Serious Fun at the Outdoor Science Lab

Children's Center staffers Jason Mytar and Monica Wood, and two potential Nobelists in the outdoor lab.

It's not rocket science, but it may lead to rocket scientists. Catering to three- to five-year-olds, the Children's Center at Caltech's Outdoor Science Laboratory was dedicated on May 12. The Children's Center is Caltech's daycare facility, and the lab is the brainchild of director Susan Wood, who came to Caltech from UCLA six years ago and brought a science-based curriculum with her. To the kids, however, the curriculum is hard to distinguish from fun. At that age, "inquiry-based, hands-on educational opportunities," as they tend to be called in the ed biz, consist of such things as a trek across campus to Millikan Pond to see the turtles, which on a recent day the Koalas—the three-year-olds—were doing.

The Koalas were in the midst of a unit called "Dead or Alive," in which their assignment was to figure out how to decide if something is living or nonliving. Observations and hypotheses are noted in their journals, which is to say the budding investigators draw pictures and dictate one-on-one to a grown-up who writes down the words. Sample entries:

"Jason [Mytar], you are alive because you have eyes."

"The strawberry is alive because it is green."

"Q: [to Jason] Are these *Curious George* monkeys? A: Yes. The monkeys are not living because they are in a picture."

"Monkeys. Not living because I don't like monkeys."

Every child gets a turn to speak in the discussion sessions that follow, says Wood—"We teach the value of collaboration"—and the group's collected wisdom is distilled into posters. It's an open-ended conversation, she adds. "I don't want it to be a quiz show—'What color is my blouse?' 'Blue!' 'That's right!'" Another day's discussion might focus on toys with moving parts, or machines in general—if something moves by itself, does that mean it's living? "We will carry this through several months. Kids learn through repetition."

Another experiment involves comparing natural loofahs to the rectangular sponges you get in four-packs. "Water play is very big in the summer, and it gives us the chance to introduce exotic words like 'saturated' into the discussions," says Wood. "We don't expect them to retain every word they hear, but they pick up a lot. We're learning as we go that they are more capable than we expected, and we had very high expectations."

It's Tool Time! Jason Mytar hands out the protective gear as Children's Center director Susan Wood (background, at left) and Anne Chandler, science curriculum coordinator, look on from the shade of the lab.

The four-year-old Raccoons, meanwhile, are learning about energy by estimating how far a paper airplane will go, throwing it, and measuring the result. Another day they'll be putting a thermometer in a shaft of sunlight to see what happens. Their workroom has quantitative tools of all kinds—measuring cups, rulers, a kitchen scale.

The Beavers, age five, have moved on to the six simple machines—the wheel and axle, the wedge, the lever, the inclined plane, the screw, and the pulley. The underlying lessons are about form and function, and about tools in general. The Beavers' journals are full of drawings of machines seen around campus: a telescoping construction crane (pulleys), the ubiquitous electric carts (wheels), a cherry picker trimming tree branches (levers), and even a washing machine full of clothes (gears).

Each day offers a host of activities, including a class on drawing from life. This teaches close observation—really *looking* at things, which is of course the basis of science. Today the Beavers are doing watercolors of a pot of lilies in bloom. A snippet of overheard conversation between the teacher and a student: "What are you going to draw first, the stem or the flower?" "The stem." "Where is the stem?" "This is the stem." Says Wood, "She's making them aware of the details, but she's not telling them what to draw. There's a big difference between this and doing crafts." Mapmaking is big, too. Explains Wood, "A map, like this one of our trip to Millikan Pond, is like a story. It has a beginning, a middle, and an end. It's a lot like reading, and it's a very good activity for our pre-readers."

The Children's Center occupies four 1920s vintage bungalows, two on either side of Chester Avenue on the northern border of campus. The Koalas, Raccoons, and Beavers live in the two houses on the west side of the street. The Outdoor Science Laboratory is nestled between the Beaver house and the Koala/Raccoon house. It is largely shielded from the street by the houses, and has no wall on the yard side "to help facilitate the exploration of nature." Under a rakishly slanted corrugated-steel roof, the central, U-shaped work island has a built-in light table, whiteboards that flip over to reveal overhead mirrors for better views of things on the counters, and portable electrical power from a pair of overhead cable reels. There are even microscopes for looking at bugs and leaves. The walls are lined with cabinets, sinks, and another whiteboard. Construction cost about $200,000, half of which was financed by five years of fund-raisers; the balance came from a grant from the Howard Hughes Medical Institute arranged by Stephen Mayo (PhD '87), the Bren Professor of Biology and Chemistry, whose sons were a Koala and a Beaver last year.

