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THIS PAGE, CLOCKWISE FROM TOP: AFP/ GETTY IMAGES; OLENA ISTOMINA/ ISTOCKPHOTO; SIKORSKY AIRCRAFT CORP.

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An *IEEE Spectrum* editor stays home for a week and sends a robot proxy to the office. Here's what happened. *By Erico Guizzo*

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To smooth the speed bump in supercomputers—which lies between the chips rather than within them—IBM integrates optical links right into the circuit boards. *By Clint Schow, Fuad Doany & Jeffrey Kash*

36 THE FASTEST HELICOPTER ON EARTH

Sikorsky Aircraft aims to break the helicopter speed record with an unusual coaxial rotor design. *By Thomas Lawrence & David Jenney*

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The 2010 Shanghai World Expo isn't like the giddy technology jamborees of the past 150 years. *By Sally Adee*

UPDATE

OPINION

DEPARTMENTS

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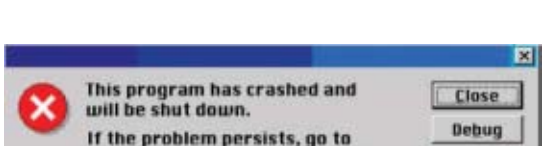
Video: Office Life Through a Robot's Eye

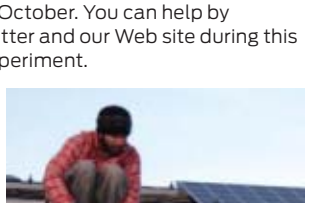
This month's cover story describes an *IEEE Spectrum* editor's experiences working through robotic telepresence. In a behind-the-scenes video, see what the interactions were like, both for the remote pilot at home and his coworkers in the office. Watch as the robot attends meetings, navigates treacherous hallways, and makes small talk. Judge for yourself whether robot avatar technology is suitable for your own job or whether it needs a few more years of development.



CRASH WEEK IS COMING

IS YOUR iPHONE dropping calls again? Did your online banking site just go down? Are the brakes on your neighbor's Toyota a little wonky? Join contributing editor Robert N. Charette and a crack team of computer scientists and *Spectrum* journalists as we try to document as many software and hardware failures as we can during the week of 1 to 8 October. You can help by reporting crashes via Twitter and our Web site during this unprecedented social experiment.

MY FIRST YEAR WITH SOLAR: After installing photovoltaic panels on his roof and letting them run for a year, an engineer crunches the numbers and discovers that solar makes good sense.



PHOTOS, CLOCKWISE FROM TOP: RANDI SILBERMAN KLETT; STEVEN JOHNSON; MAY TRUONG (2)

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WHERE THE CANDIDATES STAND

The election for 2011 IEEE president-elect is at hand, with ballots sent out in August. *The Institute* asked candidates Gordon W. Day [left] and Joseph V. Lillie [right] to weigh in on important issues. They discussed topics such as which technological areas IEEE should be involved in, ideas for boosting society membership, and ways to help unemployed members.

HIGH-TECH HEALER

Sanna Gaspard is developing a device that mimics a manual infant massage and might significantly influence neonatal care. The IEEE graduate student member's work landed her on the list of the U.S. National Engineers Week Foundation's New Faces of Engineering for 2010.

COMMUNITY SERVICE PROGRAM EXPANDS

Read about the Engineering Projects in Community Service (EPICS) in IEEE, an outreach program in which section volunteers and IEEE student and graduate student members mentor high schoolers on engineering projects that help their communities. EPICS is expanding to IEEE sections around the world.

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Rotorcraft Revival

Ask David Jenney about his career in helicopters and he'll likely tell you that he worked on the Black Hawk for 15 to 20 years. What he'll probably neglect to say is that he conjured the key innovation—a funny-looking tilt to the tail rotor—that made the Black Hawk one of the most successful and ubiquitous helicopters in history.

He may also fail to mention his many rotorcraft patents, or his time as the engineering director in charge of some 400 employees at Sikorsky Aircraft Corp., in Stratford, Conn. What he *will* talk about, with a wistful smile, is 1980, which he spent shuttling between his home in Stratford and an airfield outside West Palm Beach, Fla., where he was flight-testing an experimental aircraft that he hoped would claim the helicopter speed record [see "The Fastest Helicopter on Earth," in this issue].

Each day at sunrise, he'd stroll into the control room at a test facility built on land reclaimed from a sprawling alligator swamp. He'd watch the helicopter push to higher and higher speeds, but a nagging question weighed on his mind: With money left for only about 20 more hours of flight, what would happen next? Neither the military nor NASA had pledged money for further development.

"So we went on the road and tried to sell it," Jenney recalls. At Fort Rucker, a U.S. Army base in Alabama, the helicopter flew on what's known as a map-of-the-Earth course, blazing over streams and ducking into forest clearings. The vehicle's unusually short rotor blades allowed it to maneuver through tighter spots than most aircraft could, and at significantly faster speeds. "We flew it very low, over rivers, popping over the trees and dipping back down," Jenney says. "The pilots came back raving."

But it wasn't enough. "I gave talks all over the place, but I couldn't pry loose more than a few dollars," he says. In 1981, his project—his long-held dream—was declared a dead end. In the aircraft's final hours of flight, a test pilot took Jenney for a ride for the first time, over Stratford. He admired the streaks of gridded streets below and tried to hide his immense disappointment.

Jenney retired from Sikorsky in 1993. A decade later, however, his beloved high-speed helicopter concept was revisited and soon became a full-blown project. A modernized version is now tackling the speed record once more. "I cheer them on!" he says. ❑

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. 47, no. 9 (INT), September 2010, p. 9, or in *IEEE Spectrum*, Vol. 47, no. 9 (NA), September 2010, p. 11.

PATRICK O'CONNOR/WORCESTER POLYTECHNIC INSTITUTE

contributors

SCOTT DORMAN of Smalldog Imageworks started with an untouched photograph of Anybots' telepresence robot ["When My Avatar Went to Work," p. 24] to create a dynamic composite of six separate shots for this month's cover. Dorman says that "painting with pieces of photography" has gotten a lot easier since the pre-Photoshop days, when professional digital retouching required a US $300 000 system called the Quantel Paintbox. "Compared to today's standards, it was a dinosaur," Dorman remembers. He has enhanced photographs for BMW, Coca-Cola, and Puma and is a regular contributor to *IEEE Spectrum*.

DAVID LAMMERS is a veteran chip industry reporter. He began covering semiconductors as a correspondent for the Associated Press in Tokyo in the 1980s. He continued there and in Austin, Texas, with *EE Times* and most recently with *Semiconductor International*. Reporting "Resistive RAM Gains Ground" [p. 14] confirmed for him that "this is one of the most interesting times in memory research in the past three decades."

LUCAS LAURSEN is a freelance journalist based in Madrid. While writing "When Chickens Attack" [p. 9], he began to feel some sympathy for hens when he learned that "they take out their [pecking] instincts on each other." He'll still eat poultry products, though, he says. Laursen also writes for *Science*, *Nature*, and the *Financial Times* weekend magazine.

THOMAS LAWRENCE, a technical fellow at Sikorsky Aircraft Corp., has made a career of peculiar projects. First he helped design an airship lifted by four conjoined helicopters. Next came the XH-59A, a futile effort to break the helicopter speed record. He then focused on the X-Wing, an aircraft that could take off like a helicopter but switched midair to fly like a fixed-wing airplane. None succeeded. Before turning to the very successful X2 ["The Fastest Helicopter on Earth," p. 36], Lawrence says, "I wasn't sure what my career path was."

CLINT SCHOW, FUAD DOANY, and **JEFFREY KASH,** who wrote "Get on the Optical Bus" [p. 30], work at the IBM T. J. Watson Research Center in Yorktown Heights, N.Y. Their mission is not to speed up processors but to deal with the shortage of bandwidth between them—an irksome problem that must be solved if future generations of supercomputers and servers are to be more powerful than today's.

PAUL WALLICH, when not reporting on oddball technologies, takes to his shop to make small household parts by casting, carving, forming, filing, sawing, drilling, riveting, tapping, soldering, and gluing up laminated assemblies. He was, in other words, the natural choice to write "3-D Printers Proliferate" [p. 21], about systems for sending a CAD file from a computer to a device that extrudes or sinters an object into being.

CLOCKWISE FROM TOP LEFT: DAVID STUART; SIKORSKY AIRCRAFT CORP.; JULIE ROBICHAUX; MOLLY CROCKETT; DAN HUTCHESON

Technical Sweetness Isn't Enough

When you see something that is technically sweet," said J. Robert Oppenheimer, "you go ahead and do it, and argue about what to do about it only after you've had your technical success. That is the way it was with the atomic bomb."

Each profession has a right to its own indulgence—technical sweetness for engineers, elegance for designers, contrarianism for journalistic pundits. It is not the professionals but their bosses who must curb such enthusiasms. Sometimes, though, the bosses are out to lunch.

A case in point is the Chevy Volt, a fundamentally new kind of hybrid gas/electric car whose corporate parent, General Motors, has chosen a technical solution that is not only sweet but courageous. Rather than hook an internal combustion engine to an electric motor in parallel—with the engine sustaining cruising speed and the motor helping with the acceleration—the Volt links its power plants in serial configuration. The motor alone drives the wheels, with the engine kept in reserve to recharge the batteries. This technology allows the car to realize many of the advantages of all-electric drive while extending its range with that still-unbeaten energy-storing medium, gasoline.

Sadly, this scheme costs a great deal to implement. That would be a mere detail if the car were a prototype backed by the Defense Advanced Research Projects Agency or some bored billionaire. The Volt might even make a certain devil-may-care economic sense to boutique car companies, such as Tesla Motors, that need only sell cars to a handful of rich people to stay in business.

MARTIN KLIMEK/GENERAL MOTORS

Now for our contrarian view: The Volt won't sell in sufficient numbers to make a difference to General Motors. This wounded giant, recalled from bankruptcy by a US $57 billion federal bailout—the largest granted to any manufacturing concern in history—must sell the Volt in vast numbers to make even a slight change in its bottom line. And at the recently announced base price of $41 000—even with the $7500 tax credit factored in—the car just isn't going to rack up the kind of sales figures that will matter to GM. "There are not enough idiots who will buy it," Johan de Nysschen, the president of Audi of America, told auto writer Lawrence Ulrich, a contributor to this magazine.

Plainly, the bosses at GM were out to lunch. That, or they were so hard pressed by their company's economic troubles that they had to punt, hyping the Volt as the secret weapon that would turn the tide of war. In that sense, the company's gamble can be called a success: Congress wrote GM the necessary check, which has prolonged the life support.

The technologies that the Volt's engineers developed could make the world a better place many years from now, but by then GM may well have been broken up and sold for scrap. The moral of the story is that brilliant engineering doesn't translate reliably into commercial success, whether for a start-up or a long-running concern.

By the same token, a technical failing need not result in commercial failure. Consider Apple's iPhone 4, whose sweet-but-courageous solution to the problem of wireless reception involved wrapping two antennas around the edges of the device.

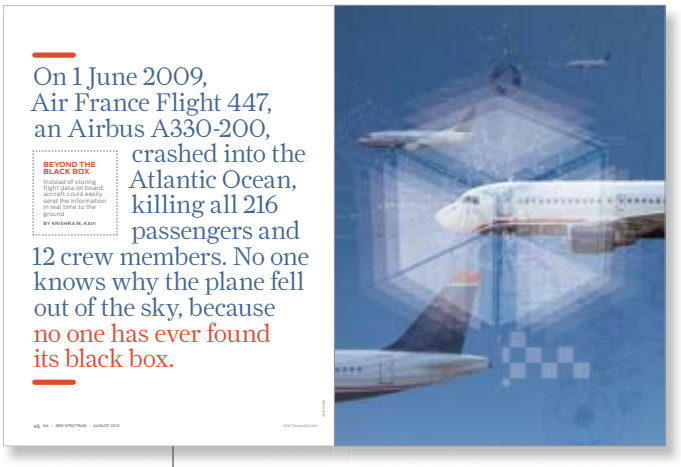
Hold the phone in a particular way—the infamous "death grip"—and you connect the two antennas, which will attenuate the signal and probably drop your call. *Consumer Reports,* the venerable nonprofit rater of consumer products, decided not to recommend the product; worse yet, comedians poked fun at what has become known as "antennagate." It was the glitch mocked round the world, in blogs and on TV talk shows.

Yet none of that seems to have made the tiniest dent in iPhone 4 sales, which are already in the millions. Apple says it is selling every single unit it can make. Tech glitches or no, Apple products have bold and clever industrial (as opposed to technological) design. They're stylish and captivating; GM's cars, not so much.

When does technical brilliance matter, and when does it not? It may be a question of pure luck or the equally unanalyzable quality known as charisma. GM long ago lost that charisma, and Apple has it—in truckloads. "For he that has, to him shall be given, and he that has not, from him shall be taken even that which he has."

—Philip E. Ross

forum



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THINKING OUT OF THE BOX

KRISHNA M. Kavi ["Beyond the Black Box," August] has the right idea for supplementing black-box data so that all the information isn't lost if the black box is.

But Kavi writes that "the boxes were painted black in those days to fend off the stray rays of light that might have ruined the photographic film that stored the data." David Warren launched the line of instruments we have today by recording cockpit voice and flight data on wire, a medium partially replaced a decade later by magnetic tape. Until tape's digital bandwidth later blossomed, five and then eight channels of analog data were incised by a polygraph onto stainless-steel foil. The recorder developed by François Hussenot and Paul Beaudouin in 1939 was based on photography. This device needed its film changed with every flight and never made it out of test aircraft into commercial aviation.

Warren never invented a black box. He painted his 1956 prototype red before getting the Australian Department of Civil Aviation to review it. The department later wrote that "Dr. Warren's instrument has little immediate direct use in civil aviation." Warren pushed on with prototype refinements, prompting his boss to tell him, "If I find you talking to anyone, including me, about this matter, I will have to sack you."

JERRY NELSON
IEEE Member
McLean, Va.

NO DAZE AT FCC

HAVING READ "Radio Daze" [Spectral Lines, July], I must say that the Federal Communications Commission already recognizes and embraces the way today's tinkerers work and has done so for many years—in the amateur radio service. The FCC allocates frequencies in the MF, HF, VHF, UHF, and microwave spectrum for amateur radio experimentation. Modifying commercial radio equipment and home-built antennas is legal in the amateur service.

The FCC isn't trying to rain on anybody's parade, but protecting radio users from harmful interference is its responsibility. Limiting effective radiated power from the antenna system is one way to meet that goal.

DONN DENGEL
IEEE Senior Member
Palatine, Ill.

Senior Editor David Schneider (call sign N2LVD) replies: Indeed, Part 97 rules give amateurs a lot more leeway for experimenting. But you'd need to control both ends of the connection, and there would be encryption and content restrictions. In any event, the point of my essay was that the FCC nicely recognizes homebuilt devices under Part 15—it's just that its definition of homebuilt seems a bit musty.

MONTE CARLO NO SURE BET

I WISH AUTHOR David Patterson ["The Trouble With Multicore," July] had explored his algorithms for computing the value of pi in greater depth. The Gregory-Leibniz series, which he used as an example of a sequential algorithm, is fairly easy to parallelize for *n* terms over *N* processors. Even more important, though, parallelizing the Monte Carlo algorithm holds its own pitfalls. Many of the most popular routines for random-number generation are not safe to use in this context. In some cases, multiple threads executing in parallel could repeatedly receive identical "random" numbers, which would produce results no better than those of a single processor.

DAN BRESLAU
IEEE Member
Chicago

David Schneider responds: Dan Breslau brings up some important practical issues. He could also rightly point out that the Gregory-Leibniz series converges too slowly to be useful. We chose these examples to illustrate as simply as we could that the same problem could be solved in a sequential or parallel fashion.

CORRECTIONS

In "Careers: Where the Jobs Are" [July], Gordon Day should have been described as the past president of IEEE-USA.

In The Data ["Who Has the Fastest Internet?" August], we incorrectly reported South Korea's average Internet connection speed as 11.7 megabytes per second. The correct speed is 11.7 megabits per second.

update

more online at spectrum.ieee.org

When Chickens Attack

A computer system can tell when hens have murder on their minds

Robotics engineer Stephen Roberts was taking his lunch at Somerville College at the University of Oxford, in England, when the conversation turned to chicken. It wasn't the food, though. His dining companion was animal welfare specialist Marian Dawkins, and she thought that the pattern-recognition technology Roberts was explaining might help identify misbehaving hens.

Laying hens aren't ordinarily antisocial, but under the stress of incarceration, they are known to peck one another, sometimes to death. It usually starts with a couple of chickens and can spread quickly. Once a bird starts to peck, others follow suit. For poultry farmers, the behavior is costly and difficult to deter. Many farmers resort to clipping the chickens' beaks, but some countries ban the practice on humanitarian grounds. Environmental adjustments, such as dimming the lights or improving foraging material, can prevent attacks, but those work only if farmers know which hens need the changes, and each adjustment has its costs.

The key to detecting unruly hens might be in observing how they run, Roberts says: "Movement patterns [at an early age] are a proxy for behavior later on."

Dawkins hoped that by recording the shuffle and flow of chicken flocks over time, Roberts might train his software to distinguish between healthy flocks and stressed-out, violent ones before the feathers flew. Previously, Roberts studied human crowd movement using a machine-vision system based on optical flow. Optical flow is a measure of the pixel-to-pixel changes between subsequent frames of a video. The principle is the same for humans and

EVIL INTENT? Laying hens sometimes peck their coop mates to death. Applying image-processing algorithms to a video feed of a flock can predict when hens will cause trouble.

PHOTO: OLENA ISTOMINA/ISTOCKPHOTO

update

Frankfurt Tower's Power Trick

A sensor-tuned facade lets fresh air in without throwing energy out

SENSIBLE SYSTEM: The Westarkade tower integrates data from dozens of sensors to keep the tower from consuming power. PHOTO: KFW BANKENGRUPPE

You don't need to seal yourself in to live green. That's the message from the engineers of the Westarkade, a colorful high-rise that officially opened in Frankfurt in July.

The 15-story glass tower glows with natural light and offers windows that open—a comfort that can wreak havoc with energy efficiency. But the Westarkade's first-of-a-kind "pressure ring" facade and sophisticated, sensor-rich control scheme promise to consume no more than 100 kilowatt-hours of energy per square meter per year. That would make it a world-class energy miser, using half as much energy as a conventional office building in Europe and as little as a third of the U.S. average.

"It's an aggressive goal, especially with this building that's all glass," says Mark Perepelitza, a facade expert with Zimmer Gunsul Frasca Architects, based in Portland, Ore.

The Westarkade's dynamic facade is a descendant of a 1990s German design that was developed to manage excess sunlight in glass towers. Horizontal venetian blinds installed outside of the tower's glass envelope reject unwanted summer heat, while a pane of glass installed over the blinds and ventilated at the top and bottom protects the blinds from high winds. The "double skin" design comes up short, however, when architects add windows that open, which is typically mandated under European labor codes. Winds create

WHEN CHICKENS ATTACK

Continued from previous page

chickens: Each image is slightly different from the last, with humans or chickens moving relative to one another within the video's frame, and each kind of crowd has its own signature flow pattern.

To show that the method could apply to hens, Dawkins, Roberts, and their colleagues did experiments in which some statistics from the optical-flow pattern correlated well with an established but much more arduous method: watching how individual chickens walk. Farmers can hire trained experts to evaluate the health of flocks by scoring each chicken's gait, but those experts can't constantly monitor a flock, says animal behaviorist Harry Blokhuis of the Swedish University of Agricultural Sciences, in Uppsala.

"It was an engineering challenge," Roberts recalls. "Could we mimic the laborious labeling with a computer?"

Roberts turned to hidden Markov chains, a kind of mathematical model that uses noise in a data set to estimate the underlying "normal" signal and then identify when the signal is going awry. Then the team applied it to footage of more than 300 000 commercial free-range chickens. They found telltale behavioral disturbances in the flocks that had the most feather damage. Zoologists who saw the results "were certainly really surprised that we could forecast so well

4 terabits per square inch

The new record for data storage on a ferroelectric medium. The density is about eight times that of the most advanced magnetic hard drive, according to scientists at Tohoku University, in Japan.

a pressure differential around the tower, sending drafts ripping across floors when workers exercise their right to natural ventilation. "Sheets are blowing from the tables and the doors are smashing and the heat is going out," says Tom Geister, a senior architect with Berlin-based Sauerbruch Hutton, the firm that designed the Westarkade.

Sauerbruch Hutton worked with Stuttgart-based firm Transsolar KlimaEngineering to solve the problem. The firms installed 180 vertical ventilation flaps in the outer skin to manage air flows, creating what they call a pressure-ring facade. The building's control system takes constant feedback from a rooftop weather station and from 40 sensors deployed throughout the building that measure temperature, pressure, and sunlight. The system continually opens and closes individual flaps to maintain a ring of consistent positive pressure around the structure, preventing strong winds from entering.

