PICTURE CREDITS: 3, 4, 6 — Doug Smith; 5 — Kathy Svitil, Will Heltsley; 8, 9 — NASA/JPL/STScI

The Loh Down on Science

Performance artist, author, and public-radio personality Sandra Tsing Loh, BS '83 in physics, has come to terms with her inner geek.

Can "funny" and "science" be used in the same sentence? Caltech and public radio think so. On December 5, KPCC—located just blocks from Caltech on the campus of Pasadena City College, and at 89.3 on your FM dial—began giving its listeners their recommended daily allowance of science along with a healthy dose of humor. *The Loh Down on Science* is hosted by Sandra Tsing Loh (BS '83) and marries her hard-earned physics degree with her wry on-air persona. It airs daily at 9:19 a.m. and 7:04 p.m., and is available as a download or podcast at http://KPCC.org.

Produced by Caltech's public relations office, the *Loh Down* aims to bring science to people who don't consciously encounter it on a daily basis—including those who don't know the difference between a quark and a quasar or who flunked trigonometry. Says Loh, "We believe even the intellectually nervous deserve to explore the wonders of science and technology in all their infinite variety. But not too infinite. Like some strange new franken-vitamin, *The Loh Down on Science* is a convenient, easily digestible one minute a day."

Loh feels her listeners' angst. "I have a Caltech diploma entirely made of partial credit. Yes—my degree was glued together, faintly pulsing with radioactivity, graded less on a curve than on a kind of wild hyperbola asymptotically approaching some imaginary actual answer." But seriously, folks, she received Caltech's Distinguished Alumni Award in 2001, and last spring became the first alumna to speak at commencement.

National public radio audiences have been hearing Loh monthly on the business program *Marketplace*. She has also been a regular on *Morning Edition* and *This American Life* with Ira Glass. Her weekly commentary on life in Southern California, *The Loh Life*, has been airing locally since 1998.

In other media, Loh's latest one-woman show, *Mother on Fire*, is running at the 24th Street Theatre in Los Angeles. She is a contributing editor to the *Atlantic Monthly* and the author of the books *A Year in Van Nuys*, *Depth Takes a Holiday: Essays from Lesser Los Angeles*, *Aliens in America*, and *If You Lived Here, You'd*

Caltech's robot van Alice, side doors open, sits in the starting chute at the second running of the DARPA Grand Challenge. To her right, wearing number 38, is Virginia Tech's Cliff; to her left is the Gray Team's KAT-5, a crowd favorite. Originally dubbed GrayBot, KAT-5 (for Category 5) was begun in Metairie and finished in Hammond, Louisiana, despite fully three-quarters of its team having been rendered homeless by Hurricane Katrina. Waiting for its turn is number 08, Team Cimar's NaviGATOR, from the University of Florida.

Be Home By Now. The last was chosen by the *Los Angeles Times* as one of the 100 best fiction books of 1998. She won a Pushcart Prize for her short story "My Father's Chinese Wives," which has also been featured in the *Norton Anthology of Short Fiction*.

The *Loh Down*'s writers have previously written for *Nature*, *Science*, and *Discover* magazines, and even for Bob Hope. (If anyone out there has the itch to write short, snappy scripts about science—for pay!—contact Kathy Svitil, ksvitil@caltech.edu.)

For more details about the program, visit http://pr.caltech.edu/public_relations/lohdown/.

KPCC is the flagship station of Southern California Public Radio, and the fastest-growing public radio station in the country. The program is being sponsored in its first year by TIAA-CREF, a national financial services organization and the leading provider of retirement services in the academic, research, medical, and cultural fields. □—*JP*

Alice's Adventures in Primm

Fame, prestige, and a hefty check were riding on the outcome of the Defense Advanced Research Projects Agency (DARPA) Grand Challenge, the off-road race of robotic vehicles held on October 8 in Primm, Nevada. The machine that drove itself, without human intervention, over a 132-mile course—a route not divulged until 4:30 a.m. on race day, in order to prevent vehicles from being programmed to drive it from memory rather than figuring it out as they went—in the fastest time under 10 hours would net its builders a $2 million prize. But for some members of Team Caltech, more was at stake: fish tacos.

