ieee spectrum
THE MAGAZINE OF TECHNOLOGY INSIDERS
02.09

SPECIAL REPORT

DREAM JOBS '09

SOME PEOPLE GET PAID TO HAVE FUN. WE MET 10 OF THEM. HERE ARE THEIR STORIES

Shannon Bruzelius masters a blaster at Wild Planet Toys

IEEE
Celebrating 125 Years
of Engineering the Future

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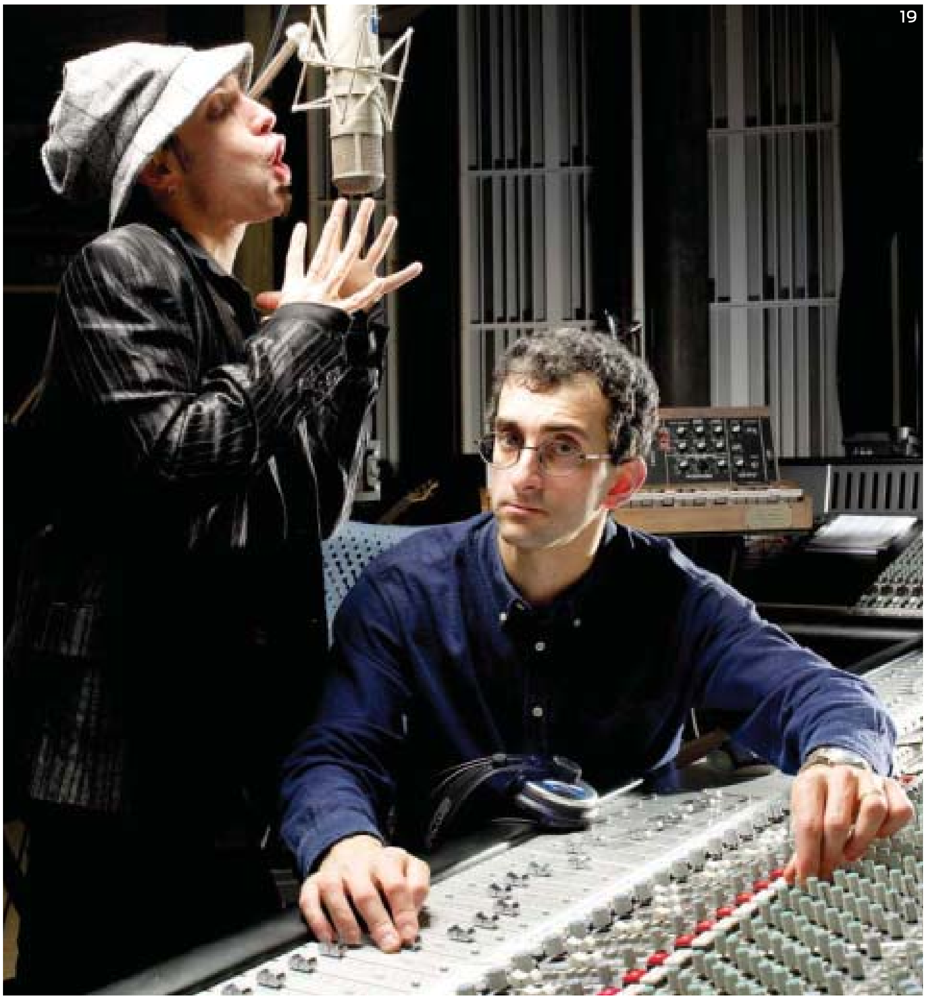

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STUDIO ARTIST: Sound engineer Marco Migliari mans the boards at Real World Studios while Gadi, lead singer for the Moonfish, does his thing.

SPECIAL REPORT

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Crafting clever toys, making beautiful music, lighting up the South Pacific—the 10 technologists in our special report have engineered exciting careers that meld their passions with their professions.

36 TECH TITANS BUILDING BOOM

Google, Microsoft, Amazon, and others are racing to build computer facilities that can power the next generation of Internet applications. *By Randy H. Katz*

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The switch to digital TV is prompting people to take a new look at antennas. What they find may surprise them. *By Richard Schneider & John Ross*

COVER: TIMOTHY ARCHIBALD

THIS PAGE: ROSS KIRTON

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OPINION

DEPARTMENTS

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LEFT: DAIMLER; RIGHT: PNC/GETTY IMAGES

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AVAILABLE ONLINE 1 FEBRUARY

CARWARE

Did you know that your car probably has more software running in it than the latest military fighter jets? Or that it has 50 or more embedded microprocessors that control everything from meeting governmental emission-control standards to automatically increasing the volume of your radio as you drive faster? This month, *IEEE Spectrum* Contributing Editor Robert N. Charette looks at the growth of software technology in cars, from the single microprocessor chip in the 1977 GMC Oldsmobile Tornado to today's S-Class Mercedes, which has as many microprocessors as the new Airbus A380. He also looks at how software is changing cars—and drivers' interactions with their driving environment.

ONLINE FEATURES:

THE DRAM BAILOUTS: The governments of Germany and Taiwan have stepped in to keep their DRAM industries from collapsing. Get the inside story from reporters on the ground in both countries.

FOR YOUR EARS ONLY: In our exclusive podcast series, Dream Jobbers from all four corners of the globe talk to *IEEE Spectrum* reporters about what makes their engineering jobs so compelling.

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FIRST IEEE GREEN CONFERENCE

IEEE will host its first Green Technology Conference, to be held 16 and 17 April in Lubbock, Texas. Topics include emerging technologies in renewable energy sources, alternative vehicular power sources, and energy-usage reduction.

CD MILESTONE

The CD marked the start of the worldwide development of consumer digital optical recording and reproduction equipment. That's why the CD will be recognized with an IEEE Milestone in Electrical Engineering and Computing at a ceremony on 6 March at the Philips Research High Tech Campus, in Eindhoven, Netherlands.

NETWORK ATTACKS

Attacks on computer networks are on the rise. A white paper titled "The Global Pandemic—The Silent Threat," presented at the recent IEEE Globecom 2008 conference explains how millions of computer systems are being compromised and what can be done to reduce these attacks.

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back story

Coming of Age in Fiji

SANDRA UPSON

IF YOU'RE a fan of our profiles, you've probably noticed a pattern: Early on, they mention degrees earned from vaunted institutions and then describe illustrious steps on the road to the top. The subject's grade school days, by contrast, tend to evoke skirmishes with acne and squeaky-voiced humiliations. So when Associate Editor Sandra Upson visited Arieta Gonelevu in Fiji for this year's Dream Jobs report, she wasn't expecting to end up at the energy specialist's rather epic high school reunion.

In October, hundreds of alumnae descended upon the campus of the all-girls Adi Cakobau School, outside Suva, the capital of Fiji, for the academy's 60th anniversary. Dressed identically by graduating class, the women met on a central lawn ringed with palm trees. A yellow-clad group of graduates unfolded pages of newspaper on the grass and arranged themselves next to a floral-print cluster of women. Gonelevu's classmates, in mauve skirts and blouses, sat daintily on their shoes. The head of the school began speaking from a podium. Under the intense noon sun, the Old Girls of Adi Cakobau chatted quietly in Fijian and watched frogs hop over their feet.

An SUV with pure black windows drove up a side road and onto the grass. The field fell into a hush. Ratu Josefa Iloilo, the 88-year old president of Fiji, emerged from the vehicle and tottered up to a dais on the arm of a guard. "At first I was startled," Upson recalls, noting that Iloilo had been deposed in a military coup d'état in December 2006. "Then someone explained that Fiji's military dictatorship had effectively cleared the president of all responsibilities," allowing him to return nominally to office. A group of boys from a neighboring school, ceremonially bare-chested and wearing grass skirts, presented Iloilo with gifts: a pig wrapped in leaves, mats woven from pandanus leaves, and several bowls of kava, the tranquilizing drink that forms the backbone of Fijian social gatherings, which he obediently consumed.

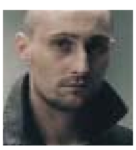
Later, with the speechifying done and the president off in his giant black car, Gonelevu and her friends danced in a procession and sang school songs. Mindful of her guest, Gonelevu soon left the reunion to show Upson solar panels that she'd installed long ago at a nearby farm. It was a first step for her as a professional, on a road less traveled. ❑

CITING ARTICLES IN IEEE SPECTRUM

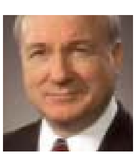
IEEE Spectrum publishes two editions. In the international edition, the abbreviation INT appears at the foot of each page. The North American edition is identified with the letters NA. Both have the same editorial content, but because of differences in advertising, page numbers may differ. In citations, you should include the issue designation. For example, the first Update page is in *IEEE Spectrum,* Vol. 46, no. 2 (INT), February 2009, p. 7, or in *IEEE Spectrum*, Vol. 46, no. 2 (NA), February 2009, p. 9.

contributors

RANDY H. KATZ, an IEEE Fellow, is a professor of electrical engineering and computer science at the University of California, Berkeley. His current interest is the architecture of Internet data centers. In "Tech Titans Building Boom" [p. 36], he describes how engineers are increasing the density of servers in a facility by more than tenfold. He's still trying to get a peek at Google's mega data center in Oregon.



ROSS KIRTON photographed sound engineer Marco Migliari, backed by progressive Brit-rock band the Moonfish, for Dream Jobs [p. 20]. "We didn't want it to look like Marco was the band's manager," Kirton says, so he placed Migliari in front of the mixing board, with the musicians on a platform behind him. The London-based photographer's work has appeared in the UK editions of *Vogue*, *GQ*, and *Vanity Fair*.



JAMES E. LUKASZEWSKI explores the challenges of relating to upper management in "Managing Your Boss's Boss" [p. 13]. A corporate consultant and author of *Why Should the Boss Listen to You? The Seven Disciplines of the Trusted Strategic Advisor* (Jossey-Bass, 2008), he coaches IEEE's incoming volunteer leadership each year.

THE MOONFISH took a three-day break from its Italian tour to come to England for a photo session with the band's sound engineer Marco Migliari [p. 20]. Bassist and singer Gadi says Migliari is "like a fifth member of the band. He understands us and pinpoints our ideas, which a producer needs to do with a bunch of messy lads like us!" For more on the band, go to http://www.myspace.com/themoonfish.

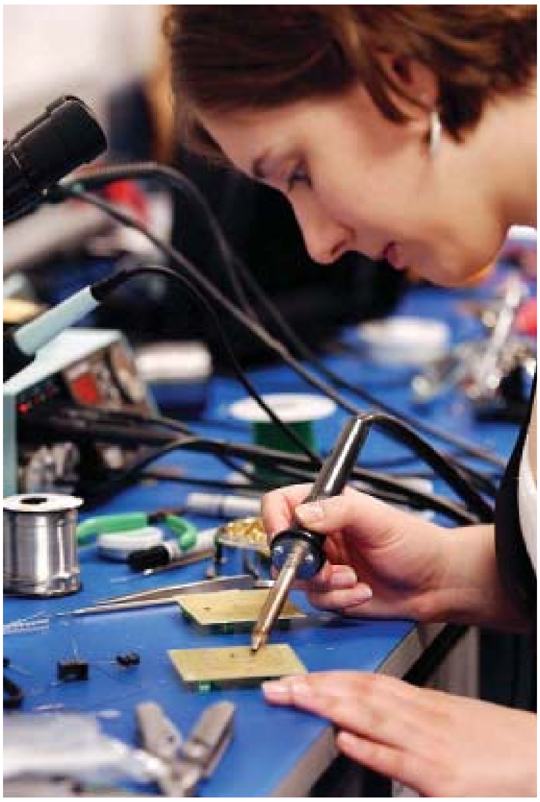
JOHN ROSS & RICHARD SCHNEIDER explain why this month's planned conversion to all-digital television broadcasts in the United States has sparked a revolution in antenna design. Ross, an IEEE senior member and coauthor of "Antennas for the New Airwaves" [p. 40], consults on antenna design and RF electromagnetics. His home antenna is an old prototype ClearStream1 that sits on a bookshelf and receives 24 digital stations from the Salt Lake City area. Coauthor Schneider, president and founder of St. Louis–based Antennas Direct, uses a ClearStream4 antenna mounted on his roof to receive over 20 stations, including a half dozen from Columbia, Mo., some 160 kilometers away.

GISELLE WEISS is a freelance writer based in Basel, Switzerland. In Dream Jobs, she profiles Philippe Lauper, project manager for a team building a solar-powered airplane designed to circumnavigate the globe [p. 34]. This is the second time that Weiss has written about the project for *IEEE Spectrum*. In 2004, she interviewed one of its leaders shortly after the effort got under way. Back then, she says, "You could actually get [cofounder] Bertrand Piccard at home at night on the phone." These days the project is a bigger, glossier enterprise, but the challenge of getting the plane in the air remains—to say nothing of getting Piccard on the phone.

CLOCKWISE FROM TOP LEFT: PEG SKORPINSKI; MITCHELL WEISS; ROSS KIRTON; THE LUKASZEWSKI GROUP; ZANNA spectral lines

The 21st-Century Engineer

Our Dream Jobbers provide a glimpse into why it's an exciting time to work in engineering



JOHN NORDELL/THE CHRISTIAN SCIENCE MONITOR/GETTY IMAGES

IN THE popular imagination, all engineers are Dilbert: socially stunted idiot savants who sit in cubicles all day, fiddling with numbers on a computer. Part of the problem is that the gulf between technologists and the general public has never been greater. As technologies have become sophisticated to the point of boggling the mind, mainstream press outlets, particularly in the West, have reacted mostly by marginalizing thoughtful technology coverage.

Five years ago we started the Dream Jobs series—back again in this issue—to challenge the stereotype of who engineers are and what their work worlds are like. Like many engineers, our Dream Jobbers have fun at work: They've found ways to live for their work and not just work for a living, often by combining their passions and interests with a paycheck.

Dream Jobs is also our way of celebrating National Engineers Week, which takes place in the United States every February. EWeek, as it's called, is one of a number of activities developed by the U.S. National Engineers Week Foundation to promote engineering education and careers. The foundation and many other organizations—IEEE foremost among them—are working hard to help young people understand the value of engineering education in a world that depends utterly on technology developments for its economic growth, environmental health, and social well-being.

Although we don't aim our profiles at youngsters, every year we get letters of appreciation from grade school educators who tell us that they use the coverage to inspire their students. We get requests for digital and print copies of the Dream Jobs issue from teachers around the globe.

Engineering education has been a priority in the United States for decades. Even so, there's lots to be done. Most engineering students are bombarded with abstractions for a long time before they get a sense of what they'll be doing with their newly developed analytical skills. They sweat through lectures on device physics, circuit analysis, and feedback without ever being told that these are the fundamental concepts behind hi-fi stereo amplifiers. They're expected to absorb the basics of Boolean logic and MOS semiconductors without knowing that these underpin all modern computers. In other words, students don't get an idea of the big picture, let alone a sense of the value of the work they'll be doing. Experimental schools like the Frank W. Olin College of Engineering, in Needham, Mass., where students get to tackle design work almost immediately, are the exception rather than the rule. In addition, at most engineering schools, there's relatively little emphasis on the development of communication skills, languages (no, we're not talking about C++ here), or management and leadership skills.

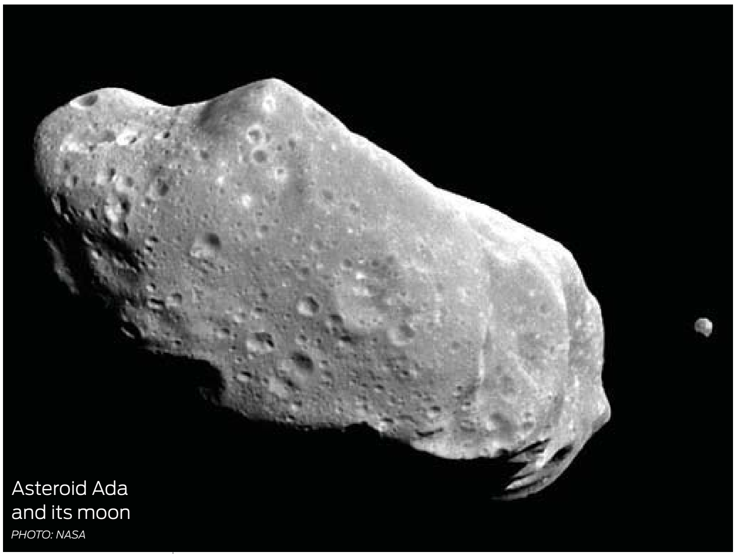
And then there's that image issue. Although people think of engineering as the engine behind economic growth, they often fail to realize its contributions to improving health care, the environment, and our overall quality of life.

Entry-level positions in engineering and technology also pose a challenge. These jobs should be as rewarding and stimulating as possible if newly minted engineers are to be persuaded to stick things out and make a career of it rather than jumping ship at the first opportunity for more money in some other industry.

People pursue technology for a living because they are passionate about making things, making things better, and making a difference in the world. Today's engineers also need to be quick, nimble, and able to learn new things all the time. They need the knowledge to tackle classical engineering problems but also the sensitivity to understand the social impact of technology on people and the environment. They need the sophistication to be able to work in multidisciplinary settings with people from faraway places and with notably different cultural beliefs. Nowadays, especially, they should have some understanding of the business side of technology.

It's a lot to ask of any one person, of course. But as our profilees in this issue would attest, the psychological rewards—the only ones that really matter—can be very great. —SUSAN HASSLER

forum


Asteroid Ada and its moon
PHOTO: NASA

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NAME THAT PLANETOID!

THE STORY "A Rock Named Judy" [Careers, December] on the naming of minor planets (asteroids) for winners of science competitions mentioned the Intel-sponsored competitions run by the former Science Service, now the Society for Science and the Public. The program was established a number of years ago by the MIT Lincoln Laboratory to use as part of an effort to encourage science and engineering education. MIT Lincoln Laboratory has discovered the largest number of minor planets, and with all those discoveries has come the right to name them. The lab reports the names to the Minor Planet Center of the International Astronomical Union.

Grant Stokes, now head of the Aerospace Division at the MIT Lincoln Laboratory and an IEEE senior member, was the key figure in establishing this program. More information can be found on the MIT Lincoln Laboratory Web site, at http://www.ll.mit.edu/outreach/ceres.html.

ROGER W. SUDBURY
MIT Lincoln Laboratory
Cambridge, Mass.

WHAT PRICE CONVERSION?

I WAS INTRIGUED by "A Poor Man's Tesla" [Hands On, December]. In comparison with the Tesla, the electrified Porsche 914 weighs 100 percent more. The 914 also has only 60 percent of the Tesla's range, 20 percent of the acceleration (0 to 100 kilometers per hour), and 23 percent of the power. Now consider the power-to-weight ratio, which is a more useful measure of performance. And to make it as useful as possible, compute the power while the vehicle is within a range of speed used for passing—say, from 85 km/h to 115 km/h. I don't know about you, but based on these figures I'd rather drive the Tesla.

And the price? The 914 is cheap only if all the costs—labor, overhead, and so on—are excluded. Suppose it takes one skilled electro-mechanical engineer/machinist 2000 hours to convert the 914. If you value his/her time conservatively at US $50 per hour, then the cost of the labor alone is $100 000. So the complete cost of the conversion would be $160 000. Thus, the 914 costs 52 percent *more* than the Tesla and has considerably lower performance.

Of course, somehow we must factor in the pedagogical value. Still, I'll take the Tesla any day. Whatever the electric 914 might be, it's not a *poor man's* Tesla.

IAN PATTERSON
IEEE Senior Member
Montreal

Coauthor David Schneider responds: Here's why the proposition of converting a 914 might not be so terrible. First, we made an error in the table: The approximate weight given for the Porsche is in pounds, not kilograms. So both cars weigh about the same. The Porsche 914 is a popular model for an electric conversion because you can buy a kit that comes with all the components, which means that the hard engineering has already been done. It might take a few weeks or more of full-time work for the conversion, depending on one's skill level and work style, but not 2000 hours. I agree that the Tesla is a much more desirable car. But if all you wanted was a cute electric sports car, converting a 914 using either relatively inexpensive lead-acid or lithium-ion batteries might well be an attractive proposition.

MEMRISTOR MECHANICS

I AVAILED MYSELF of a quiet Sunday afternoon to read R. Stanley Williams's article "How We Found the Missing Memristor" [December]. A question occurred to me when I read Williams's analogy in which he compares the oxygen deficiencies in titanium dioxide to bubbles in a glass of beer (good choice!). As Williams explains it, the key to the memristor's switching mechanism is the polar attraction of migrating oxygen atoms and switching molecules. So my question is, has anyone actually tested how the memristor behaves in situations where there is no oxygen, for example in a deep vacuum, or while undergoing extreme temperature variations? Unless the device is totally stable across a wide spectrum of environmental conditions, the device will never be suitable for use in space or other extreme environments.

ROBERT C. SCHROEDER
IEEE Member
Overland Park, Kan.

update

more online at www.spectrum.ieee.org

Technology vs. Pirates

Unmanned aircraft may be the best bet to fight Somalian piracy

OVER THE past few months, the popular image of pirates has morphed from drunken swashbuckler to Somali bandit, as raiders in the Gulf of Aden, off the Indian Ocean, have brazenly taken on larger targets—like the oil tanker *Sirius Star*—and more of them. During the first nine months of 2008, there were more than 120 pirate attacks off East Africa, compared with 60 in 2007 and 13 in 2004, according to the International Maritime Organization. Military missions haven't succeeded at stemming piracy so far, but could there be a technological fix?