That should keep windows from sabotaging the Westarkade's high-efficiency heating and cooling systems, which rely on such tricks as geothermal heat exchangers, heat captured from a basement data center, and heat recovered from vented air. Better still, in the fall and spring, air from the open windows should eliminate the need for mechanical ventilation altogether. Throughout the year, the control system will advise occupants via an LED panel in offices when open windows are a good idea, but it gives the occupant the last word.

SECOND SKIN: The Westarkade's control system manipulates ventilation flaps on the building facade to maintain a ring of air pressure around the building.
PHOTO: KFW BANKENGRUPPE

Of course, that's all theory. "We will see if it works," said Axel Hinterthan with a nervous laugh, as he led journalists around the nearly completed Westarkade a few months ago. Hinterthan is director of project management for KfW Bankengruppe, which commissioned the Westarkade as an expansion of its Frankfurt headquarters complex. He admits that KfW is taking a chance on new technology to further green-building design, which is an important role for the state-owned development bank. Created decades ago to implement the Marshall Plan, KfW now administers, among other things, low-interest federal loans for energy-efficiency upgrades.

Transsolar engineer Björn Röhle says his company is confident that the pressure-ring facade is the most efficient means of building windows into a tower. He says that a team at the University of Karlsruhe, in Germany, will monitor the Westarkade's energy consumption for two years to test whether this approach works.

Oregon architect Perepelitza expects that it will take two years just to tune the Westarkade's control systems for optimum energy performance. He cautions that the double-skin design was overhyped and that some similar early projects "didn't live up to the promise." But he is nevertheless bullish about the pressure ring's potential, which he says was extensively modeled by Transsolar and builds on the earlier designs. He thinks it could point the way forward for glass towers as natural ventilation and energy efficiency grow in importance. "This building represents a new generation," Perepelitza says.

—Peter Fairley

the prevalence of feather pecking," Roberts says.

What isn't clear yet is whether the method will provide an early enough warning of future problems, says animal behavior and welfare researcher Bas Rodenburg of Wageningen University, in the Netherlands. Fatalities in flocks seem to result from the tension between the way chickens are raised and some of their basic instincts. Chicks hatched into today's system are likely to be raised in large numbers, in close quarters, and with very little training in how to be hens, he says. Since they can eat their fill with little effort, their age-old instinct to forage and peck for food all day doesn't have an outlet. "It's really important to stimulate healthy foraging early on," Rodenburg warns, because birds who can't forage the normal way—by pecking the ground in search of food—are likely to peck at other things instead, including their neighbors.

In recognition of these problems, in 2012 the European Union will outlaw the smallest poultry cages in favor of cages with more room for chickens to wander and express their foraging instincts. But Rodenburg notes that the trend toward free-ranging flocks may enable the most deranged hens to harm more of their coop mates. Dawkins and Roberts, meanwhile, are making larger-scale versions of their system and aim to share future detectors with farmers and animal welfare agencies for real-time monitoring of other variables and other species. "It doesn't replace observant farmers," says animal scientist Blokhuis, "but it could focus the farmer's attention."

—Lucas Laursen

PHYSICS FRIGHT: Extreme low-temperature experiments such as some at CERN are imperiled by a shortage of helium-3. One cause is fewer thermonuclear weapons.
PHOTO: CLAUDIA MARCELLONI/CERN

Physics Projects Deflate for Lack of Helium-3

U.S. radiation detectors suck up the existing supply

Earlier this year, a panicked U.S. congressional panel traded barbs about who was at fault for a sudden and surprising shortage of helium-3. The stable isotope is crucial in MRI lung research, low-temperature experimental physics, and—at the heart of the congressional dustup—in neutron detectors that can reveal smuggled nuclear materials. The United States has historically been the biggest global supplier of He-3, so the shortage there is affecting the entire world. In many countries, authorities are scrambling to find ways to procure more of the gas, stretch their remaining supplies, and find alternatives. But for some users, there are no substitutes.

He-3 is one neutron short of the two neutrons and two protons that make up its heavier cousin, the helium-4 of party balloons and silly voices. The lighter isotope is rare in nature, but it is a by-product of the decay of tritium (hydrogen-3) in thermonuclear weapons.

The unique structure of He-3 makes it ideal for refrigerating science experiments and other machinery to below 1 kelvin. That's critical at major laboratories such as the European Organization for Nuclear Research (known as CERN), in Geneva, where exotic experiments demand extreme cold. He-4, which cools the superconducting magnets inside CERN's Large Hadron Collider, can push temperatures only to about 1.8 K, says Johan Bremer, a physicist who designs and builds cryogenic installations for CERN's experiments. He-3 pushes that number to 0.01 K.

The isotope has also brought about a recent revolution in pulmonary science and medicine, says Dr. Jason Woods, an assistant professor of radiology at Washington University, in St. Louis, who testified before Congress on the shortage. The development of a new kind of He-3 diffusion MRI, he says, has allowed "our scientific knowledge of lung physiology and pathology [to accelerate] exponentially over the past few years."

The problem started after the terrorist attacks in New York City and Washington on 11 September 2001. U.S. government agencies dedicated to national security commissioned large quantities of neutron detectors. Now, many thousands of such scanners are used to watch for plutonium at airports, shipyards, and border crossings. These scanners all rely on He-3 and consumed 80 percent of the gas used in the United States from 2005 to 2009.

But the annual production of He-3 in the United States has fallen to less than 8000 liters, according to John Pantaleo, who directs the U.S. interagency committee in charge of disseminating the gas. Most He-3 is extracted from decaying tritium in thermonuclear warheads—about every five years, when that tritium is replaced. Because the United States has been reducing its nuclear weapons stockpile, the amount of He-3 produced has plummeted over the last

130 terawatt-hours per year

Wave energy available to Australia from tapping the resources of 10 percent of its southern coast, according to scientists at the Centre for Australian Weather and Climate Research, in Hobart, Tasmania.

two decades. And because demand grew rapidly after 9/11, the U.S. He-3 stockpile has dropped from more than 200 000 L in 2001 to less than 50 000 L today.

According to Steve Fetter, assistant director at large with the White House Office of Science and Technology Policy, global demand is about 40 000 L in 2010. But Pantaleo's group will dole out just 12 000 L. Programs like Woods's, which rely on the unique physical structure of the gas, get first priority, neutron detectors second, and everything else comes third. Woods expects about 1800 L to be distributed to medical imaging researchers this year.

But as much as the shortage may constrict U.S. research, it has a bigger impact on researchers in other countries. Since Russia stopped selling its He-3 supply abroad in 2008, the world is dependent on U.S. gas. The result is an out-of-balance international market. *Physics Today* reported in June that Netherlands-based Leiden Cryogenics, which makes dilution refrigerators for low-temperature physics, paid US $2150 for one liter of He-3 in early 2010, an amount that just one year earlier would have cost $100.

Scientists feeling the He-3 pinch have three choices: Get He-3 from expensive and unpredictable sources, make more He-3, or find a suitable substitute. The first option is prohibitive. AEGIS, a project Bremer is working on at CERN that measures the effects of gravity on antimatter, needs He-3, but at today's price he estimates that 12 grams of the very light gas would cost $200 000.

The second choice—making more—is not a short-term option. The half life of the tritium in nuclear weapons is 12.4 years. Tritium can also be separated from heavy-water reactor by-products, an option that Pantaleo says is under investigation. However, that option requires diplomatic footwork as well as time.

That leaves the third option: Come up with a substitute. Rebecca Nikolic and her group of engineers at Lawrence Livermore National Laboratory's Center for Micro- and Nanotechnology may have found one alternative to today's neutron sensors, which are the biggest He-3 gluttons. The team has replaced the traditional He-3 gas with solid sensors made of silicon and boron.

For a long-term supply, Pantaleo says the U.S. government is looking into separating the isotope from the U.S. helium-4 reserve near Amarillo, Texas. There, several tens of billions of liters of He-4 could provide several hundred thousand liters of He-3, he says.

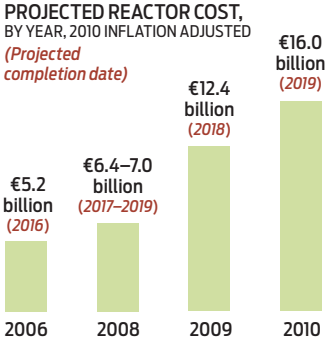
Unfortunately, the He-4 reserve may not be an inexhaustible resource, either. According to the United States' National Research Council, that supply is on track to be depleted within the next 40 years.

—Sally Adee

Fusion Is Not Free

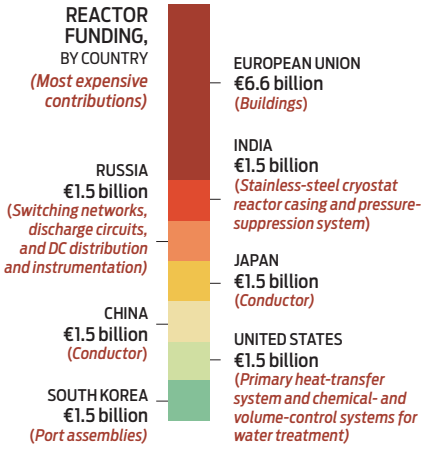
THE WORLD'S biggest bet on fusion, the ITER nuclear fusion reactor, may finally be getting over its money troubles. Delegates from ITER's seven international partners agreed in July on a new budget for the construction of the experimental reactor. They estimate that the total costs of the machine and its facilities, slated for completion at Cadarache in southern France by 2019, will tally about €16 billion, or US $21 billion. When the partners signed the original ITER agreement in 2006, they estimated the construction costs—in 2010 currency—at just €5.2 billion (US $6.9 billion). But tweaks to the original reactor design, coupled with rising prices for building materials, have inflated budget projections, inviting some criticism from scientists who say the money could be better spent on nearer-term green-energy R&D. Under the new budget agreement, the European Union will contribute no more than €6.6 billion (US $8.7 billion) to construction costs. Each of the six other member countries will be responsible for delivering about €1.5 billion worth of hardware—conductors, coils, shields, power supplies—instead of cash. Now that ITER's budget issues are settled, construction crews can start putting pickaxes in dirt.

—*Ariel Bleicher*



CLIMBING COST

Each time the ITER reactor has been reassessed, its estimated cost has expanded and its completion date has been nudged further out.



WHO'S BUYING WHAT?

Countries will pay in casings, concrete, and conductors. The European Union must find €600 million in cuts to meet its budget.

Resistive RAM Gains Ground

Faith in phase-change memory falters

THE SEARCH for new memory types that can store more data than the dynamic RAM of computer memory and the floating-gate flash of portable electronics is intensifying. The erstwhile favorite of the memory R&D community, phase-change memory, or PC-RAM, is entering limited commercial production but has run into power issues that could constrain its future. In its wake, the research spotlight is turning to resistive RAM, or RRAM.

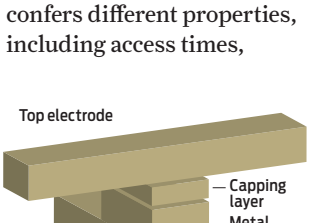
Today's dominant memory types—DRAM, flash, and static RAM—store data as charge. But memory researchers believe these memory cells have gotten nearly as small as they can get, so researchers are turning to storing bits as resistance instead. There are two contenders for this method, and both are nonvolatile memories. The first, phase-change memory, heats up a material, changing it from a polycrystalline to an amorphous state and thereby creating a measurable but reversible difference in the material's resistance. RRAM, by contrast, uses a voltage rather than heat to reversibly change the resistance. (If this sounds like a memristor, it's because that device is actually a special class of RRAM.)

One of the big advantages of RRAM is that it can be constructed in incredibly dense crossbar arrays, so that the switching material is sandwiched between perpendicular arrays of electrodes. In July at Semicon West, a major semiconductor manufacturing conference, Luc Van den hove, CEO of Belgian nanotech research firm Imec, told the engineers assembled in San Francisco that crossbar arrays of RRAMs "are the most likely candidate" as a technology for memory chips with features smaller than 20 nanometers. Such memories are due out sometime after 2015.

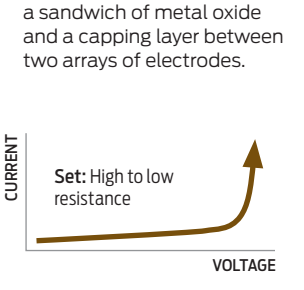
Compared with phase change, RRAM is "still at a very early maturity level, but the promise is so good that we have put our top technologists to work on RRAM," says Laith Altimime, memory program manager at Imec.

Indeed, RRAM promises a lot. It has the potential to meet the stringent power requirements for smartphones and other mobile devices, now the biggest market for flash. It could also satisfy the needs of servers used in data centers. Paul Kirsch, director of the front-end process program at semiconductor research consortium Sematech, in Austin, Texas, says RRAM is on the way to reaching a milestone for integration in both applications: consuming just one femtojoule when switching a bit.

Not all RRAM is alike. Each type has a different underlying material that confers different properties, including access times, endurance, retention, and power consumption. Some types show the data retention properties essential for any non-volatile memory, while other types exhibit the very fast read/write times required for a DRAM-like main memory, says Jorge Kittl, chief scientist at Imec.



CROSSBARS COMING: One type of RRAM is built as a sandwich of metal oxide and a capping layer between two arrays of electrodes.

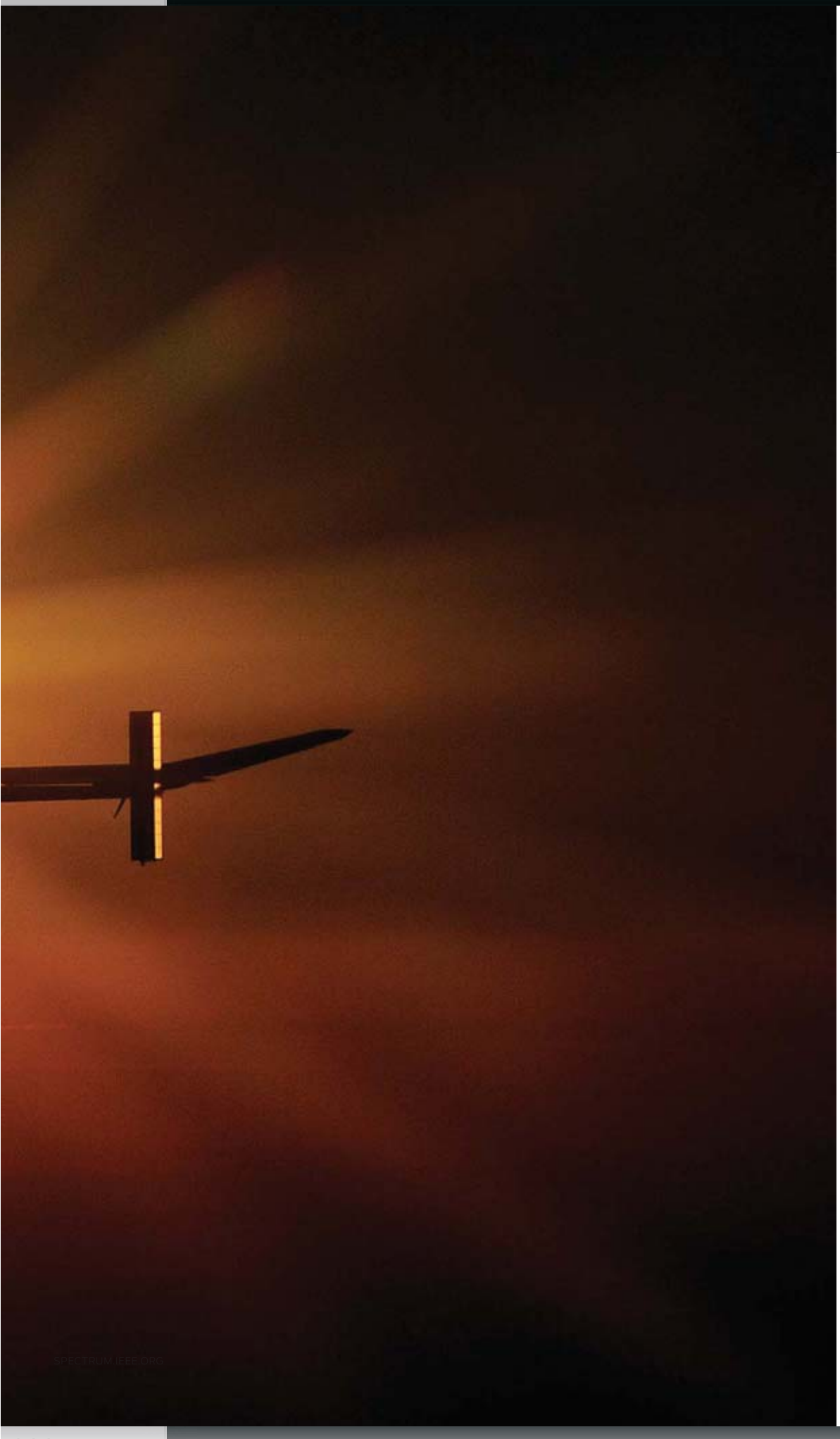


WRITE STUFF: Writing a bit involves using voltage to reversibly change the RRAM's resistance.

The basic physics underlying RRAM "is not completely understood," Sematech's Kirsch says. An RRAM cell formed by a sandwich of metal oxide, for example, stores a bit when a voltage induces conductive paths to form across the normally resistive device. Researchers once thought the paths were metal filaments. But they now believe that the paths are best described as lineups of oxygen vacancies.

The picture is clearer for phase-change memory, but that picture reveals a few warts. This year, memory giant Samsung announced a PC-RAM product, as did Numonyx, now owned by Micron Technology, in Boise, Idaho. But as of July, experts say, Samsung had yet to deliver engineering samples, largely because phase-change power consumption remains too high for handsets. Micron says it plans to ship a 1-gigabit phase-change chip in 2011, but the technology is meeting increasing skepticism. "PC-RAMs are not going to replace flash or DRAM, because of switching-power issues," says Imec's Altimime.

Bob Merritt, a memory analyst at Convergent Semiconductors, says many labs have either switched from phase-change memory to RRAM or started new RRAM research programs. "There are a number of companies working on RRAMs, and they are expressing a lot of confidence," he says. —DAVID LAMMERS



the big picture

TRAVELING LIGHT

This sleek aircraft, the Solar Impulse HB-SIA, remained aloft for an entire day in July, completing the first-ever night flight for a solar plane. During the day, the 11 628 monocrystalline silicon solar panels blanketing its wings—63 meters from tip to tip—generated enough electricity to power its four 7.46-kilowatt motors and top up its 70 polymer lithium batteries. The batteries' 96-kilowatt-hour total capacity was enough to keep the plane cruising along at an average of 70 kilometers per hour between dusk and dawn. Designers are working on a version with lighter batteries that will circle the globe without touching down.

PHOTO: FABRICE COFFRINI/REUTERS

geek life

The Engineers of Comedy

Six high-tech comics share their best jokes

YOU RARELY see the words *engineering* and *comedy* together in a job résumé. But these stand-up comics found new careers mining old lives in technology. Collectively, they've appeared in movies and television shows, but it's only at corporate events held by the likes of Apple, Genentech, and Intel that they can joke in shorthand. "Engineers have minds that break things into components and see connections between parts," explains comic Wayne Cotter. "Comics apply the same kind of analysis to everyday life."

—SUSAN KARLIN

"I ran a red light once. Tried to talk my way out of it by explaining that the light looked green because of the Doppler effect. Now, here's what's wrong with that argument. I would have to be doing 144 million in a 25-mile-per-hour zone."

By day, **NORM GOLDBLATT** is a senior optical engineer at OptiMedica Corp., an ophthalmic laser systems designer in Santa Clara, Calif. By night he tackles Silicon Valley and science onstage. He's also written jokes for Jay Leno.

"Nuclear fission is the energy source behind atomic weaponry. To start the process, you need a fissile material, such as uranium 235. Uranium is inherently unstable, and it has a certain probability of just breaking down and ejecting a neutron at its neighbor. Which destabilizes the neighbor, causing it to eject multiple neutrons, and the process is propagated in a chain reaction. I've actually seen the same thing happen at a Raiders bar."

TIM LEE holds a Ph.D. in ecology and evolution and worked as a software engineer for Hewlett-Packard, Borland, and several Silicon Valley start-ups before turning to "PowerPoint comedy" for companies like Microsoft.

"In two years, supermarket shopping carts are going to have TV sets in them. I read this. Someone has cracked the problem of getting a TV into a shopping cart. Is that a priority? I'll tell you what. How about we get the fourth wheel to work first, then we start thinking about the TV."

