and postdoc Rainer W. Friedrich, now at the Max Planck Institute in Heidelberg, Germany, report that certain neurons respond to an odor through a complicated process that evolves over a brief period of time. These neurons, called mitral cells because they resemble miters—the pointed hats worn by bishops—are found by the thousands in the human olfactory bulb.

"We're interested in how ensembles of neurons encode sensory information," explains Laurent. "So we're less interested in where the relevant neurons lie, as revealed by brain mapping studies, than in the patterns of firing these neurons produce and in figuring out from these patterns how recognition, or decoding, works."

The researchers used zebra fish because these animals have comparatively few mitral cells and because much is already known about the types of odors that are behaviorally relevant to them. But the study likely applies to other animals, including humans, because the olfactory systems of most living creatures appear to follow the same basic principles. After placing electrodes in the brains of individual fishes, they were subjected to sequences of 16 odor components found in foods they normally seek. Analyzing the signals from the mitral cells showed that the information the fish could extract about a stimulus became more precise as time went by. The finding was surprising because the signals extracted from the receptor neurons located upstream of the mitral cells showed no such temporal evolution. "It looks as if the brain actively transforms static patterns into dynamic ones and in so doing, manages to amplify the subtle differences that are hard to perceive between static patterns," Laurent says.

"Music may provide a useful analogy. Imagine that the olfactory system is a chain of choruses—a receptor chorus, feeding onto a mitral-cell chorus, and so on—and that each odor causes the receptor chorus to produce a chord. Two similar odors evoke two very similar chords, making discrimination difficult. What the mitral-cell chorus does is to transform each chord it hears into a musical phrase, in such a way that the difference between these phrases becomes greater over time. In this way, odors that initially 'sounded' alike progressively become more easily identified."

In other words, when we

detect a citrus smell in a garden, for example, the odor is first conveyed by the receptors to the mitral cells. This initial firing allows for little more than the generic detection of the citrus nature of the smell. Within a few tenths of a second, however, new mitral cells are recruited, leading the pattern of activity to change rapidly. This quickly allows us to determine whether the citrus smell is actually a lemon or an orange.

However, the individual tuning of the mitral cells first stimulated by the citrus odor does not become more specific. Instead, the manner in which the firing patterns unfold through the lateral circuitry of the olfactory bulb is ultimately responsible for the fine discrimination of the odor. "Hence, as the system evolves, it loses information about the class of odors, but becomes able to convey information about precise identity," says Laurent. □—*RT*

## THE INS AND OUTS OF OVER- AND UNDERVOTES

In December, following the contentious vote counting in the presidential election, Caltech and MIT decided to join forces to develop a voting system that will be easy to use, reliable, secure, and modestly priced. The project was the brainchild of the institutions' two presidents—Caltech's David Baltimore and MIT's Charles Vest—and, with $250,000 funding from the Carnegie Corporation, faculty from both campuses began collecting data and studying the range of voting methods across the nation.

Early in February, the Caltech/MIT Voting Technology Project submitted a preliminary report to the task force studying the election in Florida. Their nationwide study of voting machines offers further evidence supporting the task force's call to replace punch card voting in Florida. The statistical analysis also uncovered a more surprising finding: electronic voting, as currently implemented, has performed less well than was widely believed.

The report examines the effect of voting technologies on unmarked and/or spoiled ballots. Researchers from both universities are collaboratively studying five voting technologies: paper ballots with hand-marked votes, lever machines, punch cards, optical scanning devices, and direct-recording electronic devices (DREs), which are similar to automatic teller machines.

The study focuses on so-called "undervotes" and "overvotes," which are combined into a group of uncounted ballots called "residual votes." These include ballots with votes for more than one candidate, with no vote, or that are marked in a way that is uncountable.

Careful statistical analysis shows that there are systematic differences across technologies, and that paper ballots, optical scanning devices, and lever machines have significantly lower residual voting rates than punch-card systems and DREs. Overall, the residual voting rate for the first three systems averages about 2 percent, and for the last two systems averages about 3 percent.