Combating pirates has proved tricky for several reasons. The sheer length of the Somali coastline—just over 3000 kilometers—makes it hard to cover. Pirates typically operate from mother ships resembling legitimate fishing vessels, from which the bandits send out speedboats. This allows the pirates to cover a huge area and to capture ships far from the coast. Also, the merchant vessels they target often have small crews and don't see the pirates coming until it's too late.

Because the 4 million square kilometers of ocean off Somalia make up an area far too large for a navy to guard by ship, Rand Corp. senior analyst Peter Chalk argues that ship crews should take steps to protect themselves. First, ships should increase the size of their crew, which would help spot pirates early enough to evade them or to call for help. But there are also nonlethal technologies that can make boarding a ship more difficult, such as putting an electric fence around its perimeter or equipping the ship with high-pressure fire hoses.

Cruise ships have succeeded in keeping pirates at bay by using long-range acoustic crowd-control devices, such as those made by HPV Technologies, based in Costa Mesa, Calif. When a vessel's crew spots an unidentified ship, the device's operator tries to fend off the ship with an amplified verbal warning. If the warning goes unheeded, the crew can blast the ship with an excruciatingly painful noise. Such devices, depending on

EASY TARGETS: Pirates seized this fishing vessel and forced it to Somalia last November. Experts say shipboard technology and unmanned aerial patrols can help prevent piracy.
PHOTO: JASON R. ZALASKY/ U.S. NAVY/GETTY IMAGES

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update

their size (and cost), have a range of 0.4 to 16 km, says Vahan Simidian II, chief executive officer of HPV.

Martin Murphy, a piracy expert and senior fellow at the Center for Strategic and Budgetary Assessments, in Washington, D.C., says his pick for a technology solution is surveillance by unmanned aerial vehicles (UAVs): "They're small and difficult to detect. They can stay up for many hours, and their loops can cover very large areas." UAVs could get a picture of activity in the area and pick out patterns, potentially making a naval mission more effective, Murphy says.

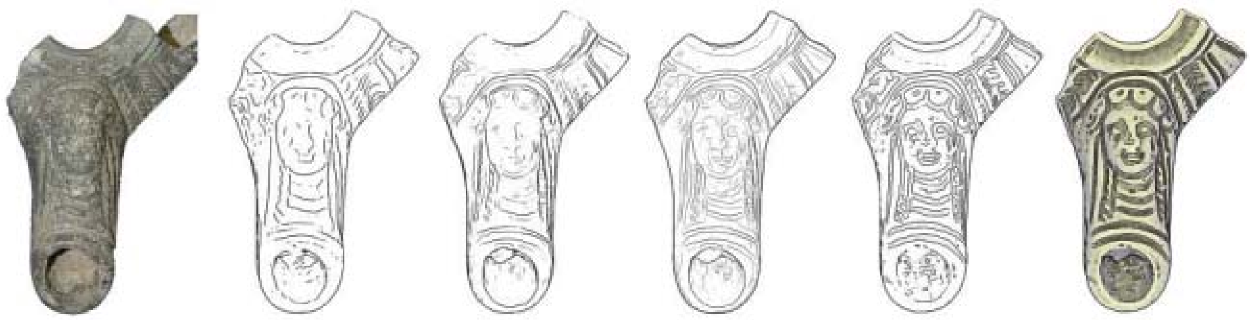
But not just any UAV will do. The aircraft that would probably work best to survey the Gulf of Aden would need to communicate by satellite instead of via a local base station as many craft do, says William Semke, a UAV researcher and associate professor of mechanical engineering at the University of North Dakota. He thinks that the ScanEagle, made by Insitu, in Bingen, Wash., is close to what's needed, because it has demonstrated more than 20 hours and 2000 km in flight without refueling. Semke estimates that the aircraft's camera could spot a human on a boat at about 32 km, so one vehicle could potentially survey about 64 000 km² in a day.

At about US $120 000 per plane, "it's not a cheap and easy thing to do, but it could still be cost-effective compared to other solutions" like manned aircraft surveillance, says Semke. Despite the use of UAVs in Iraq and Afghanistan, the technology is still relatively new, and many kinks would need to be worked out before the planes could start patrolling the oceans.

The main problem, says Semke, is that UAVs cannot sense objects in their path and thus avoid collisions with things like commercial airplanes or a flock of birds. A potential solution is to add a forward-looking radar or infrared system, he says, but this technique has not been perfected.

—Monica Heger

LOW TECH: Ships have few options beyond holding off pirates with high-pressure hoses. PHOTO: PO LUIGI COTRUFO/NATO/REUTERS



Relief for Digital Relics

When archaeologists swap tales from the field, they tend to use hand-drawn images of relics. But hand drawings can be time-consuming, expensive, and rife with error. Three-dimensional laser scans are beginning to gain traction, but without additional analysis, a 3-D scan can miss meaningful details, especially after it's reduced to a 2-D image. Automatically tracing an object's curves helps. The question is how to identify the best curves to trace.

One technique traces the ridges and valleys defining each bump on a surface [third from left]; another finds features by analyzing how a silhouette changes with small shifts in perspective [third from right]. A group of computer scientists at the Technion-Israel Institute of Technology and the University of Haifa, in Israel, has found a new set of curves to make 3-D scans really pop [far right]. Known as demarcating curves, these lines capture the strongest points of transition between a ridge and a valley. Here, a fragment of a Hellenistic lamp from between 150 and 50 B.C.E. becomes clear.

MICHAEL KOLOMENKIN, ILAN SHIMSHONI & AYELLET TAL

Commercial Communications Satellites for the Moon

NASA wants a for-profit network to support lunar missions

NASA is planning to rely on commercial communications and navigation services to support missions to the moon in the next decade, say engineers at Johnson Space Center, in Houston. The network, consisting of moon-orbiting satellites and ground stations on Earth, would initially serve robotic lunar missions by NASA, other governments, and private ventures. It would expand to provide 70 percent of the communication requirements for human space missions by the end of 2020, according to NASA documents. The network is especially needed for future low-power sensors on the moon and to reach lunar areas not directly visible from Earth or Earth-orbiting satellites, such as the moon's farside and the insides of craters at its poles.

Lead engineer Rob Kelso says NASA has already begun discussions with satellite communications industry experts to figure out the bandwidth and system architecture requirements needed for such a network. However, at this point, NASA is focused on the business structure of the network and finding "a mutually acceptable approach to balancing investment, commitment, and risk," says Kelso.

NASA could take a number of paths toward a commercial moon network, but according to Kelso the agency is leaning toward using satellite communications firm Intelsat as a model. With its fleet of more than 50 orbiters, Intelsat is now the largest commercial satellite operator in the world. The company began as an intergovernmental organization serving its member nations and was privatized in 2001. The U.S. government would be a major stockholder in the new lunar-network company, and the corporation would choose and develop the technology to serve its customers. NASA engineers have dubbed the entity LunaCorp. (A firm carrying that name once planned private robotic moon rovers, but it was disbanded in 2003.)

NASA would still directly develop basic low-data-rate systems for voice, biomedical data, vehicle safety, and health monitoring functions. But LunaCorp would augment that with high-data-rate services for telemetry, navigation, video, science data, surface-to-surface communications, and biomedical imaging. Kelso says that as a safety net, the space agency would retain the right to buy out LunaCorp.

Judging by the slew of comments and studies submitted to NASA regarding the privatization proposal, commercial communications and navigations suppliers are interested but wary. Industrial leaders recognize that "their future does include servicing markets on the moon," according to a study by Jon Michael Smith written for Wyle Laboratories, in El Segundo, Calif. But for LunaCorp or some other form of private lunar communications scheme to take off, NASA needs to "make an early long-range commitment to buy commercial lunar high-data-rate services—and agree not to compete with industry on this capability," writes Smith. —James Oberg

JACK AMBROSE/GETTY IMAGES

news briefs

NANO-DREADLOCKS
Harvard University scientists admit being distracted by the appearance of the helical nanometer-scale bristles they've made. "Often we would stop the scientific discussion and argue about mythology, modern dreadlocks, alien creatures, or sculptures," says materials scientist Joanna Aizenberg. But the self-assembling bristles are for more than just aesthetics. They could lead to better adhesives, optical components, and drug-delivery devices, say the scientists.

PHOTO: AIZENBERG LAB/HARVARD SCHOOL OF ENGINEERING AND APPLIED SCIENCES

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WORKING IN TANDEM: Engineers are teaching robocopters to cooperate. PHOTOS: TU BERLIN

update

Robocopters Unite!

Robotic helicopters divide and conquer to tackle tough tasks together

THE METER-LONG helicopters lined up under the fluorescent lab lights at the Berlin Technical University might look like overgrown toys, but they've got a little more under the hood. These are flying robots. They take off, land, and scout terrain autonomously and are being wired to deploy ad hoc communications sensor networks. And unlike any other robocopters, they can work together.

Researchers expect they'll be used to distribute sensors that would help coordinate firefighting efforts or search flood zones, to track or find people and vehicles, or to shoot movies and cover sports events. Hoisting communications gear, they could one day help channel radio, Wi-Fi, or mobile phone traffic where infrastructure has been wiped out by an earthquake or other natural disaster.

Several groups around the world are working on miniaturized robot helicopters with advanced intelligence, notably in California, South Carolina, the Netherlands, South Korea, and the UK. But the Berlin team believes it is the first to write software and build systems that get multiple robot copters to collaborate. The project brings together a half-dozen institutions and companies from across Europe.

The copters' control systems allow small craft to work together in lifting loads and scouting environments. Coordinated, the copters can lift weights that would normally require larger, exponentially more expensive machines. Estonian robotics engineer Konstantin Kondak, a professor at TU Berlin and

one of the project's leaders, says that having three or four copters in the air, each sharing the load while tethered by a rope to a single object, creates too many contrary forces for a set of human pilots to handle: "If you try to do this flying manually, it is not a stable system. You have to correct at all times; it's too much." But autonomous robots, making instant and coordinated adjustments, can do the job, he says.

Each robot must account for the location of the other helicopters, the forces coming from them, and the load on the rope, to jointly lift something. The helicopters' coordination comes from a system that integrates four software modules for stabilizing the copter: one for navigation, one for exploration, one for obstacle avoidance, and one for processing orientation, horizon, and position.

The robocopters are good for much more than just lugging things around. Project manager Aníbal Ollero, a professor of engineering and automated systems at the University of Seville, in Spain, says that a flexible, easy-to-transport team of choppers makes for more efficient scouting because they automatically divide an area among themselves.

They're also faster at another important task: deploying distributed communications networks by dropping off sets of tiny sensor nodes. These nodes combine a data processor, a radio, a battery, and—depending on what needs measuring—temperature, light, radiation, location, or chemical sensors. For the autocopter project, off-the-shelf nodes from wireless-sensor firms Crossbow Technology and Ambient Systems were optimized and linked by data-routing experts at universities in Stuttgart, Germany, and Twente, Netherlands. Just a few centimeters across and 7 millimeters thick, the individual nodes transmit over a range of just 25 meters, but as a network they pass radio messages to one another to get to a central unit (or hovering robocopter). Hundreds of thousands of these nodes could be distributed by robot to survey a forest fire or flood zone for rescue efforts, according to the researchers.

Final trials for the project get under way, far from the Berlin winter—this spring in southern Spain, Ollero says. If all goes well, helicopters will deploy a sensor network, track mobile objects and people, follow movement inside and outside of buildings, and capture it all with high-end airborne cameras.

—MICHAEL DUMIAK

Bailouts for Memory Makers

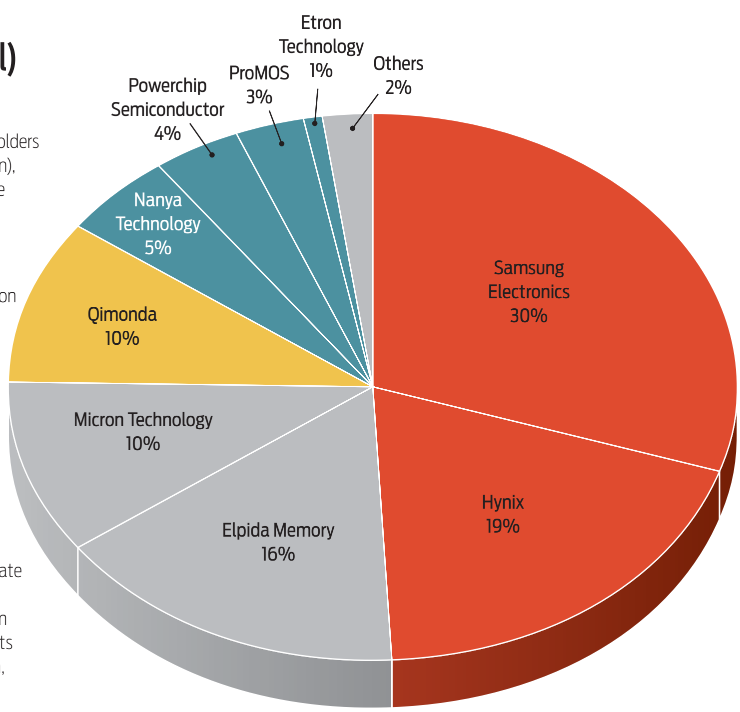
PITY THE makers of memory. Prices for DRAM, the principal memory in computers, have fallen more than 80 percent in the last two years, dropping below cost [see "Plummeting Prices"]. With cash running out, way too much production capacity, and markets in recession, DRAM makers are scaling back fast. Analysts say a wave of consolidation is needed to shed capacity. But no country wants its own industry to disappear. So governments in Germany and Taiwan spent the start of 2009 orchestrating bailouts, while in South Korea big banks came to the rescue. Many analysts are concerned that the bailouts will prolong the pain of consolidation. In the end, will there be only a few DRAM makers left standing? "I've never believed [the DRAM industry] will just consolidate to two or three companies," says Nam Hyung Kim, chief DRAM analyst at market research firm iSuppli, in El Segundo, Calif. Following each orgy of oversupply [see "Capital Expenditure Cycles"], he notes, chipmakers have exited the field, only to be replaced by others as DRAM becomes profitable again. Look for a Chinese entrant within the next five years, Kim says. —SAMUEL K. MOORE

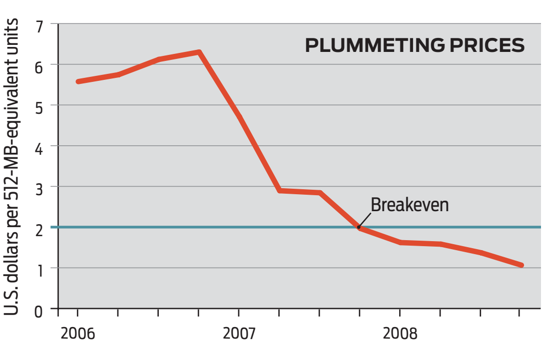
Third Quarter 2008 Market Share (US $6.685 billion total)

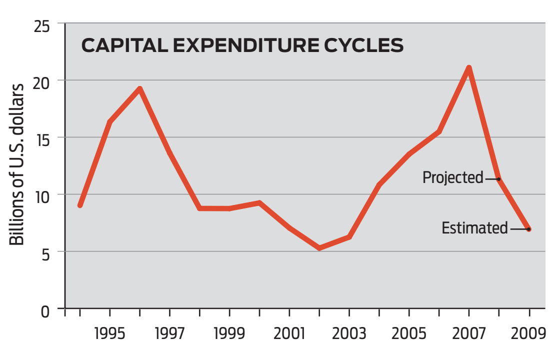
■ **SOUTH KOREA** (Samsung, Hynix)
Korea Exchange Bank and four other large shareholders are offering Hynix 500 billion won (US $386 million), promising to participate in the company's issuance of 300 billion won in new shares and rolling over the company's debt until the end of 2009.

■ **GERMANY** (Qimonda)
The State of Saxony will loan Qimonda €150 million (US $205 million), and Infineon Technologies, Qimonda's parent company, will contribute €75 million. A Portuguese bank will kick in €100 million because of Qimonda's facilities in that country. For the situation in Germany, see http://spectrum.ieee.org/feb09/GermDRAM.

■ **TAIWAN** (Nanya, Powerchip, ProMOS, Etron)
The government plans to offer NT$200 billion (US $6 billion) to keep its DRAM makers afloat. The Taiwanese industry is expected to consolidate and develop closer technological ties with the United States' Micron and Japan's Elpida to form a more powerful competitor to the Korean giants Samsung and Hynix. For the situation in Taiwan, see http://spectrum.ieee.org/feb09/TaiDRAM.







Source: Graphs and chart, iSuppli

news briefs

CELLULAR KUNG-FU GRIP
Researchers at Johns Hopkins University have developed 700-micrometer metallic grippers that can be remotely triggered to clench. The microgrippers, which can be maneuvered into place using magnets, could be useful for removing cells for biopsy or other medical applications. Inspired by the joints of crabs, the scientists built their microgrippers using a layer of prestressed metal that is held open by segments of organic polymer. Increasing the temperature or adding certain chemicals softens the polymer and releases the tension in the metal.
PHOTO: NATIONAL ACADEMY OF SCIENCES

update

Cellphones for Science

Scientists want to put sensors into everyone's hands

Being at the right place with a camera phone can make anyone an amateur reporter nowadays. How about turning cellphone users into amateur scientists? Cellphones can take pictures, record sounds, reveal location, and even measure temperature and sense light. And they are everywhere—there are more than 260 million subscribers in the United States alone. So cellphones seem an ideal tool for collecting research data, according to Eric Paulos, assistant professor at Carnegie Mellon University's Human-Computer Interaction Institute, in Pittsburgh.

Paulos has lofty goals. He wants to incorporate various environment sensors into cellphones. Everyday cellphone users would then become "citizen scientists," measuring temperature, wind speed, pollen count, or air pollution levels and sharing the data with researchers. He will be presenting his ideas next month at the ETech 2009 conference in San Jose, Calif.

Environment sensing is usually done using a few reading stations spread around cities. Cellphones would give researchers thousands of mobile sensors gathering rich sets of local data at almost no cost. "Scientists would love more data, even if it's not as high quality, just to have [it] for modeling and for understanding a lot of phenomena," Paulos says.

Meanwhile, the compilation of measurements taken at every city block would give people more-accurate, up-to-date readings on weather conditions like temperature or humidity near their offices rather than for the city as a whole. Allergy or asthma sufferers could figure out which areas to avoid. Plus, says Paulos, the average cellphone user would become more aware of science and the environment: "This digital object people carry around can suddenly participate in helping them view their world in a very different way."

A test run in Accra, Ghana, proved the idea could work. Paulos's team gave portable air pollution sensor packs to taxicab drivers and students for two weeks. The resulting model showed microclimates and block-to-block variations, giving a much more nuanced view than the overall city air-quality index. What surprised the researchers was the participants' response. People started exchanging pollution information with friends, Paulos says, and the data prompted one cab driver to take his car in for an emissions inspection.

Paulos and investigators at Intel Research are performing a similar study using sensors that sample the air and send data to a person's cellphone via a Bluetooth link. The cellphone then text-messages the data, along with coordinates from the cellphone's GPS unit, to a central server.

ENVIRONMENTAL SENSOR: Cellphones could broaden scientists' ability to collect data. PHOTO: TIM ROBERTS/GETTY IMAGES

A cellphone's GPS unit on its own can make for valuable data, other researchers have found. Alexandre Bayen, a civil engineering professor at the University of California, Berkeley, is using GPS signals for real-time traffic monitoring in the San Francisco Bay Area. People who have downloaded Bayen's software onto their cellphones automatically send their coordinates to a central server. The data is fused with information from speed sensors and traffic-light sensors deployed by the transportation department. The reconstructed traffic flow is then sent back to cellphones. "On your phone you see a map of wherever you are with a color map on top of it representing a level of traffic exactly like you would see on the Traffic.com Web site," Bayen says—except it would be more accurate, up-to-the-minute, and sent to you automatically so you can plan your route as you drive.

New York City start-up Sense Networks, meanwhile, is combining GPS location data with sophisticated machine-learning algorithms to predict consumer and social behavior. The software pools data about where people are, where they go and when, and the distances they travel. This could help financial services firms predict how retailers are doing or tell shop owners where to put their next store, says cofounder Tony Jebara, a computer science professor at Columbia University, in New York City.

Paulos believes that many new applications for cellphones might open up. The time is just right, he says, because of the collision of sophisticated technology with "people and culture being more participatory."

—Prachi Patel-Predd

careers

CARL WIENS

MANAGING YOUR BOSS'S BOSS

Can you walk a mile in a manager's shoes?

YOU'VE OFTEN told your colleagues, "If those guys upstairs knew what we know down here, they'd do things completely differently." Now here's your chance. Your boss brings you to a meeting with a bunch of C-level executives. Instead of just throwing you a technical question or two, the executives ask you to tell them what you think, their questions moving further and further from your areas of expertise. The CEO is listening to you attentively, your boss is watching you warily, but all you can think about is the bead of sweat forming on your forehead. Your dream moment is about to turn into your worst nightmare. What should you do?

Unfortunately, you should have taken a moment beforehand to consider things from management's perspective. Let's do that right now, shall we?