"I'm a recovering engineer now. I had my pants lowered in a series of 12 operations—that was the hardest part. I was slowly disappearing into my trousers. Didn't even wear shirts; there was no point. Turtleneck pants. Had to undo the fly to shake hands."

DON McMILLAN turned to high-tech comedy after earning a master's in electrical engineering from Stanford and designing chips, first for AT&T Bell Laboratories and then for VLSI Technology (now NXP Semiconductors). He seriously upped his geek cred with stints on "Star Trek: Voyager" and "Babylon 5."

"When I applied for the job at Intel, they said, 'You're Indian and Japanese...you don't even have to interview!' "

DAN NAINAN was a senior technical marketing engineer at Intel when he took a stand-up comedy class to overcome his fear of public speaking. Today, he's likely the world's sole Japanese-Indian comic, appearing in *The Last Airbender*, an Apple commercial, and nearly 200 gigs a year.

After studying electrical engineering at the University of Pennsylvania, **WAYNE COTTER** worked at a New Jersey computer manufacturer by day and Philadelphia's comedy clubs at night. He hosted Fox's "Comic Strip Live" and Discovery Channel's "Amazing America" before taking his engineering anecdotes to corporate audiences.

"Galileo did not invent the telescope, but he was the first to turn it skyward and make astronomical observations with it. Before that—like all new technologies—it was mostly used for porn."

A recovering premed who once sold computer accessories, **BRIAN MALOW** is now a *Time* magazine science video correspondent and a USA Science and Engineering Festival adviser. He does corporate comedy for science associations and technology giants.

CLOCKWISE FROM TOP RIGHT: THE DARKROOM; MIKE CARANO; DOMINIC HART/NASA AMES RESEARCH CENTER; JIM BROGAN; MIKE POINTER; ABIGAIL MILLER

OVER-ENGINEERING THE SODA MACHINE

Coca-Cola reinvents the soda fountain for the 21st century

With a sleekness imparted by a Ferrari designer, a mixology controlled down to the microscale, and a stock of ingredients monitored with RFID tags, Coca-Cola's new soda fountain, the Freestyle, is loaded with geek panache. Customers tap its touch-screen LCD panel to select one of 106 drinks, from caffeine-free Raspberry Diet Coke to Vault Red Blitz.

The machine mixes its beverages not from syrups—the foundation of soda fountains since their invention well over a century ago—but from tiny flavor concentrates delivered using a microdosing technology developed for chemotherapy drugs. And every time Freestyle mixes a drink, it uses its own Wi-Fi modem to report back to Coke's Atlanta headquarters through the Internet.

Even with the fountain's curvilinear shape (courtesy of Italian car design firm Pininfarina), is all this beverage nerdiness too much tech for consumers who just want 12 cool, no-fuss ounces of the trademark cola? Maybe, but even if the Freestyle's market is a niche one, it needn't be a small niche, seeing that Coke is perhaps the biggest brand in the world. So far, the Freestyle is found in only about 50 restaurants and stores in Georgia, California, and Texas, but there are plans for another 450 by year's end.

Food blogger A.J. Wolfe thinks the Freestyle has mainstream potential, with enough flashy appeal to pry consumers away from their plain old red-and-white cans. "It's an imagination-inducing machine," she says. "People are going to be excited about personalizing things they'd never personalized before."

—Mark Anderson

THE COCA-COLA COMPANY

1 THE HUMANITARIAN NOZZLE

The chief challenge in designing a fountain nozzle that dispenses dozens of beverages is ensuring that each drink keeps to itself. No one ordering a Dasani water with a hint of lime wants relics of a previous Pibb Xtra or Powerade Ion4 Fruit Punch. Enter inventor Dean Kamen, creator of the Segway personal scooter and the first wearable insulin pump for diabetics. Kamen partnered with Coca-Cola as a way to mainstream some of the technology behind his latest dream project: cheap, powerful filtering systems that can deliver potable water to the developing world. Kamen applied innovations developed for his vapor-compression water distillers to what Coke calls its Perfect Pour system. Part of its secret is shooting the flavors into an airborne water stream.

2 THE DOWNLOADABLE POUR

A touch-screen menu on Freestyle's Windows CE–powered computer lets the user choose a parent brand—Sprite, Coke, Fanta, Minute Maid, Powerade, Dasani—and then the specific beverage it'll be pouring for you. Selecting Diet Coke, for instance, calls up six tinted icons representing Diet Cherry Coke, Diet Coke with Lime, Diet Vanilla Coke, Raspberry Diet Coke, Orange Diet Coke, or just plain Diet Coke. Pick the second option, for instance, and a microstream of the Diet Coke flavor concentrate is shot with a second trickle of lime flavoring. So if Coca-Cola's mad scientists come up with a new diet drink (Cantaloupe Sprite, anyone?), Freestyle can easily test-market it. A software patch containing both the new recipe and the new menu layout would be sent to the machine. At the next restocking, a service technician would install the new microflavor cartridge, reboot, and voilà! A new hit drink could be on its way to your cup.

3 FREESTYLE, PHONE HOME

Freestyle keeps tabs on its supplies via an RFID inventory system that tells it which microflavor cartridges are on board. It also comes with Wi-Fi, which it uses to send Coca-Cola headquarters in Atlanta both inventory (which cartridges are running low, for instance) and marketing data: what time of day caffeine-free sodas are most popular or when and where diet drinks win the hour.

tools & toys

Doxie
http://www.getdoxie.com

SPEED-DATING PORTABLE SCANNERS

They're small, sleek, and sexy—but would I really fall for one?

I LOVE THE idea of a portable scanner. I picture myself quickly scanning receipts, business cards, and clippings when traveling instead of shoving them, crumpled, into a suitcase pocket.

So I was sure I was going to love at least one of these three portable scanners, which came out this year: the US $299 DocuPen X05 from PlanOn, the $129 Doxie from Apparent, or the $269 MobileOffice AD450 from Plustek. All scan in color and black and white, at resolutions of up to 600 dots per inch.

The MobileOffice and I didn't get past "hello." For one, it's a PC-only device, and I'm a Macintosh gal; this match was not meant to be. But frankly, even if it had worked brilliantly, at 10 by 29 by 7.5 centimeters and 1300 grams it's a little too big for my computer bag (or even my crowded desk).

The DocuPen sits at the other end of the size scale. It's just 22.6 by 1.5 by 2.0 cm and 50 grams, sleek and futuristic, designed to inspire gadget lust. I could immediately see a future with this sweet gizmo. I'd pull it out of my purse for a quick scan and conversation would stop—it's that cool. It could even come with me when my computer stayed home; it scans on its own and stores documents for you to download later.

Unfortunately, to make the DocuPen Mac-compatible, I needed a little something extra—a microSD card of 2 gigabytes or less. That size isn't easy to track down these days. Then I had to call customer service to find out where to insert it.

I scanned the first thing I could reach—a FedEx shipping label. It worked pretty well, creating a legible document. And the process was indeed magical—turn it on, roll it gently over the document, stop, and the device stores the scan. Plug it into the computer, and drag the document over to the desktop. Done.

Sadly, this love affair was short-lived—I could never repeat that first, magical experience. All my subsequent attempts to scan were frustrating—either I went too fast, earning a warning flashed on the tiny screen, or too slow. Often, I didn't move from "on" to "scan" quickly enough, and the DocuPen automatically powered off. At one point it choked entirely, going into an automatic "save" halfway through my attempt to scan a magazine page; as I could find no way to reset, I simply had to wait for the battery to run down (because battery life isn't great, it didn't take long). Photos were a disaster. I set the DocuPen aside; I wanted the relationship to work, but we clearly weren't even going to get to the second date.

DocuPen http://planon.com/products/docupen/xseries

Already disappointed by DocuPen and frankly put off by the toylike appearance of Doxie, my third and final suitor—its styling leans heavily on pink and hearts—my expectations were low. I was pleasantly surprised.

How to use the Doxie is obvious. It has just one button (identified, of course, with a heart) to scan; you select resolution and color or black and white on the screen of whatever computer you've attached it to. It saves documents to the computer or to cloud accounts like Google Docs or Flickr. I tested that FedEx receipt—perfect. It also did well with business cards, smaller receipts, and standard printed documents; it had a little more trouble with a portrait on thick photo paper and a thin page ripped from a magazine—both resulted in slightly stretched images.

For most purposes, Doxie works just fine. And at 29 by 5 by 4 cm and 309 grams, it easily slipped into my laptop bag.

So while Doxie and I may not be entering a long-term relationship, it's been the perfect summer romance.

—TEKLA S. PERRY

MobileOffice http://plustek.com/product/ad450.asp

FROM TOP: DOXIE; PLANON; PLUSTEK

hands on

3-D PRINTERS PROLIFERATE

But desktop manufacturing isn't yet ready for your desk

For years, visionary engineers have been touting the idea of a cheap box about the size of a microwave oven that could build arbitrary solid objects out of plastic, ceramics, metal, ice, and even living cells.

During most of the 20-plus-year history of 3-D printing, "cheap" has been a distant vision, with industrial rapid-prototyping machines going for anywhere from US $15 000 to over $1 000 000. That number started to drop precipitously in 2007, with 3-D–printer designs from RepRap and Fab@Home that could be built for $500 to $2000 in materials (depending on what materials you wanted to print and how good you were at scrounging parts). This spring, 2-D printer giant Hewlett-Packard jumped on the moderate-price bandwagon, announcing it would introduce HP-branded 3-D printers (actually built by Stratasys) in Europe for €13 500, or about $17 500.

If the price of a new compact car is more than you or your boss would like to spend, New York City start-up Makerbot Industries offers a small RepRap-derived printer kit for about $900. British RepRap parts supplier Bits From Bytes sells parts for a rather larger, reportedly more reliable unit for £750 (about $1200) and offers fully assembled machines for $3000 and up.

But what are these machines actually good for? PR representatives for HP and Stratasys make it clear that their new machines are for mechanical engineers and designers to make mock-ups and prototypes of new ideas (and for educators teaching the next generation, who will likely work in a world where 3-D fabrication is commonplace), but not for consumers: Despite HP's reputation for building high-end consumer printers, this is not one of them.

And although the fully assembled machines have established a strong reputation for reliability, do-it-yourselfers must beware the 3-D equivalent of the paper jam, which often involves scattered blobs of solidified plastic, smoking circuit boards, or half-melted motor mounting brackets. Internet forums and builder blogs are full of stories about hours spent rebuilding extruders, days tweaking the alignment of build platforms, and nights rewriting the software that "slices" designs into layers that can be built up on top of one another without drooping or warping or overtaxing a printer's tiny CPU. There is even a cottage industry of higher-strength spare parts for the kit components that are most likely to fail. If atoms are indeed the new bits, as the futurati have declared, then consider what the world will be like when mechanical objects are as buggy as the typical piece of software.

PART SOLUTION: Make small plastic parts on your own with a 3-D printer, such as HP's [above right]. PHOTOS: HEWLETT-PACKARD

Indeed, at the hacker level, the most popular print runs seem to be 3-D printer parts. If you want something built for use, you might have better luck shipping your design to one of the rapid-fabrication services that have sprung up all over the world.

But Ian Adkins, technical director of Bits From Bytes, views things a little differently: Engineers, hackers, and educators have purchased thousands of the company's kits—initial production of the new fully assembled model is fully spoken for—and he is happy to report that at least some of his customers are building actual products as well as prototypes and models. If your annual production of any particular plastic bit is only a few hundred pieces, he says, the cost of a 3-D printer can be a fraction of the setup costs for machining or injection molding.

And if tinkering is part of the attraction, you'll join thousands of other hackers who are getting the design of extruders, construction platforms, structural frames, controller boards, and other parts just right. Yours could be the innovation that makes cheap fabrication a turnkey process for the rest of us.

—Paul Wallich

3-D printers, kits, and parts
http://www.bitsfrombytes.com
http://www.makerbot.com
http://www.makergear.com

Manufacturers of 3-D printing equipment
http://www.stratasys.com
http://www.zcorp.com
http://www.objet.com
http://www.3dsystems.com

Fab services
http://www.shapeways.com
http://www.redeyeondemand.com

Open-source design repository
http://www.thingiverse.com

Ongoing development
http://www.fabathome.org
http://www.reprap.org

books

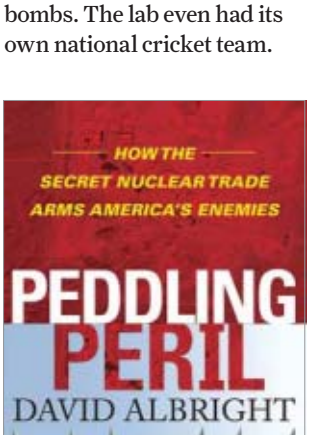
Evil Genius

How one man's theft of nuclear secrets dispersed atom bomb technologies to North Korea and Libya via Pakistan

First, I'd like to thank author David Albright for implicitly dedicating this book to me, as one of those "who strive for a world free of nuclear weapons and terror." Second, and kidding aside, I want to say that this is a really excellent book.

Peddling Peril: How the Secret Nuclear Trade Arms America's Enemies, is about A.Q. Khan, the Pakistani metallurgist who got a job in the 1970s with Europe's uranium enrichment consortium, where he learned most of what there was to know about centrifuge technology and equipment makers—and then stole the technology, offering it first to his home country and then to anybody for whom the price was right.

An evil genius if there ever was one—and as it turned out, an able engineering manager—A.Q. (as I'll now call him, to distinguish him from his archrival, Munir Khan, head of the Pakistan Atomic Energy Commission) soon obtained near-total control over the country's enrichment program. A.Q. was particularly good at winning people's trust and figuring out how to obtain needed equipment from foreign suppliers. By the end of the 1980s, the Khan Research Laboratories at Kahuta, in Pakistan, had grown into an industrial city with thousands of specialist employees, not only operating huge centrifuge cascades but also developing missiles, conventional weapons, and almost certainly atomic bombs. The lab even had its own national cricket team.



Peddling Peril: How the Secret Nuclear Trade Arms America's Enemies
By David Albright;
Free Press, 2010; 304 pp.; US $27;
ISBN: 978-1-4165-4931-4

In September 1974, months after the first Indian nuclear test, A.Q. wrote to then prime minister Zulfikar Ali Bhutto about the urgency of developing a Pakistani nuclear weapon. After General Muhammad Zia ul-Haq overthrew Bhutto and had him hanged, A.Q. wrote to the new leader, saying he was in a position to test an atomic bomb on short notice. Less than a decade later, Zulfikar Bhutto's daughter Benazir visited North Korea and traded A.Q.'s centrifuge technology for missile designs.

By that time, A.Q. was peddling a package that included first-generation centrifuges and the blueprints for an early Chinese atomic bomb to countries like Iran and Iraq. Initially, the price for this "starter kit" was surprisingly low—just US $5 million to $10 million—until A.Q. hit the jackpot, with an order of $100 million to $200 million from Muammar al-Gadhafi. But that turned out to be hubris: Western intelligence caught on, a key shipment was intercepted, and Gadhafi was persuaded it was in his country's best interests to give up its nuclear weapons program. He handed everything he had obtained over to the West, including a Chinese bomb blueprint hand-annotated by A.Q.

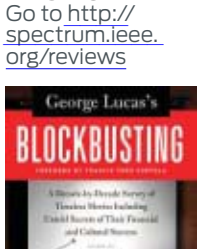
A.Q., a Pakistani national hero, was forced to apologize publicly and was put under house arrest.

Albright is not the first to tell this amazing story: Journalist William Langewiesche laid out the essentials several years ago in *The Atomic Bazaar: The Rise of the Nuclear Poor* (2007), which, oddly, Albright doesn't mention. Nor does he acknowledge *Nuclear Express: A Political History of the Bomb and Its Proliferation* (2009), by Thomas C. Reed and Danny B. Stillman, which claims that after China gave Pakistan its CHIC-4 bomb design, it then tested the first bomb Pakistan built to its specs at its Lop Nor site.

Langewiesche, a well-regarded writer associated with *The Atlantic* and *Vanity Fair*, may have written the most readable of the three books. But Albright's is by far the most complete, accurate, and authoritative, and it will be the most satisfying to the technically minded reader.

—William Sweet

REVIEWED ONLINE THIS MONTH
Go to http://spectrum.ieee.org/reviews



George Lucas's Blockbusting
Edited by Alex Ben Block & Lucy Autrey Wilson; It Books/HarperCollins, 2010;
976 pp.; US $29.99;
ISBN 978-0-061-77889-6
Reviewed by Mark Anderson

Cosmic Noise: A History of Early Radio Astronomy
By Woodruff T. Sullivan III;
Cambridge University Press, 2009; 574 pp.; $140;
ISBN: 978-0-521-76524-4
Reviewed by Kieron Murphy

BY ROBERT W. LUCKY

Cyber Armageddon

RAN ACROSS ONE OF THOSE THE-END-IS-NEAR CARTOONS. A scruffy person holds a sign that says "The World Will End in 2000"—except the "2000" is crossed out and amended to "2012." The many dire predictions about cyberwar feel a lot like that. The word has shown up frequently on magazine newsstands this summer—but, my editor reminds me, it was also on the cover of *Time* back in August 1995.

I've had the opportunity to listen to lots of smart people about the cyber problem, and to be honest, I don't know what conclusion to draw. My fear is that no one else knows, either. There is no lack of information about how bad the problem is, but there is almost nothing written about what to do about it. In the end, I believe it comes down to intelligent risk management—something we're often not good at.

For one thing, much of the threat comes from users already behind the Maginot Line of network firewalls. Even well-intentioned people do risky or forgetful things, such as leaving a laptop at airport security. Moreover, an insider isn't just a systems administrator; it's anyone or anything that touches your network, including all the equipment and the whole supply chain behind it. All it takes is one employee using the same USB drive on two different networks—the IT equivalent of a surgeon not washing his hands between operations—to fatally compromise a system's security.

If your data is valuable enough, there is almost nothing you can do to provide total security against an expert adversary. Simply put, the attacker may be smarter than anyone you have defending the network. Cyberattacks are not only impossible to block, they're often difficult to detect; you may not even know you're under attack in the first place. Then there's the problem of attribution—not just identifying the source of the attack but also determining intent and responsibility.

JAMES STEINBERG

If you talk to knowledgeable defenders about attribution, they will say that they know how to trace attacks. If you talk to offensive experts, they will of course say nothing, but with a smile that projects an unmistakable confidence. An expert in the field summed it up by observing that there is a huge imbalance between the probability of detection and attribution—and the relatively minor consequences to the attacker even when caught—and the enormous impact of a defensive failure.

Yet for all that, what cybercatastrophes have we actually experienced? The financial system has been seen as particularly vulnerable—so much so that a proposal has been floated in diplomatic circles for nation-states to eschew attacks on the financial structure, much as in conventional warfare we agree not to harm churches and hospitals. Yet of all the banks that have gone under recently (and there have been a lot of them), none did so because of a cyberattack. The Internet itself has proven resilient, and though parts of it can go down, the organic growth of pathways and the diversity of equipment provide enormous robustness. Many of us engineers remember when Bob Metcalfe, one of the pioneers of the Internet, famously—and quite literally—ate the words he had written in 1995 predicting a collapse of the Internet the following year.

The cybersecurity problem has many dimensions, and technology can be only a part of any proposed defensive strategy. I think that any objective analysis of the situation would conclude that perfect security is not possible, other than through the draconian proposition of complete isolation from networks. But if computer security is fundamentally impossible, what is Plan B? My own belief is that it can only be the acknowledgment of fallibility, the acceptance of risk, and the preparedness for continued operation under degraded cyberconditions. I wish I had better wisdom, but this is truly a wicked problem. ❑

MOVE OVER, HUMAN: The Anybots QB telepresence robot acted as the author's stand-in at work. The robot's head has a video screen, a camera, and an eye that shoots a laser—for pointing at things.

When My Avatar Went to Work

A robot surrogate took my place at the office. Here's why one may take yours, too

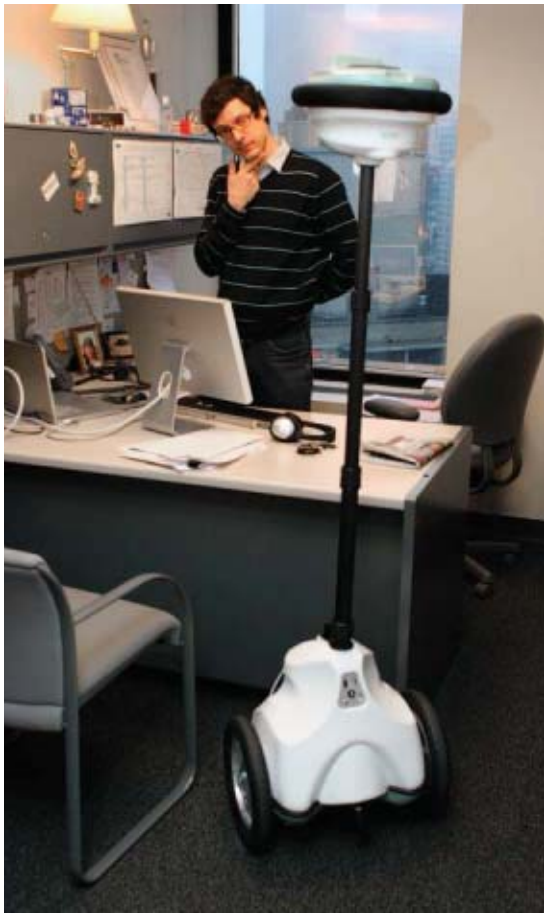
By Erico Guizzo

PHOTOGRAPHY BY RANDI SILBERMAN KLETT

ROBOCOMMUTING: From his home in Brooklyn [above], the author uses a Web browser to control the QB robot at the *IEEE Spectrum* office in New York City. The robot's mobility and voice and video capabilities make it ideal for participating in impromptu meetings and interacting with coworkers [below].