"I have two bets of ten fish tacos apiece with [Caltech senior] Jeremy Gillula—one on whether we finish the race, and one on whether we win," said senior Jeremy Leibs, who was sitting with other team members in the spectator grandstands in the parking lot behind Buffalo Bill's Resort & Casino as Team Caltech's

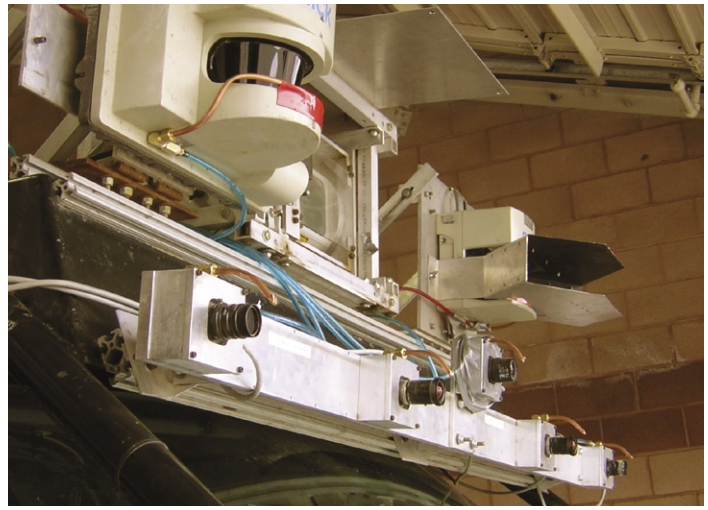
Terra Engineering's TerraHawk had the most unusual design, consisting of three articulated segments not unlike a toddler's pull toy. Seen here at the qualifying course at the California Speedway in Fontana, it failed to navigate the track and advance to the finals.

entrant, a heavily modified Ford E-350 van named Alice, rolled up to the starting chute. "If we don't finish, Jeremy owes me 10 fish tacos. If we win, I owe him 10. I don't even like fish tacos," Leibs admitted, "but I can use them as currency with other team members."

"That's true. They are legal tender around here," agreed Richard Murray (BS '85), professor of control and dynamical systems and leader of Team Caltech, a disparate group of undergraduate and graduate students, faculty advisors, volunteers, and professional engineers from the Jet Propulsion Laboratory, Northrop Grumman, and elsewhere.

Fueled by fish tacos, Team Caltech members had been working toward this day for a year and a half—ever since the finals of the first Grand Challenge, held on March 13, 2004. That race, which began at the Slash X Ranch Cafe just outside Barstow, California, and was supposed to run 142 miles through the mountains and dry washes of the Mojave Desert to Primm, saw no winner. In fact, the best effort was the mere 7.4 miles logged by Carnegie Mellon's Red Team. (See *E&S* 2004, No. 1.) The unclaimed $1 million purse was doubled for this year's event.

During the first Grand Challenge, Team Caltech's Bob, a '96 Chevy Tahoe 4x4, plowed into a barbed wire fence at mile 1.3 to end his race. This year, the team was determined to build upon, and better, Bob's performance. Alice contains the next generation of hardware and software from Bob, and her license plate reads, "I8BOB." ("Alice" and "Bob" are famous monikers from communications and encryption theory, where they represent two people sending messages to each other. Bob had gotten *his* name from his license plate, 5BOB235.)

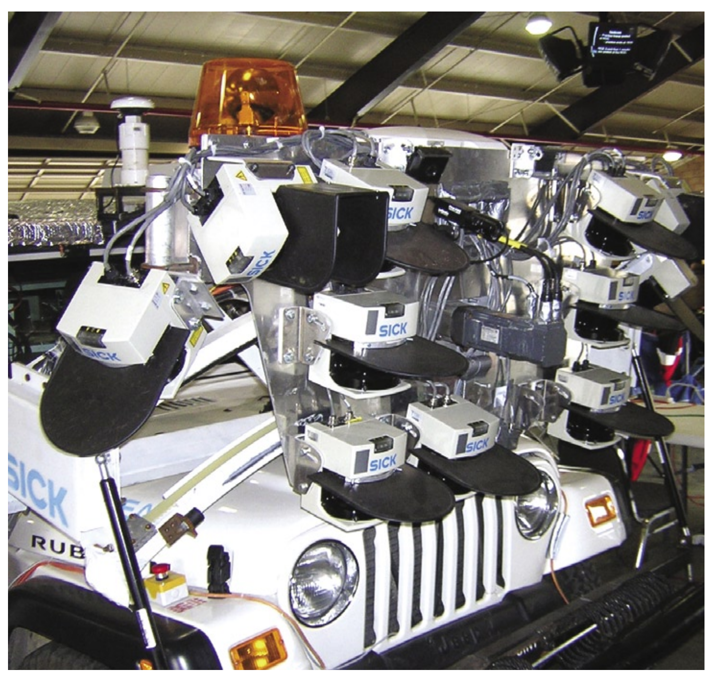


Attention to detail: Alice's LADAR units (the things resembling coffee makers) and her cameras each had a compressed-air line to blow dust off their lenses.

