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THE MAGAZINE OF TECHNOLOGY INSIDERS

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special report

2011: an occupational odyssey

TECH EMPLOYMENT IS SLUGGISH, BUT DREAM JOBS ARE STILL OUT THERE

PLUS: RECRUITERS TELL US WHAT GOOGLE, RIM, AND TESLA ARE LOOKING FOR IN JOB CANDIDATES

THE END OF SUPER-COMPUTING?
Why we won't see an "exaflops" computer for a *very* long time

POLAR PARTICLE HUNTER
Detecting neutrinos at the South Pole

IEEE

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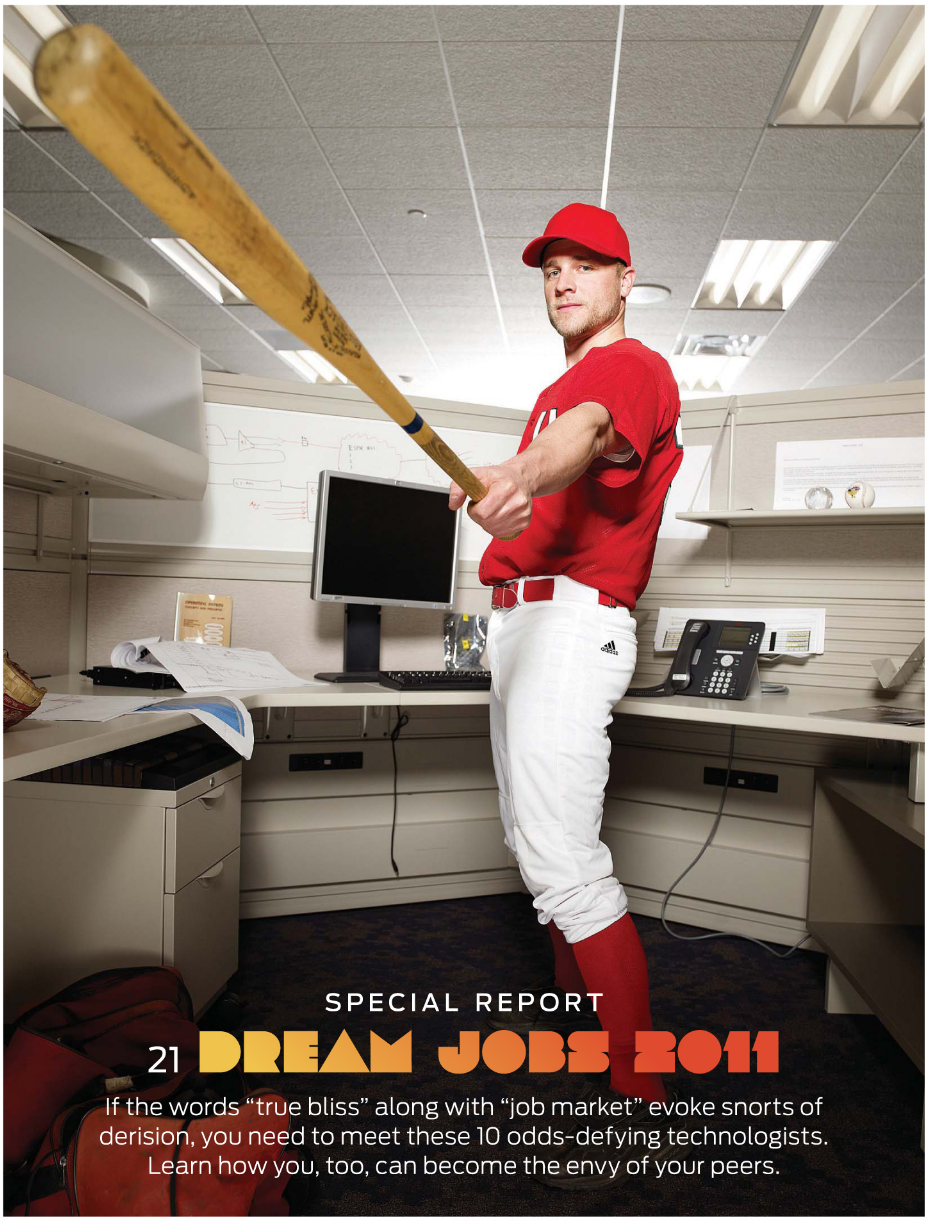
ieee spectrum 2.11



OUT OF THE PARK: Ricky Langer [above] loves playing baseball, but he says his engineering job at ESPN is pretty cool, too. Loredana Bessone [cover] prepares European Space Agency astronauts to venture off-planet.

COVER: ANDREAS TEICHMANN
THIS PAGE: DAVID YELLEN

UPDATE

OPINION

DEPARTMENTS

volume 48 number 2 international

ieee spectrum 2.11

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AVAILABLE 1 FEBRUARY

Digital Dashboards

MyFord Touch and other digital dashboards turn your car into a mobile man cave with access to directions, restaurant recommendations, and spoken e-mail, plus music, movies, tunable lighting effects, and the ability to personalize the entire cockpit by configuring the look and position of gauges. With more buttons to push and multimedia to enjoy, getting from point A to point B has never been such an afterthought.

LITTLE SCREEN, BIG DOCUMENT

IT SURE WOULD BE NICE to leave the laptop or piles of paper at home and do all your reading on your smartphone or tablet computer. And soon it may not be quite so painful, thanks to some clever software tools.

CLOCKWISE FROM LEFT: FORD MOTOR CO.; FX PALO ALTO LABORATORY; U.S. NAVY

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NEXT-GENERATION SHIPS
The Electric Ship Technologies Symposium will be held 10 to 13 April, in Alexandria, Va. The conference will cover integrated electric power systems, system architecture, electrical power conversion, standards, and more.

IEEE MEMBERS MAKE ADVANCES IN CANCER RESEARCH
Learn about two IEEE members who are working on ways to make cancer detection and treatments more effective, with fewer side effects.

WHAT'S GENDER GOT TO DO WITH IT?
Despite numerous initiatives over the past 30 years, women are still the minority in engineering classrooms. A recent IEEE webinar explored how gender affects engineering curriculum and ways to make courses more inclusive.

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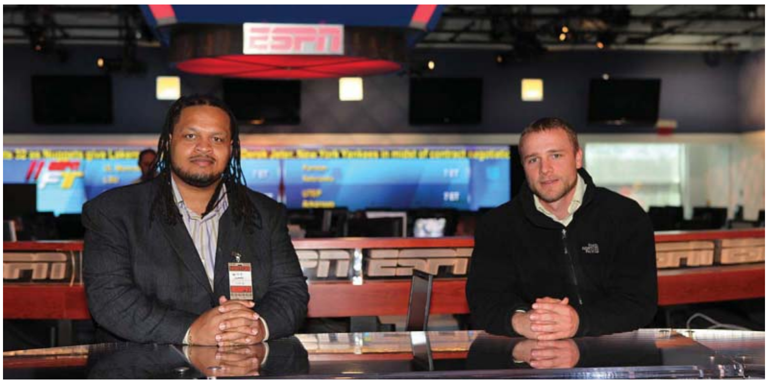
back story



Fantasy Sports Reporting

How great is Ricky Langer's job? Well, for *IEEE Spectrum* assistant editor and sports fanatic Willie D. Jones, it was a dream assignment simply to spend a day with Langer, one of the 10 subjects picked for this year's Dream Jobs coverage.

Langer is a senior systems engineer at ESPN who led the team that recently brought full-motion 3-D video broadcasting to the network. Jones visited him in November at the dazzling and very high-tech ESPN mother ship in Bristol, Conn.

Just as pilots are never supposed to be scared, journalists are never supposed to be starstruck. But by his own admission, Jones's poker-faced and world-weary demeanor—which is mandatory for journalists at all times while they are working—was utterly dissolved the moment he encountered former National Football League stars. It started right after he was badged for entry into the campus: "Was that Tedy Bruschi?...Hey! That's Torry Holt!... Would it be unprofessional to ask for an autograph?"

Whatever shreds of dispassionate objectivity might have remained were obliterated when Jones [above, left, seated next to Langer] got to sit at the anchors' desk in the studio from which "SportsCenter," "SportsNation," and ESPN News are broadcast.

He met Langer at Building 13, whose lobby is a shrine to great U.S. athletes who have worn the number 13 (the group includes Wilt Chamberlain, Dan Marino, and Alex Rodriguez, which exposes triskaidekaphobia for the absurdity that it is). Even as the mini museum gave way to offices, walls adorned with posters, banners, and the ultimate throwback sports-jersey collection continually caused Langer to have to wait while his guest acted like a goggle-eyed tourist and a disgrace to journalists everywhere. The tour then finally went on to Langer's engineering projects—including the master control room that allows ESPN to broadcast in 3-D.

For Langer, who sees sports greats every day, it's the technology that really enthralls. "What makes this job cool is that every day on my way to work I'm thinking 'What new piece of technology am I working with today?' " Yeah, who cares if the guy headed down the hall is headed to the hall of fame? ❑

CITING ARTICLES IN IEEE SPECTRUM

IEEE Spectrum publishes two editions. In the international edition, the abbreviation INT appears at the foot of each page. The North American edition is identified with the letters NA. Both have the same editorial content, but because of differences in advertising, page numbers may differ. In citations, you should include the issue designation. For example, the first page of Update is in *IEEE Spectrum,* Vol. 48, no. 2 (INT), February 2011, p. 7, or in *IEEE Spectrum*, Vol. 48, no. 2 (NA), February 2011, p. 11.

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COLLEEN LYNCH

contributors

SALLY ADEE,

formerly an associate editor at *IEEE Spectrum*, is now a technology features editor at *New Scientist*, in London. She says it was an honor to write her last feature for *Spectrum* about the European Space Agency's Loredana Bessone [p. 22], a woman she considers a role model. "One day, I'm going to hit her up at ESA to start training me as an astronaut," she says with a wink. "Right after I get sick of playing roller derby in London."

D.L. ANDERSON

of Durham, N.C., photographed John Q. Walker for Dream Jobs [p. 28]. A music fan, Anderson says he hit it off immediately with Walker, whose company reproduces the sounds and styles of long-gone masters. After listening to a re-created performance of late jazz pianist Oscar Peterson, "we were definitely nerding out together," he says. "I was amazed." Anderson, also a filmmaker, recently completed a documentary about Percy Flowers, a notorious North Carolina moonshiner.

SPENCER KLEIN,

a senior scientist in the Nuclear Science Division at Lawrence Berkeley National Laboratory, wrote this month's feature on the South Pole's IceCube Neutrino Observatory [p. 38]. He has traveled to Antarctica twice in the name of neutrino astronomy. The second time he camped for 11 days on the Ross Ice Shelf at an isolated spot 30 kilometers off the continent's shore. "The air was so clear," he says, "that it seemed you could see forever."

PETER KOGGE,

an IEEE Fellow, is a professor of computer science and engineering at the University of Notre Dame, where he also holds an appointment in the department of electrical engineering. While at IBM in the 1970s, he worked on the space shuttle's input/output processor and on the IBM 3838 Array Processor, which was the fastest single-precision floating-point processor the company sold at the time. "Today your cellphone probably has an order of magnitude more computing power," says Kogge, who writes about coming advances in supercomputing in "The Tops in Flops" [p. 44].

SUSANA RAAB,

based in Washington, D.C., has shot photographs for such publications as *The New York Times*, *Time*, and *Newsweek*. She says engineer Gus Lott, whose mother is a photographer, proved perfectly at ease in front of the camera for his Dream Jobs profile [p. 27]. For one photo, which didn't make the final cut, Lott crawled around on the floor as if he were one of his lab's test subjects in a tracking camera maze. "It was basically like Big Brother for rats," Raab says.

CATHERINE SHU

is a features reporter for the *Taipei Times*, in Taiwan, where she covers pop culture, style, and art. Her favorite part of profiling new media artist Hsin-Chien Huang [p. 31] was watching children gleefully shove each other out of the way for a turn at one of his interactive installations, something that would get them kicked out of most art exhibits. Shu has also written for *Barron's*, the *Wall Street Journal*, and *Psychology Today*.

CLOCKWISE FROM TOP LEFT: RANDI SILBERMAN KLETT; UNIVERSITY OF NOTRE DAME; SUSANA RAAB; RON BROWNLOW; RUTH EHRENKRANTZ; KAVANAH ANDERSON spectral lines

The E-Word

THE WORD least likely to be spoken by politicians was once a simple one: “engineer.”

I was reminded of the invisibility of the E-word recently when studying the origins of President Dwight D. Eisenhower’s famous farewell address to the nation, which he delivered 50 years ago last month on 17 January 1961.

The address is well remembered for Eisenhower’s warning about the emergence of a “military-industrial complex,” which might distort government policies in pursuit of profits from the development and sale of weapons. Less famous, but no less significant, was Eisenhower’s other warning: that “public policy could itself become the captive of a scientific-technological elite.” At the same time, Eisenhower warned that scientists could become prisoners of government funding, with contracts becoming, in his words, “virtually a substitute for intellectual curiosity.”

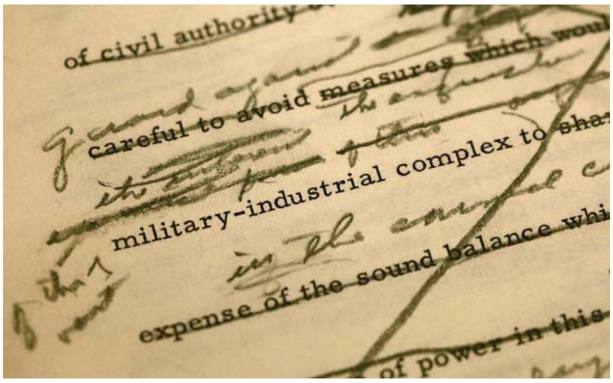
President Eisenhower complained vigorously about the potential perils of elite scientists ignoring the popular will—and of themselves, paradoxically, becoming tools of power.

What’s gone unnoticed until now—what I discovered when reading an early copy of Eisenhower’s farewell speech that had been ignored in the Eisenhower archives until last month—was that the President’s speechwriters, Malcolm Moos and Ralph Williams, wanted Eisenhower to highlight engineers as well as scientists. In a draft of the farewell, penned one month prior to Eisenhower’s speech, Moos and Williams made two references to engineers and engineering, placing both the occupation and the activity on an equal footing with scientists and science.

And yet by the time Eisenhower read his speech in a nationally televised address, the words “engineer” and “engineering” were absent. Instead, Eisenhower talked of research, technology, and science—but not a word about engineering.

To be sure, Eisenhower was merely reflecting a widespread mental habit, common some half-century ago, of subsuming engineering under the larger rubric of science and technology or research and development. But by writing engineers out of the politics of science, the president diminished the public’s understanding of technological change.

The tradition of emphasizing science and scientists at the expense of engineers and engineering continued under later U.S. presidents. In 1980, under President Carter, the government launched the National Medal of Technology with no mention of engineers, even though they create most technologies. In 2007, President George W. Bush updated the medal, adding “innovation” to its name, but again refusing to use the E-word.



CHARLIE RIEDEL/AP PHOTO

Words matter, and times are changing. President Obama has embraced the E-word, putting engineers on a par with scientists in his vernacular—and giving engineering a public status that the diverse field has never held in relation to science, at least within political discourse.

In November 2009, for instance, Obama declared, “Scientists and engineers ought to stand side by side with athletes and entertainers as role models.” In April of 2009, he told a gathering at Georgetown University that he’d like to see “our best and brightest commit themselves to making things. Engineers, scientists, innovators...what we can really use is some more scientists and some more engineers who are building and making things....”

In October 2010, Obama continued his promotion of engineering as a career, and as an activity. At an event called the White House Science Fair, the president went out of his way to highlight the contributions of engineers, showing an awareness, unique among modern presidents, of the essential equality between careers in science and engineering. “This is an interesting statistic,” Obama said, “particularly at a time when young people are thinking about their careers: The most common educational background of CEOs in the S&P 500 companies—all right, the nation’s most successful, most powerful corporations—the most common study of CEOs is not business, it’s not finance, it’s not economics—it’s actually engineering. It’s engineering.”

To be sure, some proud engineers might argue that engineering is *more important* than science. But that’s not a view widely shared, and it misses the point that in the politics of technoscience, engineering has too long been ignored, or been conflated wrongly with science.

Names are important. Engineers and scientists represent parallel occupations, harder than ever to distinguish and yet distinguishable. To speak their names properly helps clarify and illuminate in subtle ways complex issues facing experts of all dominions. That Eisenhower edited engineers out of his famous farewell address—and that Obama today includes engineers on an equal basis with scientists—shows that the public understanding of technological change does not stand still.

—G. PASCAL ZACHARY

G. PASCAL ZACHARY is a professor of practice at the Consortium for Science, Policy & Outcomes at Arizona State University.

A version of this article appeared online in January 2011.

more online at spectrum.ieee.org

update

Network Defense Gone Wrong

Some distributed denial-of-service defenses could in fact make a Web site more vulnerable

After WikiLeaks began publishing confidential communications of the U.S. State Department late last year, a spate of incidents put distributed denial-of-service attacks back in the news. These attacks can take many forms, the most straightforward of which is simply to overwhelm the targeted file server with requests. If that server can't keep up with the barrage, legitimate users are effectively shut out.

An attractive defense is to employ a large number of servers at far-flung locations. Such content-delivery networks are common enough, and plugging into one isn't difficult. Akamai Technologies runs the largest such network; it has 73 000 globally distributed servers, which, according to the company, handle 15 to 30 percent of all Web traffic.

With such file-serving clout in your corner, your site should be able to stand up to almost any pummeling, right? That's what Akamai boasted in the wake of the recent attacks. And in most situations, linking up with a content-delivery network is undoubtedly a good defense. But many of the companies doing so probably don't know that if the bad guys are clever enough—and if the good guys are not quite on the ball—using a content-delivery network might actually *increase* a Web site's vulnerability.

That troubling possibility came to light in 2009 at the 14th European Symposium on Research in Computer Security in work reported by Michael Rabinovich, a professor of electrical engineering and computer science at Case Western Reserve University, in Cleveland, and two graduate students then studying under his direction, Sipat Triukose and Zakaria Al-Qudah.

"Content-delivery networks have this intuitively understood claim that they improve the resiliency of Web sites to distributed denial-of-service attacks," says Rabinovich. "If an attacker tries to launch an attack, he will exhaust his resources before the content-delivery network notices a blip." But while Rabinovich's group was studying the performance of content-delivery networks, they stumbled on a subtle weakness. To appreciate the trouble it could cause, you need to understand a little bit about these networks.

When your computer requests something from the Web site

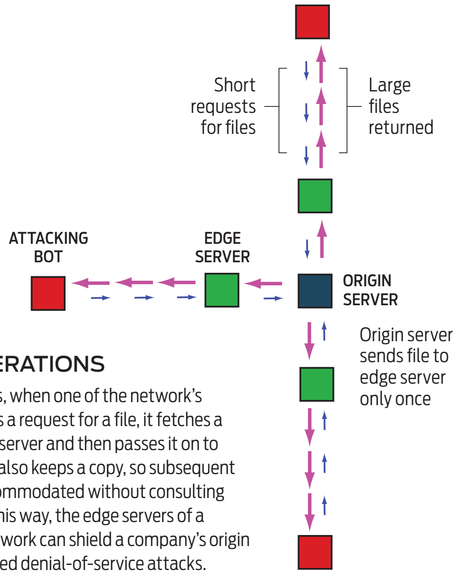
ANONYMOUS ATTACKS: Members of the hacker group Anonymous have targeted distributed denial-of-service attacks at companies that have ceased serving WikiLeaks.
PHOTO: VINCENT DIAMANTE

update

of a company that uses a content-delivery network, you are invisibly routed to one of the network's many so-called edge servers. If that edge server does not have the content you are looking for, which might include rather large files, such as video clips or images, it retrieves a copy from the company's server (the origin server) and passes it to you. The edge server also keeps a copy in its cache. Subsequent requests for that content can thus be accommodated without consulting the origin server. This is what protects that server from being swamped with requests.

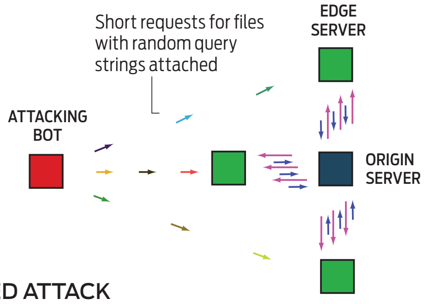
The basic problem, Rabinovich's team found, is that a bad guy can add what's known as a query string to the URL he is targeting. Query strings are common enough—you often see them at the top of your browser introduced by a question mark. They are used to communicate parameters to the server, such as the particular keywords you are Googling.

The conundrum here is that if a random query string is added to a URL, the content-delivery network's server will typically treat the request as new and pass it on to the origin server. If the origin server is not expecting a query string, it will most likely disregard it and just supply the file normally. That is to say, an attacker can force an edge server to consult the origin server—perhaps to ask for a copy of a large file.



NORMAL OPERATIONS

In normal operations, when one of the network's edge servers receives a request for a file, it fetches a copy from the origin server and then passes it on to the requester. But it also keeps a copy, so subsequent requests can be accommodated without consulting the origin server. In this way, the edge servers of a content-delivery network can shield a company's origin server from distributed denial-of-service attacks.