M)Arch. (yes, that's their preferred spelling) of Santa Monica designed the project. The firm was chosen because of their highly collaborative approach—they worked with Wood, the CCC staff, and the CCC board "for many months before the pencil hit the paper," says Wood. The industrial look was chosen, she adds, because it "tells the kids that what we are doing is real, and it's important. And a lot of them have seen labs, so the architects and I went into several labs and took pictures before they began designing." This is in keeping with the center's philosophy. For example, in the make-believe kitchens "the tea sets are all real china—we want to give them as many real things as possible. The message is, we trust them. These things are delicate, and they know that." The outdoor lab stocks tools—real ones, including saws with sharp teeth that really cut. Similarly, the clay-modeling supplies include sculpting tools from an art-supply house instead of the typical assortment of repurposed kitchenware. "Good tools are just easier to use."

The lab won gold in the Spark Design Awards' Architecture and Interiors category. The awards, given annually by Pasadena's Art Center College of Design, are in seven categories ranging from mobility to architecture. The finalists were culled from hundreds of entries worldwide. (Other honorees included a design for a Dutch rental-bike dispenser and an ergonomic chair made from sustainable bamboo.) Juror Robert Hale, a principal at the Rios Clementi Hale Sudios, called the lab "minimal intervention in architecture that achieved maximum results."

The fully accredited Children's Center at Caltech is a private, nonprofit organization that offers childcare to the Caltech/JPL community; it is also open to children from the surrounding area. □—*DS*

Mira, Mira

Truly the fairest one of all, the "comet" above is an aging red-giant star named Mira. Although Mira has been studied for more than 400 years, its tail has just been discovered by Caltech's Galaxy Evolution Explorer (GALEX) spacecraft. Shed from Mira's surface over the last 30,000 years, the tail contains carbon, oxygen, and other elements that will eventually be recycled into new stars and planets—enough material, in this case, to form at least 3,000 Earths or nine Jupiters. Most stars travel at more or less the same speed as the interstellar gas around them, but Mira is hurtling along at a relative velocity of 130 kilometers per second, piling up a "bow shock" whose hot gas mixes with the cooler hydrogen being shed by the star. As this hydrogen swirls away in a turbulent wake, the atoms fluoresce in the ultraviolet. The tail of gas and dust stretches 13 light-years across the sky—for comparison, Proxima Centauri, the nearest star to our sun, is only about four light-years away.

Mira, a pulsating variable star 350 light-years from Earth, will be bright enough to see with the naked eye in mid-November. It lies, appropriately enough, in the tale of Cetus, the whale.

Professor of Physics Christopher Martin, GALEX's principal investigator, is the lead author of a paper announcing the discovery in the August 16 issue of *Nature*. □—*DS*

Flight of the Phoenix

The Phoenix Mars Mission blasted off on August 4 en route to a May 25, 2008, landing on the red planet. The first of NASA's Mars Scout missions, Phoenix is led by the University of Arizona in partnership with JPL and Lockheed Martin Space Systems, which built the spacecraft. Phoenix was so named because it reuses the body of the Mars Surveyor, built for a 2001 mission that was canceled before launch. Phoenix will alight on the plains around Mars's north polar cap. A JPL-built robot arm will sample the soil, and the water ice believed to lie just below it, to see if the site has ever had conditions favorable for microbial life. □—*DS*

Dopamine Economics

From investing in the stock market to trying the new sushi bar down the street, you make decisions every day that balance risks and rewards. Researchers working at the interface of neuroscience and economics—neuroeconomists, as they've dubbed themselves—have been watching brains at work to understand this decision-making process. Two studies involving Caltech neuroeconomists have identified certain regions of the brain that are responsible for interpreting risk as well as reward. These regions are controlled by a neurotransmitter called dopamine, which, among other functions, stimulates the brain's pleasure centers.

While neuroscientists have been studying reward for decades, very little has been known about the brain's internal representation of risk. In economics, one financial "model assumes risk and reward are computed separately and then integrated," says Steven Quartz, associate professor of philosophy. "We looked for biological evidence for this model, such as brain signals that correlated with reward and risk."

Subjects in Quartz's study played a simple game while lying inside a functional Magnetic Resonance Imaging (fMRI) machine, like the ones doctors use to diagnose torn muscles. Here the fMRI allowed the neuroscientists to observe changes in blood flow in the brain, pinpointing regions that became active during the game.

Each round of the game consisted of the subjects being shown two cards, one at a time, on a video screen. The deck consisted of 10 cards, numbered 1 through 10. Before seeing either of the cards, the subjects placed a $1 bet on whether the second card would be higher or lower than the first. "It was kind of mean. Since they didn't have any information, it was a 50-50 gamble on every trial," says Kerstin Preuschoff (PhD '07), a former grad student in Quartz's lab and lead author of the study, which appeared

in the August 3, 2006, issue of *Neuron*. Preuschoff is now a postdoc in the lab of Peter Bossaerts, the Hacker Professor of Economics and Management and professor of finance, and the third author of the study.