A big, tough gal, Alice was outfitted for off-roading as a donation to Caltech by Sportsmobile West Inc., of Fresno, California. She's got heavy-duty shocks, a Dynatrac high-performance front axle, skid plates, and four-wheel drive. And she has more bells and whistles than did Bob: seven computer servers, a Global Positioning System (GPS) receiver to measure her absolute position, and an inertial measurement unit (IMU) consisting of accelerometers and gyroscopes. GPS and IMU data are processed to produce an estimate of Alice's "state"—her exact position and orientation in space. To plot terrain and detect obstacles, Alice's front bumper and roof bristle with a pair of short-range and a pair of long-range stereo cameras, a road-finding camera, and five laser "radars," called LADARs, that scan the road ahead at various ranges.

The stereo camera and LADAR readings are fed into a program the undergrads developed that creates a 3-D map of Alice's world. The planning software uses that map, the state data, and the route information provided by DARPA to plot Alice's best path. A trajectory-following program and an executive program translate that path into commands to the actuators that control Alice's throttle, brakes, and steering. The data transfer between the various servers and modules is overseen by SkyNet, a communications system named for the artificial intelligence–based neural network that controlled the machines in the *Terminator* movies.

Bob didn't run autono-



Got LADARs? The Indy Robot Racing Team, which included students and faculty from Indiana and Purdue Universities, may have bought up the Midwest's entire supply. Alas, IRV also failed to qualify.

mously until a little over a week before the first Grand Challenge. Alice was far more precocious; her first self-guided runs began at the beginning of the summer. By summer's end, she'd driven a few hundred miles on her own across increasingly more arduous terrain in the desert near Stoddard Wells, just a couple of hours from Pasadena. The team did encounter a few roadblocks; in late August, for example, Alice began blowing fuses, causing her to occasionally (and unpredictably) stop dead in her tracks. For a while Murray and others thought she might have to be scrapped, and her computers, sensors, and other equipment moved into Bob.

A week before the start of the qualifiers in late September—during which 43 teams (out of a starting pack of 195) would be narrowed to 23 finalists—team members discovered why Alice was stalling. "A wire that fed power to the rear winch had come loose and dropped down against the exhaust pipe," explained team member Tony Fender, lecturer in engineering. "The heat burned through the insulation, so as we drove, every now and then it shorted out."

With the wire repaired, Alice was set for her stab at the finals. During her first run, she got hung up on a hay bale, which she dragged a few hundred feet as it turned into shredded wheat, and then lost her way after leaving a tunnel designed to block out signals from the GPS satellites overhead. She went into reverse, and began turning, haltingly, off the course. DARPA officials eventually stopped the trial. Team members tinkered with her planning software, and over the next five days she sailed through three more test runs.

Alice's adventure in Primm began at 9:02 a.m., as she pulled cautiously out of the starting chute, headed west past the grandstands, and hung a right to trek north across a dry lake bed. Team members watched from the stands through binoculars as she disappeared into the dust. "I'll feel better when I can't see her anymore," said one student.

Half an hour and a little over seven miles later, Alice headed back toward Buffalo Bill's. The course passed along the eastern edge of the casino's parking lot, paralleling a berm before turning east again into the desert. The berm's northern half was reserved for media; team members and visitors waited for Alice to streak by from the southern end. Alice's software was set for a maximum speed of 35 mph, and the flat expanse around Primm was a piece of cake compared to the rough-and-tumble terrain Alice was used to, so she should have been running flat out. But when she appeared, she seemed slow and hesitant. She made the turn to parallel the berm, then stopped, cogitated a bit, started, stopped, cogitated a bit more, turned left, and then straightened out. Finally, she cocked her wheel hard right, toward the berm, and began driving at about 10 mph toward it—and the media. From the perspective of those in her path, it seemed much faster.

A line of K-rails, those concrete barriers you see in freeway construction zones, prevented carnage. Alice climbed one and knocked it flat—a tribute to her off-roading prowess—before being paused part way up the berm, and eventually disabled, by the DARPA chase team's wireless kill switch. Her day was over.