AMPLIFIED ATTACK

A clever attacker could append random query strings to his requests for a file. He could also terminate the connection after making the request to one edge server and then issue more requests to other edge servers. Unless they are configured properly, those edge servers will see each of these requests as being for novel information and so will consult the origin server, which will most likely just ignore the query string and serve a file. In this way the attacker can enlist the edge servers to amplify his attack.

Actually, it's worse than that. The attacker's computer can make such a request and then swiftly terminate the connection. The edge server, however, still contacts the origin server to obtain the requested file, which consumes the origin server's computing resources. Meanwhile, the attacker moves on to make more such requests through the content-delivery network's other edge servers, which, Rabinovich's group also showed, the attacker can reach at will.

Because the attacker can issue these requests with relatively short messages and doesn't have to wait around for files to be returned, little computing power is needed. Meanwhile, the origin server could be inundated with requests from hundreds or even thousands of edge servers asking it to provide large files. In this way, an attacker could effectively enlist the content-delivery network in his assault.

"Before I submitted the paper, I contacted Akamai," says Rabinovich. "As a good Internet citizen, I thought I should let them know before letting the cat out of the bag." Akamai's response, according to Rabinovich, was that it already provides its customers with all they need to guard against such attacks. "Akamai was putting the problem on the content provider," says Rabinovich. "That's sort of like talking the problem away."

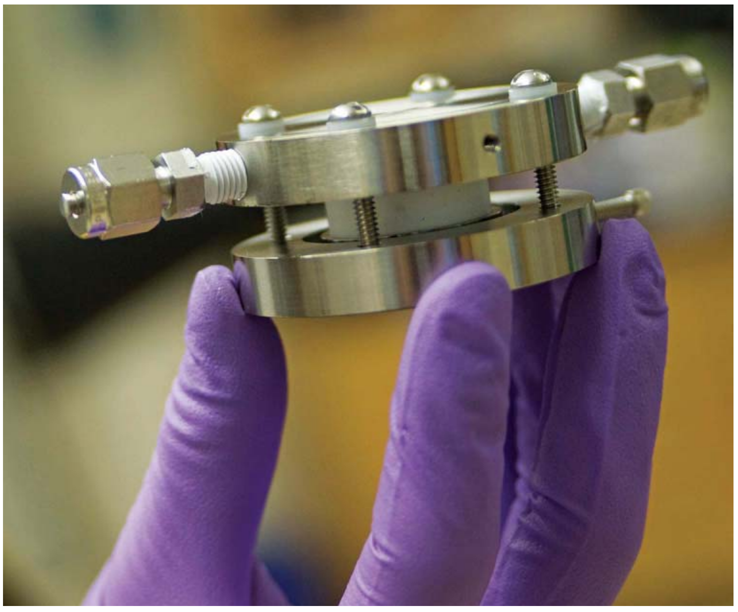
Bruce Maggs, vice president for research at Akamai and a professor of computer science at Duke University, in Durham, N.C., sees things differently. He views the vulnerability that Rabinovich pointed out as only a minor worry. Because Akamai offers its customers ways to have the edge servers ignore query strings, or even process many valid ones, these companies, according to Maggs, can easily forestall such an assault by using the right configuration when they hook into the network. But they just don't do that. "This attack doesn't happen in practice, so customers don't bother," he says.

Of course, if a miscreant were ever to take advantage of this weakness to paralyze a high-profile Web site, the companies using content-delivery networks to defend against denial-of-service attacks would probably pay more attention to all those pesky settings.

—David Schneider

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

2000 hertz The resonance frequency of buried human bones, according to researchers at Oak Ridge National Laboratory. They've developed an electromagnetic transceiver to locate clandestine graves.



DAVID FEINBERG/UNIVERSITY OF CALIFORNIA, BERKELEY

Batteries That Breathe

Using oxygen as a cathode could give lithium batteries 10 times the energy

With the launch of the Nissan Leaf and Chevy Volt, it's been a big year for electric vehicles, but their batteries still have a fairly limited range without a recharge. For a car running on today's lithium-ion batteries to match the range provided by a tank of gasoline, you'd need a lot more batteries, which would weigh down the car and take up too much space.

But what if you could take away one of the electrodes in a battery and replace it with air? Researchers estimate that a lithium-air battery could hold 5 to 10 times as much energy as a lithium-ion battery of the same weight and double the amount for the same volume. In theory, the energy density could be comparable to that of gasoline.

"No other battery has that kind of energy density, so far as we know," says Ming Au, principal scientist at Savannah River National Laboratory (SRNL), in Aiken, S.C. Au was one of several scientists who reported new research into rechargeable lithium-air batteries during the fall meeting of the Materials Research Society, in Boston.

In such a battery, the anode is made of lithium. The cathode is oxygen, drawn from the surrounding air. As the lithium oxidizes, it releases energy. Pumping electricity into the device reverses the process, expelling the oxygen and leaving pure lithium.

"You can certainly make a lithium-air battery for one-time usage," says Au. In fact, such lightweight batteries are commonly sold to power hearing aids. "But to make this battery rechargeable is difficult," he says.

Rechargeable lithium-air batteries face several challenges. For one, lithium reacts violently with water, so the battery's electrolyte cannot contain any, and water

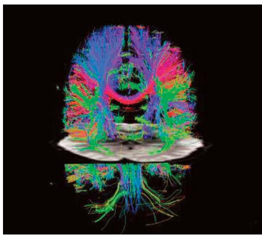
AIR SUPPLY: An oxygen cathode increases energy density but makes it hard to recharge.
PHOTO: PATRICK GILLOOLY/MIT

vapor must be separated from incoming air. Turning the lithium oxide—the product of discharging the battery—back to lithium is difficult and only partially possible even when assisted by special catalysts: The oxide builds up and retards the process, limiting the number of charge-discharge cycles to a mere handful. Before lithium-air batteries can find use in hybrid and electric cars, they must be able to handle thousands of such cycles.

As for the time it takes to discharge and recharge the battery, "that process is very sluggish," says Yang Shao-Horn, associate professor in the Electrochemical Energy Lab at MIT. But she recently reported that she could increase that round-trip efficiency to 77 percent by incorporating nanoparticles of gold and platinum into the cathode end. Gold speeds the combination of oxygen with lithium, and platinum catalyzes their separation.

The SRNL group, meanwhile, is in the midst of a two-year, US $1 million project on lithium-air batteries. So far, they've demonstrated a coin-size battery with a current density of 600 milliampere-hours per gram of material. That's a leap from traditional lithium-ion batteries, with current densities of 100 to 150 mAh/g. But lithium-ion batteries have upward of 100 000 charge/discharge cycles, and Au's device tops out at about 50.

It could be many years until a rechargeable lithium-air battery reaches the market. Au points out that lithium-ion batteries were first described in 1976 but weren't for sale until 1997. "You have to have some big investment from the government or some corporation," he says. And that hasn't arrived yet. —Neil Savage



news briefs

Superscanner
Physicists and neuroscientists in the United States and the United Kingdom say they've found a way to combine two techniques to reduce the time needed to produce an MRI brain scan from 2 to 3 seconds to 400 milliseconds. The technique works on ordinary scanners, so researchers expect its use to spread quickly. It was developed as part of the Human Connectome Project, an effort to map the connections in the brains of 1200 people.

IEEE spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

update

Edison Vindicated

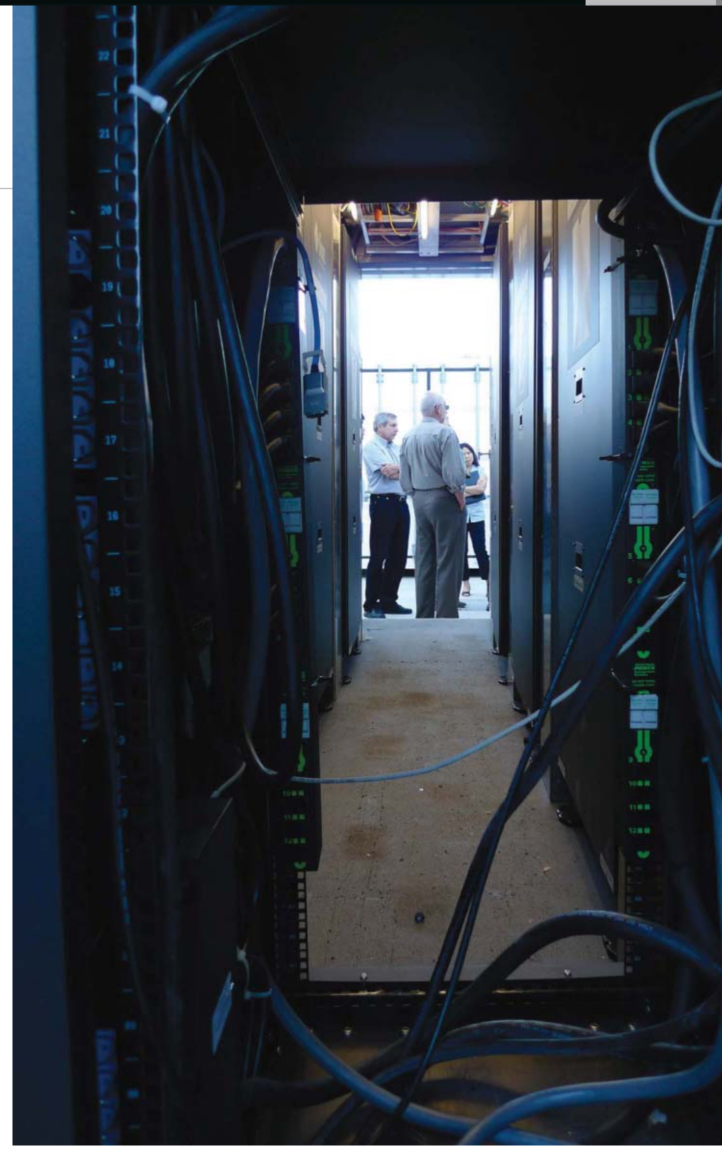
Efficiency tempts computer centers to go DC

Manufacturers and energy efficiency gurus are joining forces to battle the black bricks multiplying in offices and homes, each one providing a dribble of direct current for a distinct electronic or battery-driven device. Their chosen remedy, DC power distribution, promises simpler equipment and significant energy savings. After more than a dozen beta installations worldwide, DC wiring is going commercial as manufacturers start selling the first products challenging AC power's 120-year dominance of electrical distribution.

Standards efforts are coalescing to accelerate DC's commercial adoption, notes Bill Tschudi, an energy efficiency expert at Lawrence Berkeley National Laboratory, in Berkeley, Calif. In November the EMerge Alliance, in San Ramon, Calif., representing more than 70 manufacturers of power equipment, electronics, and building components, certified the first commercial products meeting its standard for 24-volt DC circuits—aimed initially at overhead lighting systems.

And by this month EMerge and the European Telecommunications Standards Institute (ETSI) both expect to issue draft standards for 380-V DC wiring for building-wide power distribution. DC supporters hope to merge the standards in the months ahead. "Our goal is to develop a worldwide standard," says Tschudi.

DC distribution's primary attraction—the promise of simpler equipment and significant energy savings—stems from the increasing proportion of electrical loads with DC-based electronic components or batteries. Distributing DC enables replacement of AC-DC converters within individual devices with a smaller number of larger, more efficient converters. LED-lighting installations that run on 24-V DC lines, for example, will require up to 15 percent less energy than the same lights running on fixture-level rectifiers, according to the EMerge Alliance.



DC DATA: A test of DC distribution at a data center at the University of California, San Diego, could show big energy savings.
PHOTO: TOM DEFANTI/PROJECT GREENLIGHT

Losses in the lines limit 24-V DC distribution to 10 meters, so manufacturers are developing 380-V DC wiring to extend similar benefits to entire buildings. Telecommunications firms and data centers are the likely early adopters of 380-V DC.

Today's data centers generally take 480-V AC power from the grid and convert that to DC to charge up a battery-based uninterruptible power supply, or UPS. The secure DC stream is then converted back to AC and transformed to 208-V AC for distribution, only to be rectified back to 380-V DC by the first stage of each server's power supply to charge up power-smoothing capacitors.

DC distribution offers a comparatively simple scheme, whereby a single rectifier turns 480-V AC into 380-V DC that can both charge the UPS and supply the servers. The University of California, San Diego, began testing a 380-V DC data center last year, and in

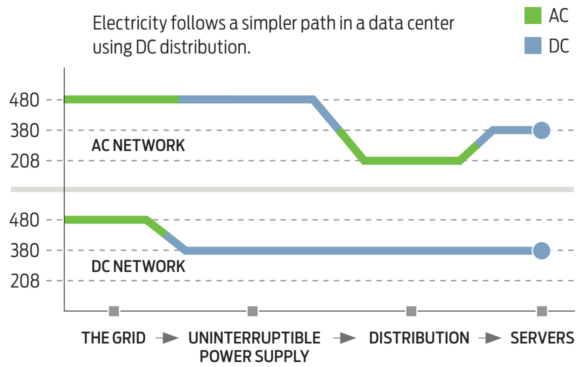
DELTA PRODUCTS CORP.

SPARKLESS PLUGS Nobody thinks twice about unplugging an AC device, but with DC there's a danger. With 60-Hz AC, the voltage zeros out 120 times per second, nipping potential arcs in the bud. But DC's continuous current doesn't have that inherent safety. So manufacturers are building it into the plug itself. Taiwan's Rong Feng Industrial Co., which expects safety certification early this year, adds a short data pin whose early disconnection signals the attached device to shut off. "By the time you unplug the actual power wires, there's no current going through them," says Dennis Symanski, a senior project manager at the Electric Power Research Institute.

update

DATA CENTER DANCE

Electricity follows a simpler path in a data center using DC distribution.



November, the Electric Power Research Institute (EPRI) and Duke Energy Corp. measured a 15 percent reduction in power consumption in a test of 380-V DC distribution at the utility's Charlotte, N.C., data center. Net energy savings could be twice that, they claim, once the cooler-running equipment's reduced air-conditioning burden is factored in.

The U.S. Environmental Protection Agency's Energy Star program and similar initiatives to drive up the efficiency of AC power supplies should narrow DC's advantage. However, a 2008 analysis by Intel predicts that, even compared with premium high-efficiency AC systems, DC distribution will use 7 percent less power.

Though right now up-front costs are about equal, DC systems' simpler components should also provide a cheaper, more reliable power supply. "The price isn't lower right now, simply because of volume," says Dennis Symanski, EPRI's senior project manager and chairman of EMerge's 380-V DC standards committee.

That volume might come from a combination of solar panel installations and battery-powered vehicles. DC distribution is an efficient means of combining these inherently DC devices, according to Dragan Maksimovic, a power electronics expert at the University of Colorado at Boulder. "PV/DC chargers have a target efficiency of 98 percent. Compared to 90 percent for the round-trip efficiency of inverters, that's a 5-to-1 difference in losses," says Maksimovic. Intel Labs is incorporating a 10-kilowatt solar array and electric vehicle charging stations into a microgrid at its New Mexico Energy Systems Research Center, in Rio Rancho, and the enterprise software firm SAP is doing much the same in Palo Alto, Calif.

Symanski predicts that EMerge and ETSI could harmonize their respective drafts to forge a worldwide 380-V DC standard before the end of the year. If that happens, equipment for 380-V DC power could be available within months.

—Peter Fairley

Chevy Volt Sparks a Series of Plug-in Hybrids

Expect many new plug-in cars to use the gasoline engine only as an extra battery

ICONIC U.S. car company General Motors turned a page in its history on a cold day this winter in suburban New Jersey. It sold the first production version of its Chevrolet Volt to a retail buyer—a retired pilot named Jeffrey Kaffee. With that sale comes the start of the first real test of consumer appetites for two concepts long in the making: hybrid cars whose battery you can recharge by plugging them in at home, and so-called series hybrid technology.

The Volt is the world's first production series hybrid-electric vehicle. Like a conventional hybrid, it has both an electric traction motor and a gasoline engine. Once its 16-kilowatt-hour battery pack is depleted, the 1.4-liter 4-cylinder engine switches on but does not drive the wheels mechanically. Instead, it turns a 55-kW generator that provides current to the 111-kW electric motor that powers the front wheels. It's not a new concept—minus the battery pack, that's the same way diesel locomotives work. But until now, all hybrid cars have used their gasoline engines in parallel with their electric motors, combining their torque to turn the wheels.

The Volt's series-hybrid credentials came into question briefly last fall when GM power-train engineers revealed that in

PLUGGED IN: A mechanic preps the first Chevrolet Volt for sale.

PHOTO: EMILE WAMSTEKER/CHEVROLET


Tanabata Festival

ADVERTORIAL

IGARSS2011—a Conference Which Will Expand Frontiers

Jane Ambrose looks at just what this conference will do for its delegates.

IGARSS1993 was held in Japanese capital city Tokyo and, during the last two decades, Japan has launched many earth observing satellites. In fact the technical contribution of Japan to remote sensing technology has been quite significant. IEEE GARSS Japan Chapter has invited IGARSS to hold its conference again in August 2011 and has chosen Sendai as one of the centers of remote sensing research in Japan.


Matsushima

What can delegates expect from the area? Sendai, the largest city in Tohoku region, is located about 180 miles from Tokyo on the Pacific coast of the main island of Honshu. It is also one of the country's most environmentally conscious cities and has enjoyed the alternative name 'City of Trees'. Its proximity to both mountains and sea means that its summer climate is very pleasant. There are more than 10 universities here with many research institutes working with university researchers and one of the IEEE milestones, 'Directive Short Wave Antenna 1924' is located at Tohoku University to commemorate the invention of Yagi-Uda array and is one of the key technologies used for radar remote sensing.

General Chair of the conference, Motoyuki Sato says that the IEEE Geoscience and Remote Sensing Society and, in particular, the IGARSS2011 Organizing Committee are very pleased to be hosting the conference in Sendai which also hosts a famous 'Tanabata' or 'star festival' each August. He continues: "On the last day of IGARSS2011 we shall enjoy a fireworks display near to the conference venue which will celebrate the start of 'Tanabata' when it is hoped that the stars Vega and Altair will be clearly visible."

One of Sendai's major advantages is its accessibility. It takes only an hour and a half from Tokyo by 'bullet train' or "Shinkan-sen" and it serves as a gateway to the whole of


Jozenji Dori Avenue

Japan by air, sea, road and rail. Offering easy international access it takes only one hour by air from Tokyo International Airport (Narita). Accommodation is also excellent with a wide choice of hotels and restaurants.

The conference itself will have a wide and varied program with more than 2000 papers being selected for symposium presentation alone. To this end the Technical Program Committee meets in San Francisco in March 2011 to finalize the papers to be selected. Motoyuki Sato's message is 'Beyond the Frontiers: Expanding our Knowledge of the World' how does he see the conference contributing to today's environmental needs?

"To enjoy glittering stars in the sky," he says, "we must keep the atmosphere and the earth clean." He continues: "It is our task to observe the earth's environment and it is the work of geoscience and remote sensing technology to aid us in this task. We are surrounded by many different types of frontier and remote sensing is definitely a technology which will expand our knowledge of these frontiers."


Sendai International Center

He comments too that boundaries between countries have no meaning when the earth's environment is observed by remote sensing technology and comments: "In addition to this observation, technologies to store and utilize the information are also quite important for earth's environment. We hope that IGARSS2011 will provide our delegates with the opportunity to think about how we too can expand our frontiers."

IGARSS2011 will take place at the Sendai International Center and Tohoku University from the 1-5 August 2011.

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Japan Tourism Agency

45 billion Projected growth in the number of international Skype-to-Skype call minutes in 2010, according to the telecom analysis firm TeleGeography. It's more than twice the volume of the growth in ordinary international calling.

update

DELIVERED: The first Chevrolet Volt arrived at a dealership in New Jersey on 15 December 2010.
PHOTO: EMILE WAMSTEKER/CHEVROLET

one mode, its engine directly contributes torque to the final drive. In other words, a Volt is sometimes a parallel hybrid, too. Crucially, in GM's view, it does not offer direct mechanical drive to the wheels. Instead, engine torque is transmitted through the generator—locked by clutches on both ends—into a set of gears that work only if they simultaneously receive torque from the electric motor.

For North America, where daily commuting distances are higher than in Europe or Asia, GM chose a series hybrid because it felt the design offered the best combination of electric use and limitless range. As the company points out, 78 percent of U.S. vehicles travel less than 64 kilometers (about 40 miles) per day—the pure electric range that it attributes to the Volt. Beyond that, the gasoline tank and combustion engine act as a backup battery.

While the Volt may be the first series hybrid, more are coming. The next one will be the 2011 Fisker Karma, a luxury sports sedan from the venture-funded car company started by former BMW designer Henrik Fisker. The Karma uses a 2.0-L 4-cylinder engine to generate current that drives a pair of 150-kW motors to power the rear wheels. Other makers plan even more complex hybrid systems that can operate in series-hybrid mode at certain times, parallel at others. Most notable of these may be Audi's planned A1 e-Tron, a subcompact hatchback that uses a tiny Wankel engine as its range extender. Even more esoteric, Jaguar's C-X75 concept car uses a pair of microturbines as its range extender.

The fossil-fueled engines alleviate the "range anxiety" that may come with such battery-powered EVs as the 2011 Nissan Leaf, which has a stated 160-km range. (Four days after that first Volt delivery, Nissan delivered a 2011 Leaf to its first paying customer.) The phenomenon refers to a driver's fear of being stranded with a dead battery pack. As the saying goes, you can't pour a gallon of electrons into the tank.