NOT C-3PO: Anybots experimented with anthropomorphic robot bodies but in the end decided for a simpler "head on a stick" design. The QB's telescopic neck can be adjusted to set the robot's head at the eye level of people sitting around a table or with a computer monitor—but with no arms, don't expect any typing.

OFFICE ALIEN: The QB drives on two wheels using a self-balancing system [above]. The system allows the robot to maneuver nimbly in tight areas and be as tall as a person [below] without relying on a wide, heavy base.



AS I COME DOWN THE HALLWAY, heads start popping out of cubicles and offices, all eyes turning in my direction. Some of my colleagues laugh, some frown. One looks terrified and flees. That's what happens, I suppose, when you show up at the office as a robot.

The robot is acting as my stand-in at work. For a week last spring, it roamed around *IEEE Spectrum*'s New York City office while I sat in my pajamas at home in Brooklyn. From my laptop, over the Net, I could steer the robot, peer through its cameras, and talk to my colleagues. It's a bit like a video game, but instead of a virtual character, you're controlling a real avatar.

The robot has an alien-looking head with two big round eyes that's perched on a thin carbon-fiber pole. One eye captures high-definition video; the other shoots a green laser beam. The laser isn't for zapping coworkers you dislike but for pointing at things. My robotic proxy rolls on a two-wheeled base that balances just like a Segway. This is no humanoid C-3PO. It looks more like a floor lamp.

UNDER THE HOOD: Anybots engineer Erin Rapacki opens the robot's base to show its hardware, which includes a battery pack, a computer, wireless cards, motors, gyroscopes, and a laser range finder.

The robot is called QB, though my colleagues promptly nickname it EriBot. QB is what is known as a telepresence robot. It's the creation of Silicon Valley start-up Anybots, which will start selling the machines this month. Each will cost US $15 000—not exactly a bargain for a robot that doesn't even have arms (or a positronic brain, for that matter). But Anybots says that as a communications platform, QB lets remote workers collaborate with others in ways that a wall-mounted monitor in a conference room could never permit.

Embodying a QB, you'd be able to join impromptu meetings, drop by a coworker's office, even gossip at the water cooler. You could tour a distant facility or observe a live demonstration without having to hop on a plane. To paraphrase management guru Peter Drucker, why transport a whole body to work when all you need is the brain—a brain you can upload into a robot anywhere?

Indeed, becoming a robot has its advantages. Every morning, while my colleagues dragged their carbon-based bodies to the office, I'd open my laptop at home or in a coffee shop and, with a few mouse clicks, incarnate my robotic self. Call it robocommuting.

My goal was to find out how my robotic life compared to the real thing. But I also wanted to explore something more profound: Will telepresence robots eventually take people's places at work, whether we like it or not?

Artificial intelligence pioneer Marvin Minsky extolled the promises of telepresence in a 1980 manifesto in *Omni* magazine. "Eventually telepresence will improve and save old jobs and create new ones," he wrote. "Later, as we learn more about robotics, many human telepresence operators will be able to turn their tasks over to the robots and become 'supervisors.' "

Today at least five companies are selling or will soon start selling telepresence robots. Like QB, these are still relatively simple machines—glorified laptops on wheels. But proponents say that as computers, sensors, and motors get better and cheaper, telepresence robots will advance too, revolutionizing engineering collaborations, health care, even manual labor. Could this be the future of work?

TO PREPARE AN ARTICLE LIKE THIS ONE, I'd normally travel to different places to talk to people and see things up close. But given that this story is about telepresence, why not let robots do the reporting for me?

Here's how it started. Sitting at my computer in New York City, I log on to a QB robot at the Anybots office in Mountain View, Calif. There I meet Trevor Blackwell, Anybots' founder and CEO, an amiable guy with gray-white hair, thin glasses, and a soul patch. An entrepreneur, he founded Anybots in 2001 because he couldn't believe "there still weren't robots helping around [my] home and office."

Using QB, I follow Blackwell as he shows me around. Hanging from a crane is one of the first robots he and his small crew built. It's a sophisticated humanoid called Monty. Slap on sensor gloves and a backpack of electronics and you can get the robot to instantly replicate your movements, whether you're grasping a teacup or operating a power drill.

Monty also has a technology that became a key part of QB: a custom self-balancing wheel system. Blackwell says it's better than standard three- or four-wheeled bases for driving over bumps and around tight corners. It's also quite stable, which he once demonstrated by planting a kung fu kick on Monty's chest. The robot held its ground.

Blackwell's initial goal was to design a robot servant like Rosie from "The Jetsons." But rather than build an autonomous robot, which technologically was just too difficult, his idea was to have a human worker remotely control the robot. He envisioned the machine doing chores at people's homes or operating the fryolator at McDonald's.

Cost issues and technical complications eventually forced Anybots to scale back its vision. The company decided to focus instead on telepresence. Teleoperated robots have long been used to extend a human's reach into distant locations, such as space and deep under

This Is Your Brain on Robots

Could people adapt to being robots—and decide never to log off?

During my week as a robot, I often felt entranced by the experience of seeing and talking through a machine. The illusion of inhabiting a different body is quite powerful.

People who have teleoperated robots for extended periods report that their brains can become intimately connected to the machine. Filmmaker James Cameron, for example, said in a talk this year that while shooting his documentary on the *Titanic* wreck, he had a revelation. Piloting robotic submersibles into the murky depths, he said, made him realize "you actually can have these robotic avatars, then your consciousness is injected into the vehicle, into this other form of existence." He later took those ideas to the extreme in his 3-D blockbuster *Avatar*.

Hiroshi Ishiguro is a Japanese roboticist who creates telepresence robots that look like real people [see "The Man Who Made a Copy of Himself," *IEEE Spectrum*, April 2010]. He's built robot copies of himself, his daughter, and a young woman [photo, left]. Ishiguro claims that while teleoperating his clone he could feel a tingle on his own cheek when someone touched the robot's cheek. If that phenomenon could be amplified, could our brains "forget" about our old bodies and adopt robots as their new vessels?

Philosophers have pondered similar questions for ages. Descartes proposed that our knowledge of the world was always indirect and imperfect and that we couldn't trust our senses. "What do I see from the window," he wrote, "beyond hats and cloaks that might cover automatic machines?" Kant and others refuted that view, arguing that we indeed sense and understand the world directly.

The answer probably lies somewhere in between. We sense the world directly, but our brains interpret the data and create their own versions of reality. That means that our sense of embodiment—or disembodiment—is more malleable than most people think.

Researchers have shown they can induce out-of-body sensations by delivering electrical shocks or electromagnetic waves to the temporal lobes of volunteers. More recently, scientists have used virtual reality to make subjects experience other people's bodies, or even a mannequin's, as their own.

But when it comes to robots, "little is known about how teleoperation affects the operator," says Victoria Groom, a researcher at Stanford's Communication Between Humans and Interactive Media Lab. She says a number of factors affect how "embodied" the operator feels. These factors include the robot's appearance, whether it's partly autonomous, and whether the operator is using a monitor or virtual-reality goggles.

Will robotic telepresence ever come closer to the real thing? And will people then decide to give up their human bodies and become avatars for good, as some characters in *Avatar* did? It's a prospect that appeals to some and shocks others.

"Even the most gentle person-robot interaction would never be a caress, nor could one use a delicately controlled and touch-sensitive robot arm to give one's kid a hug," Hubert Dreyfus, a philosopher at the University of California, Berkeley, argues in *The Robot in the Garden: Telerobotics and Telepistemology in the Age of the Internet*, a compendium of essays on telerobotics.

"Whatever hugs do for people," he writes, "I'm quite sure telehugs won't do it." —*E.G.*

water, and in hazardous places like mines and nuclear reactors. But such robots are designed to perform specific tasks. Anybots wanted to focus on robots that let people *be* at a remote location. "After 100 years of advances in communications, where we discovered how to transmit text, voice, images, why not try to transmit presence?" Blackwell asks.

Building on what the company learned with Monty, it designed QA, a humanoid-looking robot with a sleek, white plastic body. That design got streamlined further, and QB was born. Behind its simple appearance is a neat combination of hardware and software. Inside the robot's base, the engineers crammed a computer running FreeBSD—a Unix-like operating system—two Wi-Fi cards, two DC motors, a pack of four 14.4-volt lithium-ion batteries, and a set of gyroscopes and accelerometers. Blackwell and three colleagues wrote software from scratch to control the robot and handle all networking and communication functions.

At the end of my tour at Anybots, I asked Blackwell if I could borrow a QB, expecting him to say, "Sure, just send me a $15 000 check." Instead he said, "When do you want it?"

ONE FEBRUARY MORNING, FedEx delivered a huge, military-grade Hardigg case to *Spectrum*'s office. This is how QB travels, nestled amid custom-formed foam. Anybots once tried to buy QB a plane ticket and bring it into the cabin, but the airline was not keen on the idea of a mechatronic passenger.

The robot I borrowed, QB No. 7, came with a companion: a friendly Anybots engineer named Erin Rapacki. Her job was to help set up the robot—a preproduction prototype—and probably to babysit it, too, to make sure I wouldn't drive it out of the office onto the streets of midtown Manhattan.

Setting up QB took several hours. Rapacki started by loading its base with the batteries, which can keep the robot going for 6 to 8 hours. Working out of the Anybots office in California, Daniel Casner, another engineer, logged on to the robot to tweak its network configuration so that data packets could get through our firewall. He also programmed the robot to switch seamlessly among the different Wi-Fi routers in the office. With the robot ready, my robotic existence commenced.

Sitting at my laptop at home, I launched Firefox and installed a plug-in created by Anybots to establish a link between my computer and the robot. I then went to the Anybots Web site, logged on with a password, and clicked on a button to connect to the robot. A video appeared on my screen, indicating I could start driving by tapping on the arrow keys of my keyboard.

At the office, the QB played a short jazz tune, announcing to those nearby that the robot, as Rapacki put it, "had a soul in it."

During my tests I experienced a delay of up to a second between pressing a key and the actual movement of the robot. It took me a few minutes to adjust to these conditions. Soon, though, driving became so natural I didn't even think about it.

OSAKA UNIVERSITY

The robot's main camera is a 5-megapixel wide angle, but it doesn't have the same field of view as the human eye. To see the floor just ahead of the wheels, you have to press the shift key, which switches the video to a secondary camera that faces down. The robot also has a scanning laser range finder for detecting obstacles. It steers or stops the robot if you're about to hit something—very helpful for avoiding furniture and feet.

QB has a small LCD on its forehead. Normally, it would show a live video feed of my face. But at the time of my experiment, Anybots was still debugging this feature, so the LCD displayed only a generic avatar. This meant that my voice was my main means of communication. The audio stream had some crackling, but otherwise I could chat normally.

That afternoon, I ran into the colleague who had fled earlier. He again tried to avoid me, but I gave chase (QB's top speed is 5.6 kilometers per hour, enough to follow people at a fast pace). I cornered him near the pantry and told him it was just me in a robot body.

"I get nervous," said Alan Gardner, our editorial researcher. "I have trouble relating to robots."

Other colleagues, though, were bolder. They wanted to know what I saw and how I controlled the QB. But just as I was showing off my capabilities, pirouetting and zigzagging down the corridor, I got disconnected from the robot. EriBot was now mindless.

I clicked on my computer and reestablished the link. "Where did you go?" someone asked. I explained what had happened. But something was still wrong: I couldn't steer the robot. I then asked senior editor Phil Ross something I'd never imagined asking anyone: "Phil, can you please reboot me?"

SO WHAT IS IT LIKE TO BE A QB? It's not exactly "Star Trek" teleportation, but being transplanted to another place as a robot is really cool. And if you were wondering, yes, you can get actual work done.

As a robot, I tried to interact in different ways with my colleagues. QB and I sat in on a typical editorial meeting, with two dozen people in a conference room and a few more participating via speakerphone. The editors who call in always complain that being "in the box" for hours is an ordeal. Participating as a robot, I think, makes a huge difference, mainly because when you speak, people look at the robot and you feel you have their attention. Even rolling into the room and choosing your place around the table gives you a better sense of "being there."

But the best interactions I had as a robot were the informal ones. One day, I wheeled over to photo editor Randi Silberman Klett's cubicle, where we held a spontaneous meeting to discuss art for this very article. Casual encounters like this, I realized, are the big advantage of telepresence robots over conventional communication systems. There are times when you just have to walk over to a colleague and look together at a screen or a piece of paper and see each other's reactions.

Pamela Hinds, codirector of Stanford University's Center for Work, Technology, and Organization, says there's a "huge need" for better technologies to support such "on the ground" collaboration. "Almost all of the technology that is out there is primarily geared to support meetings," says Hinds, who's tested a QB. She predicts that more and more companies will embrace telepresence robots.

As a robot, I participated in social events that I wouldn't have been able to while working at home. Our editorial tea was one example. Once a month, the *Spectrum* staff gathers in the conference room to hang out, drink tea, and eat an assortment of snacks. Attending this kind of gathering may not seem like a big deal, but a common complaint among remote workers is that they feel isolated and lonely, a problem some refer to as "water cooler withdrawal."

When I showed up at tea as QB, my colleagues dressed the robot in a scarf and hat and then took pictures. I got back at them by having editor in chief Susan Hassler log on to the robot from her home in Connecticut, unannounced.

"Hello there," she said.

"Who's...who's there?!" they answered, bewildered to be hearing her voice suddenly coming from the robot. Yep, the next time you notice a robot standing over your shoulder, it might be your boss.

Continued on page 48

You, Robot

Telepresence robots for all needs and wallets

Rovio is a small rover with a webcam and omnidirectional wheels for home use. Created by Hong Kong toy maker WowWee. **Price: US $140**

Vgo is a sleek, 1.2-meter-high office robot with a tilting camera and small LCD. Sold by Vgo Communications, of Nashua, N.H. **Price: $5000**

TiLR is a rugged robot for offices and factories with a powerful mobile base. Created by RoboDynamics, of Santa Monica, Calif. **Price: $10 000**

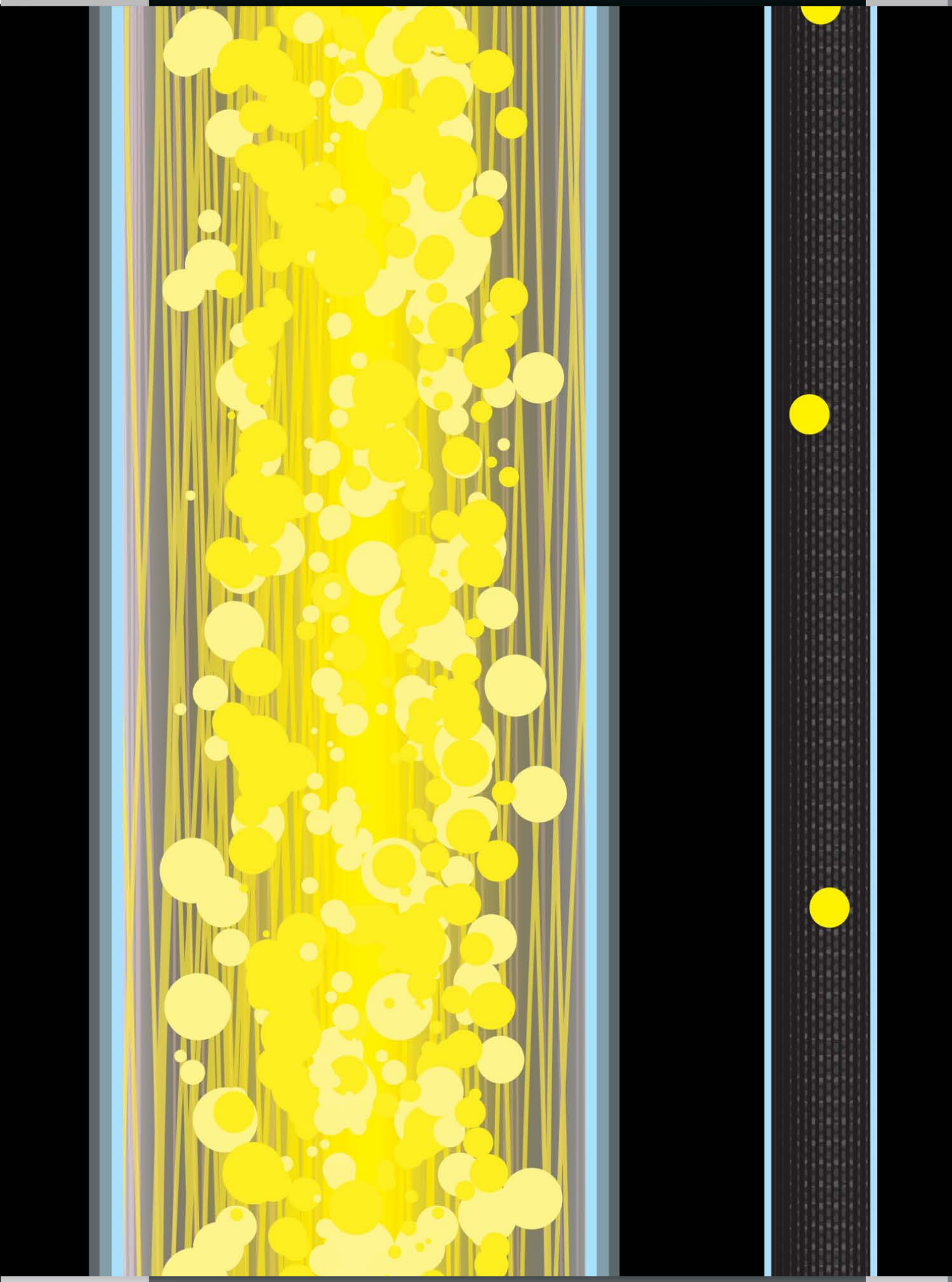
Giraffe is a 1.7-meter-high robot with a large display designed for healthcare and home use. Sold by HeadThere, of San Francisco. **Price: $3000**

RP-7i is a hospital robot used by doctors to check on patients. Created by InTouch Health, of Santa Barbara, Calif. **Price: About $50 000 per year**

Sparky Jr. is a DIY project that anyone can replicate. Designed by San Francisco–based artist Marque Cornblatt. **Parts cost about $1000**

Texai is a robot that uses off-the-shelf parts and the Robot Operating System. Created by Willow Garage, of Menlo Park, Calif. **Price not available**

FROM LEFT: WOWWEE; VGO COMMUNICATIONS; ROBODYNAMICS; HEADTHERE; INTOUCH HEALTH; MARQUE CORNBLATT; WILLOW GARAGE



Get on the Optical Bus

IBM'S LIGHT-POWERED LINKS OVERCOME THE GREATEST SPEED BUMP IN SUPERCOMPUTING: INTERCONNECT BANDWIDTH

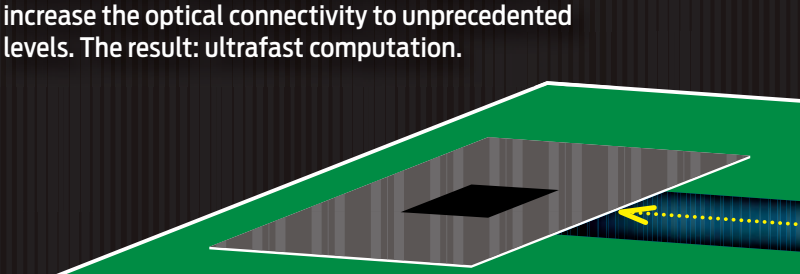
By CLINT SCHOW, FUAD DOANY & JEFFREY KASH

Illustrations by McKIBILLO

ANATOMY OF AN OPTOMODULE

IT TAKES A BAG OF ENGINEERING TRICKS TO ROUTE LIGHT ALONG AN OPTICAL PRINTED CIRCUIT BOARD

Today's supercomputers link modules by means of optical fiber, and as the modules proliferate with each new generation of machines, the fibers form an increasingly unmanageable rat's nest. By incorporating the light channels in an optical printed circuit board and by conveying light to and from the modules with integrated lens arrays, IBM plans to increase the optical connectivity to unprecedented levels. The result: ultrafast computation.