"I'm frustrated. I didn't spent two and a half years of my life to have it end at mile eight," said mechanical engineering student Tully Foote, a member of the embedded systems team, who helped get Alice off the K-rail so she could be removed from the course. "We all worked on this thing for so long. We want to know what went wrong, why it went wrong, and how to fix it."

Leibs, of fish taco fame, was not terribly surprised. "I've been kind of pessimistic the whole time. Our architecture has too many interfaces, and too many things that weren't sufficiently tested. This was a clear, wide-open straightaway that should have been trivial to drive. It was just a random screwup."

In fact, a number of system failures—and a power line—contributed to Alice's attempt to take out the media. Postrace analyses showed that while her long- and short-range LADARs, which detect obstacles at around 3 meters and 35 meters, were fine, the two medium-range LADARs quit just four minutes into the race. (They now work perfectly, so the team has no idea why they malfunctioned.)

This shouldn't have been a death blow, but Alice had other issues. Just before making the turn to get onto the dirt road paralleling the berm,

Above: The media's-eye view of an onrushing Alice.

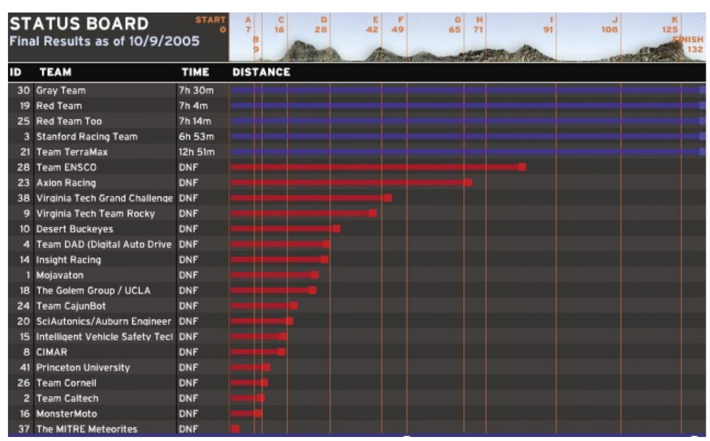
Below: Alice grinds the K-rail, taking some steering-system damage in the process.

she passed under a power line that temporarily knocked out the GPS signal. When the GPS came back, the state estimator realized that its dead-reckoning position and the GPS readings had drifted about five meters apart. This meant that all the obstacles in Alice's field of vision suddenly appeared on her map as new obstacles, offset by five meters from the original set, which remained on the map. As part of the correction process, Alice stopped while the software erased all the obstacles and waited for the real ones to reappear. But, says grad student Lars Cremean (MS '00), manager of the planning team, "The state estimator corrected itself, but not completely; when the GPS measurements resumed, the unit reported an unusually low confidence in these measurements. And because of its incomplete correction, the state estimator continued to accumulate drift."

When Alice turned right to get back onto what she thought was the course, her assorted sensors should have put the looming K-rails back on the map. The long-range LADARs did just that, says Cremean, but by now "the state estimator had accumulated a pointing error of several degrees. This put the K-rails in the wrong location. Alice thought she was heading south, paralleling the rails, but she was really heading toward them at a shallow angle." Even so, she still could have recovered, had not both pairs of stereo cameras chosen that exact moment to join the medium-range LADARs on the disabled list. "Our current hypothesis is that stereo didn't detect the obstacles because of the orientation of the sun," says Murray. Put bluntly: Alice was blinded. The short-range LADAR units did eventually spot the barriers, but not in time. It was a perfect convergence of failures.

"We were designing a vehicle that could complete the course, and we didn't do that, so in that sense it was a failure," says Murray. "But if you look back two and a half years ago when this project began, we didn't think we would do as much research as we did, we didn't think we would be as innovative. We accomplished far more than we thought would come out of an undergraduate class."