The researchers observed what happened after the first card had been seen. "I deliberately used numbered cards, so I knew that they knew what the probabilities of the outcomes were. The idea was for the subjects to experience different probabilities," says Preuschoff. These probabilities, in turn, led to different levels of expected reward and risk. Say you bet your buck that the second card would be higher, and your first draw proved to be the 1. Your sense of expected reward would be at its highest, as any card you could draw next would be a winner. At the same time, your sense of risk would be zilch. But if the first card drawn was a 5, you would have a 50-50 chance of winning, and thus experience maximum risk.

Activity in a dopamine-controlled region called the ventral striatum proved to mirror the levels of both expected reward and risk. Located deep inside the middle of the brain, below the cerebral cortex, the striatum has been associated with movement control (another of dopamine's functions; in fact, dopamine therapy is a treatment for the tremors of Parkinson's disease) and reward-related behaviors for decades. But its involvement in judging risk came as a surprise. "We found two signals in this system—first, an immediate reward signal, and then a delayed risk signal," says Quartz. The risk signal peaked when the second card was shown. Because the subjects weren't warned when the second card would appear, the researchers speculated that the risk signal might also serve as an unconscious alert to anticipate the resolution of the bet.

Besides explaining stock-market strategies, the researchers hope future studies may illuminate gambling addiction and bipolar disorder. People with these illnesses may have distorted perceptions of risk or reward, which leads them to choose risky behaviors.

Meanwhile, Colin Camerer, the Axline Professor of Business Economics, has been collaborating with researchers at Baylor College of Medicine and George Mason University to study a different type of reward. These neuroeconomists found that dopaminergic systems not only respond to rewards people experience directly, but also to rewards that people imagine could have been theirs.

To understand the distinction, imagine you are investing in the stock market. Each month, you invest the same small portion of your paycheck and watch the market's activity. Say the market has skyrocketed for a few months, and you are pondering how much to invest next month. In the past, when you invested a small portion of your paycheck, you got modest rewards. But had you been investing half of your earnings, you would have landed a large windfall. So now you decide to go for it, and put more of your next check into the market.

"The empirical fact is that people will often switch to strategies they never picked before. They couldn't have learned these strategies by reinforcement" from experienced rewards, says Camerer. In these situations, people use imagined rewards, or rewards that could have been theirs, to guide their decision making. This process, called fictive learning, is similar to the emotion of regret. "Regret is essentially the bodily sensation or name we give to fictive learning when there was a better choice than the one we chose."

Subjects in this study played a similar stock-market game while the fMRI scanned their brains. The researchers matched activity patterns in their brains with the "fictive error," which was defined as the difference between the best possible reward and the reward actually experienced.

Camerer and colleagues found that activity in the ventral caudate nucleus mirrored the differences between imagined and experienced rewards. The caudate nucleus is a subdivision of the striatum, the region highlighted in the Quartz study. "Almost everything you would naturally call a reward, or an anticipated reward, seems to activate the striatum," says Camerer. "It's quite interesting because it means that simply imagining something rewarding might turn on the reward signal."

Camerer hopes to expand this research to examine how we learn through observing others' actions. Imitation may be a socially transmitted form of fictive learning. "If I see you do something and I see it makes you smile or see it makes you vomit, then, even though I didn't have to do it myself, I may learn something from your actions," says Camerer.

Although the ability to use imagined rewards has obvious advantages, there could be a dark side. "That same capacity for imagination to activate brain areas as powerfully as actual experiences could lead to paranoia, delusions, and phobias. So, as we come to understand fictive learning better, it may help us to understand these mental states."

The article describing this work appeared in the May 29 issue of *The Proceedings of the National Academy of Sciences*. The other authors of the article were Terry Lohrenz and P. Read Montague of Baylor College of Medicine and Kevin McCabe of George Mason University. ☐—*MT*

Michael M. Torrice is a chemistry grad student who uses amino acids not found in nature to study how signals cross the synapses between nerve cells. He is working with Dennis Dougherty, the Hoag Professor of Chemistry.

Jackson's lab designers, David Mispagel and Anneline Van Benthem-Weil, recreated in linoleum an infrared laser beaming through a diamond-anvil cell. In the cell (inset sketch), two semi-flawless diamonds squeeze a sample grain of deep-mantle rock while an infrared (IR) laser heats it. With Earth's deep-mantle conditions thus simulated, its material properties can be scrutinized from the relative comfort of the lab.

Getting at the Core

If you want to know what's going on deep inside Earth, step into the brand-new lab of Jennifer Jackson, assistant professor of geophysics in Caltech's Seismological Laboratory. Jackson started at Caltech last December, and just five months later her lab—the Institute's first to use a so-called diamond-anvil cell to study mineral transitions under the intense heat and pressure of core-mantle boundary conditions—was up and running. Hers is one of fewer than a dozen labs in the United States equipped to tackle this kind of research. Her tools: a couple of gem-quality diamonds, a laser, and a speck of super-dense deep-mantle mineral of the perovskite family, made of iron, magnesium, aluminum, and silica.