OPTICAL PRINTED CIRCUIT BOARD: The IBM prototype linked only two modules, but more waveguides could be routed to link many modules.

SAD BUT TRUE:

About three-quarters of the time, your computer processor is doing nothing more than waiting for data—the cybernetic equivalent of twiddling one's thumbs. It doesn't matter whether you've got the latest processor, surrounded it with high-speed RAM, or lovingly hot-rodded your system with the latest in liquid cooling. Your speed is primarily set not by the processing power you have but by the connections that stand between that processor and the data it needs.

The problem is that data transfer is accomplished by the movement of an electronic signal along old-fashioned copper wires—the same basic phenomenon that a century and a half ago carried news of the U.S. Civil War over telegraph lines. It's time we saw the light—literally—and stopped shackling ourselves to electrons moving along copper conductors.

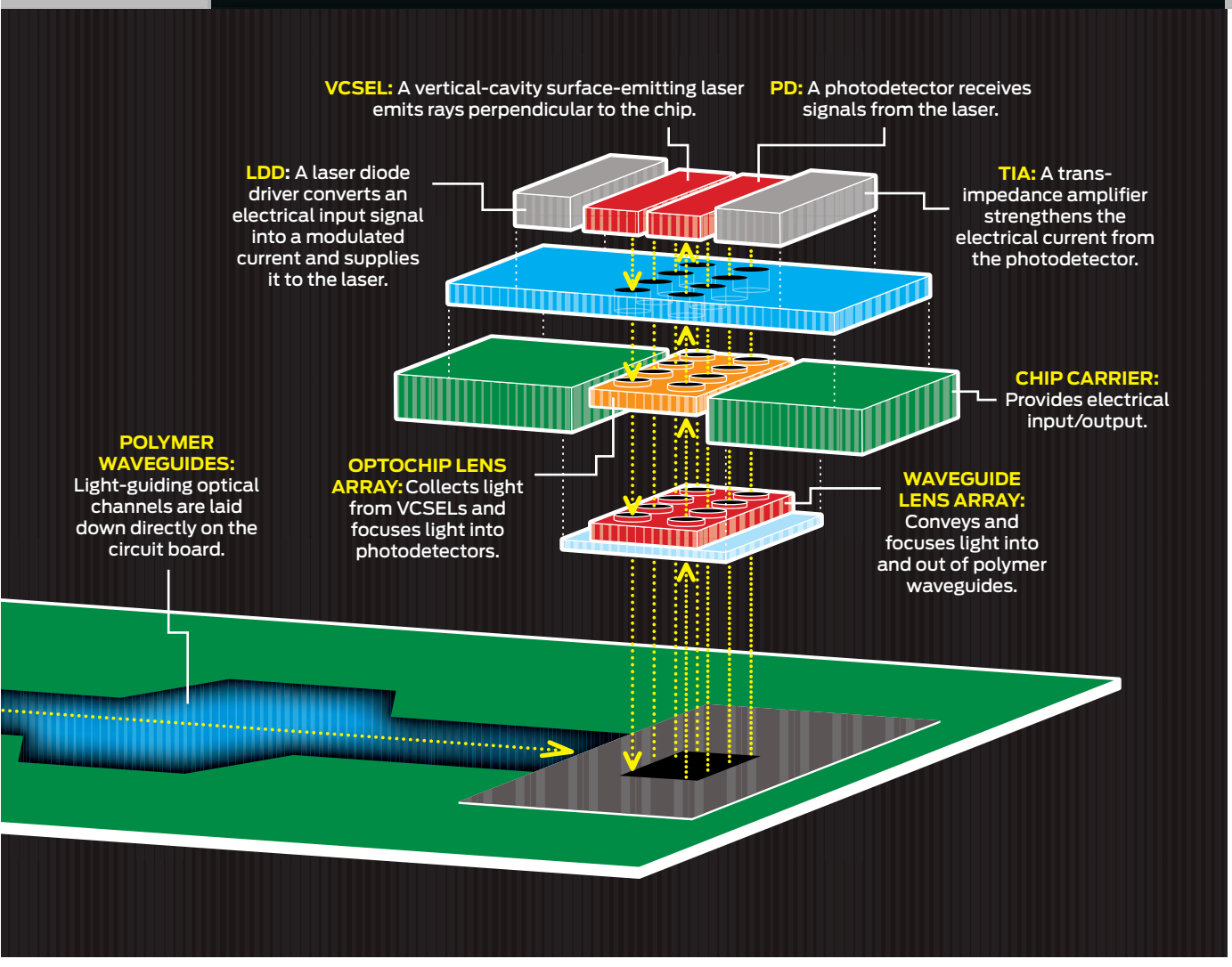
For decades, engineers have sought to transfer signals from chip to chip with photons. Photons are more than just fast; unlike electrons, they lack an electric charge. That means they can't interfere with each other, causing cross talk that, like the din of a boisterous party, can turn a conversation into a game of charades. For many years, however, the optoelectronic strategy has been hindered by the problem of getting photons to go where you want them to go. Metal connections can be laid down on semiconductor wafers with exquisite precision, and they can easily be formed into networks that branch out from central lines, the same way capillaries branch out from arteries. It's far harder to accomplish this feat when laying down a system of tiny optical channels.

At IBM, we have now developed a first-of-its-kind optical data-transfer system, or bus, built right onto the circuit board. With it, we will soon unveil computer systems 100 times as fast as anything available today. With that much muscle, scientists will at last be able to visualize wondrous things in detail: how the climate will react to man-made greenhouse gases, how neurons organize to form a brain, how to custom design a drug to treat an individual patient.

EVER SINCE THE EARLY DAYS of microprocessors, data has shot back and forth far faster inside the chip than between the chip and external components, such as memory and input/output ports. Data transfers within a microprocessor—for example, between the processing core and on-chip cache memories—have been operating at multigigahertz clock rates for more than a decade. But transfers between the chip and external memories along those copper conduits are typically an order of magnitude slower. This bandwidth gap will continue to widen as processor performance continues to climb and multicore architectures become more elaborate.

Copper can't keep up, because it faces simple physical limits. Shoot an oscillating signal down a long copper line on a printed circuit board and it'll lose about half its strength at 2 gigahertz—and a staggering 98 percent at 10 GHz. Most of that loss stems from two effects. First, the oscillating signal induces stray currents in the board's conductors that suck away energy. Second, induced currents inside the wire itself push electrons to the surface of the metal, reducing the effective cross section of the wire and thus raising resistance. The higher the frequency—that is, the clock rate—of the signal, the greater the losses will be.

To make matters worse, severe resonances occur at a few gigahertz, at which point the signal begins to reflect off metal



paths in the vias, the vertical conductors that connect elements of a circuit board. It gets worse still as bit rates approach 10 gigabits per second, when cross talk blurs the signal, even at distances of less than a meter.

These problems are particularly bad when you're yoking together the multichip modules of a massively parallel computer. When one module must link up with another at the other end of a circuit board or, worse still, in a different rack of equipment, the bandwidth bottleneck becomes particularly severe. That's why today's highly parallel machines can reach peak performance only when solving those specialized problems that can be readily divided into many tasks that can be processed independently.

By avoiding all those signal-loss and cross-talk problems, an optical bus would make supercomputers go much faster. It would also make them easier to program, because programmers wouldn't have to take special measures to compensate for such severe communication delays among processors.

FIBER-OPTIC LINES FIRST began proliferating in the 1980s in long-distance telecom networks. By the late 1990s, fiber-optic links had found their way into local and storage area networks, interconnecting systems hundreds of meters apart. Over the next decade, the technology kept moving down to ever smaller dimensions as its cost and power needs kept falling and the bandwidth requirements of computer systems kept rising.

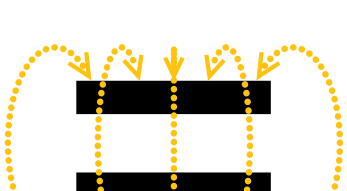
Consider the role of optical interconnects in supercomputing. In 2003 and 2004, the fastest machines on Earth were the NEC Earth Simulator and IBM's initial Blue Gene L, which had peak performances of around 36 trillion floating-point operations per second, or teraflops. All the interconnects in those supercomputers were electrical. Then, in 2008, IBM's Roadrunner set a new record by achieving a quadrillion (a thousand million million) such operations per second, which is known as a petaflop. The Roadrunner used some 40 000 optical links to connect entire racks of servers.

Sometime next year, at the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign, IBM's Blue Waters machine is expected to go 10 times as fast, using more than 1 million optical interconnects. The number of parallel optical modules inside Blue Waters will be roughly equal to the world's current annual production. IBM will be a major consumer of these optical interconnects, and though it helped to pioneer parallel optics, IBM does not plan to go into the business of manufacturing the modules. So the company is sharing much of its knowledge with potential suppliers.

Computers beyond Blue Waters will need proportionately more interconnects. Connect the dots and the resulting trend suggests that 1000-petaflop (Pflop) systems will require an astonishing 400 million optical links. In general, judging from past performance data, supercomputer processing rates have been going up tenfold every four years. So you can expect 10-Pflop, 100-Pflop,

PARALLEL OPTICAL INTERCONNECTS

SUPERCOMPUTERS ARE DRIVING DEVELOPMENT AND LARGE-SCALE DEPLOYMENT OF PARALLEL OPTICAL TRANSCEIVERS



TODAY

Rack-to-rack: Supercomputers currently use conventional optical modules and edge-of-card packaging.

2011

Intrarack: Supercomputers will use dense, parallel fiber-coupled modules that are positioned close to the CPU.

2015

Module-to-module: Supercomputers will use integrated transceivers and optical printed circuit boards such as those in the Terabus program.

2020

3-D chip stack: Supercomputers will have microprocessors with optical transceivers directly integrated into them.

and 1000-Pflop (exaflop) systems to emerge in 2012, 2016, and 2020, respectively. The Blue Waters system—starting at 10 Pflops, and scalable to 16 Pflops—is slightly ahead of the trend, with a scheduled production date of 2011.

To sustain this exponential performance increase, we'll have to cram more optical links into a given space at lower cost and integrate those links more fully into the computer's electronic processors. Since 2003, IBM has led a project, sponsored by the Defense Advanced Research Projects Agency, or DARPA, that aims to do just that, by bringing optical communications down to the level of the circuit board. This project, conducted at three of the company's global research labs (Yorktown Heights, N.Y.; Zurich; and Tokyo), is developing optical transceivers mounted on and communicating through optically enabled printed circuit boards. The boards incorporate a layer of optical "wiring," or buses, that can move data between processor modules.

The scale of the printed circuit cards and backplanes used in today's supercomputers is about 10 to 200 centimeters. For optical buses to compete with copper interconnects at this scale, the performance and efficiency of optics must become much better than they are. Optical modules with 12 parallel channels now cost several dollars per gigabit per second, offer speeds from 60 to 120 Gb/s with an efficiency of 30 to 100 picojoules per bit, and occupy about two-thirds of a square centimeter on the chip. To be practical for 100-Pflop machines, these modules must be improved on all fronts by a factor of 10 and will have to be scaled commensurately beyond that for exaflop computers.

TO SCALE UP THE MODULES, we'll have to stop using a separate optical fiber to link each transmitter with its corresponding receiver. That makes for a heck of a wiring job, now that the number of optical links in a supercomputer already exceeds 1 million. Just imagine the tangled confusion on a PC motherboard if every electrical bus were constructed with individual wires instead of traces in a multilevel printed circuit board! It would be impossible to build.

We are developing parallel optical devices that will soon have the kind of speed, density, and cost profile we are seeking. We call them optochips. Optochips are transceivers: They convert signals from electrical to optical form and back again. They simultaneously transmit and receive optical data through many dozens of communication channels—a number that may rise to hundreds in the future—to achieve a huge aggregate bandwidth. And they are similar enough to standard electronic chips to be packaged and installed using conventional, low-cost assembly techniques, such as surface mounting on a circuit board.

We have built two quite different optochips, one operating on optical signals at 985 nanometers and the other at 850 nm. They both use vertical-cavity surface-emitting lasers (VCSELs) as the light source. These lasers can be modulated at speeds of up to 40 Gb/s, and they emit light vertically through mirrors, along a path perpendicular to the chip. The lasers are particularly inexpensive to manufacture, in part because they are fabricated in two-dimensional arrays and so can be tested right on the wafer, before it has gone through further processing steps. (VCSELs are so inexpensive—just pennies per device—that they're now found in nearly all optical mice.) The first commercial parallel modules employing VCSELs appeared in the late 1990s and operated at about 1 Gb/s per channel, but the market started to take off only around 2003, when such interconnects began to link racks in computers and routers. The data rates quickly rose, recently reaching 10 Gb/s per channel.

We built the 985-nm optochip first. It has the simplest and most compact package because it takes advantage of a feature called substrate emission and detection. This enables the device to emit light downward, into the substrate—that is, in exactly the opposite direction from that of standard VCSELs. Similarly, the 985-nm optochips also receive light through the substrate. The light is detected by a photodiode integrated into the optochip.

By configuring the laser and photodiode detector this way, we can put their respective electrical contacts on one side, so they don't obscure the window for transmission. We can also put lenses that collimate the beam on the bottom, so

we're able to pack lenses in more densely. Also, because light goes in and comes out through the back surface of the optochip, the front side of these chips can be directly soldered to a single CMOS transceiver chip. This chip converts the optical signals to electrical ones, and vice versa. The chip is fabricated with a low-cost, 0.13-micrometer process and measures just 3.25 by 5.25 millimeters. It contains the circuits that amplify the signals that go into the laser and those that come out of the photodetector.

We soldered two 4-by-4 arrays of devices onto the CMOS transceiver chip, one of lasers and the other of photodetectors. Each 16-device array connects to 16 distinct amplifying circuits on the CMOS chip. This is a highly compact way to assemble this parallel design, and it could readily be scaled up to offer even more transmitter and receiver channels.

The optochip operates at up to 15 Gb/s per channel—the previous record was 10 Gb/s per channel. And all of its 16 channels together provide an aggregate bandwidth of 240 Gb/s while consuming just 2.2 watts of power.

Besides its blazing speed, the optochip can send and receive a single bit with a paltry 9 pJ, an efficiency that's about five times that of the modules now on the market. It's also able to transmit a lot of information per unit of area, achieving 28 Gb/s per square millimeter. That's the highest bandwidth density achieved to date and at least 10 times that of the latest commercial parallel optics. Density is obviously critical in large systems: If you're going to have 100 million optical links, they'd better be small.

THE TERABUS PROGRAM began in 2003 as a joint effort between IBM and Agilent Research Laboratories, in Santa Clara, Calif. IBM was responsible for developing the waveguide, circuit board, CMOS design, and packaging, while Agilent produced the arrays of lasers and photodetectors. Then in 2005, Agilent spun out its semiconductor products division and withdrew from the program. Although we had enough of the critical 985-nm lasers and photodetectors to attain the initial program milestones, we decided to redesign the optical transceivers to incorporate 850-nm VCSELs and photodiodes.

By doing so, we had to give up substrate emission—the very feature that let us make our first-generation optochip so compact and elegant. The reason was that the substrates of the lasers and detectors aren't transparent to 850-nm radiation (more on that in a moment). Nevertheless, with our new 850-nm optochips we were able to exploit a few countervailing advantages. First, the optical transceiver industry was producing 850-nm parts in high volumes; if we'd bet on another wavelength, we would have had to spend a lot of money on R&D to establish an industry standard. In fact, the 850-nm parts we now use are fabricated by Emcore Corp., in Albuquerque. They differ from Emcore's standard parts mainly in offering 24 rather than 12 channels.

Second, there was a purely technical motive behind our selection of the 850-nm transceivers. Less light is lost in the polymer waveguides at 850 nm than at 985 nm. That loss matters, particularly at links of up to a meter long—the length we had resolved to support in our Terabus project. On that scale, by working at 850 nm instead of 985 nm you get a whopping six times as much optical power through to the receiver.

Because the substrates of the lasers and detectors are not transparent to 850 nm, we couldn't solder them directly to the CMOS transceiver without blocking the path of the light. So we designed an additional simple silicon "chip" measuring 10.4 by 6.4 mm to serve as a carrier. The laser and photodiode arrays are soldered to it, along with two new 24-channel CMOS chips, one a transmitter and the other a receiver.

This silicon carrier chip (which has no transistors or other active devices) has three wiring levels on its upper surface, formed of alternating layers of copper and oxide insulation. Metal wires extending through the silicon connect these wiring layers through the chip to bonding pads on the opposite surface of the carrier. The top wiring connects each of the 24 optical devices to its own amplifier (either a laser driver or a receiver channel). To allow light to pass through the carrier, we etched holes—optical vias, that is—through the carrier below each laser and detector device.

Our 850-nm design gives us half again as many channels as the previous chip did—24 transmitters and 24 receivers, each operating at up to 15 Gb/s per channel. Together they achieve a bidirectional data rate of 360 Gb/s while consuming 2.3 W of power. The power efficiency, at 6.5 pJ per link, beats that of the 985-nm optochips, though the bandwidth density, at about 9 Gb/s/mm^2, is only about a third as good. All in all, it's a good bargain, because the 850-nm optochip was specifically designed to use only components that can be mass-produced at low cost, using lasers and photodetectors that are available today.

EXPLOITING THIS POWER requires that we raise the integration level to cover an entire circuit board. We therefore built a board-spanning optical bus by packaging optochips on a fabricated optical printed circuit board. We started by soldering optochips to chip carriers. This is the same type of electrical packaging that is used today for microprocessors in a laptop. A hole in the carrier provides a path for the light signals between the optochip and the circuit board, so the mirror can bend the light by 90 degrees.

Ours is the first optical data bus ever integrated into a printed circuit board. So far, we've been able to transfer data at 10 Gb/s along a 15-cm bus through 32 one-way links between two of our 985-nm optochips. We provided a dramatic illustration of this bus at the SC07 supercomputer trade show, in 2007. At that conference, one of our optochips transferred a video signal from an HDTV camera to a second optochip over a single waveguide channel and was displayed live on an HDTV monitor for more than three days. Although we used only a single channel, at a data rate of 2 Gb/s the card and optochips could support more than 160 simultaneous HD video signals.

Our transceiver technology clearly achieves bandwidth and power efficiencies way beyond the capabilities of anything on the market today. Can it go from the laboratory to high-volume manufacturing? We're confident that it can: Our transceivers incorporate CMOS electronics, optoelectronic devices, and microchip packaging techniques that are already in production today. Product development should be straightforward.

Within five years, we hope to connect microprocessors and memory chips right to the optochip, producing the optical analogue to the electrical multichip modules in today's big-iron machines. In these near-future supercomputers, electrical connections will supply only the power, the ground, and the control signals. All the data will shoot through optical interconnects at the speed of light. ❑

THE *FASTEST* HELICOPTER ON EARTH

SIKORSKY AIMS TO BREAK THE HELICOPTER SPEED RECORD

By THOMAS LAWRENCE & DAVID JENNEY

TO PARAPHRASE HELICOPTER PIONEER IGOR SIKORSKY: If you're in trouble, an airplane can fly over and drop flowers, but a helicopter can save your life. It can deftly maneuver through tight spots and alight in remote places. It can float next to a mountain to search for the lost. And the best sound a wounded soldier can hear is that telltale rotor beat, just minutes before being evacuated to a hospital. When roads are impassable, bridges have been destroyed, and the electricity has been knocked out, helicopters can still deliver supplies and rescue people.

What they can't do is fly fast. The world speed record for a helicopter, claimed by a modified Westland Lynx in 1986, is 400 kilometers per hour. A Curtiss biplane bested that speed in 1923. The Westland Lynx was a good start, but it was more like a race car than a family sedan—impressive but not quite practical for routine missions. Today's working helicopters tend to top out at around 270 km/h.

SPEED DEMON: Sikorsky's X2 experimental helicopter is, unofficially, the fastest on Earth.
PHOTO: SIKORSKY AIRCRAFT CORP.

THE WACKY WORLD OF VTOL

FORAYS INTO FLEXIBLE HIGH-SPEED FLIGHT

AT SIKORSKY AIRCRAFT CORP., IN STRATFORD, CONN., we decided in the 1970s that we wanted to build a really fast helicopter. The goal was to reach 480 km/h without sacrificing the vehicle's other strengths. Almost 40 years later, Sikorsky is now close to meeting that goal. In August 2010, a technology demonstrator, known as the X2, reached 435 km/h, unofficially breaking the helicopter speed record. A few hurdles remain before Sikorsky can claim the official record, which is maintained by the Fédération Aéronautique Internationale (FAI), the world's air sports organization. Having gotten this far, we anticipate that Sikorsky will soon begin producing commercial helicopters using X2 technologies.