"We've done things with Alice that I didn't think we were going to achieve in five years," says Fender. More importantly, he adds, the endeavor provided Team Caltech's student members with an unprecedented educational experience. "Caltech has taken a different approach to the whole of the Grand Challenge. Teams like Carnegie Mellon were in there to win at all costs. Richard is in this to teach these students. It is for education—and the education that these students have gotten is something I've never seen available to any student, anywhere. In a year of taking



ID	TEAM	TIME	DISTANCE
30	Gray Team	7h 30m	
19	Red Team	7h 4m	
25	Red Team Too	7h 14m	
3	Stanford Racing Team	6h 53m	
21	Team TerraMax	12h 51m	
28	Team ENSCO	DNF	
23	Axion Racing	DNF	
38	Virginia Tech Grand Challenge	DNF	
9	Virginia Tech Team Rocky	DNF	
10	Desert Buckeyes	DNF	
4	Team DAD (Digital Auto Drive	DNF	
14	Insight Racing	DNF	
1	Mojavaton	DNF	
18	The Golem Group / UCLA	DNF	
24	Team CajunBot	DNF	
20	SciAutonics/Auburn Engineer	DNF	
15	Intelligent Vehicle Safety Tecl	DNF	
8	CIMAR	DNF	
41	Princeton University	DNF	
26	Team Cornell	DNF	
2	Team Caltech	DNF	
16	MonsterMoto	DNF	
37	The MITRE Meteorites	DNF	

The standings as posted on the Grand Challenge website. (Note that the five finishers are not listed in the order of their elapsed times.) "DNF" stands for "Did Not Finish."

Left: Entrants were seeded based on their performance at the qualifying rounds, with the first three 'bots taking the line just at sunrise. Stanford University's Stanley, the second seed, is flanked by the two Hummers from Carnegie Mellon (the Red Teams) whose clocks he cleaned.

these classes, they've gotten about the same experience as I got in my first ten years as a professional engineer."

The Grand Challenge did have a winner—Stanley, a robotic Volkswagen Touareg from Stanford University—and won't be rerun. Alice is officially retired from professional competition, but will continue to be used as a platform for research and education. Meanwhile, Richard Murray and his colleagues are dreaming up new challenges for CS/EE/ME 75, the class in multidisciplinary design taken by Team Caltech's students. "I don't know what project we'll choose," he says. "Maybe it will be autonomous driving in urban environments. I'm open to anything that seems like a challenge and that will allow the students to push the envelope of what we know how to do." □—*KS*

Non-Incoming Tax

In 1789, Benjamin Franklin wrote, "In this world nothing can be said to be certain, except death and taxes." He may have been mistaken. With the possible exception of Elvis, who continues to be seen in supermarkets, death is still inevitable; but taxes are becoming easier to avoid.

This year, over $250 billion in income tax will not be collected—a sum larger than the entire amount spent on the Iraq war through November 2005. Amazingly, most cheats will probably never be caught. Says Jeffery Dubin, Caltech professor of economics, "For tax evaders, money launderers, and those involved in fraudulent tax schemes these are heady times indeed."

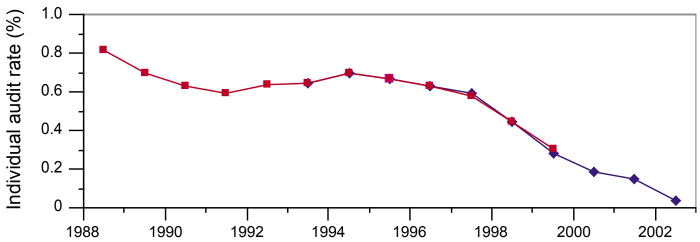
Americans have never liked paying taxes—after all, the birth of this country involved a tax revolt. But the carrot of fairness with the stick of audits and penalties makes the average Joe pay taxes honestly. Today, this system is breaking down, because the number of agents enforcing the tax code has not kept up with the increase in taxpayers. Statistics from Syracuse University's Transactional Records Access Clearinghouse (http://trac.syr.edu) reveals a plummeting face-to-face audit rate—from 0.72 percent in 1994 to 0.15 percent in 2004—and a decline in the number of tax prosecutions—from 1,176 to 546 over those same years. With this drop, many people figure they can get away with underreporting income, which accounts for about 80 percent of the tax gap.

For over a decade and a half, Dubin has been trying to understand this gap. But controlled experiments are nearly impossible. Ideally, you would like to change one variable—say increase tax penalties in Ohio—while keeping things constant elsewhere, and see what happens. Besides infuriating the citizens of Cincinnati, that is. So in reality, economists take what data they can find and work backward, like a gastronome tasting a soup and trying to figure out its ingredients.