If talking to the boss is hard, remember that the feeling is mutual. In fact, talking to engineers is one of the biggest challenges a boss faces. Engineers know important things beyond the boss's ken; at the same time, the boss sees the big picture. As an engineer, you have a different perspective, and so you have to work to discern what management wants. That task involves taking into account profitability, long-term company objectives, and—finally—corporate politics.

In a nutshell, here's what senior managers want:

REAL-TIME ADVICE: Be willing to give advice on the spot, even after receiving very little information. Many management decisions involve things that don't merit exhaustive study or rigorous analysis; other decisions must be made quickly, before a market opportunity slips away. In both cases, you must be prepared to make decisions without having all the facts.

CANDOR: Tell management what you think, support your position, and give only as much substantiation as is needed at the time. Candor is truth with an attitude.

WHAT-NEXT IDEAS: Senior managers must look beyond the completion of your project, so try to offer them sensible suggestions about what the next steps or increments might be. Providing options to consider is among the most highly valued contributions a trusted strategic advisor can make.

MANAGEMENT MIND-SET: To be an effective advisor, you have to ask yourself some very powerful personal questions about whether you fit into this environment.

1. Do you study leadership?
2. Do you care about what senior managers think, do, and need?
3. Can you keep a firm grip on your own ego in an environment filled with even bigger ones?
4. Can you learn to tolerate the fact that some decisions are based on politics? Can you accept that the technically right solution isn't always the right organizational solution?
5. Can you put yourself in senior management's shoes and look at the world through their eyes?

If your answer is yes to all these questions, I know we'll be seeing you at the table.

—JAMES E. LUKASZEWSKI

mini-profile

THE DOODLE-MEISTER

GOOGLE'S frequent logo changes owe much to the whimsy of webmaster Dennis Hwang, 30, a former Stanford University student of studio art and computer science, who joined Google in college as an intern. His reimaginings of the Google logo to commemorate the Mars Rover landing, Monet's birthday, and the 25th anniversary of TCP/IP, to name just a few, have reached a kind of cult status. "I started doing this by chance during the early days of Google—now it takes up 10 to 20 percent of my time," he says. "People are more productive when their work really excites them." With Hwang designing some 50 logos a year, Google is now building a team of artists to handle the demand.

Hwang is always looking for new ideas to celebrate innovation. E-mail logo suggestions to proposals@google.com, and visit past doodles at http://www.google.com/holidaylogos.html.

—SUSAN KARLIN

books

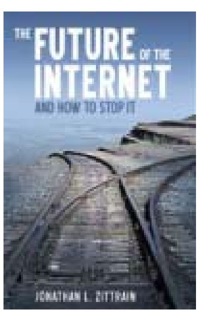
FOULING OUR OWN NET

The future is far from rosy in Jonathan Zittrain's *The Future of the Internet and How to Stop It*

IT WOULD be easy to ignore a book called *The Future of the Internet and How to Stop It*. First, it predicts the progress of technology, which as every engineer knows is a risky business. Second, it seems to inveigh against one of the most successful and transformative inventions of our time. Has author Jonathan Zittrain, a cofounder of Harvard Law School's Berkman Center for Internet & Society, suddenly become a modern Luddite, urging us to abandon the connectivity we have come to love?

Not to worry. Zittrain favors this connectivity and wants us to nurture it. The foundation of his argument is that the Internet fosters creative, collaborative invention—that it is, in a word, *generative*. This generativity arose in part because of its creators' architectural principles. One such principle called for the Internet Protocol to be like the neck of an hourglass—slender yet open to all. Another principle was to move, whenever possible, all functions to host computer systems at the edge of the Internet. Together these two principles ensured that the middle of the network didn't interfere with end-user innovations, such as better search tools or streaming media.

Zittrain considers two opposing challenges to generativity. One challenge, intrinsic to any generative network, is insecurity. Users control their computers and therefore control the network as a whole, inflicting on others any harm they please, such as spam and viruses.



THE FUTURE OF THE INTERNET AND HOW TO STOP IT
By Jonathan Zittrain; Yale University Press, 2008; 352 pp.; US $30;
ISBN: 978-0-300-12487-3

The second challenge comes from outside the Internet. Carriers, service providers, and governments impose technologies that lock down our systems so that we, the end users, cannot control anything but their most trivial aspects. Zittrain calls such imposition "perfect enforcement," and he notes that it can be brought to bear through technical and legal constructs designed to prevent creative use or to revoke existing capabilities. One key example originated outside the Internet but is all too applicable to it—a court decision that ordered EchoStar to disable the "record" function in its customers' set-top boxes, a function its users had already purchased (or thought they had).

Zittrain's most controversial and novel point concerns cloud computing, in which data and software reside on remote servers instead of securely within one's own computer. Many would characterize cloud computing and related technologies as highly generative, but Zittrain argues that rather than liberating us from perfect enforcement, the freedom to "mash up" services may make it even easier to lock down our data and software.

So is this the way the Internet's generativity ends, with robotic spies and saboteurs everywhere you click? A sterile, Stepford-like sameness? Entrepreneurs fighting to control and profit from your every move?

Not necessarily. Despite these dark and powerful forces, Zittrain suggests we can save the Internet. The temptation to create schemes for perfect enforcement can and ought to be resisted, both by governmental regulators seeking policy solutions to social problems and by users seeking safety. Zittrain has no silver bullets but argues that collective action by self-organized groups of users could solve these problems. Wikipedia is one example of such a self-governing generative system.

Zittrain concludes with a speculative discussion of what he calls "Privacy 2.0," the challenges to personal and social privacy that arise from pervasive real-time sensing, data capture, permanent logging, inference, and dissemination. Those challenges are still in their early stages, but the costs of capturing, storing, and

AUTHOR JONATHAN ZITTRAIN worries about the Internet running off the rails in *The Future of the Internet and How to Stop It*. PHOTO: JULIETTE MELTON

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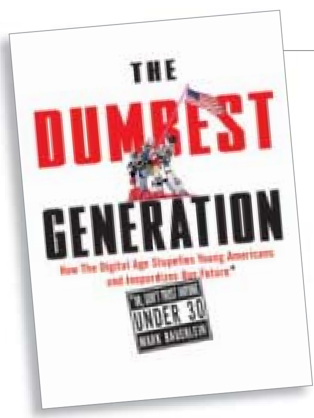
transmitting data are falling so fast that huge volumes of information about our personal and social activities are being archived throughout the Internet in places controlled by people and organizations who have never before had the ability to link to or analyze such information.

With such knowledge comes great power, and it is a remarkable fact about our age that this power accrues not just to *1984*-style Big Brother governments but to any group willing to share and trade information with other groups. Again we see Zittrain's generative dilemma: The new Internet-based capabilities are as dangerous as they are fantastic, potentially transferring control from users to those who may be interested only in narrow exploitation.

Zittrain's solution—Wikipedia-like enforcement of flexible norms under collective user control—suggests an important direction. Yet this is perhaps the point where the argument needs a systems engineer's perspective. It is understandable that Zittrain, a law professor, sees code as something relatively substantial, concrete, and visual. He imagines lines of text laboriously typed by a user, run through a compiler, or stored in a version control system or other repository. Yet today's code is anything but stable, substantial, and static. Modern software is evolving into systems that write code dynamically, sometimes even rewriting their own code in response to changes in the environment.

I suspect we are on the verge of a new kind of Internet-based, self-referential "generative engineering," which I imagine to be the emerging science of information systems that we don't construct so much as influence—systems that construct themselves out of components in the cloud. Generative engineering is likely to present control issues of a scale we have not yet encountered. Zittrain's book is extremely helpful in moving the debate forward, but his yearning for a future in which we "stabilize" generativity between the extremes of the Generative Dilemma and Perfect Enforcement may be impossible to satisfy.

If this science of generative engineering takes off, the future Internet may not be stable in any way at all. How can we stop that? —DAVID P. REED



THE DUMBEST GENERATION: HOW THE DIGITAL AGE STUPEFIES YOUNG AMERICANS AND JEOPARDIZES OUR FUTURE (OR, DON'T TRUST ANYONE UNDER 30)
By Mark Bauerlein; Tarcher/Penguin, 2008; 272 pp; US $24.95; ISBN: 978-1-585-42639-3

KATE MCALPINE (FAR RIGHT)

DUMB AND DUMBER

Are smart technologies making us stupid?

REMEMBER WHEN technology was supposed to make us smarter? Not so fast, says Emory University English professor Mark Bauerlein. In his book *The Dumbest Generation: How the Digital Age Stupefies Young Americans and Jeopardizes Our Future*, Bauerlein argues that e-mail, blogging, e-zines, and gaming have produced a culture of young people more agile with images but with fewer critical thinking skills and underdeveloped cognitive habits. Their lack of curiosity endangers the future of American ingenuity. "As teens use the Internet, they attune their brains to quick messages and flashy images," says Bauerlein. "Critical reasoning demands the slow digestion of complex ideas, but teen social networking is an onslaught of puerile banter. It's the very opposite of what we need right now." —SUSAN KARLIN

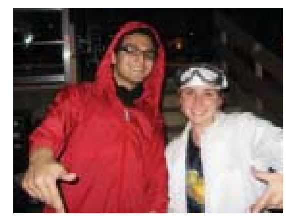
media

WHERE RAP AND PHYSICS COLLIDE

Two beams of protons
swing round;
Through the ring, they ride;
'Til in the hearts of
the detectors;
They're made to collide!

WHO SAYS rap and particle theory don't mix? A YouTube rap-video tour of the Large Hadron Collider by European Organization for Nuclear Research staff science writer Kate McAlpine, 23, [below, right] drew more than 3.5 million views in September, the month that it—and the supercollider—debuted. "Besides the fun of making a physics rap, I wanted something with good science content and no swear words, so teachers could use it in their classrooms," McAlpine says. "A few scientists think rap is an inappropriate medium for discussing science. But they're mostly happy because it's mostly accurate." —SUSAN KARLIN

See the video at http://www.youtube.com/watch?v=j6aU-wFSqt0.



invention

STRATEGIC PATENTING

Patents, like every other company asset, need to be tracked and appraised

EVERY DAY high-tech companies receive offers for "strategic patenting" and "patent mapping" services and "comprehensive patent analysis platforms." What exactly are these things?

The idea is simple. Instead of handling patent problems ad hoc, you devise a strategic plan—that is, one that establishes priorities so that you can jettison patents and filings not worth pursuing and defend yourself against the patents of others. You consider all the associated profits and losses comprehensively, as you would with finance or real estate.

Strategic patenting is a tapestry woven from disparate threads: older conceptions of patent management; studies proving that some patents are basically worthless; a realization that the best protection for a given product involves not one but many patents (a "patent fence"); the idea of defensive patents (and "patent truces"); the fairly new ability to search out existing patents and published patent applications more easily (and to present the search results in colorful charts and patent maps); and, to a certain degree, patents being asserted against non-high-tech companies and service providers.

Companies now realize that their patent portfolios can generate money even if a given patent is not being used for a new product or service. A patent "hidden in the attic" may be worth something and can be sold or licensed—even to a competitor. Nowadays, it is simply unacceptable for management to misvalue its patent arsenal, either offensively or defensively.

Consider a hypothetical case: You invent the Jpod, a handheld electronic product for which one U.S. patent has been issued, two more are pending, and many corresponding applications are in the works in patent offices overseas, as shown in the table "Portfolio."

Entry No. 1 in this patent map reveals that the basic functionality of the Jpod is fairly well protected and the cost to pursue foreign patents is reasonable, given the scope of the U.S. patent. But entry No. 2 shows that though a lot of money has been spent, the patent hasn't been issued and in any case it would cover only the user interface of the product. Maybe the idea of protecting the user interface in other countries should be abandoned, given the trouble experienced in securing even a U.S. patent. Maybe the U.S. patent should also be scrapped. Has the interface changed so much that money is being spent on patent protection for something the company doesn't even use anymore? If so, can the patent be licensed to someone else? Entry No. 3 can be evaluated in a similar manner.

This fairly simple map may also reveal something important about entries that are *not* present. Suppose engineering has touted a particular feature in the Jpod, say, a new power management circuit that lets the product run longer on a single charge. A strategic planner would ask why the spreadsheet has no entries covering this circuit, whether it's still possible to protect it, and what other things the engineers are working on right now. Project management is needed because the engineers are too close to the work and management too far from it.

The second step is to analyze what other companies have, both on the market and in the R&D pipeline. It is relatively easy to search out the patents and pending published patent applications of competitors. You can track whether or not your own patents have been cited in later patents by others.

It would certainly be good to know whether anyone else is seeking patents on a technology clearly adapted for the Jpod. There are services that will help you find out about such things; all you have to do is ask them to notify you of relevant new patent applications.

Other key questions: Are there basic patents predating yours that cover Jpod-like products? Are they still valid? If not, are there any previously patented features you can now incorporate into your product? For still-valid patents, are the patent owners litigious? Are you infringing? Obviously, you'd need more than this simple spreadsheet, but the basic idea would still be the same.

The third step involves predicting the future. Where is the market heading? Will your patents protect you there? Who is suing whom in your market and what ideas should you stay away from? When will your patents expire and how will you then protect against knockoffs?

Strategic patenting, then, is simply the confluence of patent law (what can be patented and how) and project management, with quality assurance ideas mixed in. And all these concepts apply, to a certain extent, to other species of intellectual property: trade and service marks, copyrights, trade secrets, licensing programs, and the like. All intellectual property must be managed.

Lastly, don't spend lots of money on colorful reports and maps only to file and forget them. Patent-mapping services provide lots of data, but it is up to management to analyze the data and then act—and keep doing it. — KIRK TESKA

Portfolio Patent holdings of a hypothetical company working on a consumer gadget called the Jpod

					Cost to pursue/maintain	
	Patent No.	Status	Covers	Cost to date	U.S.	Non-U.S.
1.	7214229	Issued	Overall functionality	US $12 328	$8265	$30 298
2.	60/250936	Pending	User interface	$16 291	$15 391	$60 351
3.	60/635891	Pending	Next-generation functionality	$8641	$18 250	$60 451

tools & toys

POLAROID 2.0

The PoGo Instant Mobile Printer turns your cellphone camera into a 21st-century Polaroid. Too bad it's already obsolete

POGO US $100; 10-sheet pack of paper, $5; 30-sheet pack of paper, $13; Target, Best Buy, Costco, Urban Outfitters

IT'S A NICE PARTY TRICK to pull the new Polaroid PoGo out of your purse and start printing out sticky-backed cellphone pictures. And it's as easy as can be: To go from staring at a closed package to holding a wallet-size photo of my dog and her new Christmas toy took five minutes.

You pop in the rechargeable lithium-ion battery, plug in the charger, slip a 10-pack of special Zink paper into the printer, turn on your phone's Bluetooth, wait for it to find the camera, select a picture, hit "send to," and choose Bluetooth. Thirty seconds later, your picture emerges. You can also print directly from any digital camera by using a USB connection. With the PoGo, Polaroid brings to digital photography the same instant gratification the company has offered for decades. This time, it's based on a very different sort of chemistry.

Standard printers use print heads to jet pixelated ink patterns onto a blank canvas of paper. By contrast, Zink—Zero Ink—made by Zink Imaging, uses paper filled with color waiting to be activated. The paper's three layers are each embedded with dye crystals in one of the three basic colors for printing—yellow, magenta, or cyan. A superheated plate inside the camera pulses 200 million times onto the passing material, creating the photo's pattern.

Like a standard-issue mood ring, the polymer starts out clear and changes colors depending on temperature and length of exposure. Zink's inventor, onetime Polaroid researcher and erstwhile Harvard physics professor William Vetterling, demonstrated the process with a soldering iron. When he pressed the lukewarm iron onto the paper for a long time, a cyan smudge emerged. But when he dragged a superheated iron along the paper, he left behind a streak of alternating magenta and yellow.

It's a wonderful technology, but the product itself leaves something to be desired. For one thing, it's no more convenient than uploading your pics to Snapfish, the Kodak site, or wherever else you get your prints. For another, it's more a toy than a tool.

A completely unscientific poll revealed that the target audience consists largely of new parents and 13-year-old girls. (Polaroid's marketers have wisely included the hip, teen-oriented Urban Outfitters chain in their distribution channels.) Essentially, the printer is a viable option for anyone who's already carrying around a giant bag stuffed full of cosmetics, celebrity magazines, and iPod accessories. For the rest of us, though, the fun lasts for about 10 minutes or 10 pages of printing. After that, the conversation starts to sputter, and it's time to put the novelty away.

Tragically, although the Zink printing technology is sure to live on, the PoGo is the architect of its own demise. In late November, the Japanese toymaker Tomy unveiled the inevitable marriage of Zink and Tomy's own 5-megapixel Xiao camera, which generates a sticker-backed 2-by-3-inch print exactly as a latter-day Polaroid should.

There may still be a market for the printer-only model—the Tomy combo camera-printer lists for a stiff 34 800 yen (US $365.50, at press time). That extra $265 is a hefty sum just to kick up your instant photos from your phone's camera resolution to 5 megapixels.

—SALLY ADEE

media

SCIENTIFIC SAGES

You'd think it would be the religious leaders and philosophers who had a handle on the existential, but of the 175 people that director Roger Nygard interviewed for his upcoming documentary, *The Nature of Existence*, he says it was the physicists who stood out. (Other subjects include novelists, biologists, artists, and a pair of Stonehenge druids.) Nygard, best known for the 1997 cult film *Trekkies*, figures it this way: "Breaking down man's existence to the smallest particles and comparing that to the enormity of multiple universes makes you naturally philosophical about our origins."

The Nature of Existence will premier at the Cinequest film festival in San Jose, Calif., 8 March 2009. You can see the trailer on YouTube.

—SUSAN KARLIN

ROGER NYGAARD (FAR RIGHT)

technically speaking BY PAUL McFEDRIES

The Effect Effect

They are revenge effects, and they are less the malignant ironies of a spiteful world than the results of a lack of human foresight. —Edward Tenner

SCIENTISTS AND technologists have long used the word *effect*—as in the *Doppler effect*, the *butterfly effect*, and the *greenhouse effect*—to good effect. In fact, *effect* has been so, uh, effective at naming things that it has branched out into the mainstream.

For example, the recent economic downturn has created the **poverty effect**, a reduction in consumer spending caused by a feeling of relative poverty upon seeing the diminishing value of 401(k)s and the like. This comes after years of wallowing in the **wealth effect**, an increase in spending based on the perception of new wealth.

During a recession or slowdown we also see the **lipstick effect**, the tendency for consumers to purchase small, comforting items such as lipstick rather than large luxury items. As the rich hunker down and practice **inconspicuous consumption**, purchasing goods or services that convey a lower socioeconomic status, we're less likely to see the **snob effect**, the desire to purchase something because it is extremely rare or expensive.

Television is the source of a few of these coinages, including the ***CSI* effect**, the unrealistically high expectations some jurors have for the prosecution's case in a criminal court proceeding, expectations created in part by exposure to *CSI* and other forensics-oriented TV shows. Closer to home, it's a truism that TV types want us to plunk ourselves down on the couch, tune in to their network, and stay right where we are until bedtime. Saturation coverage of fascinating or controversial events not only achieves this goal but also presents wars, famines, hurricanes, and the like so dramatically it can influence public policy, a phenomenon that has come to be called the **CNN effect**.

Just in case you missed the 2008 U.S. presidential election and all its talk of the **Bradley effect**, that phrase refers to African-American politician Tom Bradley, whom preelection polls had winning his 1982 run for governor of California. Bradley lost to his white opponent; the alleged effect is that some white voters will vote for the white candidate after telling a pollster that they plan to vote for the black one. In 2008, however, it looks like the **reverse Bradley effect** occurred—voters declaring publicly that they would not vote for a candidate because of his race but then selecting that candidate in the secrecy of the ballot booth.

Turning back to technology, there's the **Slashdot effect** (aka **/. effect**), an often overwhelming increase in a Web site's traffic, particularly after the site is featured on Slashdot.org and the **iPod halo effect**, the increase in the sales and perceived prestige of Apple products based on the massive popularity of Apple's iPod digital music player (and, yes, there's also an **iPhone halo effect**).

Then there's the **NASCAR effect**, the display of a large number of logos or advertising images on a Web site, T-shirt, or other object, as NASCAR race cars are garishly festooned with sponsor logos; the **Gulliver effect**, which occurs when a large target succumbs to an attack by numerous smaller adversaries; and even the **Streisand effect**, the widespread dissemination of information caused by an attempt to suppress that information. In 2003, when Barbra Streisand sued a photographer documenting coastal erosion to remove photos of her seaside mansion from his Web site, the pictures ended up plastered all over the Web.

Perhaps the chanteuse should have recalled the **spotlight effect**, the tendency to believe that other people are paying closer attention than they really are. I like this effect because it reminds me of Rule No. 2 in Roger Rosenblatt's great little book, *Rules for Aging: Resist Normal Impulses, Live Longer, Attain Perfection*: "Nobody is thinking about you."

Finally, there's my favorite tech effect, the **revenge effect**, coined by the writer and academic Edward Tenner in his book *Why Things Bite Back: Technology and the Revenge of Unintended Consequences* and mentioned in the quotation that opens this column. It refers to an unintended and negative consequence of some new or modified technology—like the effect effect. ❏

MICK WIGGINS

dream jobs 09

Building a solar-powered plane, creating stunning effects for Bollywood films, designing search-and-rescue robots—

it's not just a job, it's engineering

SPECIAL REPORT

WHAT'S THE DIFFERENCE between a good job and a dream job? Just ask the 10 technologists in this year's Dream Jobs report.