To take a crack at the speed record, we had to make some fundamental changes to conventional helicopter design. The reason why becomes clear when you consider the difference between how helicopters and airplanes fly.

When an airplane barrels down a runway, air flows over the wings to produce lift. At a certain speed, the pilot pitches the nose up slightly, increasing the angle of the wing to the air. That creates enough extra lift for the airplane to take off. Once a plane is airborne, its speed is limited only by the amount of thrust its engines can provide.

A helicopter generates lift quite differently. It manipulates the air flowing over its spinning rotor blades, allowing the body of the aircraft to hover. The lift generated by the rotor blades can be angled using the helicopter's flight controls, allowing it to fly sideways, pivot, or even backward.

Compared with the fixed wings of an airplane, a helicopter's rotating blades make for a much more complicated design. Each blade must withstand the forces of rotation, which can amount to many times the weight of the aircraft on each blade. A helicopter also needs a powerful engine and a large transmission to reduce the engine's rotation rate to something appropriate for the large rotors. For example, a U.S. Army UH-60 Black Hawk engine's output of 20 900 revolutions per minute turns the main rotor only 258 times per minute, a ratio of 81 to 1.

But here's the catch. When a helicopter flies forward, the rotor blades experience a dramatic variation in airspeed. That's easy to see if you imagine a miniature version of yourself perched on the tip of a helicopter rotor blade. If the helicopter were hovering, you'd feel a constant 800-km/h wind in your face as the rotor spun around. If the helicopter were to fly forward, you would note that the wind was stronger on what's called the advancing side, when the rotor was moving in the same direction as the helicopter, but that it would be noticeably weaker when the rotor was on the retreating side. By the time the helicopter reached 150 km/h, you would feel a wind speed of 950 km/h on the advancing side, versus 650 km/h on the retreating side. The relative speed of the wind on the retreating side gets lower and lower the faster the aircraft flies. At 300 km/h, the wind on the advancing side would reach 1100 km/h, while the wind on the opposite side would be 500 km/h.

Eventually, the helicopter would reach a point at which the difference between the lift on the advancing and retreating sides of the rotor could not be balanced and the vehicle wouldn't be able to maintain level flight. To complicate matters further, portions of the tip of a fast-flying helicopter's advancing blade can exceed the speed of sound, producing shock waves that cause large vibrations and generate considerable noise. For these reasons, most helicopters just don't like to go fast.

IN THE 1950S, AIRCRAFT DESIGNERS began to look at other configurations to achieve vertical takeoff and landing and reach forward speeds greater than 450 km/h. One approach was to design an

COAXIAL ROTORS: To achieve high speeds, as well as vertical takeoff and landing (VTOL), the Sikorsky X2 uses two rotors spinning in opposite directions.

CLOCKWISE FROM LEFT: SIKORSKY AIRCRAFT CORP.; BELL HELICOPTER; J. R. EYERMAN/TIME LIFE PICTURES/GETTY IMAGES; KLAUS PETERS, EXPRESS/GETTY IMAGES; DASSAULT AVIATION; PIERRE VERDY/AFP/GETTY IMAGES

aircraft whose thrust could be tilted vertically for takeoff and landing and horizontally for forward flight, during which time the vehicle would produce its lift from fixed wings. Some, such as the Bell X-22, used tilting ducted fans, while others used tilting propellers—for example, the Vought-Hiller-Ryan XC-142A and Canadair CL-84. Some had tilting jet engines, like the EWR VJ 101C. All handled poorly when hovering and produced downward air velocities high enough to blow a house down and uproot trees.

A more successful variation on this theme is the tilt-rotor, which uses helicopter-like rotor blades instead of ducted fans or propellers, with the axis of rotation switching from vertical to horizontal after takeoff. But this dual use is awkward: The rotors are too small for the aircraft to hover efficiently and larger than optimal for forward flight. The complicated tilting mechanism and excessive amount of power it requires also make the tilt-rotor option costly and complex.

Another approach to high-speed vertical takeoff used specially designed lift engines that worked only during takeoff and landing. These heavy engines produced large thrust for vertical takeoff and landing; in forward flight they were shut down and covered by doors. One such vehicle, the Dassault Mirage IIIV, was able to reach Mach 2, twice the speed of sound. Unfortunately, if you were on your roof waiting to be rescued, such an aircraft might not only fail to retrieve you, it could set your house on fire.

Aircraft engineers have also tried out jet engines with adjustable exhaust nozzles. The Hawker Siddeley Kestrel, which first flew in 1960, could aim its thrust in different directions, making the aircraft quite agile in forward flight and able to take off and land vertically. But the exhaust was again too hot and fast for the helicopter to be suitable for rescue purposes.

What we at Sikorsky settled on almost four decades ago was a design we called the Advancing Blade Concept. It uses two counter-rotating rigid rotors that spin around the same axis, which is why they are known as coaxial rotors. In forward flight, each rotor produces a surfeit of lift on its advancing side, freeing the retreating side from having to do any heavy lifting, all while maintaining good balance. Sikorsky patented the concept in 1964, but considerable engineering was needed to actually get something like this in the air.

The first flight of a demonstrator vehicle using coaxial rotors took place in June 1973. The U.S. Army, which sponsored the flight tests, called it the XH-59A. Sikorsky's test pilots took the helicopter out on a few low-speed forays to see how it handled. On one of these early low-altitude flights, the helicopter suddenly pitched nose up. The pilot was forced to land the aircraft on its tail, damaging the landing gear in the process. The helicopter rolled about 45 degrees, hitting the tips of the rotor blades on the asphalt. Fortunately, nobody was hurt.

That accident raised some big questions. For one thing, what could have gone wrong at a speed as unimpressive as 46 km/h? Sikorsky engineers launched a yearlong investigation into the incident. What we learned was that the very stiff coaxial rotors pro-

TILTING DUCTED FANS: The Bell X-22 tilted its four propellers upward for takeoff and rotated them 90 degrees for horizontal flight.

TILTING PROPELLERS: The Vought-Hiller-Ryan XC-142A's wing rotated to point its four propellers upward for takeoff or forward to cruise.

TILTING JET ENGINES: The EWR VJ 101C used swiveling wingtip engines and extra lift jets to take off vertically and hover.

TILT-ROTOR: After takeoff, the Bell/Agusta BA609 slowly tilts its rotors forward until their plane of rotation is vertical in airplane mode.

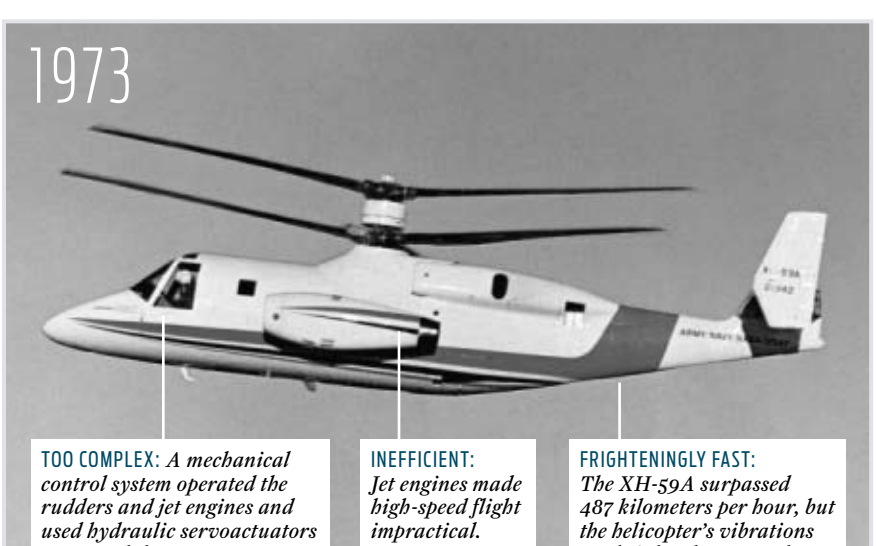
LIFT ENGINES: The Dassault Mirage IIIV's eight lift engines produced vertical thrust, and a separate engine provided its cruising thrust.

THRUST VECTORING: The Hawker Siddeley Harrier angled its exhaust through nozzles to produce lift and control the direction of flight.

REINVENTION OF *SPEED*

BEFORE & AFTER

SIKORSKY'S COAXIAL ROTOR, PLUCKED FROM THE ANNALS OF HISTORY



TOO COMPLEX: *A mechanical control system operated the rudders and jet engines and used hydraulic servoactuators to control the rotors.*

INEFFICIENT: *Jet engines made high-speed flight impractical.*

FRIGHTENINGLY FAST: *The XH-59A surpassed 487 kilometers per hour, but the helicopter's vibrations made it hard to control.*

duced greater-than-expected nose-up forces when flying forward. The aircraft's control system also turned out to be inadequate. The designers had worried that the controls would be extremely sensitive, so the pilots weren't given the usual wide range over which to manipulate the pitch of the rotor blades. In any helicopter, a pilot can maneuver by changing the blades' angle of attack in a cyclic manner, meaning that the pitch of each blade changes as it rotates around its hub, altering how much lift it generates at different points in the circle. But with less control over how much the pitch could be changed, the pilot was deprived of adequate authority for controlling the helicopter's nose.

When the second XH-59A aircraft was built, we modified its control system and moved the helicopter's center of gravity forward. We also built in electronic stabilization mechanisms to dampen the aircraft's pitch and roll by sensing the motion of the aircraft and feeding the relevant flight parameters—such as airspeed, rotational rates, and attitude—into a computer. If the aircraft rolled slightly to the right, the computer commanded the flight-control servomechanisms to roll it back slightly to the left. The computer's commands were then mechanically mixed with the pilot's input.

This new aircraft took off for the first time on 18 September 1975. During the next five years, the XH-59A was tested both as a pure helicopter and with jet engines attached to the sides of the fuselage to provide extra propulsion. It performed deftly at low speeds and managed to reach an impressive 445 km/h in level flight and 487 km/h in a shallow dive. (These speeds weren't certified by the FAI to claim the record.)

Because it was intended as an inexpensive proof of concept, the XH-59A had features, such as the strapped-on jets, that no production vehicle would likely have. The heavy and fuel-hungry jets pushed the aircraft to high speed—with some significant problems. For example, the helicopter vibrated so much at these higher speeds that its pilots struggled to control it. And when hovering, the vehicle had an annoying tendency to oscillate rather than float smoothly in place.

In May 1980, the XH-59A's supporting agencies—the U.S. Army, Navy, and NASA—held a conference to discuss the possibility of an "XH-59B." But in the end, there were no takers, and the XH-59A was retired to the Army Aviation Museum, in Fort Rucker, Ala.

A FEW YEARS AGO, HOWEVER, Sikorsky decided to review its portfolio of designs to see whether technological advances in avionics and control systems might be able to address the earlier problems. Engineers at Sikorsky were particularly interested in seeing whether the company could rescue its Advancing Blade Concept.

The first thing to tackle was the vibration problem. Sikorsky's helicopters have been using a system of active vibration control for the last five years. This technique involves a dozen or so vibration sensors distributed around the helicopter, a control computer, and several vibratory-force generators placed at select spots on the airframe. A computer monitors the helicopter's motions and activates the force generators to cancel out vibrations.

To make the revived helicopter fly more efficiently at high speeds, specialists in aerodynamics turned to computer-aided design tools to craft the airfoils, rotors, and fuselage. As a result, the X2's blades have specially designed airfoils with a variable width and an unusual twist. The modeling software indicated that this rotor would have significantly less drag and more lift than what was used in the XH-59A.

Then there was the problem of the jet engines. Simply adding jet engines to the helicopter does speed it up, but they are noisy and fuel hungry. So the X2 design team decided to use a variable-pitch pusher propeller at the aft end of the fuselage to provide forward thrust when needed. That propeller is good not only for acceleration but also for rapid deceleration.

Another critical advance was in the controls. The XH-59A had used a mechanical flight control system that was both heavy and extremely complex. It commanded six hydraulic servoactuators to change the pitch of the rotors (three actuators per rotor), operated the rudders, and controlled the two auxiliary jet engines. The X2 control system uses digi-

SIKORSKY AIRCRAFT CORP. (2)

tal computers to perform all these functions, combining the pilot's inputs with feedback from various flight sensors to ensure that the aircraft executes smooth, well-controlled motions even in turbulent conditions. The system contains three redundant flight-control computers just to be safe. If one of them fails, it instantly shuts down, allowing the aircraft to fly normally on the remaining two computers. The different sensors on which the flight-control system relies are also installed in triplicate. The output commands for the rotors, the control of the servos that cancel out vibrations, and the other complexities of the XH-59A's mechanical system are easily handled in software, something that would have been nearly impossible to do in the early 1970s.

The engine Sikorsky ended up choosing for the X2, an LHTEC T800 turboshaft, is a modern, state-of-the-art design that might well serve for a production vehicle. The rotors, propeller, and engine are coupled together with gearboxes and shafts. This approach allows the engine's power to be distributed between the rotors and propeller as needed. While hovering or moving at low speeds, the rotors consume the lion's share of the power, while at high speeds the pusher propeller gets a boost. Computer simulations indicate that the X2 should be able to reach between 465 and 490 km/h with this engine.

THE X2 PROTOTYPE MADE ITS FIRST test hop on 27 August 2008, in Elmira, N.Y. Several more low-speed flight tests also went off without a hitch. To venture to higher speeds, Sikorsky sent the test team to its flight center in West Palm Beach, Fla., which became the X2's new home. We're now on a course to push the X2, in stages, to its maximum speed. Most recently, we set our sights on 463 km/h.

On the day of that flight, in August of this year, the test team got started at the crack of dawn. To ensure that the pilots would be flying in smooth air, the crew had to be on site by 5:00 a.m., before the sun had a chance to heat the air enough for the wind to pick up. The crew rolled the aircraft out onto the runway, where a dozen safety officers in bright orange jumpsuits and noise-canceling headsets were on patrol. Two chase vehicles were there to observe the test flight—another helicopter and a fixed-wing turboprop. The latter would be needed to keep up with the X2 as it accelerated to higher speeds. The test team was on high alert as it orchestrated flight activities to keep the three vehicles a safe distance apart.

With everyone's nerves on edge, the X2 started up its engine at 6:30 a.m., and the helicopter took off. Within a few minutes the X2 had reached a speed of 350 km/h. A dozen people watched from the ground as the airspeed crept up, first to 400, then 410, and finally topping out at 435 km/h—not quite the goal we'd set, but good enough for this round. Cheers and applause broke out on the ground. The pilot slowed the X2, turned it around, and flew back to land on the runway.

Everyone involved was jubilant, but most of all relieved—especially the pilot. To train pilots to fly this brand-new vehicle, Sikorsky built a simulator that lets them preview the controls and the aircraft's responses. The real X2 has only about 14 flight hours on it, but its engineers and pilots have spent hundreds of hours flying the simulator. In part, that's because it provides valuable feedback to the designers, who devoted its first few sessions to tuning the feel of the control stick, modifying the displays on the instrument panel, and checking the X2's performance at low speeds. One of the simulator's key roles now is in evaluating higher flight speeds and maneuvers that are more aggressive than those the actual X2 has accomplished.

We'll continue to pursue higher speeds. Assuming all goes well, Sikorsky engineers are planning to adopt some of the technologies used on the X2 for the new helicopters they have on the drawing board. So expect some dramatic shifts in the way helicopters are designed.

The development of those technologies has been unusual in the helicopter industry, especially given the company's decision to pursue a once-abandoned idea with its own funding. For engineers like us, it's a thrill to see new ground broken in an industry that's usually considered mature. And it's certainly rewarding to see how new technology can benefit a four-decade-old idea for solving the helicopter's fundamental shortcoming: a need for speed. ❑

SHANGHAI EXPO SPOTLIGHTS THE CONSEQUENCES OF TECHNOLOGY ***BY SALLY ADEE***

AFTER U

AT THEIR FINEST, world's fairs are a strange amalgam of the practical and the impossible, the feasible and the futuristic, the ridiculous and the sublime. Since the first official world's fair in 1851, they have churned out giddy monuments to human industry and innovation, with the shining promise of technology taking center stage.

Many utopian dreams of world's fairs past have now been absorbed into the everyday: the first commercial escalator at the 1900 world's fair in Paris; the personal automobile in 1904; RCA's television in 1939. The potential of such inventions seemed only for the good. Escalators and elevators would enable modern skyscrapers and cities. The car offered unfettered freedom of movement.

CHINA

TIMES SQUARE WORLD

In the Pavilion of Urban Planet, visitors walk through a vertiginous cautionary tale: The garishly lit city-planet, according to the pavilion's designers, represents the ecological problems posed by unchecked development.

In this and the other 270 national, corporate, and theme pavilions, the question hangs like a challenge: Can we create cities whose citizens enjoy a fulfilling existence without destroying the planet?

PHOTO: XINHUA/LANDOV

TOPIA

The phone and TV would create an immediate connection to the outside world.

The downsides of modernity emerged later. All those skyscrapers in all those cities now soak up the electrical output of entire power plants. Hundreds of millions of cars have created a nightmare of traffic congestion and pollution. Lonely souls stare at their TV screens, cut off from real, human contact.

Although there's plenty of starry-eyed techno-optimism on display at Expo 2010 Shanghai China (which opened in May and runs through October), many of the exhibits don't share in the unbridled optimism that characterized expos of the 19th and 20th centuries. Rather than striding with abandon toward the technological marvels of the future, much of what's on display deals with the repercussions of 150 years of production and consumption, of which pollution, stress, isolation, and climate change are only a few. Even the expo's theme, "Better City, Better Life," suggests that we need to rethink just how we're living. ❑

Additional reporting by Raffaelo Pantucci

UNITED KINGDOM

SEEDS OF CHANGE

Buildings of the future will need to use energy sparingly. The United Kingdom pavilion boasts what's arguably the most stunning building on the fairground: the 20-meter-high Seed Cathedral. The structure was created out of 60 000 clear rods, each of which has a seed encased in its tip [see below]. During the day, the rods siphon daylight from outside to brighten the cathedral without artificial lighting. At night, efficient LEDs embedded in the rods make the structure glow.

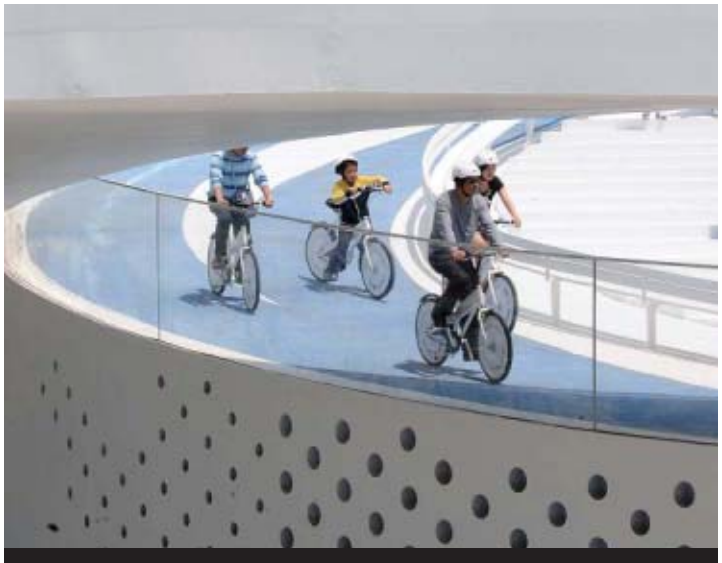
PHOTOS, CLOCKWISE FROM TOP: IMAGINECHINA (2); ALY SONG/REUTERS

SAUDI ARABIA

ARABIAN LIGHTS

Inside the US $164 million Saudi Arabia pavilion, a hallucinatory panorama of Muslim-themed lights and music flashes across an enormous Imax screen—said to be the world's largest—and has visitors waiting up to 9 hours in line for a peek.

PHOTO: XINHUA/LANDOV



DENMARK

FOOT POWER

Missing from this world's fair? Cars. Except for a few environmentally friendly offerings like a solar-powered Nissan Leaf, the transportation on offer at the exhibition is largely of the two- or three-wheeled variety. The city of the future, according to the expo, is built not around the combustion engine but rather human-powered transport, otherwise known as the bicycle. Of course, to make that utopian vision a reality, you need bike lanes. Denmark's white spiral pavilion highlights the infrastructure to make the shift from a car-centric culture to a bike- and pedestrian-friendly city.

PHOTO: WANG SONG/XINHUA/LANDOV

JAPAN CORPORATE LADDER

The most dangerous jobs in the city of the future will be handled by robots. At least that's the message of Japanese industrial equipment maker Muscle Corp., based in Osaka, which created three bubble-headed robots (the size of middle schoolers) that tirelessly scale the 20-meter-high scaffolding outside the Japanese Industry Pavilion. Aided by hook hands that fit onto the pipes of the scaffolding, they climb from 9 a.m. until midnight, with no breaks, as befits the robot workforce of the future.