But you *can* dribble electrons in. Early Leaf buyers will recharge their plug-ins largely via 240-volt home recharging stations, the installation of which their Nissan dealers must coordinate. Volt buyers, on the other hand, can recharge the smaller battery overnight using 110-V power, though Chevrolet also offers a home charging station. Toyota will launch a new Prius plug-in hybrid model during 2012, and Ford will offer an as yet unidentified model with a plug-in hybrid option. By the end of 2012, major carmakers plan to offer roughly a dozen plug-in models for sale or lease.

All three forms of plug-in vehicles—battery electrics, series hybrids, and parallel hybrids—will be offered over the next three years and marketed as meeting the varying needs of different consumers. While that happens, car dealers and electric utilities will gain more experience with the installation of home charging stations. And a network of public charging stations, many of them offered by retailers as incentives to lure customers for some shopping during a recharge, is expected to spread.

Initially, availability for the Volt will be low, so their impact on the spread of charging stations will probably be minimal. According to Volt marketing director Tony DiSalle, Chevrolet plans to build 10 000 by the end of 2011 and 45 000 the following year. But the big test for plug-ins comes in 2013, when Nissan will have the capacity to build 250 000 Leafs a year. Whether the global market is ready to buy hundreds of thousands of plug-ins remains to be seen.

—John Voelcker

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

technically speaking

BY PAUL McFEDRIES

GLUEKIT

The Coming Data Deluge

The new model is for the data to be captured by instruments or generated by simulations before being processed by software and for the resulting information or knowledge to be stored in computers. Scientists only get to look at their data fairly late in this pipeline. The techniques and technologies for such data-intensive science are so different that it is worth distinguishing data-intensive science from computational science as a new, fourth paradigm for scientific exploration. —Jim Gray, computer scientist

According to the late Jim Gray (he was lost at sea in 2007), until recently science was largely the product of three interrelated paradigms: experimental, theoretical, and computational. However, the computational paradigm is now generating so much data that a fourth is emerging, one that requires new tools and techniques to store, organize, filter, share, and analyze these massive amounts of data. Gray called this new paradigm **eScience** and characterized it as "IT meets scientists." Whether you're a scientist or a technologist, this new **data-intensive science** is fascinating stuff, and for the neologist, this new field is generating a flood of new words.

In the past, most scientific disciplines could be described as **small data**, or even **data poor**. Most experiments or studies had to contend with just a few hundred or a few thousand data points. Now, thanks to massively complex new instruments and simulators, many disciplines are generating correspondingly massive data sets that are described as **big data**, or **data rich**. Consider the Large Hadron Collider, which will eventually generate about 15 *petabytes* of data per year. A petabyte is about a million gigabytes, so that qualifies as a full-fledged **data deluge**.

And if you thought the complete human genome involved a lot of data, neuroscientists have set themselves the goal of creating a **connectome**, a complete map of the brain's neural circuitry. The problem? According to researchers Michael F. Cohen and Jeff W. Lichtman, an image of a cubic millimeter chunk of the brain would comprise about 1 petabyte of data (at a 5-nanometer resolution). There are about a *million* cubic millimeters of neural matter to map, making a total of about a thousand *exabytes* (an exabyte is about a thousand petabytes), so it qualifies as what Jim Gray once called an **exaflood** of data.

These massive data sets require **massive computation**, and so workaday scientists will have to become **data scientists** who use the latest software and database tools for *data mining*, which is the extraction of patterns and knowledge from large and complex data sets.

Perhaps the biggest data set of all is the collection of actions, choices, and preferences that each person performs throughout the day, which is called his or her **data exhaust**. Using such data for scientific purposes is called **citizen science**. This is **noisy data** in that most of it is irrelevant or even misleading, but there are ways to cull signal.

A good example is Google Flu Trends. In the past, epidemiologists would look for emerging flu outbreaks by laboriously examining physician logs, flu and cold medicine purchases, and other real-world sources. This **syndromic surveillance** has traditionally been too time consuming to be of much use. By contrast, Google Flu Trends examines search queries for flu-related terms, which enables researchers to tease out flu patterns in real time.

With Earth increasingly blanketed by sensors and other devices that provide raw data on the state of the planet, many scientists now envision combining these devices into a distributed, Earth-scale **macroscope** that they can use to "zoom in" on any one of myriad global states.

As all this **eResearch** becomes more sophisticated and more valuable, data scientists are realizing that these humongous data sets need to be shared among multiple scientists, labs, and institutions. We're starting to do a good job of making papers and other research end products more widely available, but what's needed are more **digital data libraries** that store not only documents such as research papers but also the data on which those papers were based. Now all we need is for someone to come up with a Digital Dewey Decimal System to catalog all this data. A Dewey Binary System, perhaps? ❑

hands on

BALLOON-BORNE PHOTOGRAPHY

Get a bird's-eye view on a budget

Although there's a certain awe-inspiring beauty to the images that hobbyists' weather balloons can capture from the edge of space, in fact most of the good stuff happens much nearer the ground.

These flights can be broken into three phases. The first, with cool imagery of the ground below, lasts about 10 seconds. In the second, the balloon starts to swing around wildly in the wind, and you get a long period of nausea-inducing footage. Finally, the balloon ruptures, transmitting a quicker but equally queasy view as it plummets earthward.

Since most of the interesting images come in the first 100 meters, why go higher? Besides, by keeping the balloon low, you can control the pan and zoom, rather than trusting to dumb luck.

Setting up a balloon for low-altitude observation involves some interesting logistical issues, but it isn't particularly difficult. To begin with, balloon flight is all about payload weight. The more you want to carry, the more lift you'll need, meaning a bigger balloon and more helium. In the United States, there's a practical limit to both: FAA Part 101 regulates what size and type of balloon can be operated without notifying the FAA prior to flight. Moored balloons can't have an inflated diameter of more than 6 feet (1.8 meters) or a capacity of more than 115 cubic feet (3256 liters). These requirements will pretty much drive all the other decisions you make.

The best source I've been able to find is Balloons Direct. It sells a US $35 chloroprene weather balloon with a 1.7-meter diameter and a total fill capacity of 2464 L—enough to lift 2.1 kilograms. I ordered two, just to be safe.

Next I needed a payload. There are lots of pan-zoom-tilt webcams around, but most require an Ethernet connection, which would leave little lift for the camera—an altitude of 30 meters would require an entire kilogram's worth of Cat 5 cable. I turned my attention to Wi-Fi–enabled webcams, settling on the Vivtek PZ7131. It features 640-by-480 resolution, a 2x optical zoom, and a wince-inspiring $340 price tag.

The camera required about 1.5 amperes at 12 volts. I could have used lithium-ion batteries, but because I had to tether it anyway, I decided to run 12 V up on a wire from the ground, using the power line as the mooring line as well. I spent an evening with my 15-year-old son braiding a 30-meter length of two-conductor wire out of some 22-gauge single-conductor wire and splicing it between a jack and a spare 12-V power cube. The lift penalty was well under half a kilo. A test confirmed that the camera received enough power to operate, so I was set.

I pulled a spare IEEE 802.11g wireless access point out of my closet and attached it to my MacBook via Ethernet. The camera found the access point, and the MacBook found the camera's Web browser interface, so now I had a balloon, camera, power, and networking. All that was left was the helium and the weather.

Helium isn't cheap these days. The only place it's being made locally is the interior of the sun, so we have what we have, and it's running out fast. Some analysts estimate that the cost of helium is about one-tenth of what it really should be, given the increasing scarcity.

In any event, your best bet is a welding supply house or industrial gas supplier. You'll want a 125-cubic-foot (3540 L) tank, which is about 1.2 meters tall and is definitely awkward for one person to move around. You'll probably need to put down a deposit on the tank, and be sure to ask for a balloon inflator. That's one of those things you see at party stores, but it works for weather balloons, too. My tank, courtesy of Granite Industrial Gases, in Derry, N.H., set me back $60, and the company lent me the inflator for free.

BALLOON BALLAST: Putting a webcam on a balloon is easy. Powering it without weighing it down takes a bit more doing. *PHOTO: BONNIE BARLOW TURNER*

EYE TIE: Without a tether, you'll get great photos—once. A long power cord makes your balloon and webcam retrievable and still allows a bird's-eye view. *PHOTOS: JAMES TURNER*

The last hitch was the weather. As a bunch of NASA scientists learned in the spring of 2010, a good wind can turn a small static load (the Nuclear Compton Telescope) into a large dynamic load that might bounce off a fence and a car. (In that case, the balloon detached from the crane holding it and went for a ride across 45 meters of Australian terrain.) I had no desire to see a $340 camera go sailing away because the mooring line broke. And even a modest wind would send the balloon spinning, ruining any good images.

It took several weeks for work and weather to align, but I finally woke up to a sunny November morning with only light winds. I hooked the inflator up to the helium tank, fitted the neck of the balloon over the inflator, and created a good seal around the neck with zip ties. The inflation took a good 10 minutes, in part because I kept stopping to estimate how full the balloon was by pushing on it.

With the balloon inflated, I used more zip ties to close off the neck, removed the first ties, and carefully started moving it to the open area I had planned for launch. I got as far as the porch. The balloon brushed a plant hook and burst spectacularly. Good thing I had another!

I moved the tank out into the driveway and repeated the process, this time without a hitch, although I was pretty conservative with the amount of helium. I had the MacBook, the access point, and the power for the camera all hooked up and ready on a worktable, so all that remained for my trusty crew (my wife) and me was attaching the camera. I wove a web of zip ties across its mounting plate, and after attaching the mooring/power line to the balloon itself, used more ties to attach the camera [see "Eye Tie," inset photo]. Finally, I hooked up the dangling power line. At the last minute, I added a line of light twine as an emergency backup.

As it turned out, I had been too conservative with my fill. The balloon rose barely 10 meters before the weight of the lines proved to be too much. Without a forceful lift, the wind also played havoc, sending the mooring lines into the branches of nearby trees. We got some pictures but were unsatisfied.

We returned to the tank and carefully remated the balloon to the inflator. After another influx of helium, the balloon easily carried the camera to the mooring lines' 30-meter limit. The Wi-Fi signal remained strong, and the camera operated perfectly, capturing some great stills and video of the neighborhood from above.

We returned later in the afternoon with our son and found that with the sun lower in the sky, the images were richer, with more vibrant colors. The winds had also died down. After another hour, we marked the day as a success and brought the balloon down to deflate it. Being a safe and mature person, I absolutely did not breathe in any of the gas, and rumors of a video of me singing Alvin and the Chipmunks songs are gross mistruths. In all seriousness, you can pass out or worse from too much helium, so be careful while deflating the balloon, and keep any fun and games to a minimum.

One final note about this project's legalities: Regardless of the size of the balloon or the weight of the payload, you should never fly a moored balloon within range of an airport (in the United States, the totally restricted airspace is in the shape of a cylinder with a radius of 8 kilometers, from the ground up). Other than that, wings up! —James Turner

careers

COLIN ANDERSON/GETTY IMAGES

books

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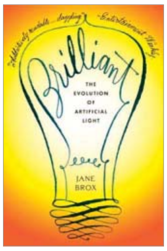
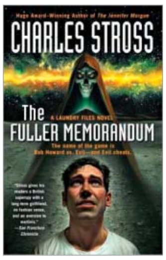


Brilliant: The Evolution of Artificial Light
By Jane Brox; Houghton Mifflin Harcourt, 2010; 320 pp.; US $25; ISBN: 978-0-547-05527-5
Reviewed by Kieron Murphy



The Fuller Memorandum
By Charles Stross; Ace Hardcover, 2010; 320 pp.; US $25; ISBN: 978-0-4410-1867-3
Reviewed by Sally Adee

PLAN B: B-SCHOOL

Whether to advance to management, work on Wall Street, or turn a ripe idea into a business venture, getting an MBA is a popular career move

QUICK, TAKE A GUESS: What fraction of MBA students are engineers? About a third, according to admissions officers at some of the top programs. It's not hard to imagine why masters programs in business administration want so many math-drenched applicants, but what's in it for the engineers?

"They may have a product idea and recognize they don't have the business skills to make it work," says Linda Abraham, who started the admissions consulting service Accepted.com, in Los Angeles, where 40 percent of MBA admission seekers are engineers.

Scott Shrum, vice president of marketing at admissions consulting firm Veritas Prep, outlines four traits that define successful applicants: leadership (initiative and impact), teamwork (working with and influencing others), creative intellect, and maturity (breadth of experience and how you face adversity). Engineers, he says, typically need help mastering the first two.

What you should look for in an MBA program really depends on what you want: to switch to finance, stay in high tech, move into product management, or do something else, Abraham says. "It's important for engineers to have an idea where they're going. Just hating your job is not a good reason to get an MBA."

IEEE Spectrum compiled a list of five key characteristics that might matter to an engineer, and a handful of MBA programs that stand out in those categories. This is by no means an exhaustive list. (The tuition charges and fees are for the length of time students normally take; median base salaries were provided by the programs themselves.)

JUMP-START A BUSINESS

Stanford Graduate School of Business, Stanford, Calif.

Tuition and fees: US $53 118
Graduates' median base salary: $120 000
Silicon Valley's proximity to Stanford and its close interaction with the engineering school through courses and research spell s-t-a-r-t-u-p. The school focuses on leadership and entrepreneurship, and top industry names visit the campus regularly and even teach jointly with professors. *Special mention:* University of California, Berkeley (Haas

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

School of Business), Yale School of Management, Columbia Business School

STRONG REP

Carnegie Mellon University (Tepper School of Business), Pittsburgh

Tuition and fees: $52 500
Graduates' median base salary: $100 000
CMU's business program and engineering school are both world renowned, and CMU consistently comes up in lists of engineers' top MBA picks. So it isn't surprising that Tepper is, as *The Economist* recently noted, "probably best known for...a quantitative approach and cutting-edge use of information technology."
Special mention: Northwestern (Kellogg School of Management), MIT Sloan School of Management, Harvard Business School, University of Pennsylvania (The Wharton School)

INNOVATIVE

MIT Sloan School of Management, Cambridge, Mass.

Tuition and fees: $50 625
Graduates' median base salary: $110 000
Sloan drinks its own Kool-Aid with the Dean's Innovative Leader Series, in which students have in-depth discussions with industry leaders, and the Sloan Innovation Period, one week of intensive leadership seminars and exposure to faculty research. Innovation "is in their DNA," MBA counselor Abraham says of MIT-Sloan.
Special mention: UC Berkeley (Haas), Stanford, University of Toronto (Rotman School of Management)

ENGINEERS—AND CAREERS—APLENTY

University of Michigan (Ross School of Business), Ann Arbor, Mich.

Tuition and fees: $45 189
Graduates' median base salary: $100 000
Forty-two percent of Ross's 500-strong MBA class of 2011 come from an engineering, math, or science background. Good news for them: Recruiters and employers rave about Michigan's MBA students, and students rave about Ross's career services.
Special mention: MIT (Sloan), Yale, Georgia Tech College of Management

CAREER SWITCH TO FINANCE

University of Chicago (Booth School of Business)

Tuition and fees: $53 225
Graduates' median base salary: $100 000
Finance is Booth's top subject, and about half the graduating class of 2009 went to work in the finance sector. Other pluses: The school has generated more Nobel laureates (six) than any other business school and has garnered the top spot in *Bloomberg BusinessWeek*'s past two rankings for U.S. MBA programs.
Special mention: Harvard, Penn (Wharton), Columbia

—Prachi Patel

WANT TO START A BUSINESS? FORGET THE MBA. JUST DO IT.

Q&A with Strategy Consultant Sramana Mitra

SRAMANA MITRA

STRATEGY CONSULTANT **Sramana Mitra** has founded three companies and consulted for 80 others. She writes a weekly column for *Forbes* and runs free online roundtables to help entrepreneurs develop their business ideas. Her four-book series, *Entrepreneur Journeys*, gives budding tech entrepreneurs an in-depth look at how to build a flourishing business. *IEEE Spectrum* contributing editor **Prachi Patel** asked her advice for entrepreneurial engineers.

***IEEE Spectrum:* Many engineers might not have business acumen. Should they get a business degree first?**

Sramana Mitra: I don't recommend going to business school. Let's say search-engine marketing may be part of your strategy to acquire customers. Take a class or read a book on search-engine marketing for dummies. Engineers are better off starting companies rather than spending two years in business school and accumulating debt.

What advice do you give to engineers who are toying with a business idea?

S.M.: There's this misconception that everybody needs to be able to raise venture capital to be a successful entrepreneur. That's fundamentally wrong. My message to engineers is, You can do a lot of things on your own. Try to validate an idea, get to some sort of proof of concept, and even potentially get some customers. And that's the time to raise money, if at all.

What does it take to bootstrap a business?

S.M.: Bootstrapping is getting a business off the ground without external financing and with as little money as possible. It does not entail hiring 15 people off the bat and raising a ton of venture capital. It involves identifying what problem you're trying to solve, identifying the customers that would help you solve that problem, and really focusing on a solution for what these customers need.

But doing all of that takes time and money.

S.M.: It will take time. But engineers could keep their day jobs and tinker on nights and weekends. When they have their first few customers, they could quit their jobs and do this full-time. Or if people have lost their jobs, I tell them, Why wait six or nine months sitting in the house waiting for something to happen? Figure out what problem you can solve and go solve it with a company.

It still takes money to get a business off the ground. How does an engineer do that without venture capital?

S.M.: I know one fellow who wanted to quit his job and start a business. He took US $400 000 dollars' worth of credit card debt and financed his business that way. He started two companies in a row that were sold for over $150 million. Another guy stayed with his future in-laws so he could put rent money into his business. There are incredible human stories of courage and creative resourcefulness.

careers

THE OTHER MEMS

Engineers who want something more tech-oriented than an MBA are rediscovering an old degree—the master's of engineering management

PRATEEK REDDY wanted to pursue an interest in economics without pulling up roots he'd put down in electrical engineering as an undergraduate. So he chose a master of engineering management degree at Dartmouth College, in Hanover, N.H., where he's now in his second year.

"The best part," he says, "is flexibility—the opportunity to pursue whatever you want, technical research, marketing, or management."

The MEM is becoming popular among engineers who want to integrate technical know-how with business and law smarts, especially those who want to manage cutting-edge technologies or steer start-ups. Robert Graves, codirector of Dartmouth's program, says the degree is ideal for the kind of person who would rather become a chief technology officer than a chief executive officer. "We want to prepare managers who are technically astute, aware of business issues, and able to exhibit leadership."

These programs have been around for years—decades, in a few cases—but their popularity has soared recently. Applications to Dartmouth's program, for example, have quadrupled in the past decade; Duke's program graduated 137 students in 2009, up from 13 in its first class of 1997. Many of the programs already boast of their steadily advancing alumni—Northwestern, for example, claims vice presidents and CIOs at such companies as Motorola, Telephone and Data Systems, and Shure.

The increased numbers reflect changes in industry, says Bradley Fox, executive director of the Duke University MEM program, in Durham, N.C. The sight of a lone engineer working in a laboratory is rare nowadays. Teamwork is the norm, and team leaders need to understand how their technical expertise fits into their company's business strategy. "Undergraduate education does a great job in preparing engineers, but when they get out in industry, they really need an understanding of business," Fox says.

The MEM curriculum falls somewhere between an MS in engineering and an MBA, but starting salaries are closer to those of engineers with an MS. A Dartmouth MEM grad made US $64 375 on average in 2010, while the average engineer-MBA made over $100 000, a difference that might have more to do with work experience than with the degrees themselves. An engineer generally works for a few years before going for an MBA, but most MEM students are fresh out of engineering school.

Northwestern—which joined with Dartmouth, Duke, Cornell, and Stanford to form the Master of Engineering Management Programs Consortium—is unique in requiring that incoming MEM students have two years of work experience. Ninety percent of Northwestern's MEM students work full-time. Most of the other programs in the consortium have summer internships for students to gather real-world experience.

MEM students take a mix of advanced engineering classes along with core business courses in marketing, finance, management, and accounting. Courses are team based, and many are taught through case studies. "We tend to skew the content towards examples of organizations that are technology based," says Bruce Ankenman, director of Northwestern's program. Some programs offer workshops to build writing, presentation, and leadership skills. It's exactly what you need to tackle a technology company's real-world problems.

Robert Hauck, a manager at GE Healthcare, recently faced one such problem. Upcoming Food and Drug Administration regulations require companies to track the location and contents of medical devices, he explains. "We work with a lot of different medical devices, so there's lots of IT and bar codes." He went looking for a program manager with the right blend of technical and management skills and interviewed an MEM grad. "This guy happens to be one of three people that established the GS1 standard for bar codes," Hauck says. "He's an operations engineer with a specialty in inventory management." Hauck quickly hired him.

—PRACHI PATEL

GETTY IMAGES

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

DREAM JOBS 2011

SPECIAL REPORT Engineers, are you ready to shake things up? We know that the economy lately has been, well, unforgiving. But we still believe that you can—and should—find jobs you adore. This year, we met 10 engineers whose abrupt turns and occasional missteps led them to question their deepest desires, right the course, and find the jobs that are best for them. We quizzed hiring managers at top companies to learn what they seek. We also caught up with engineers we've featured in the past to see how dreams may change. Aim high, dear readers, and above all, have fun.