Working on an assembly line, Shannon Bruzelius knew what a dream job wasn't. He also knew what *his* dream job was: making really cool toys. Hundreds of phone calls later, he landed it. That's not to say that a dream job can't fall into your lap: Philippe Lauper was asked to oversee the building of a solar-powered plane that will circle the globe. His reply? Yes!

Kenyon Kluge thought there must be work for an electrical engineer who also loves motorcycles. There was: Now he designs all-electric dirt bikes at Zero Motorcycles. Everyone expected Kunio Koike to follow a traditional career at a big automaker, but he found his calling creating exquisite timepieces for Seiko.

Then there are the psychic rewards. Arieta Gonelevu's job has them—she brings light to remote villages all over the South Pacific. Convinced that robots could play a vital role at disaster sites, Robin Murphy helped launch a new discipline in robotics.

Following your curiosity may just lead you to the job of your dreams. When Erlundur Thorsteinsson left a so-so job in IT to join one of the hottest online game companies, he discovered a whole new universe—literally. Tero Ojanperä's dual interests in business and culture transformed him into Nokia's music mogul.

Engineers who can straddle the worlds of technology and the arts will find lots of opportunity. Keya Banerjee turned an early obsession with computers into a career designing visual effects in Bollywood. Studio engineer Marco Migliari makes musicians like Peter Gabriel and Van Morrison sound their best.

So what have we learned? That a good job won't love you back, but a dream job just might. Take a look at the 10 profiles that follow, and maybe you'll be motivated to up the ante in your next job search.

Already have the job of your dreams? Write and tell us about it at eedreamjobs@ieee.org.

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dream jobs 09

Marco Migliari *Studio Virtuoso*

At Real World Studios in the British countryside, he masters the mix

MARCO MIGLIARI steps into the vast recording studio and shuts a heavy metal door behind him. Silence fills the cavernous space where Peter Gabriel, Van Morrison, Coldplay, and Robert Plant have all taken their turns behind the microphone. “I like this sort of steadiness, the quietness of the studio,” Migliari says. “It’s kind of waiting for something to happen.”

And a lot does happen here at Real World Studios, a recording facility founded by Gabriel and best known for its vibrantly eclectic world-music productions. Tucked amid farms and stone houses in the village of Box, a 2-hour drive west of London, it’s regarded as one of the most high-tech and innovative places for making music. Migliari has worked here as a sound engineer for 12 years. In that time, he’s kept pace with a sea change in recording technology, as digital systems and software have gradually supplanted vacuum tubes and analog electronics. And he’s worked with top recording artists from all over the world. It’s Migliari’s job to make them sound good.

His introduction to audio technology came in the early 1980s, when he was still a schoolboy in Osimo, a small town in central eastern Italy. Hanging out at a local radio station, he learned to patch cables, work the reel-to-reel recorder, and sequence music in cassettes. That experience eventually led him to enroll in electronic engineering at Università Politecnica delle Marche, in nearby Ancona, in 1988.

He found the courses dull but didn’t give up. On the side, he worked as a freelance sound technician, setting up sound systems for theater and dance performances and “lots of scruffy rock bands,” he recalls. Five years later, he was still struggling in engineering school and beginning to tire of the sound gigs. At the age of 24, Migliari had a “bit of an existential crisis.”

That summer, in 1993, while operating the sound system at an academic conference, he got to talking with a sound engineer from Rome. He told Migliari about a two-year music-technology course at Newcastle College in England. “That was a major turning point,” Migliari says. “I realized I could just get out and start again.”

He wrote to Newcastle—“with the really terrible English I had at the time”—and the college asked him to come for an interview. The interview went well, and he was accepted. He still remembers touring the school’s facilities and feeling like he’d landed “in a gold mine.” Life in northeast England, though, took some getting used to. “It was bloody cold,” he says. “I had, like, three flus in a month, one after the other.”

At Newcastle Migliari learned about technologies like MIDI (musical instrument digital interface), recording and mixing techniques, and all aspects of record production. As part of the program, he got an internship at Real World. The work wasn’t glamorous; he spent most of his time hauling gear, fixing equipment, and stringing cables. But his boss let him fiddle around in the studios that weren’t in use. “I’d stay up until 4 o’clock in the morning studying the console, trying things out,” he says.

One day, a manager asked him to help out on a studio session. “I said, ‘Yeah! No problem!’” Migliari says. The session turned out to be with Peter Gabriel himself and members of his former band, Genesis, who were remixing some archival material. Working with such famous musicians was a surreal experience, Migliari says, but he kept a low profile: “You watch, you learn.”

After he graduated in 1996, Real World offered him a job. Barbara, his girlfriend back home, agreed to join him in England. He took the job, they got married soon after, and he’s been a fixture at Real World ever since.

On a pitch-black November night, Migliari pokes around the biggest of Real World’s seven studios. It’s a 200-square-meter, high-ceilinged, acoustically sealed chamber where musicians and sound engineers square off in the same space. In conventional studios, he says, artists and engineers sit in different rooms, separated by a glass window. “Peter [Gabriel] wanted to get everyone to be part of the creative process,” Migliari says. “It works just great.”

AGE: 39
WHAT HE DOES: Records, mixes, and produces music.
FOR WHOM: Real World Studios and other clients
WHERE HE DOES IT: Box, near Bath, England
FUN FACTORS: Works at the forefront of music technology; gets to interact with famous artists.

The room itself is a technological marvel. The floor hides kilometers of cables for hooking up instruments, and a closet houses racks of computers and data-storage systems. Dominating one side of the room is a custom XL9080K mixing console, made by Solid State Logic, which is based in Oxford. The console has hundreds of input and output ports and some 2000 control buttons. “The technology choices here I haven’t seen in any other studio,” Migliari says.

During a session, he determines how to position the performers and how best to capture their voices and instruments. It’s a deceptively complex task that requires an encyclopedic knowledge of such esoterica as the characteristics of different sound-baffling materials and the capabilities of advanced audio compressors. Often musicians show up with exotic instruments, some of which he’s never seen before and a few that don’t even have names, because the performers built them themselves. “You just walk around the thing, and you think, Where does it sound best to my ears?” he says. “And then you put a microphone where your ears are.”

After setting up all the equipment, he decides what sampling rates, encoding schemes, and storage formats to use. As the session progresses, he tweaks the audio signals, adjusting gain, volume, equalization, and dynamic range. In that way, he helps transform electric current into beautiful music.

Although enamored of technology, Migliari is always conscious of its subservience, in his profession, to art. “You cannot fake a performance,” he says. “There’s no computer that can do that for you. There’s got to be someone to make it real.” —*Erico Guizzo*

RECORDING IN PROGRESS: Marco Migliari, an IEEE member, helps the Moonfish prepare their upcoming CD at Real World Studios, in Box, England. PHOTO: ROSS KIRTON

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Shannon Bruzelius
Toy Story

How a B student landed an A+ job in the toy industry

SHANNON BRUZELIUS was calling yet another toy company. He dialed 1-1-1-# and heard, "You have reached a nonworking number." Next he tried 1-1-2-#. "You have reached a nonworking number," the system repeated. Then he dialed 1-1-3-#, which got him closer to a human being: "Hi, this is Sue in customer service...."

Bruzelius was working his way through the company's phone system, trying to reach someone—anyone—in the engineering department. He'd been making such cold calls for months, convinced that if he made enough of them and talked to enough people, he'd eventually land his dream job: doing engineering in the toy industry.

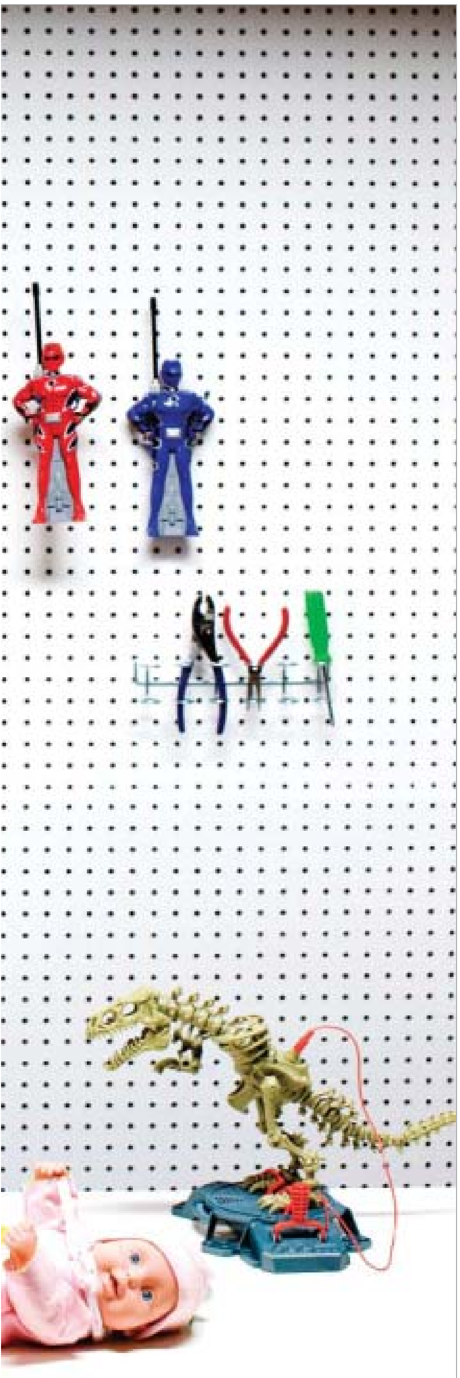
He'd always been a toy guy. "Even when I got to that age where it's not cool to play with your toys anymore, I was still collecting them," he recalls. He'd regularly check out the latest toys at the mall, and he had fond memories of the summer he spent working as a clerk in a toy store. But he never thought about a career in toy engineering until shortly before he graduated from college. Even then, what he had was not so much a plan as a fantasy hatched during a late-night bull session.

A "real career" for an engineer near Bruzelius's home in Longmont, Colo., in the late 1990s meant working in the local disk-drive industry, where Maxtor, Quantum, and Storage Technology were big tech employers. After graduating from the University of Colorado with a mechanical engineering degree in 1995, however, Bruzelius had no real interest in spinning media.

Instead he took an assembly-line job making wheels for in-line skates. He was overqualified and understimulated, and after three months, he found a slightly better job handling quality assurance at a medical-device company. Still bored, he thought back to that late-night conversation in college. Could he really become a toy-industry engineer?

He started researching the field by walking through the local Wal-Mart, turning over every toy and writing down the name of the manufacturer. He then looked up the companies on the Internet and discovered that a fair number of them were in the San Francisco area.

So in November 1997, he packed his clothes, his collection of *Star Wars* action figures, his Ed Grimley doll, his Sony PlayStation, and his new 25-inch television into his 1988 Toyota Camry and headed west to San Francisco. He moved into a friend's parents' garage and started calling local toy companies. Whenever he hit a voice-mail message that identified the person as working in the engineering department, he'd write down the name and the extension, and then he'd call the person until he got through.



ENGINEERING FUN: Shannon Bruzelius, an IEEE member, makes sure that toys made by San Francisco's Wild Planet Toys are safe and reliable. PHOTO: TIMOTHY ARCHIBALD

Bruzelius didn't ask for a job outright; he just asked people if they would meet with him to tell him about the industry. Most wouldn't. In fact, he says, many responded with suspicion, thinking he was an industrial spy. Then he reached Alan Adler, founder of Aerobie, which makes flying rings and other throwable toys. But instead of Adler telling Bruzelius how to break into the toy business, the veteran toy inventor posed a series of tough engineering problems to the young engineer, who struggled to respond.

"I realized that I wasn't smart enough to work for him," Bruzelius recalls. "I was just a B student in engineering." He also realized that starting a career in toys might take longer than he'd thought.

To pay the bills, he found a job doing quality assurance for a company that made tubing for chip manufacturers. At night, he kept making calls. "I talked to somebody at just about every toy company in Silicon Valley," he says. He finally got a lucky break in September 1998, in an unlikely place. Flying back from a wedding in Colorado, Bruzelius poured out his heart to his seatmate, all about his dead-end job and his dream to get into the toy industry. The seatmate knew someone at Wild Planet Toys in San Francisco. That contact in turn gave Bruzelius a name: Jeff McKee, the company's head of engineering at the time.

Bruzelius called McKee and left a message. Actually, he left a lot of messages—at least one a day for two weeks. Finally, McKee called back, and Bruzelius asked him if he could take him out for breakfast at an International House of Pancakes, which was about all he could afford.

Bruzelius took a day off from his tube-inspection job to make the 9 a.m. appointment. But McKee didn't show; he simply forgot. McKee did call later to apologize, and they rescheduled for later in the week.

Sometimes persistence really does pay off. The breakfast lasted three hours. McKee told Bruzelius all about the industry and how he got started. Bruzelius didn't get a chance to talk much about himself, and in any event Wild Planet didn't have any openings. But McKee said he would let Bruzelius know if something came up.

During the next six months, Bruzelius called McKee every couple of weeks to remind him that he was still interested. Finally, in August 1999, McKee told Bruzelius that a letter offering him a job was on its way. Bruzelius says he didn't even care what the job was or what it paid. He just replied that he'd be accepting the offer.

He loved it from day one. He was asked to take existing products and figure out how to make them better—identifying the best plastic to withstand hammer whacks from children, for instance. These days, Wild Planet specializes in high-tech gadget toys. It's sort of a Sharper Image for the grade-school set. Wild Planet's toys use RFID chips and readers, radio transmitters, electronic sound and motion detectors, and image sensors to turn children into Spy Kids or to set up complex challenges of memory or speed. Today, as the company's product-integrity manager, Bruzelius makes sure the toys are safe.

AGE: 38
WHAT HE DOES: Evaluates toys for reliability and safety.
FOR WHOM: Wild Planet Toys
WHERE HE DOES IT: In an office cluttered with toys, old and new, in San Francisco's financial district
FUN FACTORS: Gets to play with all the latest toys made by his company and by competitors; works with children to evaluate product designs.

On a typical day, he bikes 13 kilometers from his home near San Francisco's Ocean Beach to his office in the city's financial district. He fields calls and reads e-mail from the Hong Kong office, which is close to the company's assembly lines. Then he looks at early designs of toys and tries to identify safety issues. To research the safety aspect of a toy, he might call experts in other industries who can shed light on the problem. Cold calls, he notes wryly, are something he's pretty good at.

But mostly what Bruzelius does is play with toys—new toys, old toys, his company's toys, competitors' toys. His office is full of them: Roll-in Blaster, a toy grenade; a line of spy toys for girls called Undercover Girl; Hyper Dash and Animal Scramble, two RFID-based games; Spyder Trap, for children who want to booby-trap their rooms; Battle Crawlers, a discontinued line of robotic sumo wrestlers; and countless others, covering every available surface.

Other jobs pay more, but to Bruzelius, none offers a better working environment. "I have the job I always dreamed of," he says. "I can't imagine doing anything else."

—Tekla S. Perry

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Kenyon Kluge
Zero to 60

An electrical engineer with a passion for motorcycles finds a job designing all-electric dirt bikes

KENYON KLUGE grabs a leather jacket from his office and heads down the stairs to the manufacturing floor at Zero Motorcycles, a maker of high-performance, all-electric dirt bikes. He stops to take a pair of knee-high boots, a helmet, and gloves from a shelf and then hoists a gleaming new Zero X dirt bike off its rack.

For the next hour or so, he'll be darting cleanly and quietly up the trails that wind through the trees near the company's Scotts Valley, Calif., facility. And all the while he'll be working, too.

Until a year ago, Kluge led a double life. Monday through Friday, he was a mild-mannered Silicon Valley engineer. On weekends, he was a top motorcycle track racer, competing in events all over the United States. Now, as Zero Motorcycle's director of engineering, he has managed to merge his passion with his profession.

Kluge's journey into engineering began early, when he qualified for a physics program for middle-schoolers run by the local University of California campus. For about a year, the 13-year-old spent his Saturdays studying on campus with undergrads or out on the boardwalk at the Santa Cruz beach, measuring the *g*-forces generated by the Giant Dipper roller coaster. When he graduated from high school in 1992, tight family finances ruled out a four-year college. Instead he registered at an ITT Technical Institute in the Los Angeles area to work toward an associate's degree in electronics, expecting to transfer to a four-year EE program.

He never did get that four-year degree; real-world work proved too captivating. While still at ITT, he interned with a contractor who built new-product prototypes. After getting his associate's degree in 1997, he went to Extreme Networks, a start-up in Santa Clara that made one of the first gigabit Ethernet switches. In 2000, he moved on to chipmaker Altera, in San Jose. There he worked on one of the first "softcore" microprocessors, devices that can be implemented on a programmable logic chip, such as a field-programmable gate array (FPGA).

Much of that time, Kluge was racing. He'd first ridden a dirt bike on a visit to a California ranch when he was 11 years old, but his parents refused to let him have anything to do with motorcycles after that. In 1994, however, after he turned 18 and no longer needed his parents' permission, he got a motorcycle license and bought a Kawasaki EX500.

"From the start I wanted to race, but I didn't really know how to go about it," he recalls. He spent the next three years figuring it out. Then, in August 1997, he loaded his motorcycle into a friend's truck, and they drove to Sears Point (now Infineon Raceway) in Sonoma, Calif., camping overnight in a nearby field. For his first race, he entered the 750-cubic-centimeter Superbike class, one of the fastest and toughest categories. Way out of his league, he crashed, wrecked the bike, and dislocated his shoulder.

Two months later he went back. This time he didn't crash. He didn't even finish last. He continued as a weekend racer until 2002 and then took a year's leave of absence from his job as a senior engineer at Altera to race full time on the American Motorcyclist Association's pro racing circuit, crisscrossing the country, living out of an RV. He placed 15th out of 94 in the Formula Xtreme class. But 27 is late to turn pro in motorcycle racing, and after the season ended he went back to Altera.

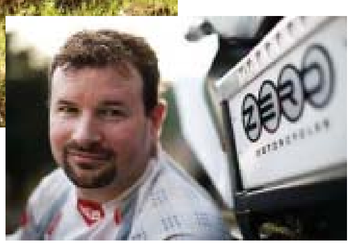
He was assigned to a group creating sample product designs to support sales of Altera's FPGAs. The work was creative, but because the group didn't build products to sell, they got little support within the company. By 2007, he was tired of hearing, as he puts it, "we want this and want it now, but we don't want to give you any resources to go do it." He began thinking about leaving.

He decided to look for an engineering job in the one field that really interested him: motorcycles. He reasoned that as an EE, his best shot would be with a company that built traction-control systems, the most sophisticated electronic component on a motorcycle. Such systems monitor wheel speeds, acceleration, throttle, braking, and other factors to determine if the vehicle is sliding; if it is, the systems make adjustments to stop the skid.

Kluge drew up a list of companies and sent out résumés. He was willing to relocate if necessary. He got a few responses but no hard offers.

Then, last February, he received a call from Gabriel DeVault, an engineer at Zero. DeVault had heard of Kluge's racing career through friends of friends, and he wondered if Kluge could put Zero's prototype all-electric dirt bike through

AGE: 35
WHAT HE DOES: Develops control systems for all-electric dirt bikes.
FOR WHOM: Zero Motorcycles
WHERE HE DOES IT: Scotts Valley, Calif.
FUN FACTORS: Combines a love of motorcycles with a love of electronics; gets to test-ride ecofriendly dirt bikes on company time.



WORLDS COLLIDE: Kenyon Kluge, an IEEE member, has merged two careers—as a Silicon Valley engineer and as a motorcycle racer—into one at Zero Motorcycles. PHOTOS: ROD McLEAN

its paces. DeVault had no idea that Kluge was an EE who was looking for a job.

Kluge rode the bike and was impressed. "I had expected it to be more of a toy, but it really wasn't. It was a full-blown bike," he says. He and DeVault chatted about the bike and the company. DeVault mentioned that he was in a bit of a jam because one of the contract engineers he'd been using to design and build circuit boards was no longer available.

Kluge told DeVault that he worked in engineering and knew some manufacturers who could do the work; soon afterward, he arranged to have a run of boards produced, billing Zero for a couple of hours of his time. In the process, he visited the company's Scotts Valley office and talked to founder Neil Saiki and other employees. In April, when some additional financing came through, Zero hired Kluge as full-time head of the electronics department, which at that point was just him and an intern. But by the end of the year, the company's ranks had tripled to 30-plus, and Kluge had advanced to director of engineering.

At Zero, Kluge designs circuit boards and arranges for their manufacture; defines the interface between the brakes, suspension, and motor; and helps determine what subsystems to use. He redesigned some of the control circuitry for the bike's power control, speed control, and user interface systems, and he rewrote the software that manages the bike's lithium-ion battery pack. He also supervises a growing staff of mechanical and electrical engineers.

And he rides. Sometimes, when he's out on the hilly trails winding through the trees and open fields on the western slope of the Santa Cruz Mountains, he thinks about what he'd like to change in the next model, a street-legal motorcycle due out this winter. Other times he just rides for the thrill of it. Unlike a gas bike, he says, the electric bike doesn't make you wait for the motor to ramp up to speed, and it has virtually no engine noise. You just crank the throttle and blast forward with a little whoosh as the air gets out of your way.