PHOTO: ZHU ZHENG/XINHUA/LANDOV

CHINA ENDURING LEGACY

Artifacts of past world's fairs sometimes become national icons—think of the Eiffel Tower. China's own bid for posterity at the Shanghai Expo is the Crown of the East, a $220 million, 63-meter-high inverted ziggurat painted bright red. Whether the edifice has staying power remains to be seen, but other expo-related outlays should leave Shanghai better off. In the run-up to the exhibition, the Chinese government reportedly spent $55 billion to build a new performance space and a new airport terminal and to revamp its subway system, among other things. To make way for the expo, though, it displaced 18 000 families from their homes, according to Amnesty International. Just as this world's fair reflects an evolution in attitude from gee-whiz optimism to a more sober contemplation of what it means to be livable and eco-compatible, perhaps the next evolution should be to consider the implications of unchecked gentrification.

PHOTO: AFP/GETTY IMAGES

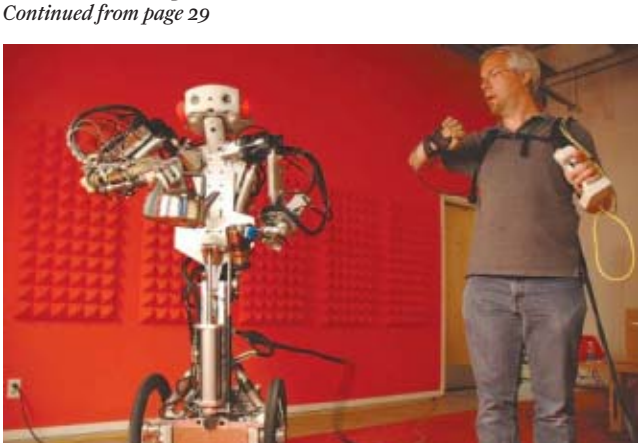
SPAIN SUPER-PREDATOR

The official party line on Miguelín, the Spanish pavilion's animated, 6.5-meter-high baby, is that it should "remind visitors that what we do to the Earth today has consequences for the children who will be here long after we're gone." But it's hard not to read a slightly more sinister message into a creature built by the special effects designers behind *Alien vs. Predator*. As the world becomes increasingly urbanized and cities evolve into megacities, planners will need to figure out how to prevent their metropolises from collapsing under the weight of their populations.

PHOTO: KYODO/LANDOV

When My Avatar Went to Work

Continued from page 29



TEA ANYONE? Anybots' founder and CEO Trevor Blackwell uses sensor gloves and a joystick to transmit his movements to Monty, a teleoperated humanoid robot with dexterous hands. PHOTO: ANDERS FRICK

OVERALL, I WAS IMPRESSED WITH THE QB. Driving it was incredibly easy, and the communication worked well. But I also see big challenges for this technology.

The first one is cost. Telepresence robots now come in various models of varying sophistication. But nobody quite knows yet how much companies are willing to shell out. The idea of offices populated by telepresence robots "sounds like a great science fiction story," says Dan Kara, CEO of Robotics Trends, a market research firm in Framingham, Mass. "But are companies willing to pay for these robots? What advantages do they have over conventional technologies?"

Telepresence robots will also have to compete with inexpensive PCs that have webcams and with mobile phones that offer videoconferencing capabilities, says Tandy Trower, a Microsoft veteran who led the company's robotics efforts and recently started his own robotics company. "A mobile telepresence robot can deliver a different experience, but there will be inevitable comparisons, especially in the corporate world," he says.

Another issue involves safety and reliability. One problem I had with my QB experiment was the spotty Wi-Fi coverage in our office (ironic given that IEEE—*ahem*—created the 802.11, or Wi-Fi, standard). Sometimes the video would freeze or become pixelated. Other times I'd get disconnected from the robot altogether, without even knowing whether the machine had stopped rolling.

Anybots insists that the robot, which weighs in at 16 kilograms, is safe around people. But still, what if someone else wrested away control of my QB and used it for mischief? Last year, researchers at the University of Washington reported that some teleoperated robots are indeed vulnerable to hacker attacks. The study focused on cheaper home robots like WowWee Group's Rovio and Erector's Spykee, but the problem may exist in the corporate sphere as well. Imagine a hacker gaining control of your robot and using it to insult your boss or escape the building.

My QB had other issues. It had to be rebooted quite a few times, a task that required manually pushing a button on its base. Having a human tend to the robot's needs seemed strange, to say the least. Is this how robots will begin to enslave humanity?

Finally, there are the social and psychological questions that telepresence robots raise. Will people *Continued on page 50*

When My Avatar Went to Work

Continued from page 48

accept robotic coworkers? And what about the person behind the robot: Can the operator get used to being a robot?

To answer that question, I decided to talk to someone with more telepresence mileage than I have. Dallas Goecker is an electrical engineer who lives in Seymour, Ind., and works at Willow Garage, a robotics start-up in Menlo Park, Calif. He and a colleague have built a telepresence robot called Texai, and for over a year now Goecker has used it to robocommute nearly every workday. Probably no one else in the world has logged as many robotic hours.

Goecker tells me he's gotten used to being a robot. It's much better than when he had only a phone and Skype for collaborating with colleagues. Like me, he especially appreciates being able to participate in casual conversations. "That's when a lot of design work happens," he says. For Goecker, inhabiting a robot has become so natural that he sometimes can't recall whether he did something—a discussion with a coworker, for example—in person or as a robot. "It can become one and the same," he says.

Willow has built 25 Texai units. The company won't say how much each one costs or what it plans to do with them, only that several companies are testing the robot. Google cofounder Sergey Brin reportedly appeared at a recent gala dinner as a Texai.

Given Goecker's experience and my own, I'm convinced that telepresence robots will become popular in many offices. I'm not saying that every worker should have one or that all companies should invest in them. But for companies with multiple offices and workers whose jobs involve lots of travel or teamwork, the robots make sense. And as the technology improves, such robots will make sense not only for office workers but for other workers, too.

Even now, several companies are testing a robot by Vgo Communications to allow their employees to observe live experiments taking place in distant locales. And doctors are interacting with patients in some 200 U.S. hospitals via telepresence robots built by InTouch Health. If this type of robot becomes cheaper, safer, and more reliable, it could be used to monitor the elderly or infirm in their own homes, even performing blood pressure measurements and other simple tests.

Some roboticists speculate that future telepresence robots will also revolutionize factory jobs. Imagine equipping such robots with strong arms and dexterous hands. Remote human workers would then be able to perform tasks that autonomous manipulators can't easily handle, like transporting materials in a warehouse or assembling circuit boards in an electronics plant.

"Manual labor could easily be done without leaving your home," Marvin Minsky wrote in his 1980 *Omni* essay, adding, "One region of the world could export the specialized skills it has. Anywhere."

If the visionaries are right, seeing the world through a robot's eyes and roaming around in an artificial body will become a familiar experience for many people. So don't be surprised if one day you're asked to vacate your office and start working from home: Your avatar may be on its way.

Now please excuse me—I think I may need a reboot. Phil? ❑

CAL POLY

Electrical Engineering Department, California Polytechnic State University, San Luis Obispo

Bert Forbes Endowed Professor of Computer Engineering

The Electrical Engineering Department, California Polytechnic State University, San Luis Obispo, California, invites applicants for a full-time, academic year tenure-track faculty position at the Assistant or Associate Professor rank, as the Forbes Endowed Professor of Computer Engineering. The nominal start date is September 2011. Rank and salary are commensurate with qualifications and experience. Prior industrial or research experience is preferred. Duties include teaching undergraduate and graduate computer and electrical engineering courses; research in an area of Electrical or Computer Engineering; and service to the department, university, and community. An earned doctorate in Electrical or Computer Engineering or Computer Science is required. Candidates must have a strong commitment to teaching excellence and laboratory-based instruction, and exhibit potential for professional recognition via research and publication. Demonstrated ability in written and oral use of the English language is required. Particular areas of interest include microprocessor embedded systems, digital system architecture and design, computer and digital standards, PC system design, software systems, robotics, autonomous systems, computer-based controls, sustainability in computing, RF and digital communications, computational issues in power grid management, and analog and digital electronics.

To apply, please complete online application at **WWW.CALPOLYJOBS.ORG** using Requisition #102119. Review of applications will begin January 1, 2011, although applications received after that date may be considered. Candidates should submit: (1) completed online application form; (2) current resume; (3) Ph.D. transcripts, (4) statement of goals and plans for teaching and research and (5) qualification summary and teaching preferences. Please see on-line posting for instructions where to mail documents that cannot be submitted on-line. Finalists will be asked to submit three letters of reference. For questions, please call (805) 756-2781 or email: **llwoods@calpoly.edu**.

Cal Poly's Electrical Engineering Department offers B.S. and M.S. degrees in Electrical Engineering. Also, the Electrical Engineering and Computer Science departments jointly offer a B.S. degree in Computer Engineering. Cal Poly emphasizes undergraduate education. Our "learn by doing" approach involves extensive lab work and projects in support of theoretical knowledge. Computing facilities are modern and extensive. U.S. News & World Report ranked the Electrical Engineering Department first among primarily undergraduate public programs in the nation. For further information about the department, see **www.ee.calpoly.edu**.

San Luis Obispo, a city of 43,000, is located 12 miles from the Pacific Ocean and midway between San Francisco and Los Angeles, on California's scenic central coast. University families live in San Luis Obispo and nearby communities both on the coast and inland. Excellent recreational facilities are available and the area has an outstanding climate. Cal Poly is strongly committed to achieving excellence through cultural diversity. The university actively encourages applications and nominations of all qualified individuals. EEO.

TEXAS STATE

MATERIALS SCIENCE, ENGINEERING, AND COMMERCIALIZATION PROGRAM

Texas State University-San Marcos is a member of The Texas State University System.

Texas State University-San Marcos

Faculty Search:

Materials Science, Engineering, and Commercialization

Posting #2011-14

Texas State University is aggressively developing a new interdisciplinary Materials Science, Engineering, and Commercialization Program based on collaborations among the Departments of Biology, Chemistry & Biochemistry, Engineering Technology, the Ingram School of Engineering and Physics. We invite applications for an open position to be immediately filled by an outstanding candidate with active and internationally recognized interdisciplinary research efforts in advanced materials for emerging technologies in biomaterials, biosensing, new epitaxial materials, nanocomposites and polymers, and energy harvesting. Other areas will be considered as well. Rank, tenure status and home department are negotiable based on qualifications. The successful applicant will establish a vigorous externally funded research program, supervise graduate students, collaborate with other faculty, and be committed to teaching at the undergraduate and graduate levels. We have received a State of Texas Emerging Technology Fund Research Superiority Acquisition Award that provides a highly competitive salary and start-up package. In accordance with the guidelines of this award, preference will be given to candidates from outside the state of Texas whose research efforts have a high likelihood of supporting technology transfer and commercialization.

Texas State is a doctoral-granting university located in the burgeoning Austin-San Antonio corridor, the largest campus in The Texas State University System, and among the largest in the state. Texas State's 30,000 students choose from 109 undergraduate and 88 master's and 8 doctoral programs offered by eight colleges. Additional information about Texas State and its nationally recognized academic programs is available at

http://www.txstate.edu

Qualifications: Applicants will hold an earned doctoral degree and possess a record of intellectual and academic accomplishments in the described areas that will qualify her or him for appointment at the appropriate level in the appropriate academic department. Other required qualifications include a strong record of funded research, and a strong record of scholastic achievement. Industrial or commercialization experience is highly desired.

Application: Review will begin immediately and continue until the position is filled. To ensure full consideration, submit the following as soon as possible– Faculty application (**http://facultyrecords.provost.txstate.edu/faculty-employment/application.html**) and accompanying materials which include: a letter of intent; vita; statements of the proposed research program, a potential commercialization strategy, and your teaching philosophy; and list of five references to: **etfmsec@txstate.edu**

Loyola Marymount University

Department of Electrical Engineering and Computer Science

The Department of Electrical Engineering and Computer Science at Loyola Marymount University (LMU) invites applications for an electrical or computer engineering tenuretrack position at the assistant professor level beginning fall 2011. A Ph.D. in electrical engineering or related field is required. The successful candidate will possess excellent teaching skills, the potential to develop undergraduate and graduate courses, the ability to develop a strong research program involving undergraduate and/or graduate students, and the ability to further the mission of the University.

The Department of Electrical Engineering and Computer Science offers Bachelors degrees in electrical engineering and computer science, and a Masters degree in electrical engineering. The department is housed in the Frank R. Seaver College of Science and Engineering with science, mathematics and other engineering departments. For additional details regarding the university, college and departments please visit our web site at

http://cse.lmu.edu

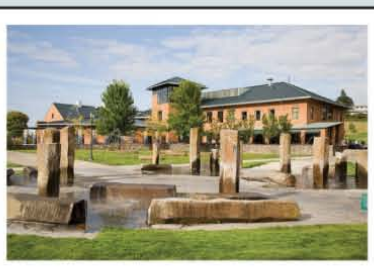
In addition to strong teaching skills and the ability to develop a vibrant research program at LMU, we are looking for individuals with a comprehensive vision, as well as the skills needed to integrate into a multi-disciplinary department. At the same time, we are committed to maintaining our outstanding reputation in undergraduate education, as well as to broadening our faculty diversity profile through the process.

Qualified applicants should submit a cover letter, a curriculum vitae including at least three references, and a statement addressing the applicant's ability to excel in teaching, to be productive in research and to contribute to the mission of the university. Kindly address correspondence to:

Electrical Engineering Faculty Search
Department of Electrical Engineering and
Computer Science
Loyola Marymount University
1 LMU Drive
Los Angeles, CA 90045-2659
eefacultysearch@lmu.edu

The committee will review applications beginning January 31, 2011, and will continue until the position is filled.

Loyola Marymount, a comprehensive university in the mainstream of American Catholic Higher education, seeks professionally outstanding applicants who value its mission and share its commitment to academic excellence, the education of the whole person, and the building of a just society. LMU is an equal opportunity institution actively working to promote an intercultural learning community. Women and minorities are encouraged to apply. (visit www.lmu.edu for more information.)



Washington State University Vancouver

ELECTRICAL ENGINEERING FACULTY— Washington State University Vancouver invites applications for its new electrical engineering program. Candidates are sought with expertise in optical devices, wireless communications, advanced device design, integrated circuit testing, power systems or nano-scale device design. There are **three positions** available. The successful candidates are expected to initiate funded research; establish strong regional industrial collaborations; teach; and contribute to the development of the new program. The positions begin 8/16/2011 and are **tenure-track at assistant or associate professor rank**.

WSU Vancouver serves about 3000 graduate and undergraduate students and is **fifteen miles north of Portland, Oregon**. The School of Engineering and Computer Science (ENCS) offers BS and MS degrees in mechanical engineering and computer science. The new BS-EE program started in 2008. **New building is under construction** for the program. The rapidly growing ENCS **equally values both research and teaching**. WSU is Washington's land grant university with faculty and programs on four campuses. For more information: **http://www.vancouver.wsu.edu/encs**.

QUALIFICATIONS: Ph.D. in Electrical Engineering, established teaching and research record commensurate with the rank. Preference will be given to candidates with knowledge of semiconductor device design; relevant industrial background; demonstrated ability to initiate collaborative research; and commitment to working with diverse student and community populations. WSU Vancouver is committed to building a culturally diverse educational environment.

APPLICATIONS must include: (1) cover letter with a clear description of experience relevant to the position; (2) vitae including a list of references; and (3) a **maximum three-page** summary statement of research, teaching and relevant experience. This statement must describe how the candidate's research activity might lead to collaborative research programs with the regional industry and research labs. Application deadline is December 3, 2010. All materials should be mailed to EE Search Committee, School of ENCS - VELS 130, Washington State University, 14204 NE Salmon Creek Avenue, Vancouver, WA 98686-9600. WSU is committed to excellence through diversity, has faculty friendly policies including a partner accommodation program, and a NSF ADVANCE Institutional Transformation grant (see **http://www.excelinse.wsu.edu/**). WSU employs only US citizens and lawfully authorized non-citizens. WSU is an EO/AA educator and employer.

UNIVERSITY SPOTLIGHT

中国科学技术大学
University of Science and Technology of China

Tenure Track Faculty Positions

School of Information Science & Technology

The University of Science and Technology of China (USTC), founded in 1958 as the only university under the Chinese Academy of Sciences (CAS), offers advanced science and technology programs, unique management studies, and well-tailored disciplines in humanities. Many USTC alumni have become world leaders in academia and industry. For more information about USTC, please go to http://en.ustc.edu.cn/.

School of Information Science & Technology (SIST) of USTC (http://sist.ustc.edu.cn/en/) is experiencing an exciting period of growth and is seeking outstanding candidates for faculty positions at Professor and Associate Professor levels. As a broad area faculty search, positions are available in all areas of information science and technology, including but not limited to

- Communication & Information Systems
- Signal, Speech, Image, & Video Processing
- Information Theory
- Information Security
- Computer Networks
- Control Theory & Systems
- Pattern Recognition
- System Biology
- Robotics
- Electromagnetic & Microwave Technologies
- Semiconductor Device Characterization & Modeling
- RF & Millimeter Wave Circuits & Systems
- Analog & Mixed Signal Circuits & Systems
- CMOS Wireless Transceivers
- CMOS Sensors and Circuitry
- Key IC Components, such as ADC, DDS, PLL, PA etc.
- Innovative On-Chip Antenna
- Minimization of Medical Devices
- Biomedical Imaging & Processing
- Biomedical Instrumentation & Devices
- Neural Engineering
- Rehabilitation Engineering
- Distributed Diagnosis and Home Healthcare
- Cryo-biomedical Engineering
- Bio-sensors
- Artificial Human Organs

Applicants must have a Ph.D. in a relevant field of research with good communication skills and a track record or demonstrated potential for quality teaching and research.

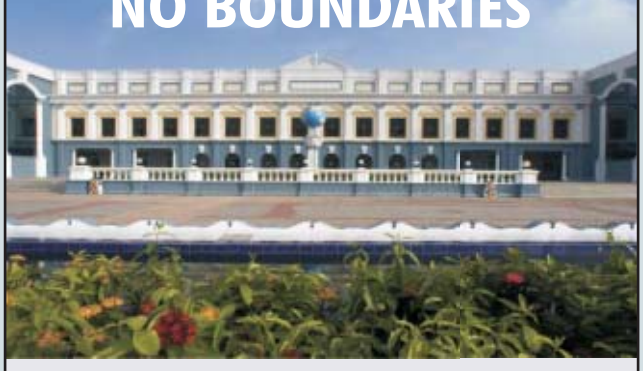
Responsibilities of these positions include teaching undergraduate and graduate courses, developing and sustaining externally funded research programs, graduate student supervision, and professional/institutional services.

For a successful applicant, USTC offers a competitive compensation package, according to the level of appointment and the credential of the applicant.

Interested applicants are invited to send a cover letter, a detailed curriculum vitae including a list of publications, statement of teaching, statement of research as well as the names, addresses (regular mail and email), and phone numbers of three references to:

Ms. Ashley Fan
School of Information Science and Technology
University of Science of Technology of China (West Campus)
433 Huangshan Road
Hefei, Anhui, People's Republic of China
Post Code: 230027
Email: fansh@ustc.edu.cn

QUALITY EDUCATION KNOWS NO BOUNDARIES



SRM University is a premier private University in India offering Undergraduate, Graduate and Doctoral programs in Engineering, Medicine, Dentistry, Para-Medical Sciences, Arts & Sciences and Humanities. The current student population is approximately 24000 apart from 3000 administrative, faculty and support personnel. Further information about the SRM University is available at www.srmuniv.ac.in.

The vision of SRM University is to be a global campus attracting scholars from all over the world. The University is actively engaged in transitioning from a regional / national institution to an internationally recognized University, expanding on the current partnerships it has developed with many prestigious Universities in the USA, UK, and Canada. As a part of its globalization efforts, the university is in search of Deans for various schools and faculty members at all levels. We invite applications from qualified professionals from international academia with an exceptional record in teaching and research. NRI academicians from other countries who wish to work / migrate to India are also welcome to submit their applications.

Requirements for the Position of Dean: The successful applicant must possess a doctoral degree and be qualified for appointment to the faculty as a tenured full professor with a strong record of research, teaching and service. In addition, the successful candidate shall demonstrate: Record of effective post-secondary academic and administrative leadership in creating an environment conducive to excellent teaching, research and scholarly activity & service, student achievement and satisfaction including preparation of teachers, administrators, counselors, and other professionals; Record of successful interaction with faculty, staff, and students and a commitment to shared governance; Record of successful interaction, collaboration, and partnerships with local, regional and state-wide school districts and officials and/or other community organizations.