IEEE spectrum Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®


esa
350

DREAM JOBS

Spelunking on Mars

LOREDANA BESSONE PREPARES EXPLORERS FOR THE RIGORS OF SPACE

IN SEPTEMBER 2008, Loredana Bessone spent six days in a pitch-black cave in Sardinia with half a dozen colleagues from the European Space Agency (ESA). No one ventured out of the 10-meter-wide base camp without a helmet, a harness, and two headlamps, one a spare. "You don't move without them," she says. "They become part of your body."

Unfortunately, your body is the problem in a cave. Hygiene is limited, and if you don't build the toilet right—far from the "kitchen" but close enough to reach without a buddy—the only smell that can begin to mask the odor is that of your companions' pungent sweat.

You'd be forgiven for wondering if this Italian excursion was the world's worst team-building exercise, but every bit of it was conceived by Bessone to teach astronauts how to survive in extreme environments. After prospective spacefarers master the draconian physical and mental tests to join ESA's astronaut corps, they show up at the European Astronaut Centre in Cologne, Germany. They're more fit than 98 percent of the human race, smarter than 99 percent of them, and 100 percent more likely to be shot to the edges of Earth's gravity well.

Newbie and veteran astronauts alike spend six weeks a year facing down Bessone, who oversees their robotics, engineering, software, and behavioral training—including the six-day cave stint, which isn't far from violating the Geneva Convention. Without it, Bessone wouldn't be sure they'd survive a six-month stay in the orbiting cigar box that is the International Space Station (ISS).

Bessone is a flinty northern Italian in teetering snakeskin slingbacks. Her sharply styled red hair frames huge, skeptical brown eyes. To serve her students, she has scoped out several stalactite-filled caves in search of the ones that will induce maximum psychological distress. She has endured several parabolic flights, ricocheting through Earth's stratosphere to briefly experience weightlessness. And she once dove to Aquarius, a laboratory 20 meters beneath the ocean's surface near Key Largo, Fla., in which trainees experience the cramped conditions of life in a metal pod surrounded by hostile territory.

There's only one goal: Give the astronauts survival skills. How to do so is entirely at her discretion.

BOBBING AROUND in a pool while wearing a 100-kilogram space suit is one component. Having practiced it herself, Bessone now teaches her trainees to float and maneuver without relying on their legs, by using the delicate bones of their wrists to grab a pole and generate torque. "It's a bit like ballet," she says. Gravity management, in a nutshell.

She's also schooled them in computer science and engineering, with tutorials on how to fix a solar array and how to manipulate the ISS's giant robotic arm. But what's most compelling to her is applying systems engineering principles to human behavior: what happens when highly competent, intelligent people fall apart. "These people are the most technically capable people you will find anywhere—they don't screw up because they didn't study," she says. Other stressors are what trip them up. And when people screw up in space, they perish.

So she designed a computer training simulation to temper overly confident astronauts and Eurocomms—the European equivalent of the guys on the receiving end of "Houston, we have a problem." In the scenario, four players embark on a routine mission to Venus. En route, the astronauts discover that the solar array charging the spaceship's batteries has broken, and the crew must charge them manually.

It sounds simple, but in the ensuing onslaught of tasks, they can't relay information to each other fast enough. By the 3-minute mark, a *Lord of the Flies* situation has taken hold. A husky Spaniard is barking orders, while a surly Canadian contradicts him. Petty gibes escalate to bad feelings as the clock ticks and the batteries drain.

LOREDANA BESSONE

IEEE MEMBER

AGE *46*

WHAT SHE DOES *Equips astronauts with engineering skills and survival strategies.*

FOR WHOM *European Space Agency*

WHERE SHE DOES IT *Cologne, Germany*

FUN FACTORS *Dives to underwater habitats; flies on ESA's "vomit comet"; hangs out in caves.*

PHOTO: ANDREAS TEICHMANN

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

DREAM JOBS

Communication soon breaks down entirely. The astronauts tell the Eurocomms to "send battery L1 down lift L1."

"What the hell is L1?!" explodes a Eurocomm. Grating Klaxons clang in the players' ears—system failure is imminent.

"We said lift one. Are you deaf?" snaps the Canadian.

The mission ends in disaster: The ship hurtles into Venus's gravity well. After the last alarm dies out, there's only defeated silence.

"So," Bessone says drily from the corner where she has been scribbling notes. "What could we have done better?"

"I DON'T HAVE a typical anything," Bessone remarks later. "My job always changes so dramatically: computer science, engineering, training, psychology, geology. There are so many things that I keep learning."

With all the caving and diving and bumbling around in space suits, fitness is key. Not one extra kilogram finds refuge on Bessone's wiry frame. Being multilingual is also essential. She was prepared for that by an accident of geography: Bessone grew up in the Piedmont region of Italy speaking the local dialect, which is closer to French than Italian. Now she's fluent in all three, plus German, English, and Spanish. Two beginner's Russian books on her shelf speak to her next conquest.

Her technical skills also came naturally. As a child, Bessone was in love with astrophysics, the stuff of star births and black holes. She couldn't afford to attend a school with a strong astrophysics program, so she studied informatics at the University of Turin, an hour's drive from her hometown. She completed a master's degree in informatics while working at CERN, the European nuclear research center in Geneva.

In 1990, ESA hired her for a student job in Cologne. A few months later, she got a real offer. She broke the news to her mother during a visit home. "I told her, 'Mom, I need to tell you something you won't like,'" Bessone says. "She looked at me, worried, and asked, 'Are you getting married?'" Bessone explained that she would be staying in Germany. Her mother breathed a sigh of relief. "Good," she said. "You can end that when you want without trouble."

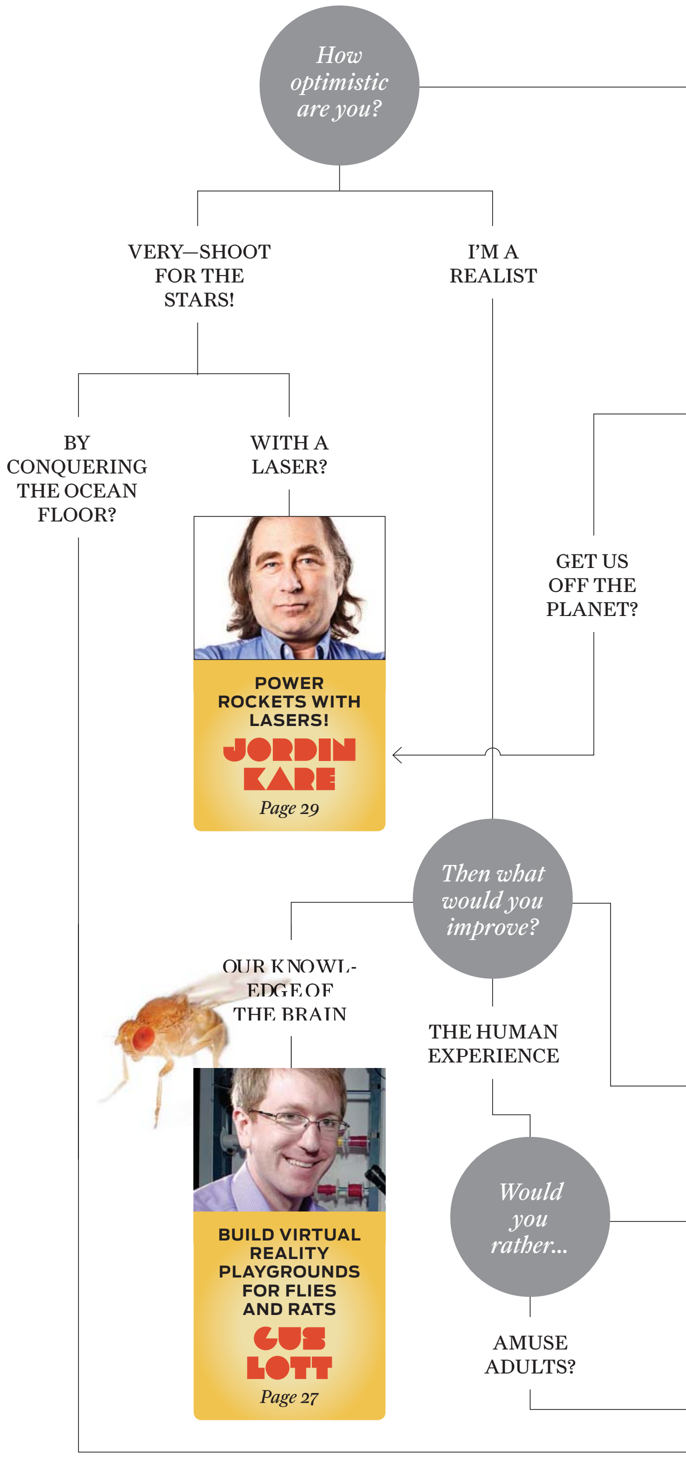
In 2001 ESA asked Bessone to research a human voyage to Mars, and her training work began. The dream of the Red Planet lingers in her work today.

Her caves lesson, for one, is about being isolated and confined in the dark. But there's more: If there's life on Mars, Bessone thinks it will be found in the relative warmth of caves, and astronauts may one day need those spelunking skills.

She realizes she may have retired to a town in the mountains by then. For now, though, like the tough little creatures she believes lurk on a distant planet, she thrives. —SALLY ADEE

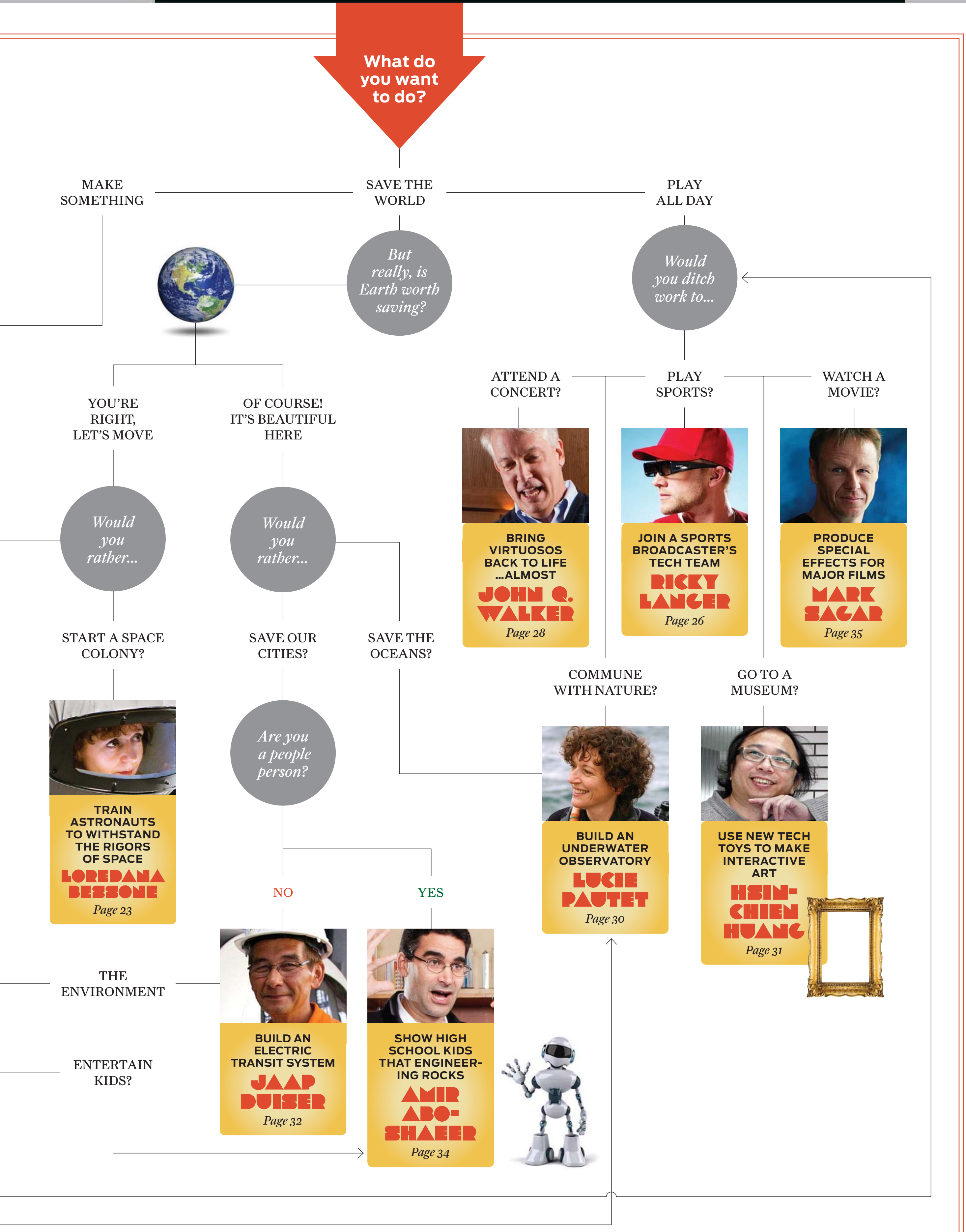
Engineer Your Destiny

GOOD CAREER ADVICE CAN BE TOUGH TO FIND. WE'VE REDUCED IT TO THE BARE ESSENTIALS



FLY, GLOBE, ROBOT, FRAME: ISTOCKPHOTO

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®


What do you want to do?
MAKE SOMETHING
SAVE THE WORLD
PLAY ALL DAY
But really, is Earth worth saving?
Would you ditch work to...
YOU'RE RIGHT, LET'S MOVE
OF COURSE! IT'S BEAUTIFUL HERE
Would you rather...
Would you rather...
START A SPACE COLONY?
SAVE OUR CITIES?
SAVE THE OCEANS?
TRAIN ASTRONAUTS TO WITHSTAND THE RIGORS OF SPACE
LOREDANA BESSONE
Page 23
Are you a people person?
NO
YES
BUILD AN ELECTRIC TRANSIT SYSTEM
JAAP DUISER
Page 32
SHOW HIGH SCHOOL KIDS THAT ENGINEERING ROCKS
AMIR ABO-SHAEER
Page 34
THE ENVIRONMENT
ENTERTAIN KIDS?
ATTEND A CONCERT?
PLAY SPORTS?
WATCH A MOVIE?
BRING VIRTUOSOS BACK TO LIFE ...ALMOST
JOHN Q. WALKER
Page 28
JOIN A SPORTS BROADCASTER'S TECH TEAM
RICKY LANGER
Page 26
PRODUCE SPECIAL EFFECTS FOR MAJOR FILMS
MARK SAGAR
Page 35
COMMUNE WITH NATURE?
GO TO A MUSEUM?
BUILD AN UNDERWATER OBSERVATORY
LUCIE PAUTET
Page 30
USE NEW TECH TOYS TO MAKE INTERACTIVE ART
HSIN-CHIEN HUANG
Page 31

Sports Knight

RICKY LANGER HAS LANDED IN THE ENVY-INDUCING VORTEX OF HIS PASSIONS: ESPN'S TECH TEAM

LET'S SAY you're an avid sports fan and a pretty fair athlete yourself. If you couldn't go pro, what would you do for a living? For a self-described tech geek, tinkering with new technologies at the world's largest man cave—a 40-hectare sports lover's paradise complete with a miniature American football field for pep rallies and concerts—is about as good as it gets. Sure, Ricky Langer, a senior systems engineer for ESPN, the sports programming giant, used to be awestruck when he saw famous athletes strolling

RICKY LANGER

IEEE MEMBER

AGE *29*

WHAT HE DOES *Designs and maintains technical systems for the world's leading sports network.*

FOR WHOM *ESPN*

WHERE HE DOES IT *Bristol, Conn.*

FUN FACTORS *Rubs elbows with pro athletes; gets discount tickets to sporting events; can watch game highlights anywhere, anytime, on ESPN headquarters' ubiquitous flat-screen TVs.*

PHOTO: DAVID YELLEN

through the halls, but he's more blasé about it now.

"Every time I walk in this place, sports is all around me," says Langer. At ESPN's headquarters in Bristol, Conn., the walls are covered floor to ceiling with commemorative jerseys, helmets, and hockey sticks. In nearly every room and corridor, large flat-panel TVs are tuned to games, highlights, and sports talk. Amid the bustle at this athletics playground, Langer is charged with finding new and better ways to broadcast sports programming across the globe.

Like so many engineers before him, Langer has a love for gadgets that emerged when his parents indulged his propensity for taking things apart and reassembling them. But as an energetic child growing up in northwest Connecticut, he says he can't remember a time when athletics wasn't a part of his life as well. "I was the youngest of six kids; I had to pick things up quickly and master a lot of skills to make up for the age difference," he recalls. He joined a traveling youth hockey team and played baseball, soccer, and basketball as a high school athlete. In college, he narrowed his focus, lettering in Division I baseball while earning an electrical and audio engineering technology degree at the University of Hartford. "Baseball is my life," the solidly built former college center fielder explains. "When I'm not working or hanging out with my fiancée, I'm playing baseball."

To Langer, who landed an entry-level technology job at the sports network before graduating in 2004, the work has been a perfect fit. On a typical day, he crosses paths with several recently retired pro ball players who serve as studio analysts, and he gets to keep an eye on the day's sports events—tuning in to games even as he completes his assignments. "I remember when I started six years ago, the Red Sox and the Yankees were playing a day game. So I pulled up the feed on the monitor I was at and kept on doing my work with the game in the background," he says. "That was a pretty cool feeling."

Chuck Pagano, ESPN's executive vice president of technology, explains that giving workers the liberty to be sports enthusiasts makes for more passionate employees. "Plus, there's no better way to serve sports fans than to understand what they're looking for. And Ricky's definitely a sports fan."

As an engineer, though, Langer finds the technology just as thrilling: "What makes this job cool is that every morning on my way to work, I'm thinking, 'What new piece of technology am I working with today?' " Langer, who says his group acquires a new project every few months, gets excited when he feels he's closing in on a design. "It propels you," he says. "You know there's an answer out there, and that's what makes you strive to get it done. That and the fact that I can actually sit in front of a TV anywhere in the world and see the result of my work."

Pagano, who has been at ESPN since its inception,

ONLINE EXCLUSIVE

Insect Imagineer

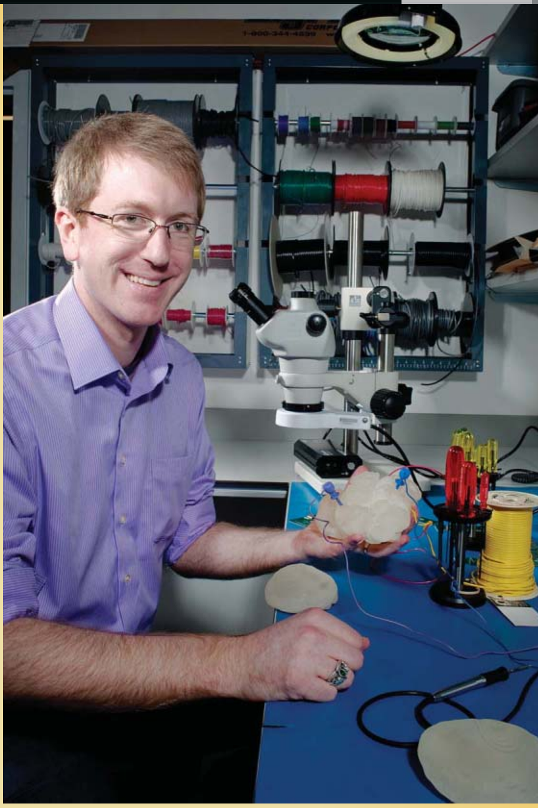
GUS LOTT'S VIRTUAL REALITY SYSTEMS FOR BUGS AND RATS LET US STUDY THEIR BRAINS—AND OUR OWN

A TREADMILL MADE out of a ping-pong ball and an optical mouse, surrounded by audio speakers. A tiny TV that produces a 200-hertz light show to send viewers running in response. A video system that translates the images of flapping wings into mating calls. A maze full of special effects that will essentially be a Disney attraction for rats. These and other strange electronic gizmos are the tools that biologists and neuroscientists use to reverse engineer the brains of fruit flies and other simple creatures, in hopes of someday understanding the circuitry of the human brain.

Gus Lott, an electrical engineer who is fascinated by biology, is the guy who designs and builds them. Lott spends his days deep in his basement lair at Janelia Farm, a research laboratory in Virginia that's part of the Howard Hughes Medical Institute.

"I feel like Q in the James Bond movies. He's down there in the basement of MI6, and all the agents come to him for crazy technology to carry out their missions," Lott says. His title, neurobiological instrumentation engineer, was created just for him. Read about how he found this perfect job, at the perfect time, almost by accident, at http://spectrum.ieee.org/lott0211.

—*Tekla S. Perry*



GUS LOTT

IEEE MEMBER

AGE *31*

WHAT HE DOES *Builds virtual reality systems for animal research.*

FOR WHOM *The Howard Hughes Medical Institute's Janelia Farm*

WHERE HE DOES IT *Ashburn, Va.*

FUN FACTORS *Creates novel tools that enable scientists to do groundbreaking research; works in a university-like environment that is free from worries about funding or making profits.*

PHOTO: SUSANA RAAB

Spectrum Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®

ONLINE EXCLUSIVE

JOHN Q. WALKER II

IEEE MEMBER

AGE *54*

WHAT HE DOES ***Develops technology to re-create musical performances.***

FOR WHOM ***Zenph Sound Innovations***

WHERE HE DOES IT ***Durham, N.C.***

FUN FACTORS ***Brings great musicians back to life—almost.***

PHOTO: D.L. ANDERSON

Play It Again, Sergei

JOHN Q. WALKER BRINGS BACK THE SOUNDS OF MUSICAL GREATS

WHEN JOHN Q. WALKER was a teenager, he took piano lessons from a middle-aged woman who lived down the street. Ruth Slenczynska was, however, no run-of-the-mill piano teacher. As a child prodigy, she had studied under Sergei Rachmaninoff, the famous Russian pianist, composer, and conductor, who died in 1943.