Someday all dirt bikes will be electric, he says. Noise pollution and trail degradation from engine exhaust have been pitting dirt-bike riders against environmentalists all over the United States. It's a conflict that has to be resolved, Kluge says, and the electric trail bike is the way to do it. An electric bike, he says, is not only "doing the right thing; it gives us more rights as riders."

Kluge also likes that his work could have a huge impact on the motorcycle world. "I could go work for a gas-bike company, but everything there has already been done. I'd be making small, incremental changes to wiring harnesses or electronics. Here I get to define what an electric motorcycle is going to be." —*Tekla S. Perry*

Arieta Gonelevu

Bright Lights, Little Islands

She brings electricity to remote islands in the South Pacific

ARIETA GONELEVU'S latest challenge is to light up the only school on the South Pacific island of Tongariki using solar power. It won't be easy. Tongariki, which is home to about 500 people in five villages, doesn't have roads or airports. Even cargo boats don't stop at this island in the Vanuatu archipelago, about 1800 kilometers off the coast of Australia.

It's just the kind of assignment Gonelevu likes: a nice, old-fashioned engineering challenge—how to provide power in a robust and cost-effective way—that will also have a huge impact on people's lives. "The happiest, most satisfying thing about my work is that what I do makes a difference," she says.

She figures that a 100-watt solar panel will let Tongariki's students take night classes and also let the school do double duty as a community center, where women could gather at night to do their weaving. A hundred watts is a paltry amount of electricity—a decent blender uses six or seven times as much—but it makes a big difference in the jungle, Gonelevu says.

In a typical rural community in the South Pacific, a cluster of 50 houses uses about 25 to 30 kilowatts of power and consumes around 235 liters of diesel a week, which powers a generator for about 3 hours a day. Her mission is to increase the villagers' access to renewable energy and reduce their use of fossil fuels. Ultimately, she'd like to connect the homes to solar-panel arrays and microhydroelectric stations and encourage the villagers to produce their own biofuel from coconut oil.

Gonelevu, in a pinstriped pantsuit and fuzzy red scarf, holds forth from her corner of the bright, wood-paneled office she shares with eight colleagues at the Pacific Islands Applied Geoscience Commission, in Fiji's capital

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of Suva. In the trees by her window, a cluster of mynahs emit startling squawks, but the native Fijian barely seems to notice. The commission's offices sit on wooden planks around an open courtyard filled with lush, broad-leaved plants. Built into the side of a hill, away from the road and the sputtering of the city's ubiquitous taxis, the complex feels like a big tree house.

Gonelevu, 33, has spent the last eight years implementing renewable energy systems in remote communities all over the Pacific. But she talks like a veteran power engineer who has been in the business for decades. In a way, she has. Her father, Viliame Gonelevu, is one of Fiji's first electrical engineers. Back in the 1960s, he had answered the call of the local government to study electrical engineering. The newly formed Fiji Electricity Authority needed qualified people to oversee the country's first public power plant, which began modestly with a 65-kW diesel generator.

When Gonelevu was 7 years old, her father took the family to see Fiji's first hydroelectric dam being built. The youngster was amazed by the roar of the water pounding over the dam. "It was like a huge waterfall coming down: Everything was so big," she says. "The engineers were installing these huge turbines, and I was told the water was going to fall through them, and it was going to make electricity." The crew showed her the flowcharts for the 80-megawatt facility, and the seeming simplicity of it piqued her curiosity. After finishing high school in 1992, she attended the University of the South Pacific, where she majored in electrical and electronics engineering.

Upon graduating, she taught math and computer science briefly before getting a job as an energy analyst at Fiji's department of energy. The job title suggests someone who spends her days poring over industry reports and statistics, but Gonelevu mostly found herself out in the field, bringing solar power to rural huts and communal buildings that had never had electricity at all. She quickly discovered that the biggest obstacles were cultural rather than technical. In many remote villages, being a woman doing what she calls "a man's job" caused tensions.

AGE: 33
WHAT SHE DOES: Designs and installs renewable energy systems for remote islands.
FOR WHOM: Pacific Islands Applied Geoscience Commission, or SOPAC
WHERE SHE DOES IT: In Suva, Fiji, and throughout the South Pacific
FUN FACTORS: Improves the lives of villagers through hands-on engineering work and travels to some of the most beautiful tropical islands to do it.

"When we visit a Pacific rural community, I don't always get acknowledged. At first, I'd get pissed off," she says. But then she came up with a different approach. At the feasts that villagers prepare to welcome the energy team, she now sits at the back of the room and retrieves her food only after all the men do, just like the other women. "I've learned to go with the flow. I let someone else tell the community, 'Oh, in fact, *she's* in charge,'" she says.

After six years, during which Gonelevu worked on most of the 110 inhabited islands of Fiji, she took time off in 2005 to earn a master's degree in renewable energy from Murdoch University, in Perth, Australia. Soon after, she moved to her current post, and her job now spans the South Pacific. "I'm in the office one week and out the next. One day it's a solar project in Vanuatu, the next it's drafting energy policy in Kiribati," Gonelevu says.

She freely admits she'd much rather be figuring out how to bring electricity to a jungle village than sitting in a conference room debating big-picture strategy. Among her projects now is a biofuel plant for Nacamaki Village, on Koro Island in Fiji. Coconut palms cover the island, and so she's hoping the villagers can learn to turn coconut oil into fuel. About 100 kilograms of the meaty beige copra from inside a coconut can be milled into 50 liters of coconut oil; if she installs an oil mill that produces 50 liters per hour, the villagers can quickly produce more than enough fuel for a week. Any leftover oil could be turned into soap, she adds, which the villagers could learn to make and sell.

But before she can teach others, she, too, must learn how to make a good coconut-diesel blend, as pure as possible and with the performance of regular diesel. "Getting the blending right, the type of catalyst, and producing the right type of biodiesel: Those are the major things I am still trying to get my head around," says Gonelevu. Once she does, she'll be ready to take on Nacamaki Village—and so much more. *—Sandra Upson*

TROPICAL ENERGY: Her early enthusiasm for hydropower led Arieta Gonelevu, an IEEE member, to an island-hopping job in renewable energy. PHOTO: SANDRA UPSON

Tero Ojanperä
Dial M for Music
From CTO to Chief Tunes Officer

LISTEN UP: Tero Ojanperä, an IEEE member, Ph.D. electrical engineer, and former CTO, now hears the beat of a different drummer: He heads Nokia's entertainment division.
PHOTO: DAVID YELLEN

NOKIA IS the world's largest maker of mobile phones, with almost 40 percent of the market and €51 billion in annual revenues (US $70 billion in 2007 revenues). Two years ago, its top executives decided that wasn't enough: The company would also become a major player in the entertainment industry. That unlikely shift in corporate strategy transformed Tero Ojanperä into a budding music mogul.

Technically, he is Nokia's executive vice president for entertainment and communities, but the blond, gap-toothed Finn doesn't exactly fit that title, either. For one thing, Ojanperä has a Ph.D. in electrical engineering and had enjoyed a distinguished research career in wide-area cellular networking before becoming the company's chief strategy officer in 2005 and, subsequently, chief technology officer.

And well before that, he was a quiet, inquisitive kid growing up in rural Korsnäs, Finland, a place so placid that on its Web site it touts itself as "a safe place to settle for people in all ages." Technology helped break the isolation and gave him something to do, Ojanperä says. "My friends and I, we were always programming with a Commodore 64, learning the assembly language for it," he says.

He earned bachelor's and master's degrees in electrical engineering at the University of Oulu and then went straight to Nokia's research division. Ojanperä worked hard and rose fast, and at 38 he was on the executive board and in command of the sprawling research organization. He was also pursuing a Ph.D. in electrical engineering, which he finally earned in 1999.

Around that time, Ojanperä and his colleagues on the board became convinced that Nokia's handsets would have to do a lot more than make calls. Many of the phones could play MP3 audio, and the board decided that Nokia should be able to sell its customers music, too—and that Ojanperä was just the guy to figure out how.

AGE: 42
WHAT HE DOES: Develops a music business for the world's largest cellphone maker.
FOR WHOM: Nokia
WHERE HE DOES IT: White Plains, N.Y., and countless sites around the world
FUN FACTORS: Hobnobs with top musicians and music producers; is helping redefine his company's future and maybe the music industry's, too.

He was relocated to White Plains, N.Y., north of New York City, and given a free hand to lure talent to the newly created entertainment group. Among his hires were George Linardos, a film-industry veteran and long-time associate of the director Oliver Stone, and Liz Schimel, who had been in charge of digital media at AT&T and then Comcast. Linardos took over business development, while Schimel became the head of the music operation.

Ojanperä now spends his days overseeing deals with record labels and considering designs for new handsets so that they not only play music but also make the company money by selling it. If he succeeds, Nokia will be one of a select few companies to do so.

He seems to relish his new role, but in a quiet and self-effacing sort of way. "I can't complain," is what he says. Then he laughs and adds, "that's Finnish for 'It's a great job!'"

The centerpiece of his music strategy is a cellphone service called Nokia Comes With Music, which lets users download as many songs as they like to their cellphones from a 4-million-title playlist. (There's no separate price for the service, but the United Kingdom's Carphone Warehouse charges about £130 ($190) for a Nokia 5310 with Comes With Music and about £60 for one without it.) The service was introduced in the UK in October and will be launching in other countries this year.

Ojanperä is on the go almost constantly. Says Linardos, "I have these weird moments when I'll chat briefly with him in the hallway, and then I'll get a call from him the next morning from California—or China. You do the math, and he must have gotten to the plane 45 minutes after our conversation. And you'll see him in the office a day later and find out that he stopped off in Espoo"—where Nokia is headquartered. "I think he flies east and just touches down every once in a while."

Ojanperä says only that it's important to visit Nokia's seven far-flung research locations and to see what's happening around the world. "In Africa, for example, the phone is their first computer," he says. "And it's used to figure out the price of a crop as well as for recording music and sharing it with friends."

So even with the endless travel, is this a great job? Ojanperä, ever the Finn, grins and says simply, "It's not so bad." —*Steven Cherry*

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Erlendur Thorsteinsson

Master of the Universe

This computer scientist breathes life into the many worlds of the sci-fi game *Eve Online*

ON A DARK November day, Erlendur Thorsteinsson strolls into the Party at the Top of the World. That's what the crowd of gamers calls this annual gathering at the Laugardalshöll arena in Reykjavík, Iceland. And it is quite a party. Crammed into a room, hordes of players battle it out in a challenge called the Super Ultimate Eve Online Mining Tournament of Awesomeness. Elsewhere, attendees share war stories over pints of beer and wait for the metal band Roxor to take the stage.

It's all part of the Eve Fanfest, an extravaganza dedicated to *Eve Online*, a science-fiction computer game with about a quarter-million subscribers worldwide. Devoted players have flocked here to see demos of new game features and meet the game's creators, including Thorsteinsson, who leads *Eve*'s software development team.

But at the Fanfest, the amiable, soft-spoken Icelander isn't fighting off the fans; instead he wanders anonymously through the raucous crowd. If he doesn't seem to mind or even notice, that's probably because what drew him to this life was not a fascination with games but a love of numbers.

Thorsteinsson graduated from the University of Iceland in 1996 with bachelor's degrees in mathematics and computer science. He wanted to get a doctorate in computer science, but first he cut a deal with his wife, Sonja: If she let him go to the graduate school of his choice, she'd get to pick where they lived after he finished.

He chose Carnegie Mellon University, in Pittsburgh, where he completed a master's and then a doctorate in "algorithms, combinatorics, and optimization." He says he loved the challenge: "A Ph.D. is a solo project, just you and your ideas."

While he was still in school, the couple had their first child, Birkir Örn, and Sonja started to miss their relatives back in Iceland. After he finished his Ph.D. in 2001, she didn't hesitate to exact her end of the deal: They were going home.

He quickly landed a job at one of the top tech companies in Iceland, Frisk Software International, a maker of Internet security programs. From mid-2001 to early 2007, he went from project manager to chief information officer. Then, in March 2007, he got a call from his old college friend Hilmar Veigar Pétursson.

Pétursson is a cocreator of *Eve* and one of the founders of CCP, the game's parent company. He offered Thorsteinsson a job, and Thorsteinsson took it. Many people see *Eve* as a creative and compelling game; he saw it as an intriguing chunk of code. The following month, he arrived for his first day at CCP's sleek headquarters overlooking Reykjavík's harbor.

It was a completely different world. Thorsteinsson had never thought about working on computer games and rarely even played them, so he spent some time catching up. "I started playing a lot more games," he says. "It's research, of course."

Eve, launched in May 2003, has been growing explosively. At any time of the day or night, thousands of people from dozens of countries are logged on, exploring the game's solar systems, jumping through wormholes, mining asteroids, and blasting away opponents in starship battles. Players create characters, band together in alliances, and accumulate virtual loot to buy more-powerful ships. Some die-hard fans play for days at a time, stopping only for a nap, a bite to eat, and maybe a shower. Maybe.

Thorsteinsson says *Eve* is different from other massively multiplayer online games, or MMOGs. It has a single universe, or shard, whereas most games segregate players into isolated shards. So even in MMOGs with more than a million subscribers, like *World of Warcraft*, no more than a few hundred people can play together. *Eve*, by contrast, has had more than 45 000 players logged on at the same time, and all of them can play together.

The technology that makes *Eve* happen—that tracks the coordinates of thousands of ships in space, computes the results of their gunfire, processes the activation of weapons, and manages other transactions—did not exist until CCP invented it. That was exactly the kind of challenge that lured Thorsteinsson to the company. His team of 14 programmers writes, debugs, and pieces together the computer code that powers *Eve*.

To keep people in the game and attract new players, CCP is always working to make the *Eve* universe larger and more intricate and interesting. "It's a big challenge," he says, "how to make something like this scale up."

CCP deploys a new version of *Eve* about every six months. The latest made great headway against an annoying technical issue: lags, the bane of MMOGs. As the number of players grows, so do the number of data exchanges between servers and the time it takes to access the databases. If the process takes too long, the game gets sluggish and players get irritated. To minimize lag, CCP started using hundreds of blade servers—thin computers that sit vertically on special racks, like books on a shelf—and solid-state drives, which are much faster than the traditional spinning hard-disk drives.

"But you can't keep throwing hardware at the problem," Thorsteinsson says. So last year, CCP revamped its network software. The new code, written in the Stackless Python language, has less overhead and vastly speeds up communication between servers, the company says. *Eve* also went from a 32-bit to a 64-bit architecture, to be able to move data more quickly to and from memory.

Deploying the new network software was tricky because CCP couldn't keep the servers off-line for too long. The company managed to make the switch in a few hours, and the payoff was immediate. With the network upgrade, space armadas encompassing more than a thousand players can now blast away at one another. "This is something that no other game does," Thorsteinsson says proudly.

Back at the Eve Fanfest, he says he likes to meet players and find out what they love, or don't love, about the game. He gets a lot more compliments than complaints. No surprise there. He's helping to keep their universe fun.

—*Erico Guizzo*

AGE: 37
WHAT HE DOES: Leads the software team developing the massively multiplayer game *Eve Online*.
FOR WHOM: CCP Games
WHERE HE DOES IT: Reykjavík, Iceland
FUN FACTORS: Works on cutting-edge game technology; attends conferences around the world; gets paid to play games at work.

GAME ON: Erlendur Thorsteinsson's love of numbers led him to a career in online computer gaming.
PHOTO: GÍSLI DÚA

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REEL TO REAL: Keya Banerjee can use a green chroma screen to give movie directors the right background for any scene.
PHOTO: MICHAEL RUBINSTEIN; SKY, PETE TURNER/GETTY IMAGES

Keya Banerjee
Magical Realism

This specialist in reality-based movie effects is happiest when you *don't* notice her work

KEYA BANERJEE says she was never destined to be a great actress. Her father, the actor Victor Banerjee, is renowned for his leading roles in such films as David Lean's 1984 classic *A Passage to India*. But Keya's one star turn, as Jocasta in her high school's staging of *Oedipus Rex*, was short and none too sweet. On opening night, the show's producers had second thoughts about her, and the production closed after only two performances. "They realized they made a mistake," Banerjee recalls.

Truth be told, she wasn't all that crushed. Her great passion wasn't drama. It was computers. She'd always been drawn to techie pursuits in school. The AV club and stage crew were her haunts. After encountering a personal computer for the first time at age 12, she thought, "Oh, my God, this is what I want to do."

Today, as a visual-effects coordinator at Tata Elxsi's Visual Computing Labs, in Mumbai, she supervises teams of designers, animators, compositors, and other computer specialists who conjure up special effects to accommodate the visions of some of India's top movie directors. Computer effects are increasingly what drive Bollywood blockbusters. But Banerjee, perhaps uniquely among her peers in India, focuses on small, independent films.

Although her dad was a pretty big star in his day, she didn't grow up on film sets or in swank hotels, she says. And she insists she still isn't a Bollywood creature. Maybe so, but late on a Tuesday night she seems in her element at Zenzi, an ultrafashionable watering hole in Mumbai's Bandra district, where many Bollywood stars live and carouse. Banerjee, in a stylish black suit, sits sipping a drink at a big round table with a few of her friends.

Beautiful people stop by every 15 minutes or so. She greets them by first name. There are eruptions of hugs and air kisses. She responds, repeatedly, to the inevitable "How *are* you?" with an ebullient and maybe slightly facetious "Super duper!"

Hard to believe she was a teenage nerd. Back then, her main infatuation was with Adobe Photoshop and Premiere, software that allowed the manipulation and layering of moving images. She spent many blissful hours assembling scraps of video and music into digital movie clips for her own amusement. "Eagles flying, people dancing. I put it to James Bond music," she says. "It was quite ridiculous, but it was fun. My parents had to tear me away from it to eat lunch and dinner."

She got her start in special effects by interning at studios during summer breaks in college, and she kept on with it after graduating from St. Xavier's College in Mumbai in 1998. Her big break came in 2003, during a stint in the motion picture division of UTV, the biggest Indian media and entertainment conglomerate. She was assigned to be the on-set supervisor for visual effects for a motion picture called *Lakshya*, set during the 1999 Kargil war between India and Pakistan. The movie wound up with 38 minutes of special effects—a huge amount for a Bollywood film in those days.

Set in the mountainous region of Kashmir, the movie tells the story of an aimless young man who finds purpose and discipline as an Indian soldier in the Kargil conflict. Many of the effects involved mountain-climbing scenes; they were shot with actors in harnesses clambering over an 18-meter-high faux mountainside on a set in Mumbai. In the finished film, the men appear to be high up on a jagged cliff. To achieve that effect, Banerjee used chroma technology, in which blue screens on either side of the fake mountain and also below it were replaced during compositing with imagery shot on location.

"On location" meant some of the most rugged and remote spots in Kashmir. "I lived there for three months with the entire crew," she explains. "It was actually in many ways the best and worst experience of my life." She was thrilled to be in charge, at the tender age of 27, of visual effects for a major motion picture. But life in Kashmir was no picnic. "The weather went to –12 degrees, and that was

AGE: 32
WHAT SHE DOES: Visual-effects supervisor
FOR WHOM: Tata Elxsi Visual Computing Labs
WHERE SHE DOES IT: Mumbai
FUN FACTORS: Works with top directors and actors; directs teams that execute state-of-the-art special effects for movies.

difficult for us because we were shooting nights and we were staying in tents and in valleys. Our bottles of water were frozen."

After *Lakshya*, she freelanced for three years, doing the visual effects for many tire commercials—in one, a man catapults out of the driver's seat of his convertible and "starts floating through space because he's on such good tires," she says. Then, in 2007, she landed a job at the Visual Computing Labs, part of the sprawling Tata conglomerate, which hired her to take charge of its work on independent films.

The typical Bollywood production has a big cast and lots of choreography and songs and at least one scene in which exquisitely dressed and coiffed lovers sing to each other while walking among scattered trees. But the films that Banerjee works on are more subtle and personal.

Her current project is a small-budget film called *Havai Dada*, about a man who never realized his youthful dream of becoming a pilot and who in his old age comforts himself with paper airplanes—lots and lots of them.

"It's a beautiful little story," she says, beaming. "It really is. There's nothing commercial about it. There's no singing and dancing around trees. It's a soft film. An actual story."

Because it's still in production, she doesn't want to divulge too many details about the effects. But she says the digital paper planes were choreographed, their motion changing with the mood of the movie. So her big challenge was portraying their tightly scripted aerial dances while still making them appear like plain old paper planes.

As soon as she finishes *Havai Dada*, she's on to the next film. Some days, she's on set or on location, advising a director on how he should shoot a scene if he cares about how much its special effects will cost. Other days, she's working with animators, designers, and others at the office to realize the director's vision for a scene. And some days she's out meeting with directors or producers, trying to persuade them to hire Tata Elxsi for their upcoming picture.

"The shoot days are my favorite," she says, "because I get to interact with new people. I get to see new systems, new ideas, new cultures of working. It gives me more exposure, and it allows me to experiment. It allows me to grow in terms of trying something new to get a new effect, or trying a different method. Before a shoot, I'll do enough research to go on set and say, 'Can we try it this way?' And if the director is open to it, well and good. I've learned. I enjoy it. It's great fun."

—*Glenn Zorpette*

Kunio Koike
Real Time

This Seiko engineer makes every second count

WHEN VIDEO-GAME entrepreneur Richard Garriott blasted off on his US $30 million space ride last October, he carried into orbit a remarkable piece of advanced technology: his wristwatch. Not any wristwatch, mind you, but a Seiko Spring Drive electromechanical timepiece, specially modified to be lightweight and work in zero gravity and fitted with an extralong Velcro strap to circle Garriott's padded space suit.