In a recent study, Dubin used publicly available data to create a model that predicts taxes due; subtracting the taxes actually collected gives the tax gap. Previous work on this topic gave a static picture, one only relevant to the particular year analyzed. In contrast, Dubin's study can forecast the tax gap for *any year*. Using his model and statistical methods to tease out one relation from another, Dubin was able to predict how factors like audit rate or media coverage affect the tax gap—crucially obtaining, not just the direct consequences of change in a variable, but also the "spillover," or indirect effects. For instance, if the IRS increased audits, it would catch more fraud and make more money in penalties. It would also scare some people—who would have cheated otherwise—into complying with the tax code. This is the "spillover."

The study disproves an IRS claim that automated corrections, known as correspondence audits, are as effective as the old-fashioned kind. "There is no evidence that correspondence audits have made up for the decline in face-to face audits," Dubin says. A computer-generated form letter simply doesn't have the same "spillover" deterrence as summoning you and your sorry shoebox of receipts to a windowless room with an IRS agent.

Predictably, the strongest motivator for compliance was found to be fear of jail time, not fines. This suggests an emphasis on both prison sentences and higher audit rates to reduce cheating. But surprisingly, the study shows that extra media attention to celebrity criminal investigations has little additional impact in making people more honest. "The key is not



Above: This plot of audit rates of individual taxpayers (as opposed to corporations) shows that the overall audit rate as a percentage of returns filed has been steadily decreasing. The two colored lines represent a change in reporting methods caused when the IRS began consolidating its operations in individual states into regional offices.

to get more publicity of those currently prosecuted, but to prosecute more," Dubin says. In other words, sending a high-profile Leona Helmsley to jail has less of an impact than a tax investigation of your neighbor.

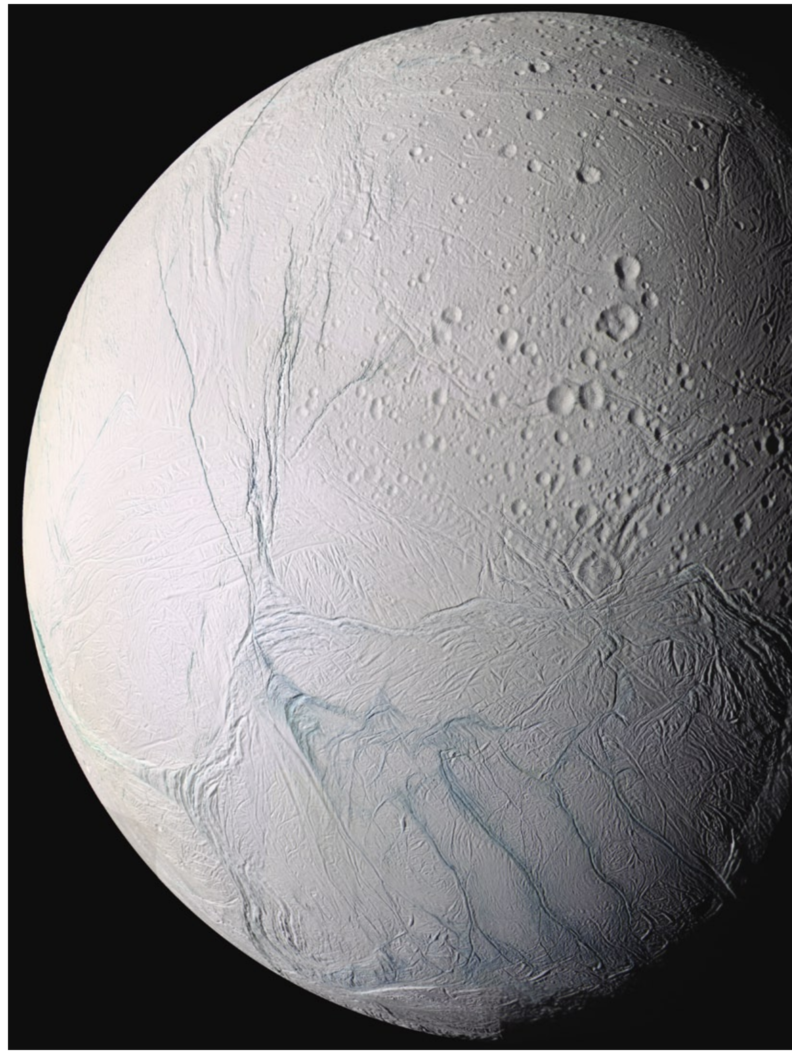
However, audits cost money. Does increasing their number really benefit the honest taxpayer, overall? The answer from the study is overwhelmingly yes. One extra dollar spent on audits leads to a reduction of $58 in the tax gap. Similarly, an extra dollar spent by the Criminal Investigation (CI) arm of the IRS provides a return of $66 in taxes and penalties.