During his lessons, the young Walker often heard Slenczynska say, "Now, that's not how Mr. Rachmaninoff would have played it." That got him thinking: Could he figure out, in full quantitative detail, how Rachmaninoff would have played a piece? Walker is still on that quest. And he's having a blast.

Walker obtained advanced degrees in computer science and spent 17 years working at IBM before founding Ganymede Software with his colleague Peter Schwaller and two other engineers in 1995. They sold Ganymede on 10 March 2000—the very day NASDAQ hit its peak.

Flush with cash and optimism, Walker decided to pursue his teenage dream of reproducing the musical style of Rachmaninoff. Partnering with Schwaller again, he invested in a robotic concert grand piano. They then turned to the task of translating old musical recordings into digitized descriptions of exactly how each note was played. Read more about the stunning technical feats their new company, Zenph Sound Innovations, has pulled off, at http://spectrum.ieee.org/walker0211.

—David Schneider

notes that Langer "really hit a home run" with one recent project. He led a team that designed the master control system that allows ESPN to broadcast games in 3-D with graphics, commercials, and promos. Though Langer modestly describes the assignment as "simple from a design standpoint—a router with a bunch of converters wrapped around it, plus a 3-D switcher that handles the left eye and right eye," Pagano points out that merging separate images to create a single 3-D picture was really tough to do.

The initial plan for ESPN 3D, first announced a year ago, called for baby steps, says Pagano. Games would be presented in 3-D, but commercials and promotional elements would not. "But at the last minute, we were asked to pull a rabbit out of the hat," Pagano says. That rabbit was the master control system, which integrates the sports programming with commercial and promotional segments—all in 3-D. No such system existed, so it was up to Langer and another engineer on the project to figure out how to pull it off.

Unlike with audio-video synchronization, where a little lag in the audio is hardly noticeable, viewers can pick up on even a single frame's difference between the left and right eye in a 3-D signal. And even when the eyes are timed correctly, the signals can end up inverted, switching the foreground and the background. In that case, the viewer perceives what ought to be the foreground as appearing behind the intended background, which is out of focus.

As Langer and his team ran sample video feeds on the equipment in the 3-D master control room, they figured out an easy way to detect whether a weirdly displayed image was the result of inversion. "If we turned our 3-D glasses upside down so the lenses were switched and the images looked perfect, then that was the issue," he reports. In just 40 days, Langer and his colleagues readied the master control for the launch of ESPN's 3-D channel with a broadcast of the 2010 FIFA World Cup. Though Langer had hoped to get his own 3-D TV set to watch the results, "my fiancée wouldn't let me," he says.

With the high-profile 3-D project behind him, Langer is enjoying a break from the spotlight. He is currently designing an IP network that will allow anyone on the ESPN campus to easily access footage constantly being brought in from game sites. Currently, that footage is stored on tapes and other media and must be carried by hand from one part of the campus to another. When he's not working on that project, he's upgrading the older studios on campus for high definition broadcasting.

Langer's eyes light up when he describes his work. That's because for the most part, the former standout athlete sees his role as an engineer as akin to a referee's: He's at the top of his game when the audience doesn't notice his input.

—Willie D. Jones

DREAM JOBS

Laser Rocketeer

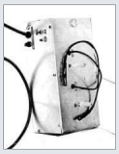
JORDIN KARE SHOOTS FOR LIFTOFF

TRIPPING THE LIGHT FANTASTIC at age 14 set Kare down a winding road to photon-powered flight. Read about it at http://spectrum.ieee.org/kare0211.

1956
Born, Ithaca, N.Y.

1968
Moves to Philadelphia, where his father, Morley, founds Monell Chemical Senses Center. Earlier, he had used young Jordin to show that toddlers have taste buds inside their cheeks.

1970
Builds helium-neon laser as high school freshman; goes on to win science-fair glory.



1978
Earns BS in electrical engineering and physics, MIT.

1980
As self-taught musician, he composes, arranges, sings, records, and sells CDs of folklike music on science-fiction and fantasy themes, a genre known as filk. He founds Off Centaur Publications, the first commercial label for such music.

1983
Kare's sister, Susan (b. 1954), joins Apple's Macintosh design team and designs fonts and icons of worldwide fame, including the cloverleaf image on the command key.

1984
Earns Ph.D. in astrophysics, University of California, Berkeley.

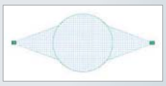
1980s and '90s
Works as physicist, Lawrence Livermore National Laboratory.

1986
Organizes workshop on laser propulsion at Livermore.

1980s and '90s
Works on Clementine lunar mapping mission, a joint program of NASA and the Pentagon's Strategic Defense Initiative Organization.

1997
Sets himself up as independent aerospace consultant.

2001
Presents proposal to NASA for "High-acceleration Micro-scale Laser Sails for Interstellar Propulsion."

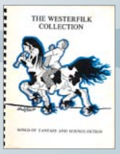


2006
Joins Nathan Myhrvold's IP firm, Intellectual Ventures.

2006
Cofounds LaserMotive in Seattle.

2009
At Intellectual Ventures, he designs and helps to build a laser-based mosquito zapper, which he describes in the May 2010 *IEEE Spectrum* article "Backyard Star Wars."

2009
LaserMotive wins a US $900 000 prize from Elevator: 2010, which promotes research into Earth-tethered satellites to which cargo could crawl. LaserMotive's laser drives a device up a 900-meter-high cable.



2010
Kare's filk song "Fire in the Sky," a eulogy for the doomed crew of the space shuttle *Challenger*, wins Pegasus award for best classic filk song.

KARE: BRIAN SMALE; THUMBNAILS, CLOCKWISE FROM TOP: ISTOCKPHOTO; JORDIN KARE (2); LAWRENCE LIVERMORE NATIONAL LABORATORY; JORDIN KARE (2); RYAN SMITH/INTELLECTUAL VENTURES; GETTY IMAGES; NASA; SUSAN KARE; ISTOCKPHOTO

DREAM JOBS

LUCIE PAUTET

IEEE MEMBER

AGE ***40***

WHAT SHE DOES ***Helps build the world's most ambitious cabled underwater observatory.***

FOR WHOM ***NEPTUNE Canada***

WHERE SHE DOES IT ***Victoria, B.C., and aboard ships off Vancouver Island***

FUN FACTORS ***Explores exotic subsea environments.***

PHOTO: MARTIN TESSLER

Deep Sea Diva

LUCIE PAUTET EXPLORES THE OCEAN FLOOR

On 1 September 2010, Lucie Pautet showed up for her first day of work. An empty, light-filled office awaited the new hire at NEPTUNE Canada, in Victoria, B.C., the aboveground headquarters of an underwater ocean observatory.

Ten days later, that sunny space was a distant memory. She was at sea and working the night shift. She'd rise daily at 9 p.m. and walk around the R/V *Thomas G. Thompson*, an 84-meter-long ship, checking in on the next day's plan for installing instruments and cables on the ocean floor. Then she'd settle in at a workbench in the low-ceilinged control room and watch the footage transmitted by ROPOS, a remotely operated submersible vehicle.

ROPOS went out for almost daily dives that lasted between 10 and 30 hours. Its front camera's saucer-size lens, protruding like an alien eyeball, fed the NEPTUNE crew a high-definition view of the submersible's pincerlike arms. Pautet and her colleagues literally worked in the dark; they spent a month at sea with the lights turned off, staring raptly at a screen at the front of the control room as the submersible explored the water, manipulated tools, and used its graspers to gently position new data-collecting instruments.

"One night we had an amazing moment," Pautet gushes. "We were in a hundred meters of water, and all of a sudden we were surrounded by a school of sunfish." Then she catches herself—there is no "we" down there, only a robot puttering through the water below. "You kind of identify with ROPOS at some point," she says with a quizzical shake of the brown curls framing her face. "Especially when the room is dark and all you have is the screen in front of you, and it's just as if you were in the vehicle, just looking around."

For Pautet and her crewmates, communing with a roving hunk of metal is a fact of life, a reflection of the inseparability of their duties. Adrift on the Juan de Fuca Plate, off the coast of Vancouver Island, the team of scientists and engineers was tending to an unconventional observatory that sprawls some 3000 meters below them on the ocean floor. Cables from the shore provide continuous power and a communications link to five underwater bunkers, called nodes, that connect 160 instruments over the seismically active plate. But to install new instruments, the crew needs ROPOS. To power them and extract their data, the team needs undersea extension cables. And to lay those cables, the scientists again count on ROPOS.

As the lead engineer, Pautet must pull off the last-minute miracles to make it all happen. "Every day, it's like being MacGyver," she says. "There are so many little problems you have to solve with a little tape, by scavenging a can, by thinking on your feet."

The team had set out to lay three thick cables, each between 4 and 8 kilometers long, to connect a new node on the plate's Endeavor Ridge. The ridge is covered with black smokers, tall and spindly hydrothermal vents that jut like chimneys and spout sulfurous, 300° C water from Earth's crust. While they spew, the black smokers easily melt ill-placed instruments, and when the water eventually cools, its minerals form new rock that encrusts whatever it lands on.

Pautet confronted the ocean floor's geologic jungle gym from her perch at a raw wooden desk in the ship's control room. With ROPOS creeping through a few hundred meters of water an hour, Pautet and her teammates surveyed a route for the cable, mapping the mountains and chasms cut into Earth's crust. She sized up whether the cable could withstand the tension imposed by each slope and drop-off, and she hunted for the flattest, cleanest path to the new node. "Between the surveying of the route, the laying of the cable, and the inspection afterward, you're talking about several days of intensive work," she recalls with a weary smile. "It's intense, but you're also accomplishing this amazing technological feat."

For Pautet, this cruise marked a new chapter in a meandering career in which the 40-year-old has trained as an engineer, a globe-trotting, cable-laying technician, and a coastal waters scientist. Now she's all three at once.

BEFORE DISCOVERING the ocean, she dreamed of the sky. As a teenager growing up in France, Pautet and a childhood friend imagined themselves becoming rocket scientists and lofting astronauts into low Earth orbit and beyond. They both applied to France's top aerospace school. Her friend got in, but Pautet did not.

She ended up at École Centrale de Lyon, a university with a strong pedigree in acoustics. She immersed herself in a broad engineering curriculum, as is the custom in French education, before concentrating in aeroacoustics—the study of noise made by rockets and airplanes. A year abroad, at Pennsylvania State University, stretched into two years.

While studying for a master's degree in aerospace engineering, she made a routine but fateful

ONLINE EXCLUSIVE

Pixel Provocateur

HSIN-CHIEN HUANG'S ART DRAWS ON HIS ENGINEERING AND GRAPHICS EXPERIENCE

HSIN-CHIEN HUANG grew up daydreaming about becoming a comic book artist. He invented his own comic strips and doodled imaginary spaceships and military bases. But his mother, an oil painter, had other ideas.

"It was 1980, and back then Taiwan's economy was not so great. Most people didn't have the money to spend on artwork," Huang says. "My mother hoped that her son would have an easier life, that I would study engineering and make a stable living."

Huang listened and earned a degree in mechanical engineering from National Taiwan University, in Taipei. But in 1986, during his third year, his outlook changed. The tragedy of the *Challenger* space shuttle dominated the news, and the images of the shuttle blowing apart left a deep impression. "It made me think that as an engineer, what if I did something that hurt someone or caused an accident?" he recalls. Building actual spaceships and military bases, he realized, was not for him.

Then it dawned on him: He could return to art. By weaving together technology and art, the soft-spoken and amiable 44-year-old has become one of Taiwan's best-known multimedia artists.

To learn how an elite artist discovered Huang—and why he abandoned a promising career developing video games—read more at http://spectrum.ieee.org/huang0211.

—*Catherine Shu*

HSIN-CHIEN HUANG

AGE ***44***

WHAT HE DOES ***Builds multimedia installations.***

FOR WHOM ***Techart Group and Storynest***

WHERE HE DOES IT ***Taipei***

FUN FACTORS ***Plays with new technologies to produce engaging, interactive art exhibits for fun and profit.***

PHOTO: JUSTIN GUARIGLIA/REDUX

ONLINE EXCLUSIVE

JAAP DUISER

AGE *59*

WHAT HE DOES *Builds personal rapid-transit systems.*

FOR WHOM *2getthere*

WHERE HE DOES IT *United Arab Emirates and other international locales*

FUN FACTORS *Gets to custom-build futuristic transit systems around the world.*

PHOTO: MARTIN VON DEN DRIESCH

Prince of Podcars

JAAP DUISER IS BRINGING A PERSONAL RAPID-TRANSIT SYSTEM TO A DESERT ECO-CITY

IT'S DAWN on a humid, 35 °C day in the United Arab Emirates, and Jaap Duiser is guiding his gas-guzzling Toyota SUV through the country's hypercharged freeway traffic. His destination? One of the world's most ambitious environmental projects: Masdar City, a multibillion-dollar carbon-neutral oasis being built on a patch of desert outside Abu Dhabi city.

For nearly a year, the Dutchman has been making this 130-kilometer journey between Dubai and Masdar six days a week. But he'd love to see such commutes eventually become a thing of the past. Since 1995, he has been working toward a world without drivers. He installs personal rapid-transit systems for 2getthere, a small Dutch company that designs magnetically guided "podcar" systems, including one for Masdar. The eco-city is expected to pioneer new modes of energy and water use in the UAE—one of the biggest per capita energy consumers on the planet—and the electric transit system is an important showpiece.

As the project's chief service engineer, Duiser troubleshoots the automated vehicles' electrical, mechanical, and wireless networking systems. Read about how Duiser battles phantom magnetic fields and meets with inquisitive sheiks from across the emirates at http://spectrum.ieee.org/duiser0211. *—Richard Deckert*

trip to the library at Penn State. Scanning the shelves, she came across a textbook on underwater acoustics and began flipping through the pages. "I thought, 'Wow. This is so cool. This is what I want to do,' " she recalls.

On the spot, Pautet shifted her focus. She moved to California to begin a doctoral program in underwater acoustics at the Scripps Institution of Oceanography. There she took up scuba diving—and the ocean came alive for her. "Whenever I go diving, it's like you open a door to another world," she reflects. "It's amazing stress relief. For one hour you're out in space."

After collecting her Ph.D., she took a job at a NATO research center in Italy, where she ran experiments on underwater acoustics along the coast of Elba, in the Mediterranean. The job was idyllic, with fine Italian food and fantastic diving, and access to a research ship whenever she needed one. "It doesn't get better than that!" she recalls.

But eventually, she says, she grew nostalgic for her engineering roots. So she left for the CTBTO Preparatory Commission, in Vienna, where she helped set up networks of seismic sensors that will one day make the comprehensive nuclear test-ban treaty verifiable. Bouncing from ship to ship, she set up monitoring stations on several remote islands around the world.

It was then she mastered the art of undersea cables. She became fluent in the language of underwater terrain, reading the hills and valleys that threatened to abrade her cable. She also learned of the dangers: Should the weather worsen, she and her crew had to know when to cut an unspooling cable, which essentially ties a ship to the ocean floor. Waiting too long could capsize the vessel, risking their lives.

After several voyages, though, Pautet again began to feel dissatisfied—this time with the lack of science. "So when I came across this ocean observatory, I thought, that's exactly what I want," she says. "A year later, here I am."

AS THE EARLY MORNING hours ticked by aboard the *Thomas G. Thompson*, Pautet and her half-dozen night shift companions launched a daily countdown to scrambled eggs. She made a point to slip out on deck each morning to watch the sun climb over the horizon. Later, in the canteen, she could relax and socialize as the rest of the ship stirred to life.

Of all her waterborne wanderings, it's the one month she spent here on Endeavor Ridge that brings a catch to Pautet's voice. "I have never been around something like that—it was breathtaking," she says. "You're so deep, and with the black smokers it's as hostile as it can get. We're installing instruments there, doing things no one has ever done."

Now back on land in her sunny, still-empty office, she eagerly prepares for her next trip out onto the ridge. Easily forgotten are the night shift's long and lonely hours, the few wrenching days of seasickness, and the storms that rocked the ocean, sending the crew flying off their chairs. What remains instead is a single image. As the aerospace expert turned underwater engineer sees it, "It's your step on the moon."

—SANDRA UPSON

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

DREAM JOBS

Help Wanted?

WHAT TECHNOLOGY RECRUITERS ARE LOOKING FOR

TODAY'S RECRUITERS want employees who can adapt. Google, for example, hires generalists instead of filling specific positions. Employees at gaming company Valve work at desks with wheels, so they can physically move from one project to the next. That's good news if you're a top-notch problem-solver who might not have years of experience. Here are practical tips from the recruiters themselves.

Our first requirement is product focus…coming into work and asking, "What's the right thing for me to do for the product today?" Sometimes it means a programmer realizing that he shouldn't write any code that day. He should go and fetch coffee for a modeler, because that day everything we can do to make the modeler more efficient is best for the product.

ROBIN WALKER
Software Developer, Valve Corp.

There are those who say, "I can play a number of positions." Those are very valuable individuals when you think about how fast technology changes. When we bring applicants in for an interview, we ask them to demonstrate their skills, whether it's going to a whiteboard and writing code or running test cases against sample challenges. It's not about the answer. It's a way to see if a person thinks in an efficient way and an elegant way.

CRAIG CAMPBELL
Director of Staffing, Dolby Laboratories

We look for candidates wherever we can. We look at mature industries like the car industry and the aerospace industry, but also universities, to find the next generation of engineers to change the way that we design our turbines.

MORTEN ENGGAARD RASMUSSEN
People and Culture Manager, Vestas Wind Systems

Seventy percent of what we're looking for is in the job posting. The other 30 percent is the ability to be agile. We're not going to ask for 10 years of 4G or LTE experience—these technologies haven't been around for 10 years.

RODNEY MOSES
Vice President of Global Talent Acquisition, Research in Motion (RIM)

The natural evolution of staff is moving away from specific domains. You may start your career as an electrical engineer, but then you shift to a project where you're in charge of a payload. There you learn mechanical aspects, test aspects, software aspects. You become less and less of an electrical engineer and more in charge of developing a whole system—integrating a variety of technologies to make a product that works.

PAOLO DONZELLI
Head of the Human Resources Division, European Space Research and Technology Centre

We always have a high demand for individuals whose skills and experience include robotics and mechatronics, autonomous navigation, machine vision, artificial intelligence, sensors and actuators, analog and digital design, and underwater design skills.

RUSS CAMPANELLO
Senior Vice President of Human Resources, iRobot Corp.

We have many individuals who have worked at other companies—whether creating medical devices or semiconductors. One individual built a robotic arm to help those with no limbs….We try to cast a wide net.

ARNNON GESHURI
Vice President of Human Resources, Tesla Motors

We want people who are not only good for the project at hand; we want people who are going to help develop the next new technologies.

ELIZABETH CALVERT
Lead Engineering Recruiter, America-West, Google

Now we're a desktop software company, a mobile company, an Internet company….People who are looking for jobs now have a lot more places where they can use their skills.

CHRIS GALY
Director of Talent Delivery, Intuit

CLOCKWISE FROM TOP LEFT: DOLBY LABORATORIES; VALVE CORP.; KERSTIN BERLINSKI; ANNEKE LE FLOCH; TESLA MOTORS; IROBOT CORP.; RESEARCH IN MOTION

High School Roboticist

AMIR ABO-SHAEER IS CULTIVATING THE NEXT GENERATION'S ENGINEERS

When Amir Abo-Shaeer told his friends and associates that he was going to quit his job as a mechanical engineer to teach high school, they warned him not to be rash. "If you decide you don't like it after three or four years, you'll have lost your skills," they said. Some cautioned that he was being too idealistic and that most teenagers couldn't care less about learning.

"Everything everybody said has been completely untrue," Abo-Shaeer reports from a classroom at Dos Pueblos High School in Goleta, Calif., where he has pioneered a four-year engineering academy.

What makes Abo-Shaeer's teaching so different is that he doesn't just lecture in front of a blackboard. Instead, he gives his students rich hands-on learning experiences. Central to that is the annual FIRST (For Inspiration and Recognition of Science and Technology) Robotics competition, which inventor Dean Kamen and MIT professor Woodie Flowers started in 1989.

So he's a teacher, yes, but he remains an engineer—and a skilled one. "I build robots with students, and we use the newest and latest, greatest technology," says Abo-Shaeer. "I'm right there at the cutting edge."

Indeed, in the eyes of many in industry, Abo-Shaeer's expertise has only grown. "I have companies come to me and say, 'Can you talk to us about how you are able to get 32 students who don't know anything to build a deliverable in six weeks?' "

ABO-SHAEER ENGINEERED his transition to the classroom because he had so enjoyed being a teaching assistant in graduate school and was

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

ONLINE EXCLUSIVE

Putting a Face on Fantasy

MARK SAGAR GIVES EXPRESSION TO THE MOVIE FACES THAT DELIGHT, TERRIFY, AND ENTHRALL US

MARK SAGAR makes faces for major motion pictures. Beautiful, shocking, unforgettable faces: giant ape faces, blue alien faces, and wizened middle-earth faces.