Kunio Koike knows that watch better than just about anyone, because he helped design its ultralow-power, battery-less, motorless mechanism. As head of the watch-products development department at Seiko, he engineers the exquisite electronics that go into the company's highest-end watches.

Even as a child, Koike loved making and repairing things—"boxes, toys, that kind of thing"—and giving them to other people. That sense of fulfillment led him to his profession, he says. "My image of my future was straightforward. I would be an engineer."

Koike grew up in the industrial prefecture of Shizuoka, about 200 kilometers southwest of Tokyo. It's the land of Honda and Yamaha, and he figured he'd go work for one of those companies after he graduated from Shizuoka University. But in his senior year, on a whim, he decided to interview at Suwa Seikosha Co., maker of Seiko watches. He traveled to Nagano prefecture, famous for its rugged mountains, fruit orchards, and ski resorts, and he visited the watch factory overlooking picturesque Lake Suwa. Koike fell in love with the area. "I could feel nature," he says, a warm smile spreading across his boyish face as he recalls the experience. It didn't hurt that his family and friends all thought highly of Seiko, which had introduced the first commercial quartz watch in 1969. "Many Japanese people are proud of the Seiko brand," he notes.

And so, after earning his bachelor's in electrical engineering in 1982, he went to work at Suwa Seikosha. His first project was straight out of *Dick Tracy*: helping to design a wristwatch TV. It was the world's first such device, and it demonstrated the watchmaker's prowess in low-power electronics. But, Koike notes, "it wasn't very popular."

In 1985 the company merged with Epson, a maker of printers and other electronics, to form Seiko Epson Corp. For an electrical engineer, the merger opened up a world of possibilities, and Koike soon found himself working on image-processing systems for TV cameras, liquid-crystal displays, and other products.

He joined the watch-development department in 1990. In his new assignment, he worked on solar watches, powered by tiny photovoltaic cells, and kinetic watches, which wind their stepping motors by scavenging energy from the ordinary movement of the wearer's arm. With no main battery to draw on, the watches had to be extremely power efficient. So Koike designed control circuits that needed less than a microwatt.

One day in 1997, he got a call from his colleague Osamu Takahashi. Had Koike heard of the Spring Drive? Takahashi asked.

Of course he had. The watch is part of company legend. Twenty

AGE: 49
WHAT HE DOES: Oversees development and design of the electronics in Seiko's high-end watches.
FOR WHOM: Seiko Epson
WHERE HE DOES IT: Shiojiri, Japan
FUN FACTORS: Gets to wear a very cool wristwatch every day; creates products that everyone recognizes and appreciates; works in one of the most beautiful parts of Japan, with an office overlooking the "Japanese Alps."

years earlier, an enterprising engineer named Yoshikazu Akahane had envisioned an extremely accurate self-winding watch with a novel mechanism that he likened to "a bicycle coasting down a slope at constant speed." Think of this hypothetical bicycle as having a dynamo that converts energy from the spinning tires and also keeps the bike from accelerating. Akahane fleshed out the idea in his spare time, filling up notebooks with sketches and descriptions of how the device would work. But he knew the technology to craft such a watch didn't yet exist, so he put off trying to build one.

Over the years, Akahane returned to the project from time to time, eventually creating two series of prototypes of the spring-drive mechanism. The first, completed in 1982, ran for just 4 hours; the second, in 1994, petered out after 10 hours. The big issue in both cases was the power balance: The watch was simply using more energy than its dynamo could generate.

In 1997, Akahane was named head of the company's entire watch development division, and he made the Spring Drive a priority, putting Takahashi, a quiet but demanding perfectionist, in charge. Takahashi in turn tapped Koike to develop the watch's control circuits. He told Koike that the watch's total power consumption had to be less than 50 nanowatts. It was a level of power one-twentieth that of the kinetic watch. To put it in perspective, consider that the muscle power required to simply lift your eyelids and open your eyes is thousands of times greater.

"I told Mr. Takahashi, 'It's impossible,'" Koike recalls. "I needed more power."

But Takahashi wouldn't budge, and so Koike got to work. He read textbooks and consulted with engineers in other departments. Eventually, a member of his team came up with a silicon-on-insulator IC that functioned on just 100 nanoamperes. Koike's group also figured out how to reclaim energy from the rotation of the watch's glide wheel, in a manner similar to that of a regenerative train brake.

Development continued for another eight years, during which the watch's power consumption was reduced still more, to just 25 nanowatts. In March 2005 Seiko finally unveiled the Spring Drive at an international watch and jewelry show in Switzerland. Selling for something over $3000, each timepiece is hand-assembled by a master artisan. Seiko says it is the most accurate mechanical chronograph on the market, losing no more than 1 second per day.

One of the things that Koike likes most about working on the Spring Drive watches, he says, is that he knows their owners will appreciate them. Noting that the Japanese have a reputation for being extremely punctual, Koike says, "this watch will make them feel safe and secure." You can't really ask more of a wristwatch.

—Jean Kumagai

WATCH MAN: Kunio Koike, an IEEE member, designs innovative low-power electronics for Seiko's high-end watches.

PHOTO: JEREMY SUTTON-HIBBERT

Robin Murphy *Roboticist to the Rescue*

Her intelligent robots help search for victims of disaster

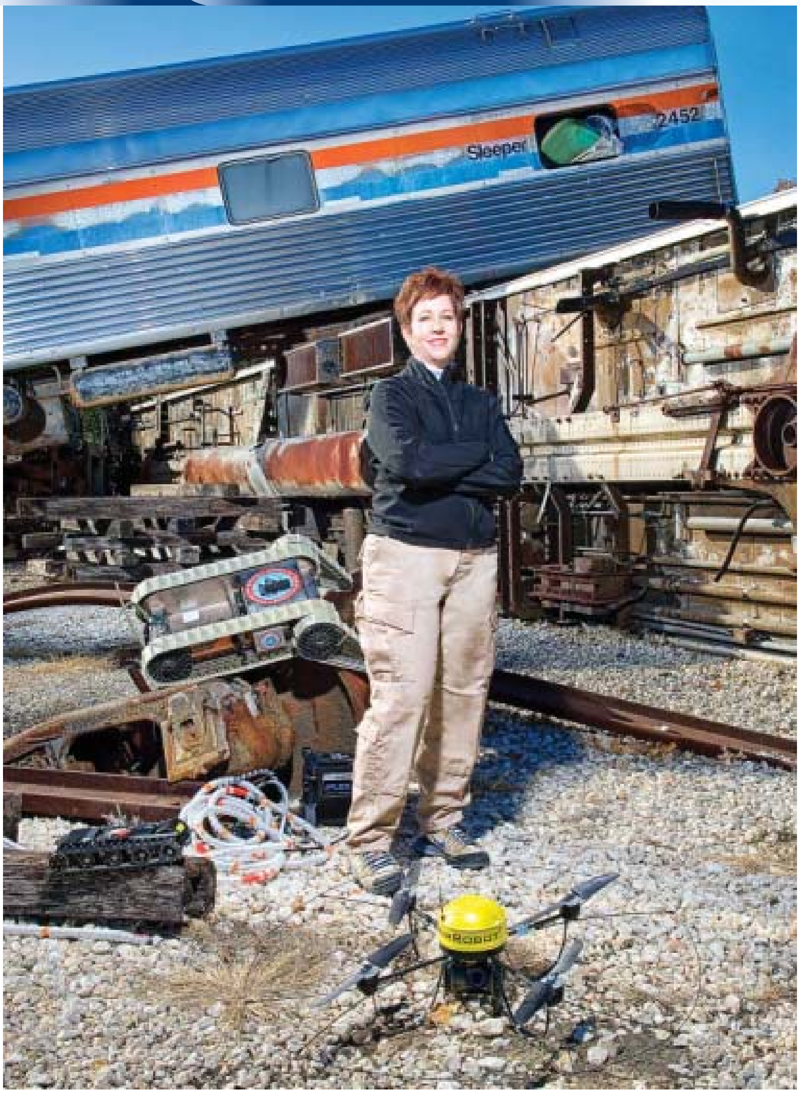
11 SEPTEMBER 2001 was a proud day for robotics expert Robin Murphy. It marked the opening of the Center for Robotic-Assisted Search and Rescue, which was aimed at promoting an idea that Murphy and one of her former graduate students had been pushing for six years: that intelligent robots could help save lives at disaster sites.

Ten days later came the attacks of 9/11.

Murphy and three students immediately packed up their robotic gear and drove 18 hours north from Tampa, Fla., to Manhattan, where they worked alongside rescuers at Ground Zero for the next 12 days. They rarely slept or ate, and the experience left them drained. The purplish-blue light that illuminated the rubble pile at night cast a surreal glow. "It looked like something out of *The Terminator*," she recalls. For Murphy, and for the technology she had been espousing, it was a baptism by fire.

Since then, she has used robots to help search for victims in the aftermath of eight other disasters, including the 2005 mud slides in La Conchita, Calif., Hurricane Katrina, and the 2007 Crandall Canyon Mine collapse in Utah. When she's not promoting the use of robots among rescue professionals, she works closely with robotmakers to tailor their designs to search-and-rescue missions. And she's educating and training a new breed of roboticists to think not just about the detailed engineering of their machines but also about how these devices might function within the larger world of emergency response.

Murphy's interest in technology came largely through the example of her father, who was head of engineering for a huge chicken-processing plant in the small town of Douglas, Ga. After earning a bachelor's degree in mechanical engineering and a Ph.D. in computer science, both from Georgia Tech, Murphy landed a faculty position at the Colorado School of Mines, in Golden. The school had strong links with Colorado's space-science community, and as a consequence, she says, "pretty much everybody in artificial intelligence was looking at planetary robots." But the



ROBOT MENAGERIE: Robin Murphy, an IEEE member, shows off her robots at a train wreck staged for rescue drills.
PHOTO: MATTHEW MAHON

1995 bombing of the Alfred P. Murrah Federal Building in Oklahoma City made her rethink her research. One of her grad students, John Blitch, a major in the U.S. Army, went to Oklahoma City to assist in the rescue efforts. That harrowing experience moved both him and Murphy to apply their knowledge of robotics to aiding the victims of similar disasters. "I made a commitment to myself to focus on rescue robots," she says.

And that's exactly what she did—at no small risk to her academic career. At the time, researchers in artificial intelligence considered search-and-rescue robots only a vague futuristic possibility, and the chair of her department wasn't supportive of the direction her research was taking. But Murphy persevered, eventually landing a tenured position at the University of South Florida, where her faculty colleagues supported her then-fanciful idea that robots could usefully assist rescuers. Elsewhere, though, most AI researchers were skeptical. Then "9/11 happened, and all of a sudden I became brilliant," she quips.

Although Murphy's work at USF mostly entailed teaching and scholarly research, she kept her feet firmly planted in the practical realities of rescue operations. She and some of her grad students joined Florida Task Force 3, a state-sponsored urban search-and-rescue team that specializes in locating and extricating victims trapped in collapsed structures or other confined spaces. Working elbow to elbow with safety professionals during training exercises and actual disasters proved invaluable in shaping Murphy's research agenda. "I love fieldwork," she says. "Fieldwork is where you learn something."

At the World Trade Center, for example, she discovered that bigger robots are a lot less useful than smaller ones in probing a collapse—for the simple reason that if an opening is large enough for a person to wriggle into, human rescuers won't hesitate to do so. They may be risking their lives, but they will almost certainly do a better job than any robot. "It's kind of ludicrous to think that you can replace the complexity of a human" with a machine, she says. "Also, firefighters don't want to be replaced."

But firefighters do want tools to do things they can't do—like squeezing through shoebox-size openings into a deep pile of rubble to see whether anyone is trapped inside. Although robots have yet to actually rescue anyone in the aftermath of a calamity, they have proved their worth by helping determine whether a partially destroyed structure is safe for people to enter.

Rescue robots need to be reasonably smart, Murphy says. They don't have to be like Lt. Cmdr. Data of "Star Trek" fame, but they should have something like the brains of a horse, she says. That is, the operator should be able to give the robot high-level commands and not have to specify its every move.

In mid-2008 Murphy left USF for Texas A&M University, where she is the Raytheon Professor of Computer Science. One of the attractions was that A&M hosts the Texas Engineering Extension Service, which has been training firefighters for many decades and boasts a 21-hectare site known as Disaster City, with facilities for simulating just about any sort of catastrophe you can imagine, including downed aircraft, collapsed buildings, and wrecked trains.

Murphy regularly takes her robots out to Disaster City and tests them alongside human emergency responders. Back at the lab, she equips these sophisticated machines with ever better sensors and intelligence, and she teaches her students the principles of search-and-rescue robotics.

The work is so rewarding that Murphy feels no pangs about forgoing what would probably have been a more lucrative career in industry. Indeed, she's delighted with how her early commitment to rescue robotics has turned out, and she's confident that the day is close at hand when a search-and-rescue robot will make a critical difference after disaster strikes. "We're really, really close to helping responders save a life," she says.

—David Schneider

AGE: 51
WHAT SHE DOES: Outfits robots for search-and-rescue operations.
FOR WHOM: Texas A&M University
WHERE SHE DOES IT: College Station, Texas, and disaster sites around the country
FUN FACTORS: Gets to put her robots through their paces at Texas A&M's 21-hectare Disaster City.

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Philippe Lauper
Chase the Sun

He and his team are building a plane that will circle the globe on sunlight alone

FLIGHT OF FANCY: If Philippe Lauper and his colleagues are successful, they'll make history with their solar-powered plane.
PHOTO: CÉDRIC WIDMER

AS A BOY, Philippe Lauper loved food so much he wanted to become a chef. But around age 15, in a moment of youthful clarity, he envisioned the reality of such a life: day after day of cooking, mopping floors, and tallying receipts. The backup plan was engineering—he enjoyed reading about famous inventors—and today he finds himself managing one of the most audacious technology projects ever conceived: building a plane that can fly around the globe on sunlight alone.

Lauper was born in 1971 in the French-speaking part of Switzerland, not far from Neuchâtel. His love of food probably comes from his parents, who bought and sold organic food, an odd occupation at the time.

In 1989 he enrolled in a local university to study microtechnical engineering, later switching to the Swiss Federal Institute of Technology in Lausanne (known as EPFL, the acronym for its French name). Many of his classmates were focusing on integrated microelectronics, but Lauper concentrated on production engineering because it seemed more practical, and he preferred working on systems to designing individual components.

In 1995, fresh out of college, he sought a job where he'd have to speak a lot of English. He soon got one with the Swiss branch of Silicon Graphics, where he was charged with ensuring the quality of the components used in the Sunnyvale, Calif., company's storage devices and sorting out any problems with the components' suppliers. The job demanded a lot of people skills, and he found that he liked the interactions. He also got to travel and learn about American culture.

But Lauper realized he wanted more than exposure to a different culture within Switzerland: He wanted to actually live abroad. "I picked a place where I could ally good climate and windsurfing—so a windy place—and still have a job where I would use my brain and not just sell cocktails on the beach." Perth, Australia, filled the bill, and Lauper's EPFL contacts helped him get a job in biomedical optics at the University of Western Australia. There his task was to help convert a refrigerator-size system for diagnosing skin cancer into a portable unit. He liked the mix of hands-on fabrication and project management. And the surfing? "Pure fun!" he almost shouts.

After a year and a half, though, he got homesick for Switzerland, and he moved back to take a project-management and systems-engineering gig with the consulting company Altran.

AGE: 37
WHAT HE DOES: Manages a team that's building the first solar plane to circumnavigate the globe.
FOR WHOM: Solar Impulse and Altran
WHERE HE DOES IT: Switzerland
FUN FACTORS: Works on technology that could someday set a world record.

Lauper first heard about the solar-plane project in 2004, when the driving forces behind it, pilot Bertrand Piccard and his colleague André Borschberg, announced they would be presenting their idea at the International Exhibition of Inventions, an annual event that attracts wild-eyed inventors from around the world. Lauper took the train to Geneva to check out the project. "You could see hundreds of inventions" at the show, he says. "But I went for this one."

At the time, the solar-powered plane, which is called Solar Impulse, existed only on paper. But the project was gaining momentum, and Lauper's employer signed on as a partner. As part of the deal, Altran agreed to assign a project manager to Solar Impulse. Offered the job, Lauper leaped at the chance to work on what would certainly be one of the most challenging engineering feats of modern times.

There have been solar planes before, but none quite like Solar Impulse. The plane's 61-meter-long wingspan accommodates 12 000 photovoltaic cells to drive its four propellers. To keep the plane flying through the night, any excess power is stored in lithium polymer batteries, which need to be encased in specially designed insulation so that they'll continue to function as the temperature dips below -40 °C. The batteries, at 400 kilograms, are the heaviest thing about the otherwise gossamer aircraft, which is designed to carry only the pilot. The initial prototype should be completed in the spring; another craft will be built for the actual round-the-world mission. Plans call for the mission flight, slated for 2011, to take place in five stages, enabling Piccard and Borschberg to take turns piloting.

With two years to go, design and engineering work have kicked into high gear. Lauper painstakingly tracks every detail of every activity, from the plane's overall design to the operational minutiae of the flight. Each week, he meets with the team leaders to go over what should be getting done and what isn't.

The Solar Impulse team numbers 60 engineers and other staff, with about 100 outside advisors. At lunchtime in the airfield's canteen, colleagues of all ages hail Lauper in a number of languages. His command of French, German, English, and the local Swiss German dialect comes in handy. He says that he spends a lot of time on the phone but that face-to-face contact is critical. "E-mail is an information carrier," he says, "not a communicating tool."

Being at the heart of a start-up appeals to him, he says: "I have this central position. I'm involved in many discussions on the technical side but also in organizing events. And if I can help somewhere, I will help, in any kind of area. So it's very, very, very diverse. It's an adventure!" *—Giselle Weiss*

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Tech Titans Building Boom

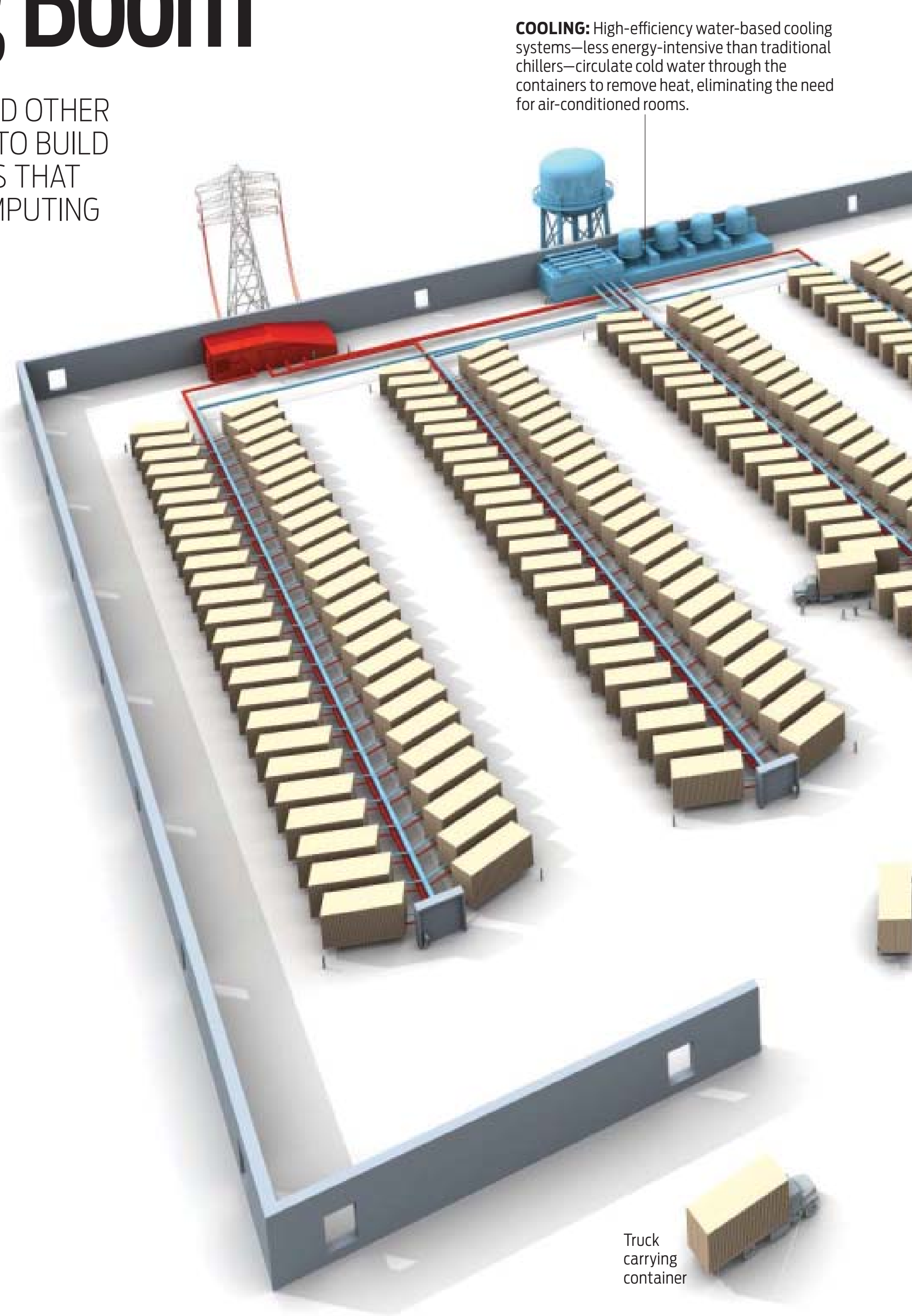
GOOGLE, MICROSOFT, AND OTHER INTERNET GIANTS RACE TO BUILD THE MEGA DATA CENTERS THAT WILL POWER CLOUD COMPUTING