Jackson has several goals in mind. She'd like to figure out how Earth's metallic core interacts with its rocky mantle, how iron-rich materials melt at high pressures, how seismic waves move under these conditions, and, ultimately, how our planet evolved to its present state. As she describes it: "We're at a middle stage in Earth's evolution, and we're using mineral physics both to understand its present state and to draw a line back to where it started."

Drills can't help Jackson's research because their casing collapses under the pressure as they inch deeper into Earth's crust. The deepest a drill ever penetrated is a mere 12 kilometers—a scratch on the surface considering the core is some 2,900 kilometers deep—and it took 24 years and more than $100 million to accomplish. But squeezed together, diamonds can both exert and withstand extreme conditions, as long as they're slowly coaxed into them. (Unfortunately, they don't survive the return trip—they develop ring fractures on decompression.) Jackson begins with two diamonds, a quarter of a carat each, with their tops and tapered tips ground flat. These gems are Type Ia, meaning they're both natural and semi-flawless, because impurities in synthetic or slightly dirty diamonds obscure the signals from the object of Jackson's study—a perovskite grain sandwiched between the diamonds, squeezed by the gems inside a metal collar. Together these parts comprise the diamond-anvil cell, and you wouldn't want to stick your finger in one of them.

A diamond-anvil cell can exert a pressure up to that inside Earth's core, which is calculated to be 360 gigapascals (GPa)—"approximately one million elephants standing on your head," as Jackson describes it—corresponding to a depth of about 6,400 kilometers. Jackson takes her samples up to 130 GPa for now, to study lower-mantle properties, but she plans to go higher. To better mimic mantle and core conditions, she also beams an infrared laser through the samples to heat them to temperatures near that of the core, which is thought to exceed 6,000 degrees Celsius. The exact figure has an uncertainty of 2,000 degrees, and is a subject of great interest because it carries implications about the true composition of the core, how heat is generated inside it, and when exactly it formed. We still don't know whether Earth retained its original core after the planet formed four and a half billion years ago, or whether Earth completely restratified after the impact that is thought to have ejected the moon and possibly melted the planet some 50 million years later. Figuring out the core's temperature could also yield insight into when Earth's magnetic field developed.

Inside Jackson's lab, the samples are pressurized, heated, or both, in incremental steps. Then she takes them to Chicago, to the Advanced Photon Source at Argonne National Laboratory, a synchrotron source of the world's most brilliant X rays. At the facility she uses X-ray scattering methods to identify the minerals' internal structures and studies how seismic waves disperse through the material under different conditions. Comparing these measurements to observations of how seismic waves travel through the whole planet after an earthquake, scientists have begun to parcel out finer and finer zones deep inside Earth.

As for *The Core*, 2003's Hollywood interpretation of what Jackson studies, she says she appreciates how the movie got people excited about such a recondite topic. But in her version, she wouldn't have put amethyst caves in the upper mantle because, as she points out, "that's clearly not allowed." □—*EN*

Like many who first venture into the blogosphere, Sean Carroll, a senior research associate in theoretical physics at Caltech, wasn't sure where it would take him. But when he wrote his first post on the Preposterous Universe blog on February 29, 2004, he set out on a path that would make him one of the most-read scientist-bloggers around.

More than three years after his first post, Carroll is still going strong. He's since abandoned the Preposterous Universe, and for two years has been writing for Cosmic Variance, a blog he shares with a group of physicists and astronomers, drawing 4,000 visitors a day. Their posts often spark lively discussions, with comments from professional scientists and the general public alike. Carroll, who is the most frequent contributor to the blog, was recently invited to speak about cosmology at YearlyKos, an annual convention of mainly liberal bloggers and like-minded political activists. This year's convention even featured a debate among the Democratic presidential candidates, showing the growing influence of the blogging community.

Although it tends to center on physics and astronomy, Cosmic Variance gives the scientists the opportunity to write about anything they like, whether it be politics or the Harry Potter finale. According to Carroll, part of the purpose of the nonscience posts is to show the human side of science. "We're all very concerned about people in elementary school, and especially girls and groups who don't traditionally become scientists," Carroll says. "We want to show them scientists are human beings, that being a scientist is something they can do someday, and that it's not that scary." Additionally, he says the blog gives the public an inside glimpse of what scientists do and think. Carroll recently wrote a three-part series on how an idea grows into a full-fledged research paper, from scribbling equations over a drink at a bar to finally posting the work to arXiv.org, the online depository for papers in physics, astronomy, mathematics, computer science, and related fields.