It's probably the tenor of the times, but increasingly moviegoers want to escape into strange and fantastic realms. However, even in these weird worlds, the traditional rules of cinema apply. So no matter how odd the creatures, their faces still have to do what actors have done for centuries: use expression to feed emotion to an audience hungry for it. It's a growth industry. And nobody does faces as well as Sagar, and no company does exotic alien worlds better than his employer, Weta Digital.

A decade ago, Sagar worked on technology that enabled technicians to capture images of an actor's face, expressions, and movement in such a way that those images could be inserted convincingly into any scene, either real or digitally created. That work led to a collaboration that produced Light Stage, a hardware-and-software system that won Sagar and three others an Academy Award in 2010.

Now, at Weta, Sagar is developing state-of-the-art software to give expression to the faces of digitally created creatures. Weta, which set the bar for cine-creatures in *Avatar*, is expected to up the ante in animation with its upcoming feature *Tintin: The Secret of the Unicorn*. For the whole story on Sagar's career sojourn, from the University of Auckland to the Academy Awards podium, see http://spectrum.ieee.org/sagar0211. *—Glenn Zorpette*

MARK SAGAR

AGE *44*

WHAT HE DOES *Creates effects for huge-budget motion pictures.*

FOR WHOM *Weta Digital*

WHERE HE DOES IT *New Zealand, Southern California*

FUN FACTORS *Does cutting-edge research with the most advanced equipment and computing platforms available; meets A-list Hollywood stars and puts dots on their faces.*

PHOTO: DEAN CARRUTHERS/THE UNIVERSITY OF AUCKLAND

AMIR ABO-SHAEER

AGE *38*

WHAT HE DOES *Teaches*

FOR WHOM *Dos Pueblos High School*

WHERE HE DOES IT *Goleta, Calif.*

FUN FACTORS *Often travels with his students to thrill-packed robot competitions.*

PHOTO: GREGG SEGAL

convinced that helping others to learn would pay off in the end. It didn't hurt that his Iraqi-born father had transformed himself in an even more drastic fashion, from a Ph.D. physics professor to a landscaper, after moving to the United States following Amir's birth.

Growing up in Southern California, Abo-Shaeer liked to tinker, but his household was one of modest means. "We had a drill and a saw; that was pretty much it," he says. During his senior year at the University of California, Santa Barbara, where he majored in physics, Abo-Shaeer took a lab course that introduced him to a machine shop. "It was like I was in heaven," he recalls.

That year he entered a school competition to build a solar water heater. He won, hands down. One of his physics professors took notice and hired Abo-Shaeer as a lab assistant. He relished the opportunity, because by that point, he had decided to pursue mechanical engineering in graduate school and was seeking more hands-on experience.

While in grad school, also at UCSB, Abo-Shaeer began working for a small aerospace company. He decided to end his education with a master's degree. But he was laid off from his job after a year and a half, which led him to a dreary position at a telephone-products company. "It was kind of sucking my soul dry," he says. Looking back, though, he views that stultifying experience as the best thing that could have happened to him, because that was when he decided to go into teaching.

AROUND THAT TIME, Dos Pueblos High School had received funding from the

DREAM JOBS

state of California to offer specialized engineering instruction. But the school had nobody to make the Dos Pueblos Engineering Academy a reality. Abo-Shaeer, who had just been offered a job at the school, was asked to develop and run the program.

Initially, he enrolled only freshmen, working out the curriculum for them on the fly. The following year he created the second year's curriculum, and the year after that the third. By the time the first class reached its senior year, in 2005, Abo-Shaeer needed a good focus for them. He chose the FIRST Robotics competition.

"It starts in January," says Abo-Shaeer. "We receive the game challenge and then from there we have six and a half weeks to design, build, and test a robot. At the end of that six and a half weeks, we put that robot in a crate, whether it's finished or not." Then they ship it off and head out to the competitions.

The build season is "not for the faint of heart—you've got to be serious about this," says Abo-Shaeer. "Sleep becomes optional." The contest allows him to teach things that classroom instruction just can't convey—"the value of endurance and perseverance" and "what it takes to create an amazing product, not just something that's adequate."

The students end up matching Abo-Shaeer's intensity and then some. "What other activity can you think of at school where it's 2 or 3 in the morning and the students say, 'Please let us stay. We're not done and we really need to finish this one thing before we go'?" he says.

ABO-SHAEER'S TEAM has scored some impressive awards, even though he swears his goal is not to win but simply to have the students build what they believe is the best robot. He himself has garnered considerable recognition outside robotics, too. Three years ago Abo-Shaeer landed a US $3 million grant from the state of California to construct a building to house the Dos Pueblos Engineering Academy. And in 2010 he was chosen as a MacArthur Fellow for his efforts to foster engineering education.

The best thing about the $500 000 MacArthur "genius award," says Abo-Shaeer, is that it gives him a lot more credibility with his students when he tells them to follow their passions, even if their dream jobs don't promise riches.

"Our society is what it is," says Abo-Shaeer. How people are perceived is "based on recognition and how much money they make," he observes. "I think my students knew that I was sincere, but I don't know that they could really feel that they could buy into it. I think [the MacArthur fellowship] is a gift to them."

—DAVID SCHNEIDER

Amir Abo-Shaeer is featured in Neal Bascomb's The New Cool: A Visionary Teacher, His FIRST Robotics Team, and the Ultimate Battle of Smarts *(Crown), which goes on sale in March.*

Where Are They Now?

FOUR TECHNOLOGISTS CHECK IN

DIVERTED BY DISPLAYS

In February 2007, Mary Lou Jepsen (Dream Jobs '07) was circling the globe in support of One Laptop per Child, a not-for-profit group that had designed a laptop for children in developing countries.

That year, a computer maker approached the team to buy its energy-efficient displays. "Painfully, we said no," she recalls.

In 2008 Jepsen left to start Pixel Qi Corp. to produce those displays. In deference to her former employer, Pixel Qi cross-licenses with OLPC "anything that we ever invent."

Jepsen hopes that her company will serve both consumers in the developed world, who demand long-lasting batteries, and those in developing countries, who may lack the infrastructure to have it any other way. "The solution was clear," she says. "Create for both groups at the same time."

COSMIC COMPUTING

Computer scientist José Antonio Losada (Dream Jobs '10) is unique among his colleagues at Gran Telescopio Canarias, on Spain's Canary Islands. "I'm the strange guy who dances," he says. His software, too, must execute graceful moves. It controls the world's largest light-collecting mirror, orchestrating the 36 hexagonal segments to focus on the far reaches of space.

A year ago, Losada had hoped that other telescopes might use his code, but that has yet to happen. So he's moved on to other projects, such as a mid-infrared imager built by the University of Florida, in Gainesville. The "CanariCam" collects infrared light to unmask cosmic bodies hidden by dust and gas. With his software, the new imager moves in sync with the rest of the telescope—another task, it seems, that's well suited to a dancer.

ROBOT RELATIONS

For Robin Murphy (Dream Jobs '09), a great day starts with a train wreck. At Texas Engineering Extension Service's 21-hectare Disaster City, a rubble-strewn training ground, she is still testing rescue robots, such as autonomous helicopters and robots that crawl like caterpillars.

This past fall, when 33 Chilean miners were trapped underground, rescue teams asked Murphy if her robots could help. But she says the mine's boreholes were only 7 centimeters wide—too slim for anything bigger than a camera.

Murphy is confident that a robot will soon rescue a human, marking a first for her field. But now she wonders how the robot and the victim should interact. "What do we do when we find somebody alive?" she asks. "How should we talk to them?"

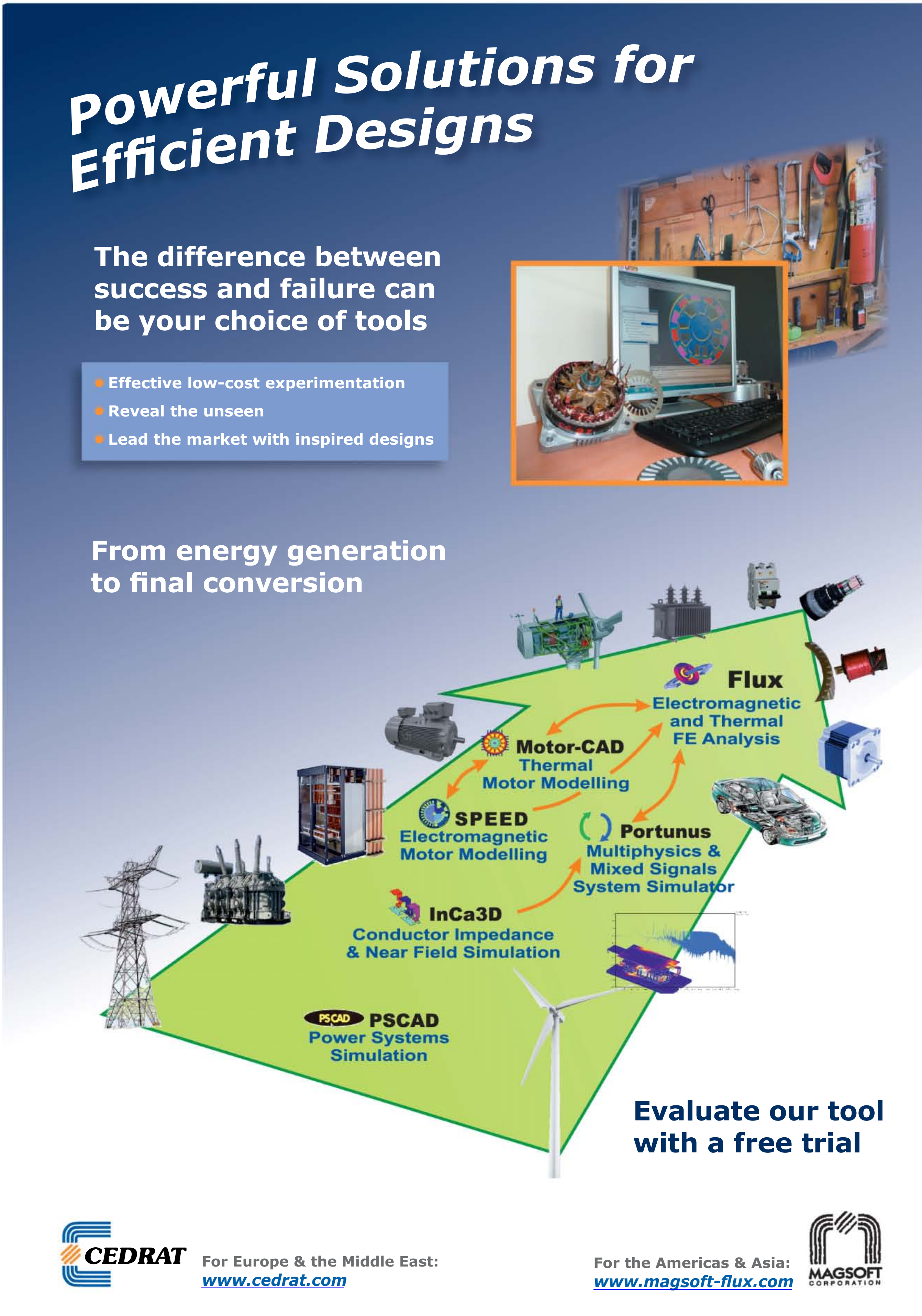
SHIFTING GEARS

Accelerating from 0 to 96 kilometers per hour in 2.9 seconds, Ian Wright's X1 electric supercar leaves most sports cars in its dust. For Wright, the vehicle has met its goal: "To bust the myth that electric cars have to be heavy, ugly, and slow."

Three years ago, Wright (Dream Jobs '07) had hoped to raise enough money to build a production model. But his company, Wrightspeed, has since changed its game. Now it focuses on building hybrid power trains to sell to other carmakers. Wright thinks trucks, too, could become a potential market.

"It is actually the right time for this technology," Wright says. "It seems like all of our needs to make this dream happen are coming together."

—Joseph Calamia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Reveal the unseen
Lead the market with inspired designs
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THE POLAR PARTICLE HUNTER

Searching Antarctica for the frozen paths of cosmic-ray neutrinos

No commercial airline flies to the South Pole. Instead, I started my trip there on a U.S. Air Force C-17 transport, which traveled from Christchurch, New Zealand, to McMurdo Station, a U.S. Antarctic research center located on the southern tip of Ross Island. I stayed at McMurdo overnight before boarding a smaller plane, an LC-130 turboprop, for the rest of the journey. After a 3-hour flight over the Transantarctic Mountains, my plane landed on skis at the bottom of the world. **BY SPENCER KLEIN**

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

TUNNEL VISION: Sophisticated particle detectors are lowered into a 2.5-kilometer-deep hole drilled into the Antarctic ice near South Pole Station.

SOUTHERN EXPOSURE: Visiting the U.S. research station at the South Pole usually entails a trip on a ski-equipped LC-130 military transport [upper left]; cables attached to each of the IceCube array's buried detectors funnel their data to a central recording facility [top right]; scientists and engineers working on the ARIANNA experiment place their particle detectors in shallow trenches rather than deep holes [center left]; circular circuit boards are stacked high in each of the spherical modules used in the IceCube array [bottom left].

PREVIOUS PAGE AND ABOVE: NSF

Stepping off the LC-130, I found the cold, thin air a real shock—the South Pole is more than 2800 meters above sea level, and the temperature was –30 °C. I staggered to the shelter of South Pole Station, from which, after suiting up in 10 kilograms of extreme-cold-weather gear, I walked to the nearby drilling camp. The goal of this operation was to bore holes 60 centimeters in diameter, each reaching about 2.5 kilometers below the surface, which is deeper than the Grand Canyon.

In 2005, a year before my visit, technicians had drilled the first of 86 holes. Initially, each one took 57 hours to make, using a jet of hot, pressurized water. By the time I arrived, the drillers had honed their technique, and the same task took 40 hours of work, weather and equipment permitting.

On the morning of 18 December 2010, the drill burrowed into the ice one final time to complete the last hole. These holes are now the permanent homes for strings of exquisitely sensitive light detectors, which more than 200 scientists, engineers, and technicians from nearly 40 institutions—including my own, Lawrence Berkeley National Laboratory (LBNL)—will use to search for signals from the far reaches of the cosmos.

We hope to solve a mystery that came to light 100 years ago, when Victor Hess, a physicist at the Institute for Radium Research of the Austrian Academy of Sciences, climbed into a hot air balloon. He wanted to measure radiation at high alti-

Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page

tudes. Scientists had discovered this radiation—what physicists now understand to be a sporadic flittering of subatomic particles—almost everywhere they looked. Some attributed it to radioactive elements in the ground, and Hess wanted to test that theory. He took off into the air, eventually ascending 5000 meters. As Hess climbed, he saw an increase in the radiation he was measuring. That meant it wasn't coming from Earth. Nighttime readings were no lower, which ruled out the sun. He concluded that the origin was likely somewhere deep in space. Hess's discovery of what were later dubbed cosmic rays won him a Nobel Prize in Physics, in 1936. Although Hess's work encouraged researchers to focus on the heavens, he was unable to determine the exact source of these energetic particles. Today astronomers and physicists still debate the possibilities.

Very likely, some of these cosmic rays originate within our own galaxy, accelerated in the magnetic fields and dense plasma that stars produce when they reach the end of their lives and explode, forming black holes or neutron stars. More energetic cosmic rays probably have more violent births, within jets spewed from the disks of matter surrounding ultramassive black holes at the center of other galaxies; during the collapse of a giant star, 100 or more times as massive as our sun; or in a collision between two black holes or between a black hole and a neutron star.

Scientists can easily detect the charged particles in cosmic rays using any number of simple detectors—even photographic film. And they have: By the 1930s, physicists had measured coincident signals using instruments separated by hundreds of meters. They realized that the background radiation that perplexed scientists of Hess's time could come from high-energy, charged cosmic-ray particles that strike nitrogen or oxygen atoms in Earth's atmosphere and create in each collision a shower of low-energy particles. By the 1960s, they knew that these downpours could include billions of particles, spread over many square kilometers. But figuring out the starting point of the original cosmic ray requires a more sophisticated approach. Any matter or magnetic field that a charged particle encounters during its interstellar journey alters its trajectory, making it hard to determine its origin.

But cosmic rays also contain uncharged particles called neutrinos, which travel more determinedly. Magnetic fields don't affect them, and they barely interact with matter, meaning that they can course unhindered through the thickest clouds of cosmic dust and gas. Because the path of a cosmic-ray neutrino points straight back to its origin, astrophysicists dearly want to trace the trajectories of these particles.

Unfortunately, the same characteristic that allows neutrinos to travel with little interference makes them nearly impossible to detect. Only very rarely will one crash into matter and create a cascade of other, more easily detectable charged particles. To witness that, researchers must be either extremely lucky or need to monitor a big target—for example, a 1-cubic-kilometer chunk of Antarctic ice.

* * *

My colleagues and I have transformed this great volume of Antarctic ice into a particle detector we call the IceCube Neutrino Observatory. With it, we can look for the aftermath of collisions between neutrinos and atoms, which, rare as they are, create fast-moving charged particles. If these particles move quickly enough, they give off the electromagnetic equivalent of a sonic boom, a bluish glow called Cherenkov radiation. Buried in Antarctica's transparent ice, sensitive light detectors look for that glow, which they can spot at considerable distances. From this signal, we can calculate the original neutrino's path.

IceCube isn't the first detector of this kind. Physicists began work on its predecessor, the Antarctic Muon And Neutrino Detector Array, or AMANDA, in the early 1990s. It used ice-entombed photomultiplier tubes to turn the faint flashes of Cherenkov light into electrical impulses. Coaxial cables provided the high voltages needed to run these tubes while also carrying analog signals upward to the surface. But the first measurements quickly revealed a nasty surprise: The ice around the detectors contained tiny air bubbles, which scattered much of the Cherenkov light before it could travel a mere 50 cm.

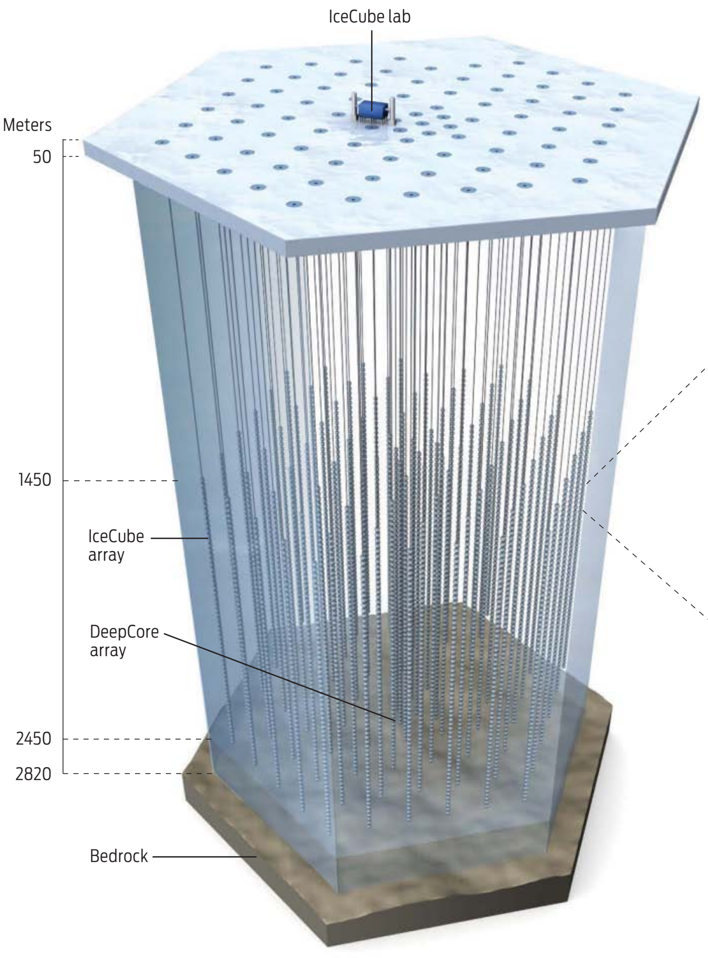
The solution, AMANDA scientists determined, was to dig deeper. Below 1400 meters' depth, the weight of the ice above squeezes these bubbles out of existence. By 1996, researchers had buried 10 strings of optical sensors up to 2500 meters below the surface. With those strings, the team observed their first neutrinos. By 2000, AMANDA was fully operational, with 677 detectors festooned on 19 separate strings. The good news: The array detected about 1000 neutrinos every year until the project ended in 2009. The bad news: As far as AMANDA scientists could tell, none of those observations had anything to do with neutrinos arriving from the far reaches of the cosmos. All of the neutrinos they detected had formed when charged cosmic-ray particles hit gas molecules in the atmosphere, a commonplace occurrence, which wasn't particularly helpful in tracking down the rays' origins.

IceCube will face the same challenges. But it has a key advantage over AMANDA—it's about 100 times as big. More volume means more space to track the charged particles born when neutrinos wallop the ice. That's key for helping the IceCube team to determine the types of neutrinos that we spot. Neutrinos come in three varieties, and we expect that extraterrestrial sources should give rise to an equal number of each type, whereas something as mundane as a cosmic-ray air shower produces a decidedly lopsided distribution of the three neutrino flavors.