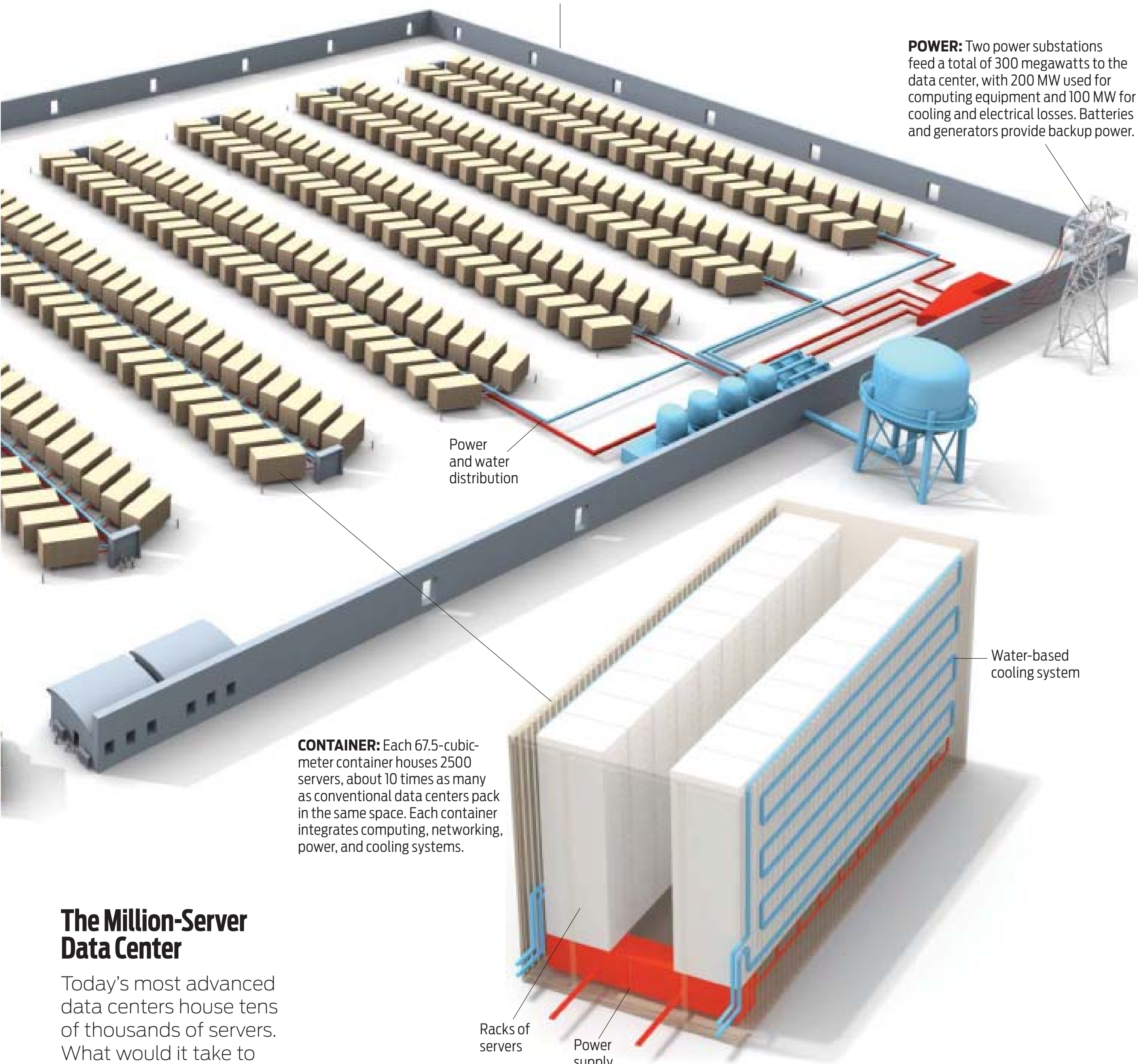
BY RANDY H. KATZ

THE SERENE countryside around the Columbia River in the northwestern United States has emerged as a major, and perhaps unexpected, battleground among Internet powerhouses. That's where Google, Microsoft, Amazon, and Yahoo have built some of the world's largest and most advanced computer facilities: colossal warehouses packed with tens of thousands of servers that will propel the next generation of Internet applications. Call it the data center arms race.

The companies flocked to the region because of its affordable land, readily available fiber-optic connectivity, abundant water, and even more important, inexpensive electricity. These factors are critical to today's large-scale data centers, whose sheer size and power needs eclipse those of the previous generation by one or even two orders of magnitude.

These new data centers are the physical manifestation of what Internet companies are calling cloud computing. The idea is that sprawling collections of servers, storage systems, and network equipment will form a seamless infrastructure capable of running applications and storing data remotely,





The Million-Server Data Center

Today's most advanced data centers house tens of thousands of servers. What would it take to house 1 million?

ILLUSTRATION: BRYAN CHRISTIE DESIGN

WAREHOUSE-SIZE COMPUTERS: Google has built a sprawling data center on the banks of the Columbia River, in The Dalles, Ore. The site, with two server-packed buildings and space for a third, houses tens of thousands of computers—the exact number is a closely guarded secret. Microsoft, Yahoo, and Amazon are also building data centers in the region, enticed by its readily available fiber-optic connectivity and cheap electricity. *PHOTO: MELANIE CONNER*

while the computers people own will provide little more than the interface to connect to the increasingly capable Internet.

All of this means that what had been not-so-glamorous bit players of the tech world—the distant data centers—have now come into the limelight. But getting their design, operation, and location right is a daunting task. The engineers behind today's mega data centers—some call them Internet data centers, to differentiate them from earlier ones—are turning to a host of new strategies and technologies to cut construction and operating costs, consume less energy, incorporate greener materials and processes, and in general make the facilities more flexible and easier to expand. Among other things, data centers are adopting advanced power management hardware, water-based cooling systems, and denser server configurations, making these facilities much different from conventional air-conditioned server rooms.

Take Microsoft's data center in Quincy, Wash., with more than 43 600 square meters of space, or nearly the area of 10 American football fields. The company is tight-lipped about the number of servers at the site, but it does say the facility uses 4.8 kilometers of chiller piping, 965 km of electrical wire, 92 900 m² of drywall, and 1.5 metric tons of batteries for backup power. And the data center consumes 48 megawatts—enough power for 40 000 homes.

Yahoo, based in Sunnyvale, Calif., also chose the tiny town of Quincy—population 5044, tucked in a valley dotted with potato farms—for its state-of-the-art, 13 000-m² facility, its second in the region. The company says it plans to operate both data centers with a zero-carbon footprint by using, among other things, hydropower, water-based chillers, and external cold air to do some of the cooling. As some observers put it, the potato farms have yielded to the server farms.

To the south, Google, headquartered in Mountain View, Calif., opened a vast data center on the banks of the Columbia, in The Dalles, Ore. The site has two active buildings, each 6500 m², and there's been talk of setting up a third. Google, however, won't discuss its expansion plans. Nor will it say how many servers the complex houses or how much energy and water it consumes. When it comes to data centers these days, there's a lot of experimentation going on, and companies are understandably secretive.

Another hush-hush data center project is taking place about 100 km east, in Boardman, Ore. Last year, news emerged that its owner is the Seattle-based online retailer Amazon, a major contender in the cloud-computing market. The facility is said to include three buildings and a 10-MW electrical substation, but the company has declined to confirm details.

Amazon, Google, Microsoft, and Yahoo are trying to keep up with the ever-growing demand for Internet services like searching, image and video sharing, and social networking. But they're also betting on the explosive growth of Web-based applications that will run on their computer clouds. These apps, which display information to users on an Internet browser while processing and storing data on remote servers, range from simple Web-based e-mail like Gmail and Hotmail to more complex services like Google Docs' word processor and spreadsheet. The applications also include a variety of enterprise platforms like Salesforce.com's customer management system. So the race to the clouds is on. It's taking place not only in the Pacific Northwest but also in many other parts of the United States and elsewhere.

With reportedly more than 1 million servers scattered in three dozen data centers around the world, Google is spending billions of dollars to build large-scale facilities in Pryor, Okla.; Council Bluffs, Iowa; Lenoir, N.C.; and Goose Creek, S.C. Last year the company released its Google App Engine, a cloud-based platform that individuals and businesses can use to run applications. Microsoft, whose Quincy facility will house the initial version of its Windows Azure cloud-based operating system, is constructing additional facilities in Chicago, San Antonio, and Dublin, at roughly US $500 million each. The company is also said to be looking for a site in Siberia.

Designing bigger and better data centers requires innovation not only in power and cooling but also in computer architecture, networking, operating systems, and other areas. Some engineers are indeed quite excited by the prospect of designing computing systems of this magnitude—or as some Googlers call them, "warehouse-size computers."

THE BIG DATA CENTERS that went up during the dot-com boom in the late 1990s and early 2000s housed thousands, even tens of thousands, of servers. Back in those days, facility managers could expand their computing resources almost indefinitely. Servers, storage systems, and network equipment were—and still are—relatively cheap, courtesy of Moore's Law. To get the computing power you needed, all you had to do was set up or upgrade your equipment and turn up the air-conditioning.

But in recent years, this approach has hit a wall. It became just too expensive to manage, power, and cool the huge number of servers that companies employ. Today's largest data centers house many tens of thousands of servers, and some have reportedly passed the 100 000 mark. The data centers of the dot-com era consumed 1 or 2 MW. Now facilities that require 20 MW are common, and already some of them expect to use 10 times as much. Setting up so many servers—mounting them onto racks, attaching cables, loading software—is very time-consuming. Even worse, with electricity prices going up, it's hugely expensive to power and cool so much equipment. Market research firm IDC estimates that within the next six years, the companies operating data centers will spend more money per year on energy than on equipment.

What's more, the environmental impact of data centers is now on the radar of regulators and environmentally conscious stakeholders. The management consulting firm McKinsey & Co. reports that the world's 44 million servers consume 0.5 percent of all electricity and produce 0.2 percent of all carbon dioxide emissions, or 80 megatons a year, approaching the emissions of entire countries like Argentina or the Netherlands.

Data center designers know they must do many things to squeeze more efficiency out of every system in their facilities. But what? Again, companies don't want to give the game away. But in their efforts to demonstrate the greening of their operations, Google, Microsoft, and others have revealed some interesting details. And of course, a number of innovations come from the vendor side, and these equipment suppliers are eager to discuss their offerings.

First, consider the server infrastructure within the data center. Traditionally, servers are grouped on racks. Each server is a single computer with one or more processors, memory, a disk, a network interface, a power supply, and a fan—all packaged in a metal enclosure the size of a pizza box. A typical dual-processor server demands 200 watts at peak performance, with the CPUs accounting for about 60 percent of that. Holding up to 40 pizza-box-size servers, a full rack consumes 8 kilowatts. Packed with blade servers—thin computers that sit vertically in a special chassis, like books on a shelf—a rack can use twice as much power.

The new large-scale data centers generally continue to use this rack configuration. Still, there's room for improvement. For one, Microsoft has said it was able to add more servers to its data centers simply by better managing their power budgets. The idea is that if you have lots of servers that rarely reach their maximum power at the same time, you can size your power supply not for their combined peak power but rather for their average demand. Microsoft says this approach let it add 30 to 50 percent more servers in some of its data centers. The company notes, however, that this strategy requires close monitoring of the servers and the use of power-control schemes to avoid overloading the distribution system in extreme situations.

THE DATA CENTERS OF THE DOT-COM ERA CONSUMED 1 OR 2 MEGAWATTS. NOW FACILITIES THAT REQUIRE 20 MEGAWATTS ARE COMMON, AND ALREADY SOME EXPECT TO USE 10 TIMES AS MUCH

How the servers are set up at Google's data centers is a mystery. But this much is known: The company relies on cheap computers with conventional multicore processors. To reduce the machines' energy appetite, Google fitted them with high-efficiency power supplies and voltage regulators, variable-speed fans, and system boards stripped of all unnecessary components like graphics chips. Google has also experimented with a CPU power-management feature called dynamic voltage/frequency scaling. It reduces a processor's voltage or frequency during certain periods (for example, when you don't need the results of a computing task right away). The server executes its work more slowly, thus reducing power consumption. Google engineers have reported energy savings of around 20 percent on some of their tests.

BUT SERVERS AREN'T EVERYTHING in a data center. Consider the electrical and cooling systems, which have yielded the biggest energy-efficiency improvements in some facilities. In a typical data center, energy flows through a series of transformers and distribution systems, which reduce the high-voltage ac to the standard 120 or 208 volts used in the server racks. The result is that by the time energy reaches the servers, losses can amount to 8 or 9 percent. In addition, the servers' processors, memory, storage, and network interfaces are ultimately powered by dc, so each server needs to make the ac-to-dc conversion, generating additional losses. This scenario is leading some data centers to adopt high-efficiency transformers and distribution systems to improve energy usage, and some experts have proposed distributing high-voltage dc power throughout the data center, an approach they say could cut losses by 5 to 20 percent.

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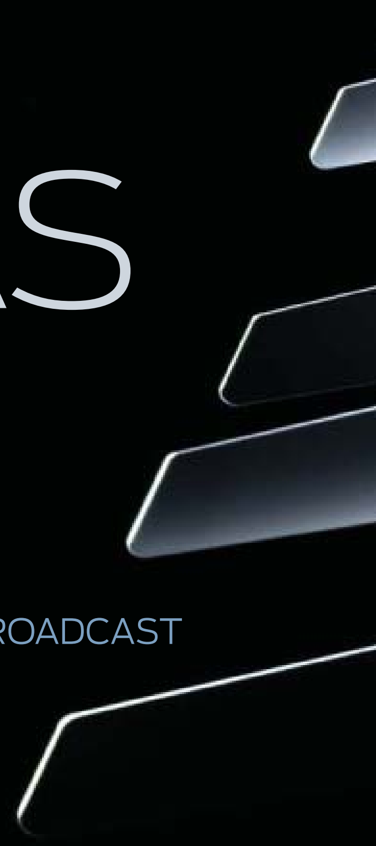

ANTENNAS FOR THE NEW AIRWAVES

THIS MONTH'S PLANNED SHUTDOWN OF ANALOG BROADCAST TV IN THE UNITED STATES WILL BRING ANTENNA TECHNOLOGY BACK INTO THE SPOTLIGHT

By Richard Schneider & John Ross
Photos by Ryann Cooley

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Philips Silver Sensor

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Winegard SquareShooter

LET'S SAY YOU'VE GONE AND BOUGHT a high-definition LCD TV that's as big as your outstretched arms. And perhaps you've also splurged on a 7.1 channel surround sound system, and an upconverting DVD player or maybe a sleek Blu-ray player. Maybe you've got a state-of-the-art game console or Apple TV or some other Web-based feed. Well, come 17 February, you just might want one more thing: a new antenna on your roof.

If you live in the United States and you're one of the 19 million people who still prefer to pull their TV signals out of the air rather than pay a cable company to deliver them, you may already know that this month the vast majority of analog television broadcasts in the United States are scheduled to end and most free, over-the-air TV signals will be transmitted only in the new digital Advanced Television Systems Committee (ATSC) format. A massive advertising campaign is now telling people who get their signals from the ether that they'll need a TV with a built-in ATSC tuner or a digital converter box to display their favorite programs.

What the ads don't mention is that most of those people will also need a new antenna. For the vast majority of you out there in Broadcast-TV Land, the quality of what you see—or even whether you get a picture at all—will depend not on your TV or converter box but on the antenna that brings the signal to them.

If you have a cable or satellite hookup, you might think that this antenna issue is irrelevant—but think again. Some owners of high-end systems complain that the signals coming from their satellite or cable provider aren't giving them the picture quality they expected. That's because cable and satellite operators often use lossy compression algorithms to squeeze more channels, particularly local channels, into their allotted bandwidth. This compression often results in a picture with less detail than the corresponding terrestrial broadcast signal provides. For videophiles who have already spent a fortune on their home-theater systems, a couple of hundred dollars more for a top-of-the-line antenna obviously makes sense. And of course, antennas are also good backup for the times when the cable gets cut or the satellite system fades out due to rain or snow. In addition, they serve second TV sets in houses not wired to distribute signals to every room.

Suddenly the dowdy TV antenna, a piece of technology that has changed little over the past 30 years, is about to be the belle of the ball.

GONE, HOWEVER, are the days when a large rooftop antenna was a status symbol. Cellphones and handheld GPS units have conditioned consumers to expect reliable wireless services in very small packages. Such dramatic changes in consumer preferences—coupled with the new frequency allocations, channel distributions, and high demand for reliable over-the-air digital antennas—mean that the time for new designs has indeed come.

Most TV viewers think of antennas as simple devices, but you're tech savvy, so of course you'd never assume this. Nevertheless, bear with us briefly as we review Antennas 101.

The decades-old designs of most TV antennas on rooftops—and in the market today—are typically configured on a horizontal fish bone, with arms of varying lengths to handle a broad range of frequencies.Though the engineering of antennas in other spheres has advanced radically over the years, manufacturers of television equipment have stuck pretty much with the old designs for economic reasons. Traditional antennas were good enough for analog television, and the shrinking customer base for broadcast reception didn't offer much incentive to plow money into new designs.

The transition to digital has changed all that. Most digital channels are broadcast in UHF, and UHF antennas are smaller than those used for analog TV, where most broadcast signals were VHF. Also, the multipath problem, arising from signals that reflect off buildings and hills, which may have occasionally caused ghosting on analog TVs, can completely destroy a digital picture.

A few designers and manufacturers have done the necessary research and development and introduced improved models. First out of the labs were the Silver Sensor, introduced by Antiference,

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based in Coleshill, England, in 2001, and the SquareShooter, introduced in 2004 by Winegard, in Burlington, Iowa.

The Silver Sensor [see "TV Topper"], an indoor antenna designed for UHF reception, is based on the classic log-periodic design, which means that the electrical properties repeat periodically with the logarithm of frequency. Done right, a log-periodic design offers good performance over a wide band of frequencies.

The outdoor SquareShooter's element has a sinuous shape, which helps it respond across a broad UHF range of frequencies [see "Under the Hood"]. It's mounted in front of an open grid that reflects UHF waves, thereby reducing the multipath problem by blocking signals arriving from behind the antenna.

Still, the pace of product introductions is slow. To this day, some manufacturers are still relabeling old designs as HDTV antennas as long as they generally cover the right part of the spectrum. But some very good designs are finally on the market—if you know what to look for.

ANTENNAS ARE MUCH better now than they used to be. But two changes will make them even better in the next several years: the introduction of powerful new software tools for designing antennas, and a slew of new regulations in the United States that will reduce the range of frequencies that a TV antenna must receive. Together, these factors will lead the way to smaller antennas [see "Loop de Loop"] that work better and look better than the apparatus that sprouted from the roof of your grandparents' house 50 years ago.

The key developments that have changed antenna design are computational electromagnetic codes, advanced search-and-optimization methods like genetic algorithms, and improved measurement tools such as the vector network analyzer. Traditionally, antenna designers used pencil and paper to wrestle with Maxwell's equations, the four equations that describe electric and magnetic fields. Then engineers spent enormous amounts of time in the laboratory, testing and tweaking designs. Computational electromagnetic codes, a breed of program that solves Maxwell's equations on a computer, have revolutionized antenna design by allowing the engineer to simulate the real-world electromagnetic behavior of an antenna before it is built.

As computer power increased in the 1990s, antenna engineers began using automatic search-and-optimization methods to sort through the successive designs their codes generated. In particular, they used genetic algorithms, which emulate the Darwinian principle of natural selection through a survival-of-the-fittest approach. After sifting through millions of possible design configurations, the algorithm can zoom in on a handful of promising optimal designs that meet specified performance and size criteria.

Thanks to these tools, antenna designers can focus more on the antenna itself and less on the math. And the months that used to be spent testing prototypes are now compressed into days—or even just hours—of simulation. Designers now go to the laboratory only for a final check, to confirm the accuracy of their computations.

And in the lab, life is a lot easier today than it was several decades ago. To check antenna performance, engineers have to measure its impedance accurately across a huge frequency range. That is what a modern vector network analyzer now lets them do easily and quickly. Decades ago, engineers had to calculate, for each channel's frequency, the impedance from measurements of voltage signals in the cable leading to the antenna. This was a laborious and often imprecise process.

REGULATIONS THAT REDUCE the range of frequencies a television must receive are driving big changes in antenna design. The new regulations relax the other two main design constraints, gain and size, making it possible for smaller and far less conspicuous antennas than the monstrosities of yore.