This study is the most extensive analysis ever of the effects of voting technology on under- and overvotes. The study covers the entire country for all presidential elections since 1988, and examines variations at the county level. When the study is complete, it will encompass presidential elections going back to 1980, and will examine a finer breakdown of the different technologies, and a breakdown of residual votes into its two components: over- and undervotes. A final report will be released in June.

The analysis is complicated by the fact that voting systems vary from county to county and across time. When a system is switched, say from lever machines to DREs, the number of residual votes can go up due to voter unfamiliarity with the new technology.

"We don't want to give the impression that electronic systems are necessarily inaccurate, but there is much room for improvement," said Thomas Palfrey, Caltech professor of economics and political science.

"Electronic voting technology is in its infancy and seems the most likely one to benefit significantly from new innovations and increased voter familiarity," states the 13-page report.

Other Caltech members of the Voting Technology Project are Michael Alvarez, associate professor of political science, and Jehoshua Bruck, professor of computation and neural systems and electrical engineering. Participating from MIT are Stephen Ansolabehere, professor of political science, and Nicholas Negroponte, chairman of the Media Lab.

Check the web at www.vote.caltech.edu for further information, or see www.vote.caltech.edu/Reports/report1.pdf for the report itself. □—*JP*

**Alan Alda is Richard Feynman in QED, a new play based on Tuva or Bust! and other Feynman tales. Fittingly, the world premiere is at the Mark Taper Forum, just down the Pasadena Freeway from Feynman's old haunts. It runs through May 13; tickets are available at www.TaperAhmanson.com or (213) 628-2772. On a recent visit to campus to soak up the atmosphere, Alda dined with president Baltimore and assorted campus luminaries.**

## THE JUPITER EFFECT

In a study that strengthens the likelihood that solar systems like our own are still being formed, an international team of scientists has reported that three young stars in the sun's neighborhood have the raw materials necessary for the formation of Jupiter-sized planets. Data obtained from the European Space Agency's Infrared Space Observatory (ISO) indicate for the first time that molecular hydrogen is present in the debris disks around young nearby stars. The results are important because experts have long thought that primordial hydrogen—the central building block of gas giants such as Jupiter and Saturn—is no longer present in the sun's stellar vicinity in sufficient quantities to form new planets.

"We looked at only three stars, but the results could indicate that it's easier to make Jupiter-sized planets than previously thought," said Geoffrey Blake (PhD '86), professor of cosmochemistry and planetary sciences and professor of chemistry at Caltech and the corresponding author of the study, which made the cover of *Nature* on January 3. "There are over 100 candidate debris disks within about 200 light-years of the sun, and our work suggests that many of these systems may still be capable of making planets."

The abundance of Jupiter-sized planets is good news, though indirectly, in the search for extraterrestrial life. A gas giant such as Jupiter may not be particularly hospitable for the formation of life, but experts think the mere presence of such huge bodies in the outer reaches of a solar system protects smaller rocky planets like Earth from catastrophic comet and meteor impacts. A Jupiter-sized planet possesses a gravitational field sufficient to kick primordial debris into the farthest reaches of the solar system, as Jupiter has presumably done by sending perhaps billions of comets safely away from Earth into the Oort Cloud, which lies beyond the orbit of Pluto. If comets and meteors were not ejected by gas giants, Blake said, life on Earth (and any other Earth-like planets) could periodically be "sterilized" by impacts. "A comet the size of Hale-Bopp, for example, would vaporize much of Earth's oceans if it hit there. The impact from a 500-kilometer object—about ten times the size of Hale-Bopp—could create nearly 100 atmospheres of rock vapor, the heat from which can evaporate all of Earth's oceans."

The researchers did not directly detect any planets in the study, but nonetheless found that molecular hydrogen was abundant in all three disks. In the disk surrounding Beta Pictoris, a Southern Hemisphere star that formed about 20 million years ago approximately 60 light-years from Earth, the team found evidence that hydrogen is present in a quantity at least one-fifth the mass of Jupiter, or about four Neptune's worth of material. The debris around 49 Ceti, which lies near the celestial equator in the constellation Cetus, was found to contain hydrogen in a quantity at least 40 percent of the mass of Jupiter. Saturn's mass is just under a third that of Jupiter. 49 Ceti, which is about 10 million years old, is roughly 200 light-years from Earth. Best of all was a 10-million-year-old Southern Hemisphere star about 260 light-years away that goes by the rather unpoetic name HD135344. That star's debris disk was found to contain the equivalent of at least six Jupiter masses of molecular hydrogen.