At first, Carroll wanted to link to as many physics blogs as possible, but with more than 50 now listed on Cosmic Variance, he says he's since given up. Despite the proliferation of physics blogs, Carroll is not very optimistic about them taking a more prominent role in physics research. From posting papers on arXiv.org to e-mail, the current way in which physicists communicate is already efficient. Blogs, however, could serve as a place for specialists and nonspecialists to interact, chipping away at the barriers separating academia from the general public. Still, most physics blogs are written by students or nonscientists who are interested in physics—and not professional physicists, Carroll says. "I think physicists have been slower to catch onto blogs than people in the social sciences or humanities," he explains. “Physics is more of an esoteric topic where we talk to each other rather than the outside world.” For instance, blogging in technical detail about the cosmological effects of Lorentz-violating vector fields—one of Carroll’s areas of research—probably has a limited audience. For him, Cosmic Variance’s purpose is clear. “We don’t have a lot of goals other than us having fun,” he says.

One social scientist and blogger is Caltech’s Professor of Political Science Michael Alvarez. (A feature article about his work begins on page 12). As part of the Caltech/MIT Voting Technology Project, which he codirects, he started the Election Updates blog. Unlike Cosmic Variance, this blog has a research-oriented purpose of disseminating news and developments among those in the field of voting technology. According to Alvarez, readers include other academics, policy-makers, those who build and develop voting machines, political junkies, and others who may not be in the circle of academic political scientists. “Our role is to push research out into the community, to people who normally won’t be exposed to it,” he says.

When he started the blog two years ago, a couple of blogs devoted to election politics already existed. But none focused on voting technology, and that’s where Election Updates found its niche. The blog, which Alvarez runs with Thad Hall, an assistant professor of political science at the University of Utah, features a small group of contributors. The blog receives about 150 views a day, but when election season comes up, so does the number of hits. The site saw more than 16,000 total visitors last November, when his graduate students and colleagues were constantly updating, he says. “It was almost a full-scale operation.”

What’s the future of blogs in academia? Alvarez anticipates that soon, the open, online communication afforded by blogging could become a regular part of political-science research. Caltech Library Services already uses blogging technology to disseminate research papers in all fields. Its Open Access Authoring @ Caltech site posts papers written by Caltech researchers that have been published in so-called “open access” journals. These journals don’t require a subscription, supporting themselves by other means such as subsidies from institutions or universities or by charging the author a production fee.

Meanwhile, Alvarez wants to take further advantage of this new platform, and in particular, to explore multimedia possibilities. His first post, in fact, was a podcast, an audio recording of his own commentary. He and his colleagues also posted their own YouTube videos of election sites. “There’s a lot of interesting things you can do with the technology,” he says. “We’ve only scratched the surface.”

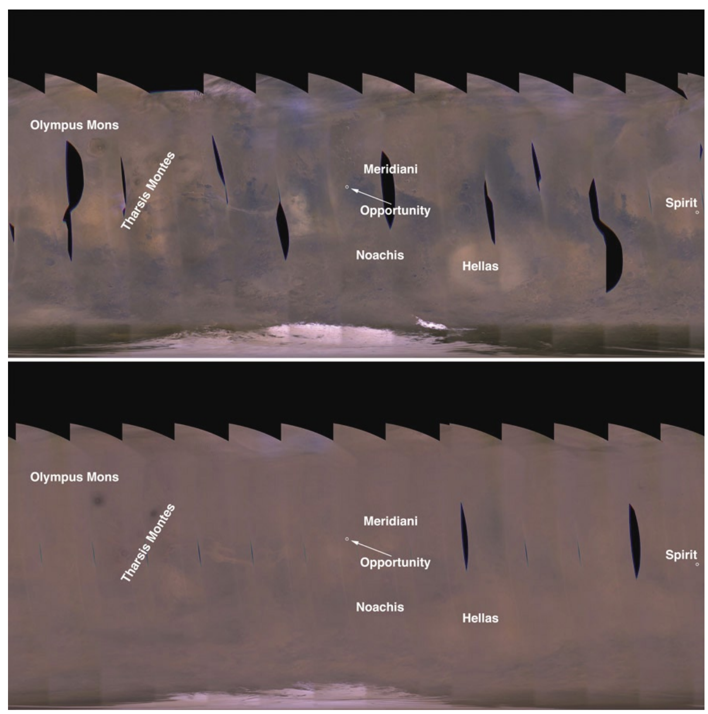
As blogs continue to evolve, so will their roles—whether for disseminating research, bridging the gap between academia and the public, or just for fun. “The power of this is pretty profound,” Alvarez says. □—*MW*

Visit Cosmic Variance at http://www.cosmicvariance.com, Election Update at http://electionupdates.caltech.edu/blog.html, and Open Access Authoring @ Caltech at http://oacaltech.blogspot.com. □