According to Dubin, no one is suggesting that the tax gap can be eliminated. However, he says, "Historically we do know that the tax gap has been smaller, even accounting for inflation and growth." He suggests modest increases in CI's budget as a way to start curbing cheating—his simulations show that a budget increase of $25 million should result in a $1 billion reduction in tax evasion.

Unfortunately, this advice seems to be lost on politicians. Recently, California governor Arnold Schwarzenegger vetoed a bill that would have increased prosecution for tax evasion. The danger in lax enforcement of tax codes is that it leads to a runaway effect—if honest taxpayers think the system is unfair, more and more of them will be tempted to cheat.

"There is no kind of dishonesty into which otherwise good people more easily and frequently fall, than that of defrauding the government," wrote Benjamin Franklin. Today, with so many incentives, that is no surprise at all. □—*SV*

Dubin's complete paper is available on the IRS's website at http://www.irs.gov/pub/irs-soi/04dubin.pdf. This is his farewell appearance in E&S*, as he will be retiring from Caltech in 2007 after 25 years at the Institute. The author, Saurabh Vyawahare, is a graduate student in applied physics. He works with Axel Scherer, the Neches Professor of Electrical Engineering, Applied Physics, and Physics.*



PRESIDENT BALTIMORE TO STEP DOWN

David Baltimore, president of the California Institute of Technology, will retire on June 30, 2006, after nearly nine years in the post. He will remain at the Institute, where he intends to focus on his scientific work and teaching, and has agreed to continue serving as president until a successor is named.

A search committee, chaired by Henry Lester, the Bren Professor of Biology and chair of the faculty, is now hard at work and hopes to present a short list of candidates to the Board of Trustees in March. Anyone who wishes to nominate a candidate, or who would like to suggest qualities that Caltech's next president should have, is encouraged to visit http://presidentialsearch.caltech.edu/.

Baltimore is the seventh person to lead "modern day" Caltech, his predecessors being James A. B. Scherer, Robert A. Millikan, Lee A. DuBridge, Harold Brown, Marvin L. Goldberger, and Thomas E. Everhart. □

Cassini's Finds: Enceladus Leaks; Hyperion Is a Sponge

The Jet Propulsion Laboratory's Cassini mission to Saturn is discovering that the ringed planet's moons are just as weird as Jupiter's. A close flyby of the ice moon Enceladus on July 14 discovered a region of prominent, bluish fractures dubbed "tiger stripes" in the south polar region. (See the image at left, taken in ultraviolet through infrared wavelengths.) These fractures are one to two kilometers wide and more than 100 kilometers long, and appear to be bluer than their surroundings because the fresher, coarser-grained ice exposed in the fractures has a bluish cast as do icebergs on Earth. Cassini's infrared spectrometer found that the tiger stripes are significantly warmer than their surroundings—around 90 Kelvin, with "hot spots" of over 100 Kelvin, versus the 74 to 81 Kelvin of the rest of the region. Enceladus's feeble ration of sunlight—about 80 percent of which is reflected by the icy surface—cannot account for this, so it appears that heat is leaking out of the interior. Add this to the detection back in January of a fine spray of ice particles over the south pole that may extend as high as 400 kilometers, and Enceladus joins a very exclusive club of worlds known to exhibit some form of internal activity.

Cassini buzzed Hyperion, whose beaten-up body is shown at right, on September 26. At 280 kilometers across, it is the largest known irregularly shaped moon in the solar system. Its surprising spongy appearance may be the result of thermal erosion, in which dark material accumulating on the crater floors absorbs sunlight and melts the ice beneath it, which then evaporates and deepens the craters. Viewed in natural color, Hyperion has a decided reddish tint that has been toned down in this false-color image to highlight the other subtle color variations that may indicate compositional differences.

And finally, on October 11 Cassini zoomed by Dione, catching this true-color shot of it against its mother planet. The rings, seen edge-on, cast shadows on Saturn's cloud tops, with the B ring at the top and the thinner C ring making the series of stripes.

Speaking of rings, the mosaic below shows how Prometheus's gravity opens channels in the F ring. The channels shear over time, causing the older ones to the left to have a shallower slope. □—*DS*