The study also confirmed that planetary formation is not limited to a narrow "window" early in the life of a star, as previously thought. Because molecular hydrogen is quite difficult to detect from ground-based observatories, experts have relied on measurements of the more easily detectable carbon monoxide (CO) to model the gas dynamics of developing solar systems. But because the CO tends to dissipate quite rapidly early on, researchers assumed that the molecular hydrogen likewise vanished. This presumed lack of hydrogen limited the time in which Jupiter-sized planets could form. However, the new study, coupled with recent theoretical models, shows that CO is not a particularly good proxy for the total gas mass surrounding a new star.

Blake said the study opens new doors to the understanding of planetary growth processes around sun-like stars. He and his colleagues anticipate further progress when the Space Infrared Telescope Facility (SIRTF) and the Stratospheric Observatory for Infrared Astronomy (SOFIA) are launched in 2002. SIRTF, which will have its science headquarters at Caltech, alone could detect literally hundreds of stars that still contain enough primordial hydrogen in their debris disks to form Jupiter-sized planets.

The other authors are professor Ewine F. van Dishoeck and Wing-Fai Thi, the study's lead author, both of the Leiden University in the Netherlands; Jochen Horn and professor Eric Becklin, both of the UCLA Department of Physics and Astronomy; Anneila Sargent (MS '67, PhD '77), professor of astronomy at Caltech; Mario van den Ancker of the Harvard-Smithsonian Center for Astrophysics; and Antonella Natta of the Astrophysical Observatory of Arcetri in Florence, Italy. □—*RT*

## Of Cell Phones, Memory Cells, and Flashy Nanocrystals

Scientists at Caltech and Agere Systems, formerly known as the Microelectronics Group of Lucent Technologies, have developed a technique that could result in a new generation of reliable nanoscale memory chips and smaller, less expensive cellular phones and digital cameras. Announced December 13 at the International Electron Devices Meeting, the work applies to so-called "flash" memory, which continues to store information even when the device is turned off. This information could include personal phone directories in a cellular phone or the pictures captured by a digital camera. A typical flash-memory chip stores 16 to 32 million bits of data, with each bit in a separate "cell." As chip sizes decrease, the cells become more difficult to make leakproof, and

## ¿Oye, CHICOS, Donde Está el Observatorio?

Los Angeles-area high school students will team up with Caltech researchers to study ultrahigh-energy cosmic rays on their own campuses, thanks to a recent grant from the Weingart Foundation, which donated $100,000 to establish the California HIgh school Cosmic-ray ObServatory (CHICOS) on four campuses in the Northridge area initially, expanding to at least 25 and possibly hundreds of sites eventually. Three of the four initial schools have a high number of students who are underrepresented in the sciences, which means the program may assist in increasing the number of future scientists in the United States. The schools are the Sherman Oaks Continuing Education School, and Sylmar, Van Nuys, and Harvard Westlake High Schools.

The research will be coordinated by Professor of Physics Robert McKeown. The program will also incorporate a high school teacher education component coordinated by Dr. Ryoichi Seki at California State University, Northridge. Teachers will develop curriculum materials to help their students participate in this research. Caltech will host a summer workshop where physics teachers and students can participate in the construction of new detector stations for deployment at additional sites.

The detector hardware, associated electronics, and computer equipment will form a networked system among the high schools. A large array of this type will enable the study of ultrahigh-energy cosmic rays through the detection of "showers," several kilometers in radius, of secondary particles the rays create in the Earth's atmosphere. These are the highest-energy particles ever observed in nature, and thus are of great current interest in the astrophysics and particle-physics community. Thus, while establishing a state-of-the-art experimental facility, this project will provide an exceptional educational experience for local high school students. When a majority of the 25 sites are operating, it is expected that the project will yield significant scientific results that will be reported in the scientific literature. □—*JP* stored data can be lost.