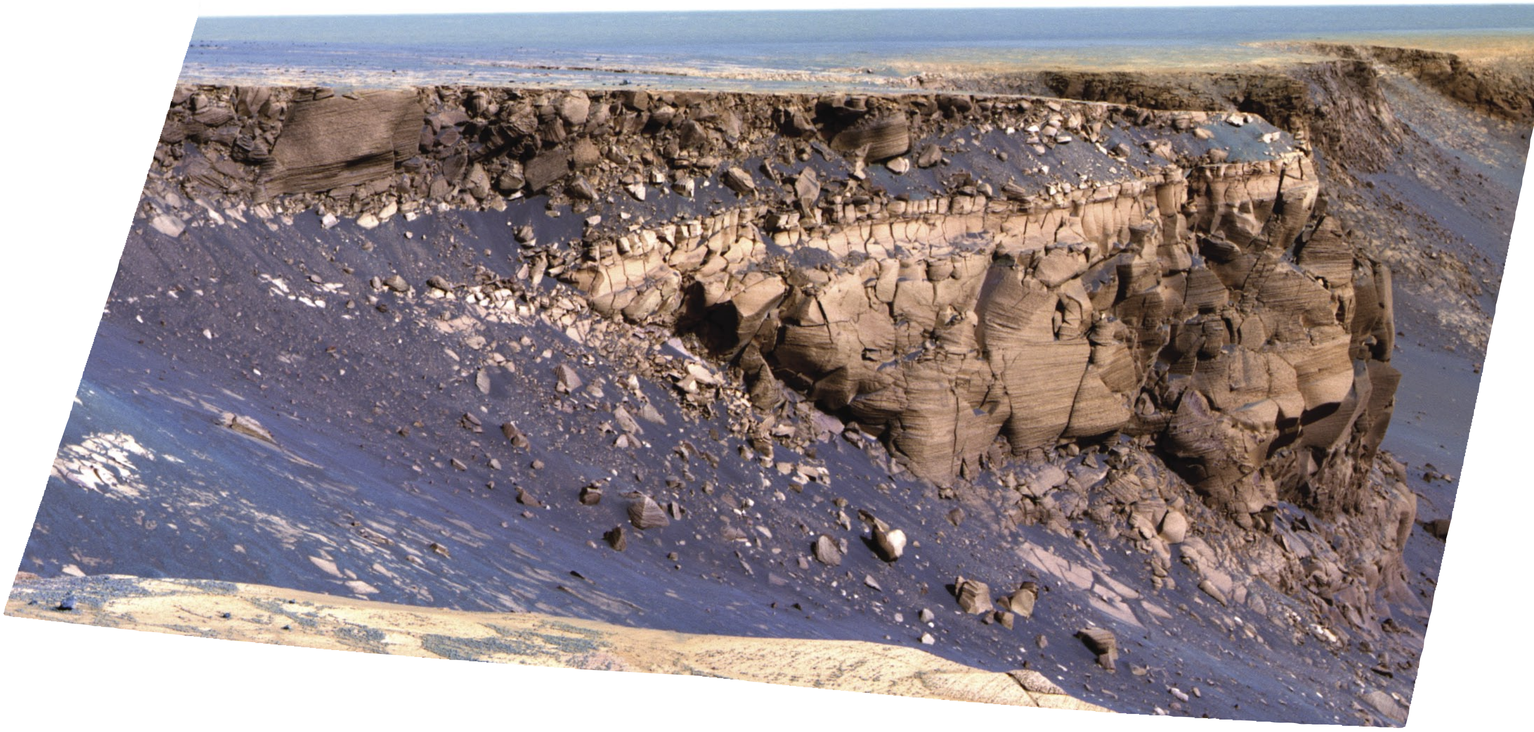
WEATHERING THE STORM

July and August here in Pasadena are usually some of the most predictable days of sunshine the year has to offer. Scientists on the Mars Exploration Rover (MER) team at JPL, however, spent the better part of their summer battling the largest dust storm in the solar system, which enshrouded nearly the entire planet in a dark haze. Project managers were forced to pull back the reins on rovers Opportunity and Spirit and hunker down for the storm.

In the biggest threat to the mission since their landings on Mars three and a half years ago, the twin rovers faced the risk of losing power and shutting down indefinitely. The situation was particularly hazardous for Opportunity, which at the storm’s peak was receiving less than 1 percent of the normal amount of sunlight on its solar panels. A heater switch in Opportunity’s arm that had been stuck in the “on” position since landing provided an additional energy challenge, draining one-third of the diminished solar-generated electricity. Both rovers parked themselves and went into a low-power mode in order to conserve as much energy as possible. While on standby, communications



Top: Mars as it appeared to the Mars Reconnaissance Orbiter’s Mars Color Imager on June 22, 2007. The first in a series of regional dust storms has sprung up, to the west of Opportunity.
Bottom: By July 17, nearly the entire planet was obscured.



opportunities were limited to once every three days, and all but the most basic functions necessary for the rovers' survival were turned off. But the heat generated by the rovers' electronics helps keep the insulated boxes housing them warm, and with much of their circuitry inactive, concern grew that the rovers might not be able to maintain their normal operating temperatures during the cold Martian nights. Damaged circuitry or a depleted battery could have spelled doom for even the most intrepid robotic explorer.