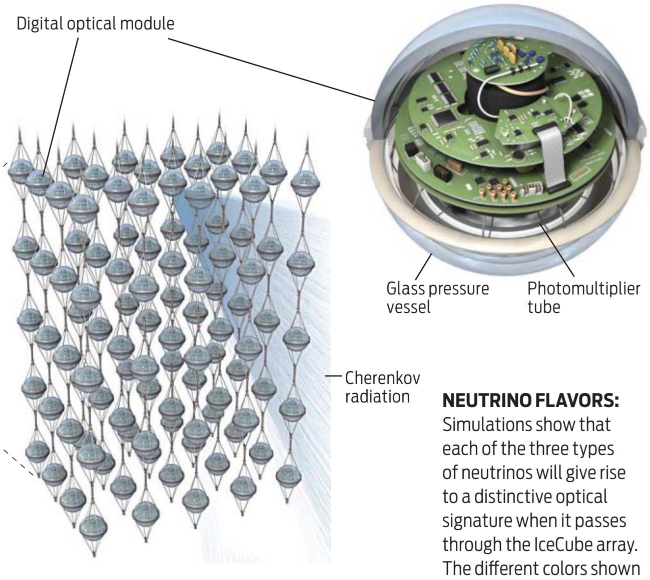
But IceCube's greater size isn't its only advantage over its predecessor. Over nine years, successive generations of AMANDA strings used different hardware to send analog signals to the surface—first coaxial cables, then twisted pairs, and finally optical fibers. Each of these approaches required a different type of data transmission, which made it hard to operate them in concert, demanded laborious calibrations, and still provided a very limited dynamic range. To avoid these problems, IceCube's designers decided to place the signal-processing electronics within the optical detectors themselves and to send only digital data back up the cables.

Slightly larger than a basketball, each module holds a photomultiplier tube for sensing Cherenkov radiation and a precision clock in the form of a quartz crystal oscillator, along with electronics for data acquisition, signal processing, and telemetry, all tightly packed inside a spherical pressure vessel made of borosilicate glass.

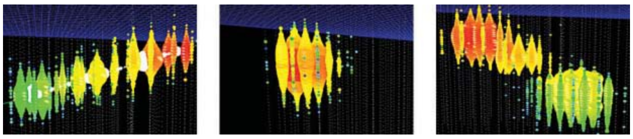
To convert an analog signal into a digital one, the onboard electronics must sample the output of the photomultiplier tube 300 million times per second while using less power than any



ELECTRONIC PEARLS: The digital optical modules used to sense the passage of neutrinos through the ice are encased in spherical pressure vessels made of borosilicate glass. They are attached to their suspending cables at 17-meter vertical intervals, from 1450 to 2450 meters' depth. After a string has been deployed and tested, the surrounding water (left over from drilling the hole) freezes the detectors in place.



NEUTRINO FLAVORS: Simulations show that each of the three types of neutrinos will give rise to a distinctive optical signature when it passes through the IceCube array. The different colors shown here represent detections taking place at slightly different times.



available commercial converter. IceCube's modules rely on two custom-made waveform-digitizer chips, which operate in a "ping-pong" fashion—while one is busy digitizing, the other is ready to receive new signals. Both chips contain four sets of 128 capacitors connected to four sets of 128 field-effect transistor switches. When the analog signal reaches these capacitor arrays, the switches close in rapid succession, allowing each capacitor to sample the incoming voltage for 3.3 nanoseconds. A slow, low-power converter can then digitize those analog samples. With this setup, each of the two chips consumes a paltry 30 milliwatts of power.

A logic chip called a field-programmable gate array, or FPGA, starts this system running and orchestrates its operation. This programmable chip allows us to update the hardware configuration from the surface, but that comes with an inherent danger: A bad command could terminate all communication with the module. To avoid that possibility, the FPGA boots from an unalterable, 1-megabyte one-time-programmable memory that includes the code for vital communication systems. We can then safely reprogram a separate 8-MB flash memory when we need to update the system.

Designing these modules was no easy feat. Each has to function reliably from room temperature down to –55 °C. The modules also have to withstand pressures that can reach up to 70 megapascals (almost 700 times sea-level atmospheric pressure) from the frozen water above. Each module also has to use less than 5 watts of power. That might seem overly strict rationing, but remember—the observatory has to generate this electricity locally, and the nearest gas station is 1400 km away. Five watts per module corresponds to about 10 planeloads of fuel each year to run the entire array.

My colleagues at LBNL helped to design instrument modules that could meet these demanding requirements. Those efforts began in 2000, when they built the electronics for a prototype string of detectors, which provided both an analog output and a digital data stream containing the results of the internal signal processing. The AMANDA team deployed that primitive digital string, and it worked well. Soon after, the U.S. National Science Foundation approved the construction of the IceCube observatory, in part because the prototype string demonstrated its feasibility.

The original IceCube design called for 4800 digital optical modules, attached to 80 vertical strings set into the ice with a horizontal spacing of 125 meters. One module is positioned every 17 meters along each string between 1450 and 2450 meters' depth. The IceCube collaboration has also developed an extension called DeepCore, which has six more strings in holes drilled with a smaller (72-meter) horizontal spacing. DeepCore will help us to detect lower-energy neutrinos. Deploying these 86 strings has taken six construction seasons, because each hole requires almost two days to drill, and installing the string usually takes another 12 to 15 hours.

During my first visit to the South Pole in 2006, I had the chance to help out with the installation of one string. There were about eight of us on the crew, and everyone had designated jobs: prepping the modules, attaching them to the cable,

EMILY COOPER

measuring the distance between them using a laser range finder, and running the winch. After we had attached and lowered all 60 modules into the ice, the winch operator rolled out the last 1400 meters of cable, which took nearly an hour. Looking into the open hole, it's hard to appreciate the depth—after about 30 meters, you see only darkness.

Descending into this particular heart of darkness would indeed be like going back in time, because the ice stores a record of prevailing conditions when the snow that formed it first fell. The deepest modules touch snowfall from 100 000 years ago. Some of the intervening layers of ice contain appreciable amounts of dust—including vestiges of the ash that ancient volcanoes shot into the air. Because that dust absorbs some of the faint light we monitor, our team needed to map it carefully by temporarily lowering an instrument called a dust logger into the freshly drilled holes. A laser probe in the logger shines a thin, pancakelike beam of light into the ice around the hole, and a detector mounted below measures the amount scattered backward.

* * *

Whenever a photon hits one of the modules' photomultipliers—hemispherical vacuum tubes 25 cm in diameter—the tube's photocathode emits a single electron. A potential of a few hundred volts accelerates this electron until it strikes a plate within the tube with enough energy to eject up to 10 additional electrons. Like pebbles in an avalanche, these in turn accelerate and strike a third plate, producing yet more electrons. After 10 such amplifications, you'll have something like 10 million electrons.

After figuring out how to convert that analog signal into a digital one, we had to grapple with how the module should filter the data before sending them to the computer-filled "counting house" at the surface. When it detects a photon, each module waits for signals from the two neighboring modules above and below on the string indicating whether they, too, have registered hits. For isolated events, the module records only a brief summary. But when an adjacent module also senses Cherenkov radiation, they both record a complete set of measurements to transmit to the surface, where computers filter the data again and begin analysis, sending more interesting neutrino recordings by satellite to a data warehouse at the University of Wisconsin–Madison.

Even before all of IceCube's strings were in place, modules were already transmitting data, and the transfer rate has only grown over time. In 2008, the array sent north 32 gigabytes per day; in 2011, we expect to transfer 88 GB per day, or about 32 terabytes per year.

Despite the complexity of this system and the demanding environment it must withstand, IceCube is performing very well. Ninety-eight percent of the deployed modules are working perfectly, a track record better than that of many space-satellite designs. As the data mount, we should soon be able to identify neutrinos from cosmic sources. However, the most energetic neutrinos, those with energies above 10^{17} electron-volts, are extremely rare and so will require still bigger detectors. By normal standards, 10^{17} electron-volts isn't much energy—barely enough to lift an apple about a centimeter—but it's a colossal amount for a subatomic particle. To detect these very rare particles, we will likely need a block of ice 100 times as large as IceCube. Antarctica has no shortage of ice, so that's not a problem, but outfitting this volume with a dense array of optical detectors would be prohibitively expensive.

Some researchers plan to use a different approach to monitor such particles. Instead of searching for visible Cherenkov light, which fades greatly within 200 meters, they intend to detect Cherenkov radio waves. When a highly energetic neutrino collides with the ice, it creates many charged particles, and the collective interactions of these particles with the ice in turn produce radio waves. The more energy the neutrino has, the stronger the waves will be. And because radio waves can travel up to 1000 meters within ice before fading significantly, the detector will need relatively few detector modules to cover the required 100-cubic-kilometer volume.

Researchers could perform such an experiment at various Antarctic locales, including the South Pole and the 570-meter-thick Ross Ice Shelf. The South Pole offers thicker and less absorptive ice, but the Ross Ice Shelf sits atop the Ross Sea, which acts as a near-perfect radio mirror, increasing the signal at the surface. In December 2009, I returned to Antarctica to deploy a prototype station for a neutrino detector that would take advantage of this effect. We call the project ARIANNA, which stands (loosely) for Antarctic Ross Ice-shelf Antenna Neutrino Array. It will use downward-facing radio antennas buried in shallow holes. A few of the neutrinos that enter the ice will generate radio waves when they strike atoms within it. The neutrinos that rain downward will be the easiest to sense, because they produce radio waves that also travel downward—but only until they hit the conductive seawater below. At that point, they bounce right back. This phenomenon allows us to pick up their signals in the near-surface antennas. If the prototype we worked on is successful, it may usher in a full-scale neutrino detector containing 900 radio antennas spread over a square patch of ice 30 km on a side. That's an awful lot of stations, but because these antennas sit on the surface, they are relatively quick and simple to put in.

* * *

One hundred kilometers south of McMurdo Station, the Ross Ice Shelf has neither runway nor ski-way, so my colleagues and I had to set out by helicopter for our ARIANNA experiments. Our three-person field team originally planned to spend nine days camping on the ice, installing and testing our equipment. On day nine, however, it was snowing at McMurdo, so the helicopter couldn't fly. The next day, clouds over Minna Bluff, which separates McMurdo from the ice shelf, again prevented the helicopter from reaching us. We finally got out on day 11, relieved.

But we had little cause to complain. Our tiny particle quarry traveled much farther, from places yet unknown, with many more obstacles in their way. And before the Antarctic sun set, we made it back to warm homes and offices, while the neutrinos continued to forge paths through the ice all winter, creating tiny glimmers of light within the frozen darkness. ❑

TELL US WHAT YOU THINK at http://spectrum.ieee.org/icecube0211.

THE TOPS IN FLOPS

ieee spectrum Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®

SUPERCOMPUTERS ARE NOW RUNNING OUR SEARCH ENGINES AND SOCIAL NETWORKS. BUT THE HEADY DAYS OF STUNNING PERFORMANCE INCREASES ARE OVER BY PETER KOGGE

SUPERCOMPUTERS ARE the crowning achievement of the digital age. Yes, it's true that yesterday's supercomputer is today's game console, as far as performance goes. But there is no doubt that during the past half-century these machines have driven some fascinating if esoteric pursuits: breaking codes, predicting the weather, modeling automobile crashes, simulating nuclear explosions, and designing new drugs—to name just a few. And in recent years, supercomputers have shaped our daily lives more directly. We now rely on them every time we do a Google search or try to find an old high school chum on Facebook, for example. And you can scarcely watch a big-budget movie without seeing supercomputer-generated special effects.

So with these machines more ingrained than ever into our institutions and even our social fabric, it's an excellent time to wonder about the future. Will the next decade see the same kind of spectacular progress as the last two did?

Alas, no.

Modern supercomputers are based on groups of tightly interconnected microprocessors. For decades, successive generations of those microprocessors have gotten ever faster as their individual transistors got smaller—the familiar Moore's Law paradigm. About five years ago, however, the top speed for most microprocessors peaked when their clocks hit about 3 gigahertz. The problem is not that the individual transistors themselves can't be pushed to run faster; they can. But doing so for the many millions of them found on a typical microprocessor would require that chip to dissipate impractical amounts of heat. Computer engineers call this the power wall. Given that obstacle, it's clear that all kinds of computers, including supercomputers, are not going to advance at nearly the rates they have in the past.

So just what can we expect? That's a question with no easy answer. Even so, in 2007 the U.S. Defense Advanced Research Projects Agency (DARPA) decided to ask an even harder one: What sort of technologies would engineers need by 2015 to build a supercomputer capable of executing a quintillion (10^{18}) mathematical operations per second? (The technical term is floating-point operations per second, or flops. A quintillion of them per second is an exaflops.)

DARPA didn't just casually pose the question. The agency asked me to form a study group to find out whether exaflops-scale computing would be feasible within this interval—half the time it took to make the last thousandfold advance, from teraflops to petaflops—and to determine in detail what the key challenges would likely be. So I assembled a panel of world-renowned experts who met about a dozen times over the following year. Many of us had worked on today's petaflops supercomputers, so we had a pretty good idea how hard it was going to be to build something with 1000 times as much computing clout.

We consulted with scores of other engineers on particular new technologies, we made dozens of presentations to our DARPA sponsors, and in the end we hammered out a 278-page report, which had lots of surprises, even for us. The bottom line, though, was rather glum. The practical exaflops-class supercomputer DARPA was hoping for just wasn't going to be attainable by 2015. In fact, it might not be possible anytime in the foreseeable future. Think of it this way: The party isn't exactly over, but the police have arrived, and the music has been turned way down.

This was a sobering conclusion for anyone working at the leading edge of high-performance computing. But it was worrisome for many others, too, because the same issues come up whether you're aiming to construct an exaflops-class supercomputer that occupies a large building or a petaflops-class one that fits in a couple of refrigerator-size racks—something lots of engineers and scientists would dearly like to have at their disposal. Our panel's conclusion was that to put together such "exascale" computers—ones with DARPA's requested density of computational might, be they building-size supercomputers or blazingly fast rack-size units—would require engineers to rethink entirely how they construct number crunchers in the future.

HOW FAR away is an exaflops machine? A decent supercomputer of the 1980s could carry out about a billion floating-point operations per second. Today's supercomputers exceed that by a factor of a million. The reigning champion today is China's Tianhe-1A supercomputer, which late last year achieved a world-record 2.57 petaflops—that's 2.57 quadrillion (2.57×10^{15}) flops—in benchmark testing. Still, to get to exaflops, we have a factor of almost 400 to go.

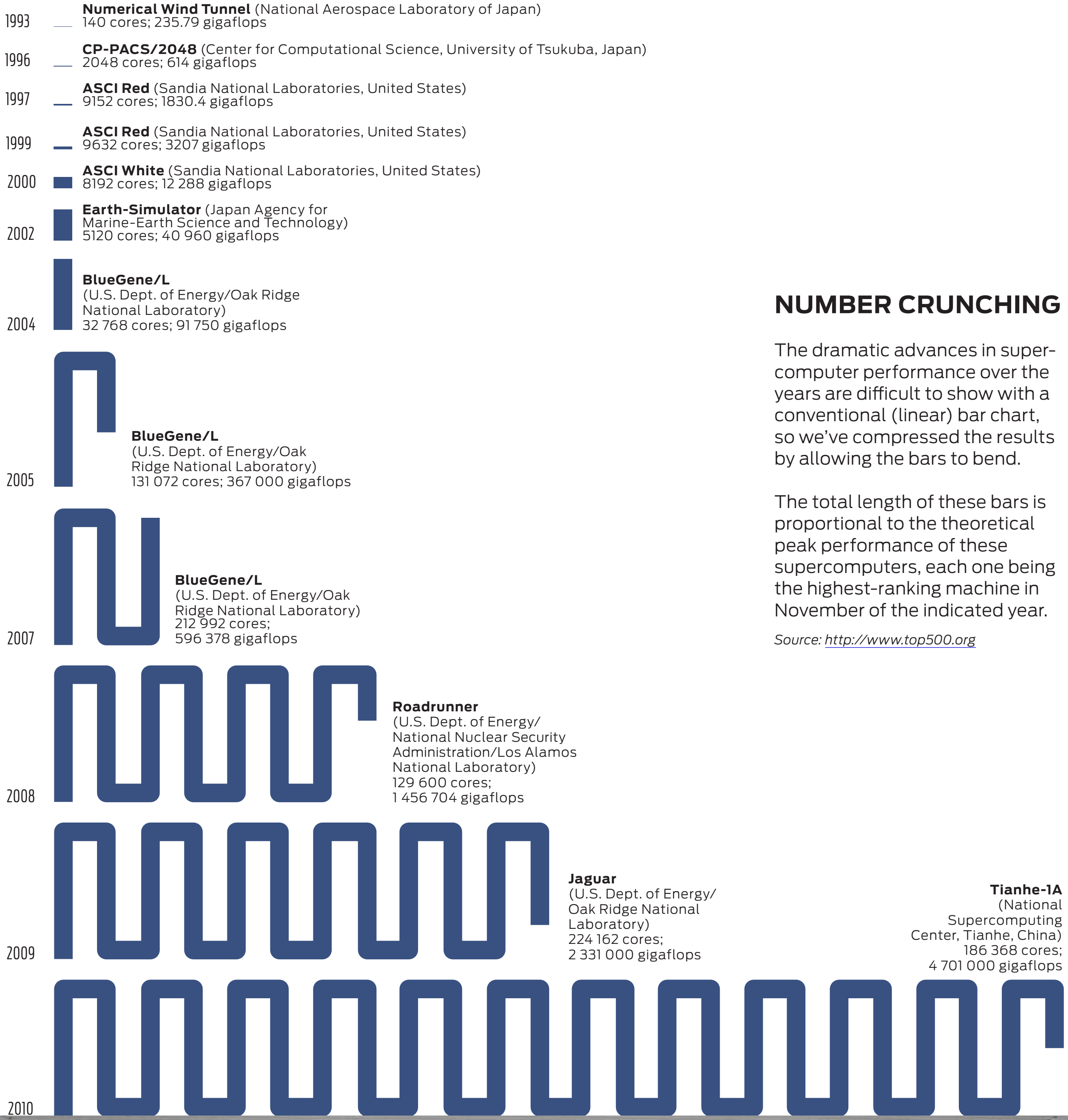
The biggest obstacle to that by far is power. A modern supercomputer usually consumes between 4 and 6 megawatts—enough electricity to supply something like 5000 homes. Researchers at the University of Illinois at Urbana-Champaign's National Center for Supercomputing Applications, IBM, and the Great Lakes Consortium for Petascale Computation are now constructing a supercomputer called Blue Waters. In operation, this machine is going to consume 15 MW—more actually, if you figure in what's needed for the cooling system. And all that's for 10 petaflops—two orders of magnitude less than DARPA's exaflops goal.

If you tried to achieve an exaflops-class supercomputer by simply scaling Blue Waters up 100 times, it would take 1.5 gigawatts of power to run it, more than 0.1 percent of the total U.S. power grid. You'd need a good-size nuclear power plant next door. That would be absurd, of course, which is why DARPA asked our study group to figure out how to limit the appetite of such a computer to a measly 20 MW and its size to 500 conventional server racks.

To judge whether that is at all feasible, consider the energy expended per flop. At the time we did the study, computation circuitry required about 70 picojoules for each operation, a picojoule being one millionth of one millionth of a joule. (A joule of energy can run a 1-watt load for one second.)

The good news is that over the next decade, engineers should be able to get the energy requirements of a flop down to about 5 to 10 pJ. The bad news is that even if we do that, it won't really help. The reason is that the energy to perform an arithmetic operation is trivial in comparison with the energy needed to shuffle the data around, from one chip to another, from one board to another, and even from rack to rack. A typical floating-point operation takes two 64-bit numbers as input and produces a 64-bit result. That's almost 200 bits in all that need to be moved into and out of

PRECEDING PAGE: ILLUSTRATION: GEORGE RETSECK



NUMBER CRUNCHING

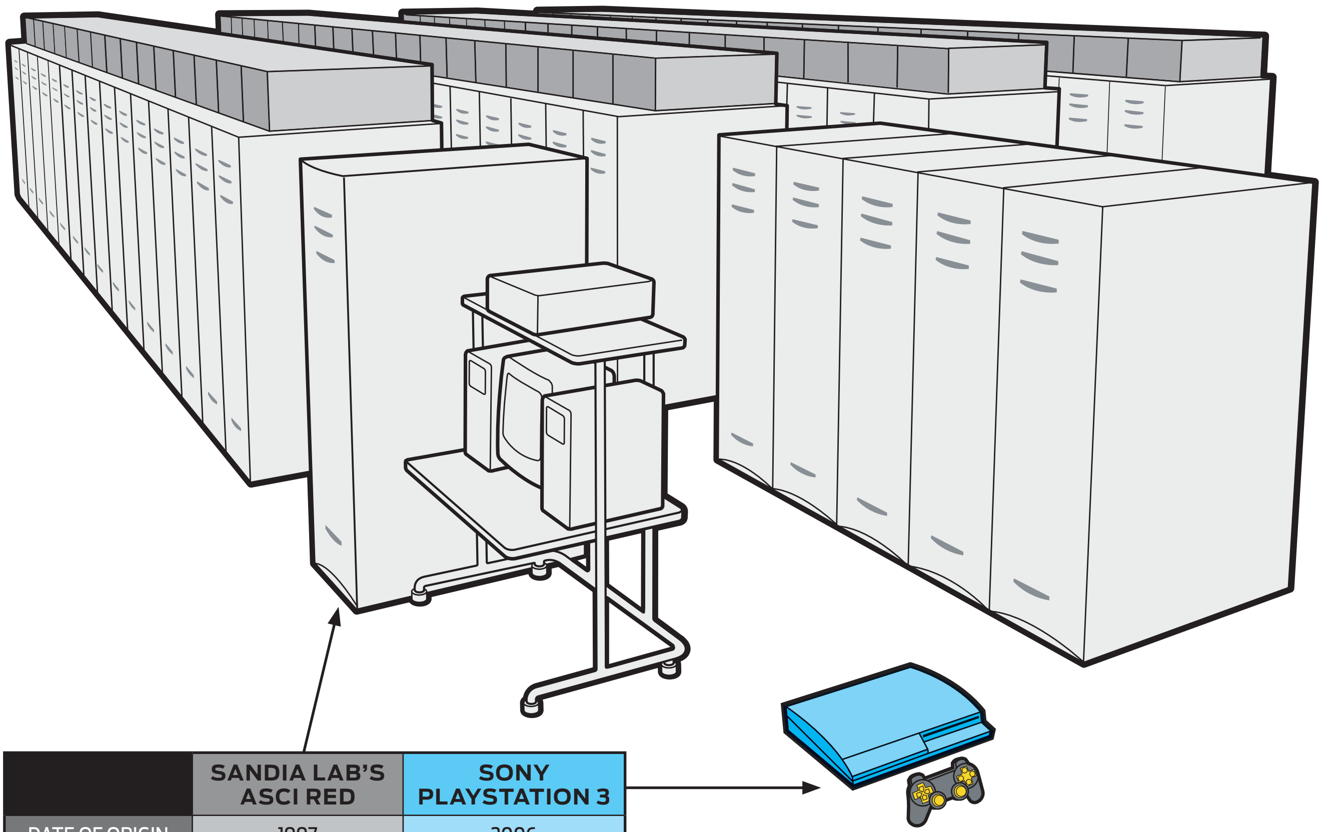
The dramatic advances in supercomputer performance over the years are difficult to show with a conventional (linear) bar chart, so we've compressed the results by allowing the bars to bend.