These changes are part of a frequency reallocation that has turned the various parties claiming pieces of the radio spectrum into players in a game of musical chairs. In the analog television world, TV broadcasts occupy three bands. The low-VHF band covers 54 to 88 megahertz, the high-VHF band covers 174 to 216 MHz, and the UHF band covers 470 to 806 MHz. Earlier the UHF band stretched all the way to 890 MHz, but some of this bandwidth was given up in the 1980s to

TV TOPPER: Introduced by Antiference, of Coleshill, England, in 2001, the Silver Sensor is an adaptation of the classic design of years past—a log-periodic array of horizontal receiving elements. Versions of the Silver Sensor are sold by LG Electronics under its Zenith brand and by Philips (shown here).

UNDER THE HOOD: The Winegard SquareShooter consists of a two-arm sinuous element and grid reflector attached to an inexpensive Mylar substrate and encased in a plastic dome. The element responds across a broad range of frequencies; its size is optimal for the UHF band. The open grid behind it is sized to reflect UHF frequencies, which reduces the multipath problem by blocking some of the signals that bounce off buildings or hills instead of coming directly to the antenna.

LOOP DE LOOP: The new ClearStream2, from Antennas Direct, uses thicker-than-traditional elements and tapers the thickness of the loops, which allows the antenna to respond to a greater range of frequencies. The resulting tapered-loop antenna is half the volume of the equivalently performing bow-tie array that has been on the market for years. As with the SquareShooter, the grid acts to defend the antenna against multipath interference.

THE NEW ANTENNAS: A SAMPLING

	Best for	Estimated range	Dimensions	Street price
INDOOR				
Antennas Direct PF7	Near the transmitter and for those who want a hidden or discrete antenna	24 kilometers	23 x 28 x 2.5 centimeters	US $40
RCA ANT1500	Near the transmitter and for those who want a hidden or discrete antenna	24 km	13 x 39 x 28 cm	$30
Philips Silver Sensor	Reception that needs higher gain and multipath rejection, for urban areas	32 km	33 x 34 x 5 cm	$25
INDOOR/SMALL OUTDOOR				
Channel Master 4220	Near to medium range	32 km to channel 13, 48 km to chan-nel 69	14 x 62 x 39 cm	$30
Winegard HD-1080	Near to medium range, with improved VHF	64 km	88 x 46 cm	$60
Antennas Direct ClearStreamC2	Near to medium range, in a smaller size	80 km	51 x 30 x 13 cm	$80
MEDIUM-SIZE OUTDOOR				
Winegard HD-7015	People who need VHF and UHF in one package	56 km, UHF; 80 km, VHF	223 x 282 x 65 cm	$50
Channel Master 4221	Medium to long-range UHF reception	72 km	51 x 13 x 92 cm	$40
Antennas Direct DB4	Medium to long-range UHF reception	89 km	10 x 48 x 74 cm	$50
LARGE OUTDOOR				
Winegard HD8200U	Long-range combination VHF/UHF	More than 97 km	427 x 279 x 84 cm	$120
Antennas Direct 91XG	Very long-range UHF reception	More than 113 km	56 x 51 x 236 cm	$75
Televes DAT75	Very long-range UHF reception	More than 113 km	180 cm long (other dimen-sions not available)	$200

provide spectrum for cellphone communications. The two VHF bands will be retained in the transition to digital TV, but the ceiling of the UHF band will be reduced to 698 MHz, making room for new wireless services and for applications involving homeland security. This is 108 MHz narrower than the current UHF TV allocations and 192 MHz narrower than the older allocations, which extended out to channel 83.

Notably, the older and wider UHF bands were in effect when most of the TV antennas on the market today were designed. The old designs are therefore rarely optimal for the new spectrum allocations because the antennas had to cover the wider bands and higher frequencies.

The transition to digital has also changed how the stations are distributed across the allocated bands. In the days of analog, most TV stations were on the VHF band, with smaller, less powerful stations in the UHF band. But now, in the fast-approaching digital world, roughly 74 percent of the stations are on the UHF band and 25 percent are on the high-VHF band (today's channels 7 through 13). Only about 1 percent of the stations will be in the low-VHF band (channels 2 through 6).

Gain is not the be-all and end-all of antenna design—far from it, as any antenna engineer will tell you. But you'd be hard-pressed to know that if spec sheets and marketing hype are your main sources of information.

Gain, usually expressed in decibels, indicates how well the antenna focuses energy from a particular direction as compared with a standard reference antenna. Because most spec sheets don't give a two- or three-dimensional radiation plot, the gain number specified is the value in the direction of maximum intensity. What that means is that if the broadcast stations you're trying to receive do not all line up like points on a single straight line from your home, you could have a problem with an antenna whose gain drops off dramatically from that sweet spot. Also, "gain" in this usage doesn't include losses from impedance mismatch. In practice, the antenna's performance will degrade if its impedance is different from that of the cable connected to it.

For these gain calculations, the reference antenna is often a half-wave dipole antenna, the most common type of antenna, which is composed of two metal rods, each one-quarter the length of the signal wavelength. The signal is taken from the antenna through a connection between the two conductors. The classic TV antenna is a log-periodic array of dipoles, with each dipole receiving a different VHF or UHF frequency.

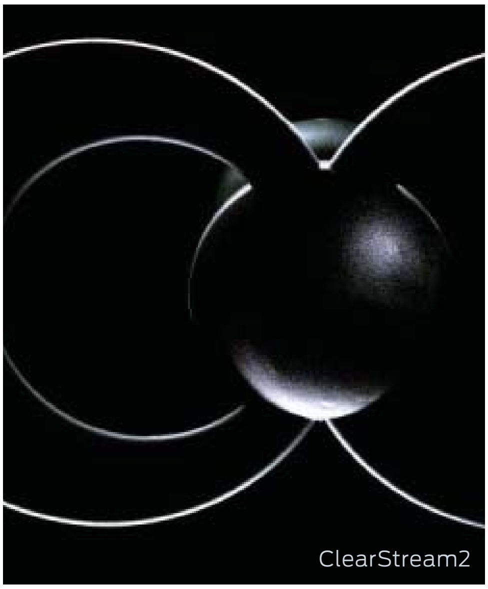
When shopping for an antenna, consider the gain, but not to the exclusion of all other characteristics. Buying an antenna based on gain and price alone would be like going shopping for an automobile and considering only power and price; you might end up with a 500-horsepower engine attached to a skateboard. While higher values of gain—in the 7- to 12-decibel range—are usually better than lower values, most consumers will be better off not focusing on gain but instead purchasing a unit that provides good overall performance, as long as it meets their reception and installation requirements [see "The New Antennas: A Sampling"].

A family in rural Nebraska, for instance, might need a large, highly directional antenna, a tower of about 18 meters (60 feet), and a preamplifier to pick up stations, which would more than likely be located somewhere over the horizon. But that would be complete overkill for somebody living in Salt Lake City, where all the broadcast towers are on a mountain ridge just above the city with a line-of-sight path between most viewers and the tower. Anywhere near Salt Lake City you'll get great reception even with a small indoor UHF antenna.

Don't be fooled by claims of astoundingly high gain. Some manufacturers are marketing small indoor antennas and labeling the boxes with gain numbers between 30 and 55 dB. This kind of unit is actually an antenna paired with an amplifier, and the gain value stated on the package is really the gain of the amplifier and not that of the antenna. While it is possible to improve reception by using a well-designed low-noise amplifier, most of the inexpensive antennas designed this way actually have cheap amplifiers and too much gain. That combination generally overloads the amplifier—and potentially the receiver as well—causing signal distortion that can degrade or eliminate DTV reception entirely. Most consumers are better off with a well-designed nonamplified unit, also known as a passive antenna. If television reception does require an amplifier, the best choice is a high-quality, low-noise model connected as close as possible to the antenna.

Consumers switching to digital TV using just an indoor antenna for reception face a more difficult problem. What was good enough to provide a watchable, if slightly snowy, analog broadcast is likely to bring nothing but a blank screen in the digital world. Even the better antennas must sometimes be readjusted to receive certain channels, forcing viewers out of their easy chairs to fiddle with their antennas.

But couch potatoes might soon be able to stay planted, thanks to a new standard approved by the Consumer Electronics Association (CEA) in 2008. The ANSI/CEA-909A Antenna Control Interface standard allows the television receiver to communicate with the antenna, instructing it to adjust and automatically lock onto the signal as the viewer channel surfs. Because the antenna and the receiver both "know" what channel the user is watching, the antenna can change either physically or electrically to adjust tuning, direction, amplifier gain, or polarization. The ability to adjust antenna tuning for each channel allows engineers to use a narrowband antenna element to cover a wide range of frequencies. This strategy is often referred to as tunable bandwidth. A simple example of tunable bandwidth is to use a switch to connect two short rods into a larger rod, thus reducing the resonant frequency.



Tunable bandwidth relaxes many of the design compromises, so manufacturers can produce smaller, higher-performance antennas. This is particularly important for indoor antennas, where compactness and aesthetics are key to adoption.

Not only will ANSI/CEA-909A eliminate having to fool with the antenna all the time, it should make it easier for engineers to design the high-performance, aesthetically pleasing small antennas that everyone wants. Audiovox Corp., of Hauppauge, N.Y.; Broadcom Corp., of Irvine, Calif.; and Funai Electric Co., of Daito, Japan, have demonstrated 909A-compliant smart antennas, but these designs have yet to be widely distributed because hardly any TV receivers on the market are compatible with them.

That might soon change. The National Association of Broadcasters (NAB)—the trade association that represents broadcast TV stations—and others are doing their best to stimulate a market for 909A-enabled antennas and receivers by promoting the new smart antennas. The NAB is particularly interested in the 909A technology because difficulty in adjusting the antenna was one of the factors that drove millions of consumers to cable or satellite in years past. In 2008, the NAB funded Antennas Direct, the company that one of us (Schneider) founded, to develop 909A-compliant smart antennas because without such a device on the market, television manufacturers would have no compelling reason to add the required interface circuitry to television tuners.

To help encourage manufacturers to do so, the July 2007 draft of the 909A standard made a change in the original specification. In the original design, the signals to the antenna went over a dedicated cable—that meant another jack in the back of TVs and another cable for consumers already struggling with a tangle of wires. The revised standard allows signals to be sent over the same coaxial cable that transmits the television signal. The single-cable solution should spur television manufacturers to adopt the standard, many being reluctant to include additional connection ports on the already crowded rear panel of a modern flat-panel TV. It will also simplify the connections for technology-challenged consumers.

With more free content, superior picture quality, and viable indoor antenna options coming soon, the broadcasters may finally be in a position to—dare we say it?—start stealing viewers back from cable and satellite.

And perhaps strangest of all, an antenna on the rooftop or perched in the living room may once again become a status symbol, as it was in the early days of television. It won't be showing off that you're rich enough to have a TV—just smart enough to get the most out of it. ❑

TO PROBE FURTHER

The CEA and NAB provide a Web site (http://www.antennaweb.org) to help consumers learn about the transition to digital television. The Web site has tools that indicate what channels are available in specific locations and how to select an antenna to receive them. Antennas Direct hosts a similar site (http://www.antennapoint.com), which also maps transmitter locations and gives distances and bearings relative to any specified location in the United States. Both sites offer advice on particular antennas and how to install them for best results.

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SELF-CONTAINED: Sun Microsystems' MD S20 is a standard shipping container housing eight racks of servers, storage systems, network gear, and power supplies [above]. The container's equipment consumes 187.5 kilowatts of power and uses a water-based cooling system [right]. PHOTOS: SUN MICROSYSTEMS

Tech Titans Building Boom

Continued from page 39

Even more significant, data centers are saving lots of energy by using new cooling technologies. Traditional facilities use raised floors above a cold-air space, called a plenum, and overhead hot-air collection. The major drawback of this scheme is that hot spots—say, a highly active server or switch—may go undetected and the overheated device may fail. To avoid such situations, some data centers cool the entire room to temperatures much lower than what would otherwise be needed, typically to around 13 °C.

Now data centers are turning to new cooling systems that let them keep their rooms at temperatures as high as 27 °C. American Power Conversion Corp., in West Kingston, R.I., offers a special server rack with an air-conditioning unit that blows cold air directly onto the servers. Hewlett-Packard's "smart cooling" techniques use sensors within the machine room to position louvers in the floor that direct cold air at local hot spots, allowing the data center to run at a higher ambient temperature and reducing cooling costs by 25 to 40 percent.

Traditional air-conditioning systems are also making way for higher-efficiency water-based units. Today's large data centers rely on cooling towers, which use evaporation to remove heat from the cooling water, instead of traditional energy-intensive chillers. Several hardware vendors have developed water-based mechanisms to eliminate heat. IBM's Rear Door Heat eXchanger mounts on the back of a standard rack, essentially providing a water jacket that can remove up to 15 kW of heat. It's back to the mainframe days!

Data centers are also trying to use cold air from outside the buildings—a method known as air-side economization. At its Quincy data center, Yahoo says that rather than relying on conventional air-conditioning year-round, it has adopted high-efficiency air conditioners that use water-based chillers and cold external air to cool the server farms during three-quarters of the year.

Finally, the most radical change taking place in some of today's mega data centers is the adoption of containers to house servers.

Instead of building raised-floor rooms, installing air-conditioning systems, and mounting rack after rack, wouldn't it be great if you could expand your facility by simply adding identical building blocks that integrate computing, power, and cooling systems all in one module?

That's exactly what vendors like IBM, HP, Sun Microsystems, Rackable Systems, and Verari Systems have come up with. These modules consist of standard shipping containers, which can house some 3000 servers, or more than 10 times as many as a conventional data center could pack in the same space. Their main advantage is that they're fast to deploy. You just roll these modules into the building, lower them to the floor, and power them up. And they also let you refresh your technology more easily—just truck them back to the vendor and wait for the upgraded version to arrive.

Sun was the first company to offer a container module. Its MD S20 includes 280 pizza-box-size quad-core servers plus Sun's monitoring and control equipment. All in all, it consumes 187.5 kW, which translates to about 12.6 kW/m². Conventional raised-floor data centers have much more modest densities, often as low as 0.5 kW/m². Verari Systems' container houses 1400 blade servers, and it can use either self-contained or chilled water cooling, consuming 400 kW, or 12.9 kW/m². Rackable Systems' ICE Cube uses a self-contained cooling system and a dc power system, allowing the containers to handle a power density of 16 kW/m².

Microsoft's Chicago data center, which will support the company's cloud initiatives, is a hybrid design, combining conventional raised-floor server rooms and a container farm with some 200 units. The space where the containers will sit looks more like a storage warehouse than a typical chilled server room. Pipes hang from the ceiling ready to be connected to the containers to provide them with cooling water and electricity. As one Microsoft engineer describes it, it's the "industrialization of the IT world."

SO WHAT KIND OF RESULTS have Google and Microsoft achieved? To interpret some of the numbers they have reported, it helps to understand an energy-efficiency metric that's becoming popular in this industry. It's called power usage effectiveness, or PUE, and it's basically the facility's total power consumption divided by the power used only by servers, storage systems, and network gear. A PUE close to 1 means that your data center is using most of the power for the computing infrastructure and that little power is devoted to cooling or lost in the electrical distribution system. Because it doesn't gauge the efficiency of the computing equipment itself, PUE doesn't tell the full story, but it's still a handy yardstick.

A 2007 study by the U.S. Environmental Protection Agency (EPA) reported that typical enterprise data centers had a PUE of 2.0 or more. That means that for every watt used by servers, storage, and networking equipment, an additional watt is consumed for cooling and power distribution. The study suggested that by

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2011 most data centers could reach a PUE of 1.7, thanks to some improvements in equipment, and that with additional technology some facilities could reach 1.3 and a few state-of-the-art facilities, using liquid cooling, could reach 1.2.

Curiously, that's where Google claims to be *today*. The company has reported an average PUE of 1.21 for its six "large-scale Google-designed data centers," with one reaching a PUE of 1.15. (The company says its efficiency improvements amount to an annual savings of 500 kilowatt-hours, 300 kilograms of carbon dioxide, and 3785 liters of water per server.) How exactly Google achieves these results remains a closely guarded secret. Some observers say that Google is an extreme case because its massive scale allows it to acquire efficient equipment that would be too costly for other companies. Others are skeptical that you can even achieve a PUE of 1.15 with today's water-based cooling technologies, speculating that the facility uses some unusual configuration—perhaps a container-based design. Google says only that these facilities don't all have the same power and cooling architectures. It's clear, though, that Google engineers are thinking out of the box: The company has even patented a "water-based data center," with containerized servers floating in a barge and with power generated from sea motion.

For its part, Microsoft has recently reported PUE measurements for the container portion of its Chicago data center. The modules have proved to be big energy savers, yielding an annual average PUE of 1.22. The result convinced the company that all-container data centers, although a radical design, make sense. Indeed, Microsoft is pushing the container design even further in its next-generation data centers, with preassembled modules containing not only servers but also cooling and electrical systems converging to create a roofless facility—a data center that could be mistaken for a container storage yard.

But the containerization of the data center also has its skeptics. They say that containers may not be as plug-and-play as claimed, requiring additional power controllers, and that repairing servers could involve hauling entire containers back to vendors—a huge waste of energy. With or without containers, the EPA is now tracking the PUE of dozens of data centers, and new metrics and recommendations should emerge in coming years.

IT'S CERTAIN THAT FUTURE DATA CENTERS will have to take today's improvements far from where they are today. For one thing, we need equipment with much better power management. Google engineers have called for systems designers to develop servers that consume energy in proportion to the amount of computing work they perform. Cellphones and portable devices are designed to save power, with standby modes that consume just a tenth or less of the peak power. Servers, on the other hand, consume as much as 60 percent of their peak power when idle. Google says simulations showed that servers capable of gradually increasing their power usage as their computing activity level increases could cut a data center's energy usage by half.

Designers also need to rethink how data centers obtain electricity. Buying power is becoming more and more expensive, and relying on a single source—a nearby power plant, say—is risky. The companies that operate these complexes clearly need to explore other power-producing technologies—solar power, fuel cells, wind—to reduce their reliance on the grid. The same goes for water and other energy-intensive products like concrete and copper. Ultimately, the design of large-scale computer facilities will require a comprehensive rethinking of performance and efficiency.

And then there's software. Virtualization tools, a kind of operating system for operating systems, are becoming more popular. They allow a single server to behave like multiple independent machines. Some studies have shown that servers at data centers run on average at 15 percent or less of their maximum capacity. By using virtual machines, data centers could increase utilization to 80 percent. That's good, but we need other tools to automate the management of these servers, control their power usage, share distributed data, and handle hardware failures. Software is what will let data centers built out of inexpensive servers continue to grow.

And grow they will. But then what? Will data centers just evolve into ever-larger server-packed buildings? Today's facilities are designed around existing equipment and traditional construction and operational processes. Basically, we build data centers to accommodate our piles of computers—and the technicians who will squeeze around them to set things up or make repairs. Containers offer an interesting twist, but they're still based on existing servers, racks, power supplies, and so on. Some experts are suggesting that we need to design systems *specifically* for data centers. That makes good sense, but just what those facilities will look like in the future is anyone's guess. ❑

TO PROBE FURTHER

For more about Google's data centers and their energy-efficiency strategies, see "The Case for Energy-Proportional Computing," IEEE Computer, *December 2007, and also the company's report on this topic at http://www.google.com/corporate/datacenters.*

Microsoft's Michael Manos and Amazon's James Hamilton offer insights about data centers on their respective blogs: LooseBolts (http://loosebolts.wordpress.com) and Perspectives (http://perspectives.mvdirona.com).

Data Center Knowledge (http://www.datacenterknowledge.com), The Raised Floor (http://theraisedfloor.typepad.com), Green Data Center Blog (http://www.greenm3.com), and Data Center Links (http://datacenterlinks.blogspot.com) offer comprehensive coverage of the main developments in the industry.

KHALIFA UNIVERSITY

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- Computer Engineering (KU-057/2008)

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Department of Electrical Engineering /or
Institute of Communications Engineering
National Sun Yat-sen University
Kaohsiung, 80424 Taiwan

EE :

E-mail: chiaying@mail.ee.nsysu.edu.tw
Phone: +886-7-5252000 ext. 4103 Fax: +886-7-5254199
URL: ***http://www.ee.nsysu.edu.tw***

ICE :

E-mail: commaa@mail.nsysu.edu.tw
Phone: +886-7-5252000 ext. 4476 Fax: +886-7-5254475
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the data

Corporate Travel Down, Telecommuting Up

TELECOMMUTING HIT record highs and business travel dropped off dramatically as oil prices surged last summer, according to research firm TNS Global, which conducted two surveys for headset maker Plantronics. An astonishing 48 percent of all knowledge workers telecommuted at least one day per week, up sharply from 35 percent in the same period the previous year. Two-fifths reported cutbacks in travel at their corporations; more than a third said they had cut down on their own business travel.

Beth Johnson, a vice president of marketing at Plantronics, says that though the price of a barrel of oil has plummeted—from an all-time high of US $147 in July to just one-third of that in early January—telecommuting hasn't fallen, and business travel hasn't risen. Reason: the miserable shape of the overall economy.

The survey defined knowledge workers broadly to include all full-time office workers who use a computer and common software applications for their daily work. —STEVEN CHERRY

Sources: Plantronics, TNS Global

PHOTO: TIM HALL/GETTY IMAGES

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Green Engineering

MEASURE IT – FIX IT

La Selva Biological Station developed a wireless sensor system to monitor the rain forest ecosystem.

Nucor Steel optimized its steel melting process to drastically reduce electricity consumption.

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Vehicle Projects created a complex control system for a zero-emission, fuel-cell-powered locomotive.

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