The storm came at an inopportune time. Spirit was poised near a plateau known as Home Plate, ready to study Mars's volcanic history. Opportunity was waiting out the storm at the rim of Victoria Crater, into which it is slated to descend to study the billions of years of geological history chronicled in the walls of the 70-meter-deep crater. Victoria Crater exposes significantly more strata than any other feature studied by the MER team, who are eagerly awaiting the chance to look further into Mars's geological past than ever before.

While the rovers were stymied on the surface, the Mars Reconnaissance Orbiter (MRO) had a field day imaging the storm and its evolution. As Richard Zurek, JPL's project scientist on the MRO mission put it, "When you get lemons you make lemonade, and when you get a dust storm you study the dust storm." Dust storms are common on Mars, but storms of this magnitude only flare up every five or six years, rather like the El Niño cycle here on Earth. With months of data from this storm, the MRO team will be in a position to answer some fundamental questions about Martian weather patterns: What triggers such a global storm? Why do they occur some years and not others? How does dust get distributed over the planet and alter surface features? This in turn will help us interpret the evolution of Mars's surface geology with more confidence.

Zurek is often asked just what it would be like to experience this dust storm. "Visibility is still a few miles," he says, "like a hazy day in L.A., but quite a bit darker. It is significantly cooler during the day since the majority of the sun's energy is absorbed or scattered by the dust, but warmer at night since the remaining heat is trapped, leaving average temperatures essentially unchanged over the course of a martian day."

Both rovers resumed driving and doing science in late August. Spirit climbed onto Home Plate the week after Labor Day. And favorable gusts of wind have removed some dust from Opportunity's solar panels almost as quickly as it settled. As *E&S* went to press, Opportunity was cautiously beginning its descent into Victoria Crater via a scallop on its edge known as Duck Bay. □—*EQ*

Elijah L. Quetin is a graduate student in astronomy, working on galaxy evolution with Richard Ellis, the Steele Family Professor of Astronomy.

This false-color view of Cape St. Vincent, a quarter of the way around Victoria Crater from Duck Bay, shows the band of bright rock just below the rim that is visible all around the crater. The band, thought to be Mars's surface just before the crater was created, will be one of Opportunity's first stops on Duck Bay's much gentler slope.

A Curious Premiere

Coming in October to a PBS station near you is *Curious*, a two-part profile of Caltech and JPL scientists in their own words. Produced by WNET, the program features many names familiar to *E&S* readers—including Nathan Lewis and Mark Davis, who appeared in our last two issues. Check your local listings for air times. □—*DS*

At first, it was just a class project. When seniors Rudy Roy and Ben Sexson took Product Design for the Developing World (E/ME 105), they didn't think their idea of turning bicycles into wheelchairs for the poor and disabled in Guatemala would go beyond the classroom. But during the fall quarter of 2006, as they designed and built a prototype chair, learned how to make a business plan, and held videoconferences with students in Guatemala, the project became a passion. "The problem became personal," Sexson says. "We really wanted to do something good." They carried on with the project after the term ended, and upon graduation teamed up with Charlie Pyott, a student at the Art Center College of Design, to form a new nonprofit organization called Intelligent Mobility International, with Roy as the chief executive officer, Sexson as the chief financial officer, and Pyott as the chief technical officer.

The class, taught by Visiting Professor of Mechanical Engineering Ken Pickar, introduces students to developmental engineering. This emerging field is about finding cheap, technological solutions to some of the most basic needs of the poorest people on the planet. The solutions must also generate income, in the proverbial way of giving a man a fishing pole instead of a fish. The class focuses on rural Guatemala and includes close collaboration with students at Rafael Landivar University to gain crucial insight into the people's culture, daily lives, and needs. Once the students identify a problem, they find a solution, and form a business plan to market and manufacture their product.

Reliable statistics are scarce, but the number of disabled in Guatemala is estimated to be at least in the many tens of thousands, as a result of decades of civil war and violence. Without the means to get around, getting a job or an education is nearly impossible. Imported wheelchairs are too expensive, so Sexson and Roy decided to build them from ready-made bicycle parts. Not only are bicycles—and local bicycle manufacturers—common in Guatemala, but this design uses mountain bikes, resulting in an off-road wheelchair capable of negotiating the rural terrain. These durable wheelchairs could last up to 10 years, Sexson says. A standard chair wouldn't come close.

The key innovation is a standardized and simplified manufacturing process. The team has designed a special workbench on which you place the bicycle. The workbench acts as a template, telling you exactly where and how to take the bicycle apart and to reassemble it into half a wheelchair—each wheelchair is made from two bicycles. Because of the process's ease and efficiency, you don't need a lot of training or education, which is essential because the designers hope to employ the same people the chairs are designed for: the poor and disabled.