The total length of these bars is proportional to the theoretical peak performance of these supercomputers, each one being the highest-ranking machine in November of the indicated year.

Source: http://www.top500.org

The Tianhe-1A supercomputer in Yianjin, China *PHOTO: CHINAFOTOPRESS/GETTY IMAGES*

TALE OF THE TAPE: SUPERCOMPUTER VS. GAME CONSOLE



	SANDIA LAB'S ASCI RED	SONY PLAYSTATION 3
DATE OF ORIGIN	1997	2006
PEAK PERFORMANCE	1.8 teraflops	1.8 teraflops*
PHYSICAL SIZE	150 square meters	0.08 square meter
POWER CONSUMPTION	800 000 watts	<200 watts

* For GPU; CPU adds another 0.2 teraflops

some sort of memory, likely multiple times, for each operation. Taking all that overhead into account, the best we could reasonably hope for in an exaflops-class machine by 2015 if we used conventional architecture was somewhere between 1000 and 10 000 pJ per flop.

Once the panel members realized that, we stopped thinking about how to tweak today's computing technology for better power efficiency. We'd have to start with a completely clean slate.

To get a handle on how best to minimize power consumption, we had to work out a fairly detailed design for the fundamental building block that would go into making up our hypothetical future supercomputer. For this, we assumed that the microprocessors used would be fabricated from silicon, as they are now, but using a process that would support chip voltages lower than the 1 volt or so that predominates today. We picked 0.5 V, because it represented the best projection for what industry-standard silicon-based logic circuitry would be able to offer by 2015. Lowering the operating voltage involves a trade-off: You get much lower power consumption, because power is proportional to the square of voltage, but you also reduce the speed of the chip and make circuits more prone to transient malfunctions.

Bill Dally (then at Stanford and now chief scientist of Nvidia Corp.), working largely on his own, hammered out the outlines of such a design on paper. The basic module he came up with consists of a chip with 742 separate microprocessor cores running at 1.5 GHz. Each core includes four floating-point units and a small amount of nearby memory, called a cache, for fast data access. Pairs of such cores share a somewhat slower second-level cache, and all such pairs can access each other's second-level (and even third-level) memory caches. In a novel twist, Dally's design has 16 dynamic RAM chips directly attached to each processor. Each processor chip also has ports for connections to up to 12 separate routers for fast off-chip data transfers.

One of these processor-memory modules by itself should be able to perform almost 5 teraflops. We figured that 12 of them could be packaged on a single board and that 32 of these boards would fit in a rack, which would then provide close to 2 petaflops, assuming the machine was running at peak performance. An exaflops-class supercomputer would require at least 583 such racks, which misses DARPA's target of 500 racks but is nevertheless a reasonable number for a world-class computing facility.

The rub is that such a system would use 67 MW, more than three times the 20 MW that DARPA had set as a limit. And that's not even the worst problem. If you do the arithmetic, you'll see that our 583-rack computer includes more than 160 million microprocessor cores. It would be tough to keep even a small fraction of those processors busy at the same time.

Realistic applications running on today's supercomputers typically use only 5 to 10 percent of the machine's peak

GEORGE RETSECK

processing power at any given moment. Most of the other processor cores are just treading water, perhaps waiting for data they need to perform their next calculation. It has proved impossible for programmers to keep a larger fraction of the processors working on calculations that are directly relevant to the application. And as the number of processor cores skyrockets, the fraction you can keep busy at any given moment can be expected to plummet. So if we use lots of processors with relatively slow clock rates to build a supercomputer that can perform 1000 times the flops of the current generation, we'll probably end up with just 10 to 100 times today's computational oomph. That is, we might meet DARPA's targets on paper, but the reality would be disappointing indeed.

The concerns we had with this approach did not end there. Accessing memory proved especially vexing. For example, in analyzing how much power our hypothetical design would use, we assumed that only 1 out of every 4 floating-point operations would be able to get data from a nearby memory cache, that only 1 out of every 12 memory fetches would come from a separate memory chip attached to the microprocessor chip, and only 1 out of every 40 of them would come from the memory mounted on another module. Real-world numbers for these things are invariably larger. So even our sobering 67-MW power estimate was overly optimistic. A later study indicated the actual power would be more like 500 MW.

For this design we added only the amount of memory that we thought we could afford without the power requirements of connecting it all together becoming too much of an issue. The resultant amount of memory, about 3.6 petabytes in all, seems large at first blush, but it provides far less memory than the 1 byte per flops that is the supercomputer designer's holy grail. So unless memory technologies emerge that have greater densities at the same or lower power levels than we assumed, any exaflops-capable supercomputer that we sketch out now will be memory starved.

And we're not even done with the seemingly insurmountable obstacles! Supercomputers need long-term storage that's dense enough and fast enough to hold what are called checkpoint files. These are copies of main memory made periodically so that if a fault is discovered, a long-running application need not be started over again from the beginning. The panel came to the conclusion that writing checkpoint files for exaflops-size systems may very well require a new kind of memory entirely, something between DRAM and rotating disks. And we saw very limited promise in any variation of today's flash memory or in emerging nanotechnology memories, such as carbon nanotubes or holographic memory.

As if the problems we identified with excessive power draw and memory inadequacies weren't enough, the panel also found that lowering the operating voltage, as we presumed was necessary, would make the transistors prone to new and more-frequent faults, especially temperature-induced transient glitches. When you add this tendency to the very large number of components projected—more than 4 million chips

IEEE Spectrum | Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page | Qmags THE WORLD'S NEWSSTAND®

with almost a billion chip contacts—you have to worry about the resiliency of such systems. There are ways to address such concerns, but most solutions require additional hardware, which increases power consumption even further.

So ARE exaflop computers forever out of reach? I don't think so. Meeting DARPA's ambitious goals, however, will require more than the few short years we have left before 2015. Success in assembling such a machine will demand a coordinated cross-disciplinary effort carried out over a decade or more, during which time device engineers and computer designers will have to work together to find the right combination of processing circuitry, memory structures, and communications conduits—something that can beat what are normally voracious power requirements down to manageable levels.

Also, computer architects will have to figure out how to put the right kinds of memory at the right places to allow applications to run on these systems efficiently and without having to be restarted constantly because of transient glitches. And hardware and software specialists will have to collaborate closely to find ways to ensure that the code running on tomorrow's supercomputers uses a far greater proportion of the available computing cores than is typical for supercomputers today.

That's a tall order, which is why I and the other DARPA panelists came away from the study rather humbled. But we also found a greater understanding of the hurdles, which will shape our research for many years to come. I, for example, am now exploring how new memory technologies can reduce the energy needed to fetch data and how architectures might be rearranged to move computation to the data rather than having to repeatedly drag copies of that data all around the system.

Perhaps more important, government funding agencies now realize the difficulties involved and are working hard to jump-start this kind of research. DARPA has just begun a program called Ubiquitous High Performance Computing. The idea is to support the research needed to get both very compact high-performance computers and rack-size supercomputers built, even if bringing a warehouse full of them together to form a single exaflops-class machine proves to be prohibitive. The hope is to be able to pack something equivalent to today's biggest supercomputers into a single truck, for example. The U.S. Department of Energy and the National Science Foundation are funding similar investigations, aimed at creating supercomputers for solving basic science problems.

So don't expect to see a supercomputer capable of a quintillion operations per second appear anytime soon. But don't give up hope, either. If rack-size high-performance computers do indeed become as ubiquitous as DARPA's new program name implies they will, a widely distributed set of these machines could perhaps be made to work in concert. As long as the problem at hand can be split up into separate parts that can be solved independently, a colossal amount of computing power could be assembled—similar to how cloud computing works now. Such a strategy could allow a virtual exaflops supercomputer to emerge. It wouldn't be what DARPA asked for in 2007, but for some tasks, it could serve just fine. ❑

TELL US WHAT YOU THINK at http://spectrum.ieee.org/exaflops0211.

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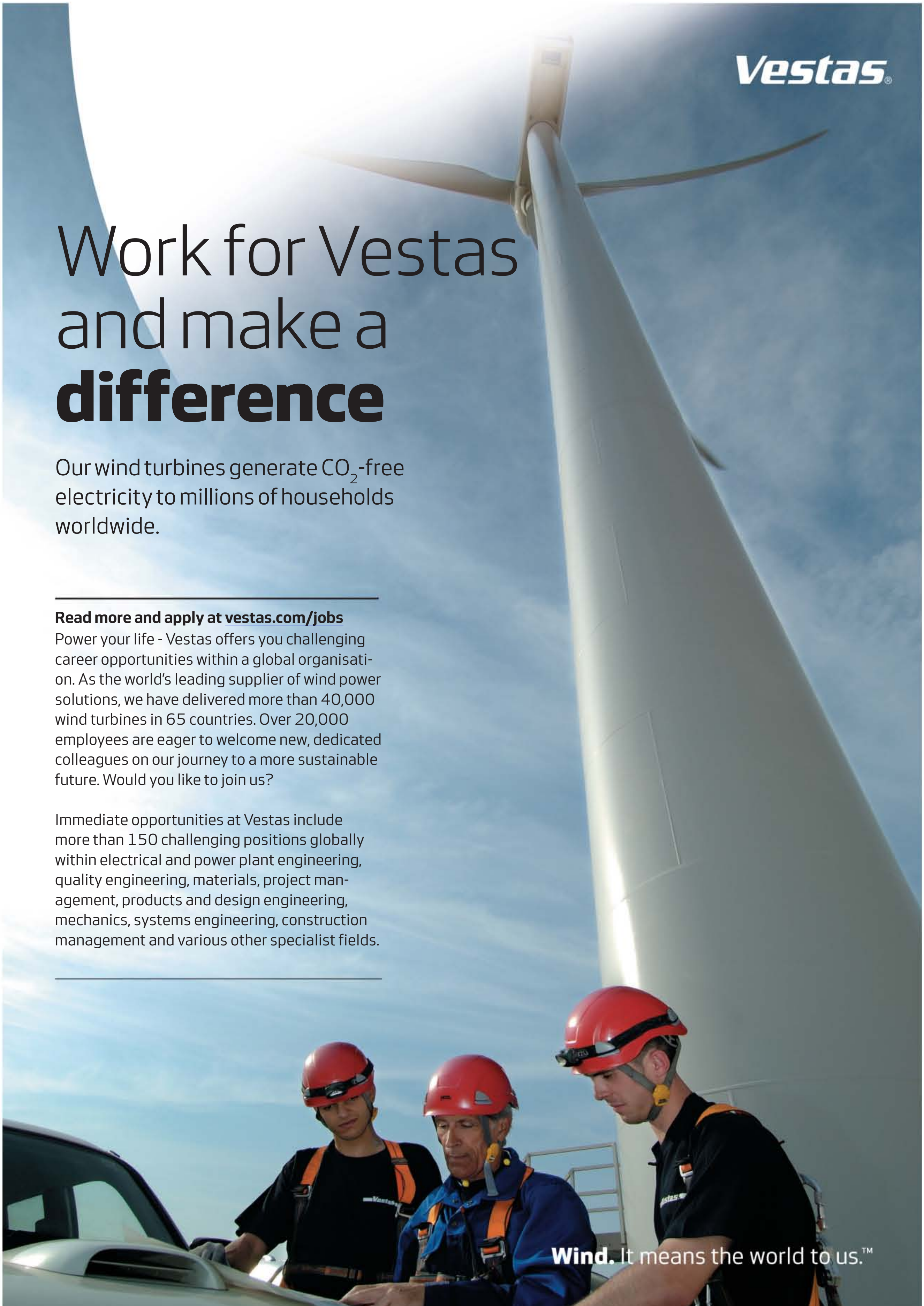
Interested candidates should submit all materials online:

http://www.pi.ac.ae/jobs

The deadline for application is 1st March 2011.

Only short-listed applicants will be notified.
Successful applicants should be available to take up post in the 2011-2012 academic year.

IEEE spectrum Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®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UNIVERSITÄT DES SAARLANDES

Saarland University is seeking to establish several

Junior Research Groups

(W1/W2)

within the Cluster of Excellence "Multimodal Computing and Interaction" which was established by the German Research Foundation (DFG) within the framework of the German Excellence Initiative.

M²CI CLUSTER OF EXCELLENCE

The term "multimodal" describes the different types of digital information such as text, speech, images, video, graphics, and high-dimensional data, and the way it is perceived and communicated, particularly through vision, hearing, and human expression. The challenge is now to organize, understand, and search this multimodal information in a robust, efficient and intelligent way, and to create dependable systems that allow natural and intuitive multimodal interaction. We are looking for highly motivated young researchers with a background in the research areas of the cluster, including algorithmic foundations, secure and autonomous networked systems, open science web, information processing in the life sciences, visual computing, large-scale virtual environments, synthetic virtual characters, text and speech processing and multimodal dialog systems. Additional information on the Cluster of Excellence is available on **http://www.mmci.uni-saarland.de**. Group leaders will receive junior faculty status at Saarland University, including the right to supervise Bachelor, Master and PhD students. Positions are limited to five years.

Applicants for W1 positions (phase I of the program) must have completed an outstanding PhD. Upon successful evaluation after two years, W1 group leaders are eligible for promotion to W2. Direct applicants for W2 positions (phase II of the program) must have completed a postdoc stay and must have demonstrated outstanding research potential and the ability to successfully lead their own research group. Junior research groups are equipped with a budget of 80k to 100k Euros per year to cover research personnel and other costs.

Saarland University has leading departments in computer science and computational linguistics, with more than 200 PhD students working on topics related to the cluster (see **http://www.informatik-saarland.de** for additional information). The German Excellence Initiative recently awarded multi-million grants to the Cluster of Excellence "Multimodal Computing and Interaction" as well as to the "Saarbrücken Graduate School of Computer Science". An important factor to this success were the close ties to the Max Planck Institute for Informatics, the German Research Center for Artificial Intelligence (DFKI), and the Max Planck Institute for Software Systems which are co-located on the same campus.

Candidates should submit their application (curriculum vitae, photograph, list of publications, short research plan, copies of degree certificates, copies of the five most important publications, list of five references) to Conny Liegl, Cluster of Excellence, Campus E1 7, 66123 Saarbrücken, Germany. Please, also send your application as a single PDF file to **applications@mmci.uni-saarland.de**.

The review of applications will begin on February 18, 2011: all applicants are strongly encouraged to submit applications by that date. Final decisions will be made following a candidate symposium that will be held in the week of March 21 – 25, 2011.

Saarland University is an equal opportunity employer. In accordance with its policy of increasing the proportion of women in this type of employment, the University actively encourages applications from women. For candidates with equal qualification, preference will be given to people with physical disabilities.

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY POSITIONS IN **Electronic and Computer Engineering**

The Department of Electronic and Computer Engineering at the Hong Kong University of Science and Technology invites applications for faculty positions at the rank of Assistant Professor. Applicants should have a PhD with demonstrated strength in research and commitment to teaching. We are particularly interested in qualified applicants with relevant research experience in areas related to Analog IC and also Energy. In the area of Analog IC, experience in RFIC would be an advantage. In the area of Energy, experience in Smart Grids or other system related aspects of Energy would be an advantage. Outstanding candidates at the Professor and Associate Professor ranks may also be considered for these positions on an exceptional basis.

The Hong Kong University of Science and Technology is a truly international university in Asia's world city, Hong Kong, and its Engineering School has been consistently ranked among the world's top 25 since 2004. The high quality of our faculty, students and facilities provides outstanding opportunities for faculty to develop highly visible research programs. All formal instruction is given in English and all faculty members are expected to conduct research and teach both undergraduate and graduate courses. The Department has excellent computing resources, state-of-the-art teaching and research laboratories and currently has about 40 faculty members, 800 undergraduate students and 350 postgraduate students. The Department is an equal opportunity employer.

Starting rank and salary will depend on qualifications and experience. Fringe benefits including medical and dental benefits, annual leave and housing will be provided where applicable. Initial appointment at Associate Professor and Assistant Professor ranks will normally be on a three-year contract. A gratuity will be payable upon successful completion of contract. Re-appointment will be subject to mutual agreement.

Applications including full curriculum vitae, list of publications, names of five referees addressed to: Professor Hoi Sing Kwok, Chairman of Search Committee should be sent by email to **eesearch@ust.hk**. Applications will be considered until all the positions are filled.

More information about the Department is available on the website **http://www.ece.ust.hk/**.

(Information provided by applicants will be used for recruitment and other employment-related purposes.)

ieee spectrum Previous Page | Contents | Zoom in | Zoom out | Front Cover | Search Issue | Next Page Qmags THE WORLD'S NEWSSTAND®

the data

Germany Leads the PV Market—for Now

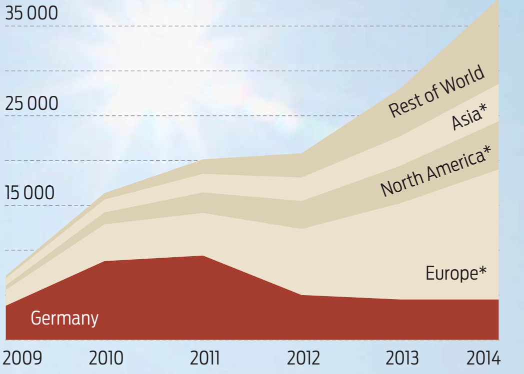
THANKS LARGELY to hefty government support, Germany's solar market has become the largest in the world. Germany has installed half the world's solar power every year since 2007, adding 8.8 gigawatts in 2010 alone. The trend is expected to continue in 2011, with German installations providing nearly half the world's 20 new gigawatts, according to data provided by research and analysis firm iSuppli Corp. and confirmed by other analysts.

But things could get shaky in 2012. Revisions to the country's Renewable Energy Sources Act are due in mid-2011. If the powers that be decide to cut "feed-in" tariffs—which encourage homeowners to add their unused alternative energy to the grid—it will put the brakes on Germany's solar surge.

New photovoltaic output is projected to continue growing globally over the next five years, as other key markets offset the relative decline in Germany. Leading the pack will be Italy and the United States. The U.S. market alone will rise almost tenfold, from less than half a gigawatt in 2009 to more than 4 GW in 2014, according to iSuppli. Japan will lead a fivefold increase in Asia. The European Photovoltaic Industry Association also foresees fresh demand from markets such as Canada, China, Greece, India, and the United Kingdom. According to Solarbuzz's 2010 industry report, "even in the slowest growth scenario, the global market will be 2.5 times its current size by 2014."

—Prachi Patel

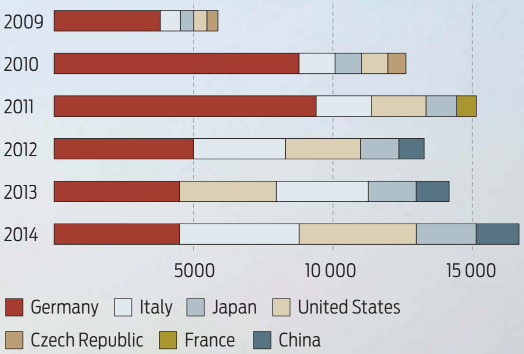
GLOBAL NEW PHOTOVOLTAIC INSTALLATIONS (MEGAWATTS)



***Asia:** China, Japan, and Korea; **Europe:** Belgium, Bulgaria, Czech Republic, France, Greece, Italy, Spain, and UK; **North America:** Ontario and United States. Data for 2010 to 2014 are projections.

TOP 5 COUNTRIES FOR NEW PV INSTALLATIONS

ANNUAL RANKINGS (MEGAWATTS)



Source: iSuppli

SOLAR SURGE: Photovoltaic output is growing quickly, but not everywhere and not at the same rate. *PHOTO: GETTY IMAGES*


F-35
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