Using an aerosol technique developed at Caltech, silicon nanocrystals were sprayed through a bath of high-temperature oxygen to create memory cells comprised of silicon on the inside with a silicon dioxide outer shell. The silicon nanocrystals store the electrical charge, whereas the insulating silicon dioxide shell makes the cells leak-resistant. "As compared to conventional flash memories, these silicon nanocrystal memories offer higher performance, simpler fabrication processes, and greater promise for carrying memory miniaturization to its ultimate limit," said Harry Atwater, professor of applied physics and materials science, and project director. Atwater; Richard Flagan, the McCollum Professor of Chemical Engineering; postdoc Mark Brongersma; grad students Elizabeth Boer (MS '96), Julie Casperson, and Michele Ostraat (MS '98); and Jan de Blauwe and Martin Green at Agere Systems developed a method to break up each cell into 20,000 to 40,000 smaller cells. Therefore, even if several of the smaller cells spring a leak, the vast majority of the charge will not be lost and the bit of data stored in the whole memory cell will be retained.

The aerosol approach has several advantages over the conventional lithographic techniques used to make today's flash memory cells. Because it requires fewer steps, it is less expensive and the chips take less time to produce. In addition, the aerosol approach will allow researchers to continue making smaller and smaller devices. The cells are also extremely robust—one cell has gone through a million charge-discharge cycles without significant degradation, whereas 10,000 cycles is considered satisfactory for a traditional chip. The research was supported by the National Science Foundation and NASA. □—*RT*

**Caltech scored first, Caltech scored last, but That Other Institute of Technology scored more often in their first ever women's basketball matchup in front of a packed house in Braun Gym on January 5. Final score: CIT 46, MIT 80.**

## In Search of the Mind's Eye

A study of patients awaiting brain surgery has shown that humans use the same neurons to conjure up mental images that they use when they actually see the real object. In the November 16 issue of *Nature*, UCLA neurosurgeon and neuroscientist Itzhak Fried and Caltech neuroscientists Christof Koch, professor of computation and neural systems, and grad student Gabriel Kreiman report on results obtained by questioning nine patients who had been fitted with brain sensors. The patients, all suffering from severe epilepsy uncontrolled with drugs, were being observed for a period of one to two weeks so that the regions of their brains responsible for their seizures could be identified and later surgically removed.

During their extended hospital stay, the patients were asked to look at photos of famous people, pictures of animals, abstract drawings, and other images. While they were looking at the images, the researchers noted the precise neurons that were active. Then, the subjects were instructed to close their eyes and vividly imagine the images. Again, the researchers noted which neurons were active. It turns out that a subset of neurons in the hippocampus, amygdala, entorhinal cortex, and parahippocampal gyrus would fire when the patient looked at the image and also when he or she imagined the image.

The results build upon work by Fried's group showing that single neurons in the human brain are involved in memory and can respond selectively to a wide variety of visual stimuli as well as stimulus features such as facial expression and gender. According to Koch, the study helps settle long-standing questions about the nature of human imagery. Particularly, the research sheds light on the process at work when humans see things with the mind's eye. "If you try to recall how many sunflowers there are in the Van Gogh painting, there is something that goes on in your head that gives rise to this visual image," Koch says. "There has been an ongoing debate about whether the brain areas involved in perception during 'vision with your eyes' are the same ones used during visual imagery."

The problem has been difficult to address because the techniques that yield very precise results in animals are generally not suitable for humans, and because the brain imaging techniques suitable for humans are not very precise, Koch says. Such techniques can image only large portions of the brain, each containing on the order of one million very diverse nerve cells. "Recording the activity of single cells allows us to investigate the neuronal correlates of visual awareness at a detailed level of temporal and spatial resolution," says Kreiman. The work was supported by the National Institutes of Health, the National Science Foundation, and the Center for Consciousness Studies at the University of Arizona. □—*RT*