Developmental engineering is about developing local economies and empowering people, says Mario Blanco, director of process simulation and design collaboration in the Materials and Process Simulation Center in the Beckman Institute. "That empowerment allows them to get a better life for them-

PICTURE CREDITS: 2, 3 — Doug Smith; 4–5 — NASA/JPL/Caltech; 6 — Ariel Shoresh; 8 — NASA/JPL/MSSS; 9 — NASA/JPL/Cornell; 10

selves," he says. Blanco, who is from Guatemala, has been involved with the course since its inception three years ago.

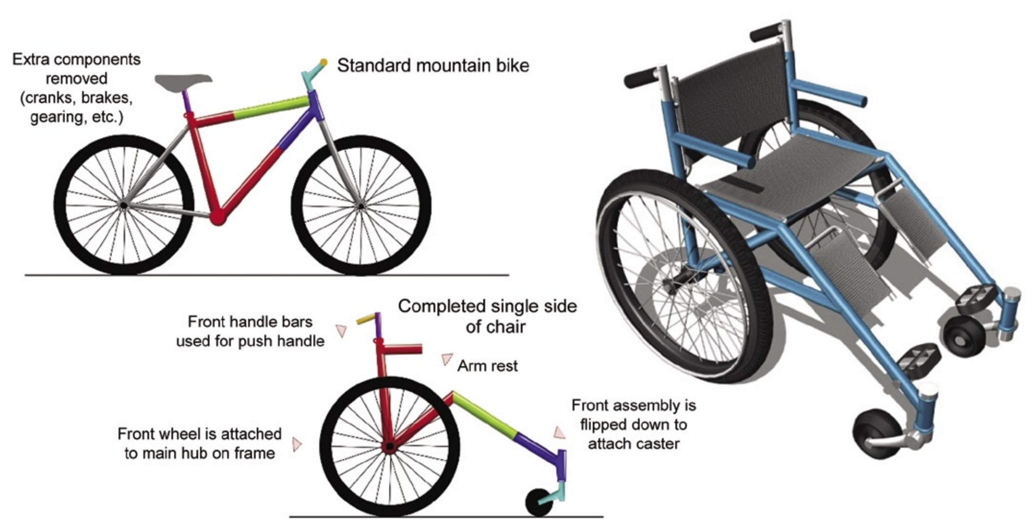
"Technology for the developing world needs to be designed and built from the ground up," says Blanco. "Because of cost constraints and socio-cultural issues, first-world technology rarely 'trickles down' successfully to the 2.8 billion people living on less than two dollars per day—a level of poverty often referred to as the 'Bottom of the Pyramid.'"

Developing a product cheaply to address the basic needs of the poor may not be as difficult as building robots to send to Mars, Blanco says, "but if you have a problem with tremendous constraints on cost, you make it an impossible problem. Caltech students like to focus on just this kind of problem!"

To solve these impossible problems, this summer Blanco and Pickar helped run the first annual International Development Design Summit at the Massachusetts Institute of Technology. Run by Caltech, MIT, and Olin College, the meeting involved nearly 50 students, engineers, and academics from 15 countries, and from all walks of life, including one participant who had never before left his village in Tanzania. In the same spirit as Pickar's class, the participants divided into teams to design products that address the needs of the developing world. At the end of the month-long summit, in which participants lived, worked, and played together, they produced 10 prototypes. Designs included a refrigerator that keeps food cool using only evaporating water, and a device that tests water safety. By detecting microbes in the water with an incubator, the device would cost less than $50 instead of the thousands needed for a conventional instrument. The goal, of course, is to turn these ideas into real products, much like what Sexson and Roy have been doing with their wheelchairs.

Intelligent Mobility International is still in the research and development stage, but the team continues to push the project forward. They have just started a campus club, Intelligent Mobility, to involve more students. Additionally, they plan to continue their collaboration with the Art Center, to recruit help with design aspects of the project, such as creating a website. "A little bit of work can go a long way," Sexson says. "It doesn't take much to make a big difference. If we keep plodding along and keep moving, we can accomplish something." They hope to finish the third prototype by October, and are talking with Bicicletas Corsario—El Salvador's largest bicycle company, which has branched out to Guatemala—to provide the bicycles. They plan to roll out 500 wheelchairs in the first year of operation. Meanwhile, they hold down other full-time, paying jobs, although they continue to meet a few days a week.

Roy says the experience has shown them what they can achieve as engineers, going beyond academics. "How many times do you get an opportunity in college to make a big impact in the world?" he says. □—*MW*



Presto, chair-o: Starting with the far left photo, Ben Sexson (in suit; after all, he is the CFO), and Charlie Pyott steady a mountain bike frame in one of the template's holders as Rudy Roy prepares to make the first saw cut. Then the frame is flipped over to position it in another holder for the second cut, and so on. The graphics at right, drawn by Pyott, continue the transformation.