Requirements for the Position of Faculty Member: The successful applicants should have a terminal degree (Ph.D) in their fields of study with demonstrated qualities of intellectual depth, professional integrity, excellent communication skills to deal with a diverse group of students. In addition, the successful candidates must have a record of publications in professional journals, commitment to teaching both undergraduate and graduate courses, dedication to students' academic and professional achievement.

Interested candidates are invited to submit the following data electronically to the e-mail id registrar@srmuniv.ac.in : A letter of interest, a current Curriculum Vitae, a brief statement outlining the candidate's contributions to the advancement of SRM University. Remuneration will be consistent with international standards.

SRM UNIVERSITY
(Under section 3 of UGC Act 1956)

Department Head

Department of Computer Science and Engineering

TEXAS A&M UNIVERSITY

The Dwight Look College of Engineering at Texas A&M University invites nominations and applications for the position of Head of the Department of Computer Science and Engineering. Texas A&M, a land-grant, sea-grant, and space-grant institution, is one of the six largest universities in the United States and has over 48,000 students. Today, the Dwight Look College of Engineering is one of the largest and best endowed in the nation, and it ranks among the top institutions in every significant national poll, including #8 for graduate programs and #9 for undergraduate programs in the recent US News and World report ranking of public institutions. It has long enjoyed national leadership status in engineering education, and currently has over 10,000 engineering students in twelve departments. Approximately 25 percent of the engineering students are graduate students.

The Department of Computer Science and Engineering has recently gone through an expansion with the hiring of 21 faculty members in the past eight years. It now has 38 tenured and tenure-track faculty members and four full-time lecturers. The Department currently has one National Academy of Engineering member, one Association for the Advancement of Science Fellow, seven IEEE Fellows, two ACM Fellows, and one ACM Distinguished Scientist; 40 percent of the faculty are holders of NSF CAREER/NYI/PYI awards. The faculty holds over 60 important and influential professional positions, including editorships for scientific journals and general chairs of technical conferences. The faculty is also well-recognized for contributions to their fields, with research known throughout the international academic community and global industry alike. The Department's annual research budget for 2009 was $10,000,000. The Department offers B.S., Master's, and Ph.D. degrees in computer science and, jointly with the Department of Electrical and Computer Engineering, in computer engineering, to roughly 350 graduate and 600 undergraduate students.

In recent years, the Department has built a strong national reputation based on the quality of its faculty and programs; its graduate computer engineering program was ranked #13 and its graduate computer science #27 in the recent US News and World report ranking of public institutions. More information is available at **http://www.cse.tamu.edu**.

In the next few years, the Department is expected to add faculty positions at both the junior and senior level. The Department is playing an active role in many campus-wide and system-wide initiatives, including in half of the eight multidisciplinary research directions identified in the recently completed University Academic Master Plan and in the newly established Energy Engineering Institute.

We are looking for an innovative thinker with a strategic vision for guiding the Department to a higher level of excellence who can communicate this vision to a constituency that includes academia, government, industry, and alumni. Candidates should possess proven leadership and administrative skills, and an established reputation as a scholar consistent with an appointment to the rank of Professor of Computer Science and Engineering with tenure.

Letters of application should include
(1) a full curriculum vitae,
(2) a two-page statement summarizing the candidate's vision and goals for the Department and leadership
philosophy, and
(3) the names and addresses of at least five references.
Applications will be accepted until the position is filled; screening will begin immediately. Nominations or applications should be sent to **csechair@tamu.edu**.

Texas A&M University is an Equal Opportunity / Affirmative Action Employer. Women and minorities are encouraged to apply. Employer paid advertisement.

BAYLOR UNIVERSITY

The Electrical and Computer Engineering Department of

Baylor University

seeks faculty applicants in all areas of electrical and computer engineering, with preference in the areas of cyber-physical systems (i.e., embedded systems, computer/network security, sensor networks) as well as power and energy. The department anticipates filling three positions in August 2010 and approximately seven more over the next five years, and invites applicants at any rank. All applicants must have an earned doctorate and a record of achievement in research and teaching; applicants at the ranks of associate or full professor must also demonstrate a record of sustained research funding. The ECE department offers B.S., M.S., M.E. and Ph.D. degrees and is poised for aggressive expansion of its faculty and facilities, including access to the Baylor Research and Innovation Collaborative (BRIC), a research park minutes from the main campus.

Chartered in 1845 by the Republic of Texas, Baylor University is the oldest university in Texas. Baylor has an enrollment of approximately 15,000 students and is a member of the Big XII Conference. Baylor's mission is to educate men and women for worldwide leadership and service by integrating academic excellence and Christian commitment within a caring community. The department seeks to hire faculty with an active Christian faith; applicants are encouraged to read about Baylor's vision for the integration of faith and learning at **www.baylor.edu/about/vision**.

Application reviews are ongoing and will continue until available positions are filled. Applications must include: 1) a letter of interest that identifies the applicant's anticipated rank, 2) a complete CV, 3) a statement of teaching and research interests, 4) the names and contact information for at least three professional references. Additional information is available at **www.ecs.baylor.edu**. Send materials to Dr. Robert Marks, Baylor University, One Bear Place #97356, Waco, TX 76798-7356 or by email to **Robert_Marks@baylor.edu**.

Baylor is a Baptist University affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Employment Opportunity employer, Baylor encourages minorities, women, veterans, and persons with disabilities to apply.

UNIVERSITY SPOTLIGHT

Arizona State University

Engineering Faculty opening in
Human Activity Capture and Analysis

The School of Arts, Media and Engineering (AME) and the School of Electrical, Computer and Energy Engineering (ECEE) at Arizona State University are seeking a jointly appointed faculty member. Of particular interest is the area of *Human Activity Capture and Analysis* with emphasis on health, education or cultural applications. Candidates are sought at the assistant, associate or full professor level.

The School of Arts, Media and Engineering (AME – http://ame.asu.edu), at the Herberger Institute for Design and the Arts and the Ira Fulton Schools of Engineering, is a leading transdisciplinary program in media arts and sciences. It offers PhD, Masters and undergraduate degrees in new media in collaboration with 12 partner units spanning arts, design, sciences and engineering. Significant federal, private foundation and industry support along with clinical, education and cultural partnerships contribute to the development and deployment of innovative media systems. The School of Electrical, Computer and Energy Engineering leads academic programs with more than 50 faculty members, 500 undergraduates and 700 graduate students. The school's programs include extramural research funding of more $20M and BSE, MSE, MS and Ph.D. degree programs. Both Schools are strongly committed to interdisciplinary research and education.

Application deadline: November 1, 2010. For complete position details and application process, please visit: http://ame.asu.edu/about/employment.php

Department Head
Department of Electrical Engineering & Computer Science

South Dakota State University
Brookings, SD

South Dakota State University invites applications and nominations for the position of Department Head of Electrical Engineering & Computer Science. SDSU, the state's land-grant and largest university, is a Carnegie RU/H (high research activity) institution with 12,400 students. The university is seeking an energetic academic leader with strategic vision, outstanding academic credentials and successful administrative experience. The Department Head, who reports to the Dean of Engineering, holds a 12-month position and oversees all of the department's administrative functions including academic, budget, facilities, research and outreach. In FY 2010 the department had 25 base-funded faculty and 390 students enrolled in undergraduate and graduate programs in electrical engineering, computer science and software engineering. The department is enjoying strong growth in enrollments and funded research, strong ties to industry and a beautiful new $12 million-72,000 sq. ft. building.

The successful applicant must have an earned Ph.D. and distinguished record of performance consistent with appointment as a tenured full professor in a discipline appropriate to the department. He/she must also have a record of innovative and strategic leadership that would apply to a progressive and growing academic environment and a record of effective university administrative experience.

For detailed electronic application instructions, a full description of the position and information on the department, university and community, please visit

http://www.sdstate.edu/eecs/

For the most complete consideration, applications should be received by Nov. 1, 2010. For questions on the electronic employment process, contact SDSU Human Resources at (605) 688-4128. *South Dakota State University is an AA/EEO employer.*

University of Delaware

One of the oldest institutions of higher education in this country, the University of Delaware today combines tradition and innovation, offering students a rich heritage along with the latest in instructional and research technology. The University of Delaware is a Land-Grant, Sea-Grant and Space-Grant institution with its main campus in Newark, DE, located halfway between Washington, DC and New York City. Please visit our website at **www.udel.edu**.

Faculty Positions in Electrical and Computer Engineering

The Department of Electrical and Computer Engineering (ECE) at the University of Delaware (UD) invites nominations and applications for tenure-track faculty positions at the Assistant, Associate, and Full Professor ranks.

The ECE Department invites candidates that complement the department's traditional strengths in (1) Computer Engineering, (3) Signal Processing, Communications & Controls, and (3) Nanoelectronics, Electromagnetics, and Photonics. A particular emphasis is placed on candidates aligned with UD's College of Engineering wide cluster searches in: (1) Energy, (2) Information Technologies, (3) Security, and (4) Biomedical Engineering. Exceptional cases outside of these traditional strengths and focused areas may also be considered.

Successful applicants will share our vision to grow the department into a leader in research and educational programs. ECE initiatives are supported by over 40,000 square feet of departmental facilities, including a state-of-the art 7,000 sq ft clean room for nano-fabrication, and fueled with over $10M/year in research expenditures. Applicants should hold a Ph.D. in electrical and/or computer engineering, or closely related field in mathematics, biomedical, computer or physical sciences. Successful candidates are expected to have demonstrated excellence in innovative research and show the potential for high-quality teaching and mentoring. The University of Delaware offers very competitive salary and start-up packages, and has a generous benefit package. The application reviews start November 1st. The search will continue until the positions are filled; however, early application is strongly encouraged.

Applicants should submit a curriculum vitae, a statement of research and teaching interests, and a list of at least four references to www.engr.udel.edu/facultysearch. Questions can be directed to f-search@udel.edu or ECE Faculty Search Committee, 140 Evans Hall, University of Delaware, Newark, DE 19716.

The UNIVERSITY OF DELAWARE is an Equal Opportunity Employer which encourages applications from Minority Group Members and Women.

TCU

Tenure Track Faculty Position. The Department of Engineering at Texas Christian University invites applications for a tenure track faculty position at the Assistant or Associate Professor level. The successful candidate should have earned a Doctorate in Engineering or a closely related field. He/she will be expected to establish an active undergraduate research program focused on either energy or bioengineering, and develop ties with the local industry. In addition, the successful candidate must have broad interests in engineering and be willing to teach undergraduate courses in either electrical or mechanical engineering fundamentals. Engineering faculty are encouraged to participate in collaborative efforts involving faculty in the natural sciences and mathematics, within the College of Science and Engineering.

TCU has a small, undergraduate, ABET accredited, interdisciplinary Engineering program with 200 students and 10 full-time staff offering a B.S. degree in engineering with electrical and mechanical areas of emphasis. The university is located in one of the premier centers of high technology activity in the US. Applications will be reviewed as received and the process will continue until the position is filled. Applicants should submit a letter expressing their interest and special qualifications for the position, a curriculum vita, and complete contact information of at least three references to: **Walton E. Williamson, Jr., Chair of the Search Committee, Department of Engineering, TCU Box 298640, Fort Worth, TX 76129.**

TCU is an equal opportunity, affirmative action employer. Qualified women and minorities are encouraged to apply.

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Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

PROFESSORSHIP IN ELECTRICAL & ELECTRONIC ENGINEERING

This is an opportunity to contribute to the development of a vibrant Department, which has very active research programmes, including a number of major research projects funded by Science Foundation Ireland, and strong links with the internationally renowned Tyndall National Institute. The Department looks forward to developing close links with the International Energy Research Centre, which the Irish Government is about to establish in Cork.

The successful candidate will have a doctorate in Electrical/Electronic Engineering, a scholarly reputation of international standing in Electrical/Electronic Engineering, a significant sustained record of internationally published research, and a proven track record of seeking and obtaining substantial funding for research.

PROFESSORSHIP IN ENERGY ENGINEERING

This is an opportunity to contribute to a sustainable future, addressing the challenges of energy and the environment and building on the School's extensive research activities across a range of energy themes, encompassing ocean, wind, biomass and solar energy, electric vehicles, energy policy, energy efficiency in buildings and industry. These research programmes are supported by substantial funding from a range of sources, such as Science Foundation Ireland, the Sustainable Energy Authority of Ireland, Enterprise Ireland, the EU and industry sponsors. The School has strong academic links to the Tyndall National Institute and UCC's Environmental Research Institute. The School looks forward to developing close links with the International Energy Research Centre, which the Irish Government is about to establish in Cork.

The successful candidate will have a doctorate in Engineering, a scholarly reputation of international standing in Energy Engineering, in one or more energy technologies and/or in the area of energy systems, a significant record of sustained internationally published research, and a proven track record of seeking and obtaining substantial funding for research.

PROFESSORSHIP IN CIVIL & ENVIRONMENTAL ENGINEERING

This is an opportunity to contribute to a sustainable future, addressing the challenges of energy and the environment and building on the Department's very active research programmes, including a number of major research projects funded by Science Foundation Ireland, the Sustainable Energy Authority of Ireland, the Environmental Protection Agency and the EU. The Department works closely with UCC's Environmental Research Institute and with the Tyndall National Institute. It looks forward to developing close links with the International Energy Research Centre, which the Irish Government is about to establish in Cork.

The successful candidate will have a doctorate in Civil/Environmental Engineering, a scholarly reputation of international standing in Civil/Environmental Engineering, a significant record of sustained internationally published research, and a proven track record of seeking and obtaining substantial funding for research.

The School of Engineering at UCC includes Civil & Environmental Engineering, Electrical, Electronic & Microelectronic Engineering, and Process & Chemical Engineering. The School attracts outstanding undergraduate students to the B.E. degree programmes and has a proud tradition of educating graduate and postgraduate engineers who occupy leading positions in the profession, nationally and internationally.

For further information on these posts please see www.ucc.ie/hr/vacancies/

For informal discussion, contact Dr Michael Creed, Head of the School of Engineering: Email: m.creed@ucc.ie/
Tel +353 21 490 2670 Website: http://www.ucc.ie/en/engfac/

Salary scale (new entrants): €113,604 - €145,953

Closing date: 12 noon on 1st October 2010

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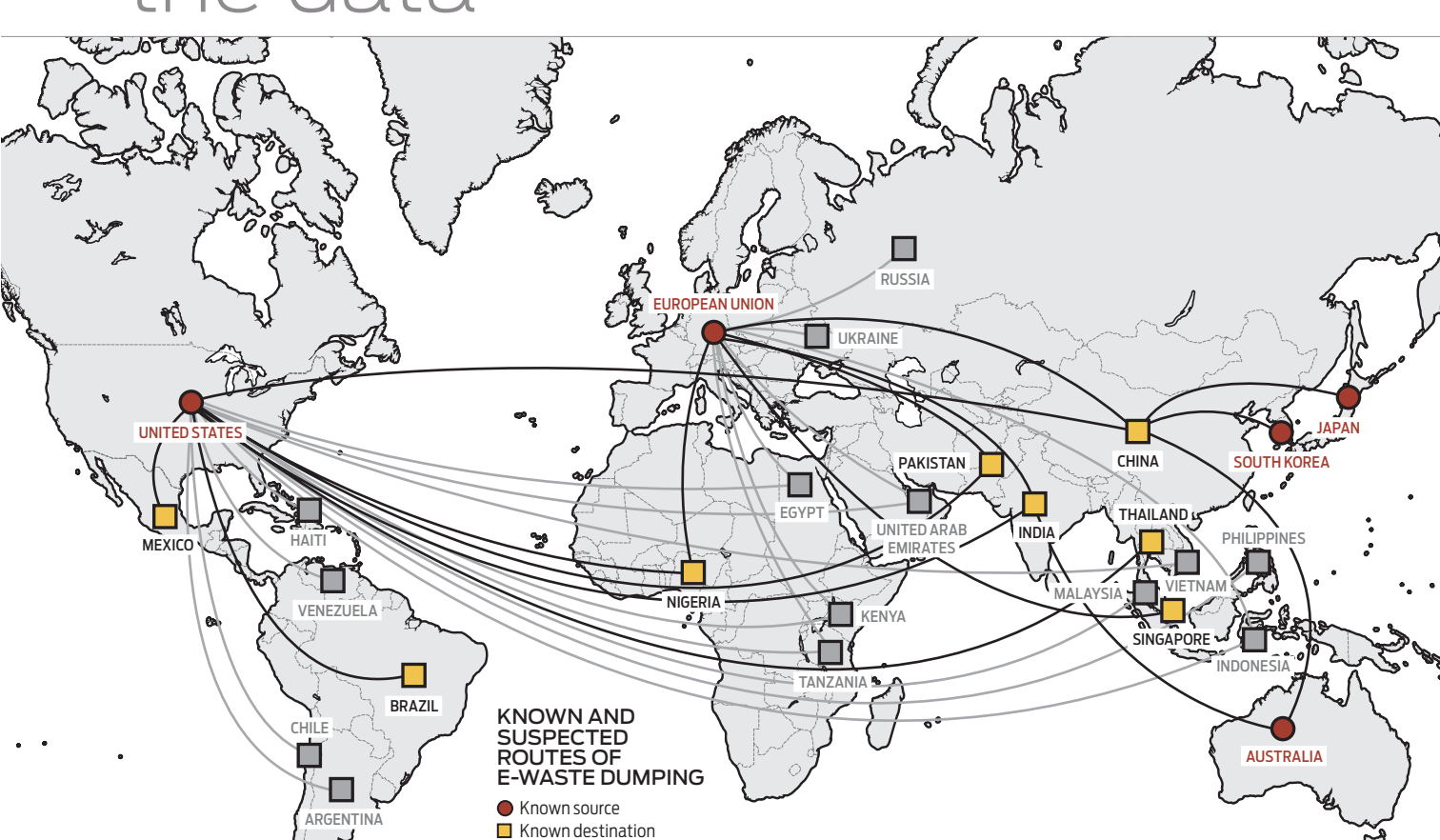

What an E-Waste

CONSUMER ELECTRONICS, critics charge, are designed for the dump. The latest gizmo enjoys a year or two of cutting-edge relevance and another two to five collecting dust. Then we throw it away. In the United States alone, 130 000 computers and more than 300 000 cellphones are trashed each day.

The discarded stuff typically goes to landfills (often illegally), where lead, mercury, arsenic, cadmium, brominated flame retardants, and other toxic and carcinogenic materials leach out from it. And donating obsolete products to the developing world is sometimes even worse.

As a new Web film, *The Story of Electronics*, graphically illustrates, all too often your supposedly "e-cycled" iPod or cathode ray tube ends up on a slow boat to China, India, South America, Africa, or Southeast Asia. There they come to black market scrap heaps where low-wage workers use alarmingly hazardous techniques—open coal fires, medieval acid baths—to extract a pittance of precious metals from circuit boards and soldered wires. In the process the workers, sometimes including children, release Superfund-level quantities of toxic waste into the environment.

The Electronics TakeBack Coalition keeps tabs on aboveboard e-cycling programs with some retailers (such as Staples and Best Buy) and in 23 U.S. states, while private organizations like Call2Recycle and e-Stewards help consumers find ethical private e-cyclers. Nevertheless, tons—literally—of improperly e-cycled goods make their way through organized-crime and other shady global networks.

—Mark Anderson

NIGERIA

WASTE TOURISM: In a 2009 report, Interpol described a disturbing new trend: brokers from West Africa and Asia traveling to developed world "e-cycling" centers to bid on e-waste for nefarious extract-and-pollute dumps in their home countries. According to Interpol, waste tourism is a small but growing US $3 million business.

CHINA

TOXIC TOWN: Thanks to its massive black market e-waste dump, Guiyu, China, has the dubious distinction of being perhaps the most polluted town in the world. Local water has long been undrinkable, while the rates of miscarriage and premature birth are much higher there than in a control group from a neighboring town. At least 70 percent of the town's children have dangerous levels of lead in their blood. On a "hazard quotient" scale of 1 (somewhat toxic) to 10 (very toxic), Guiyu scores 50.2.

INDONESIA/UNITED STATES

RETURN TO SENDER: In March, the environmental watchdog organization Basel Action Network, in Seattle, alerted authorities to nine Indonesian shipping containers full of old CRTs that it says a Massachusetts e-cycler was sending to third-world dumping grounds. By one estimate, 80 percent of U.S. e-waste is disposed of unsafely on American shores or sent overseas into the e-waste black market.

UNITED STATES

E-STING: In 2008, the U.S. Government Accountability Office (GAO) posed as a company in Hong Kong offering to buy from U.S. e-cyclers—as real-world e-waste brokers do—and found companies from California, Colorado, Illinois, New Jersey, and Washington lining up to ship their "green" e-waste into the global black market. Of the 43 e-cyclers tracked by the GAO, 42 kept e-waste shipments "below the radar."

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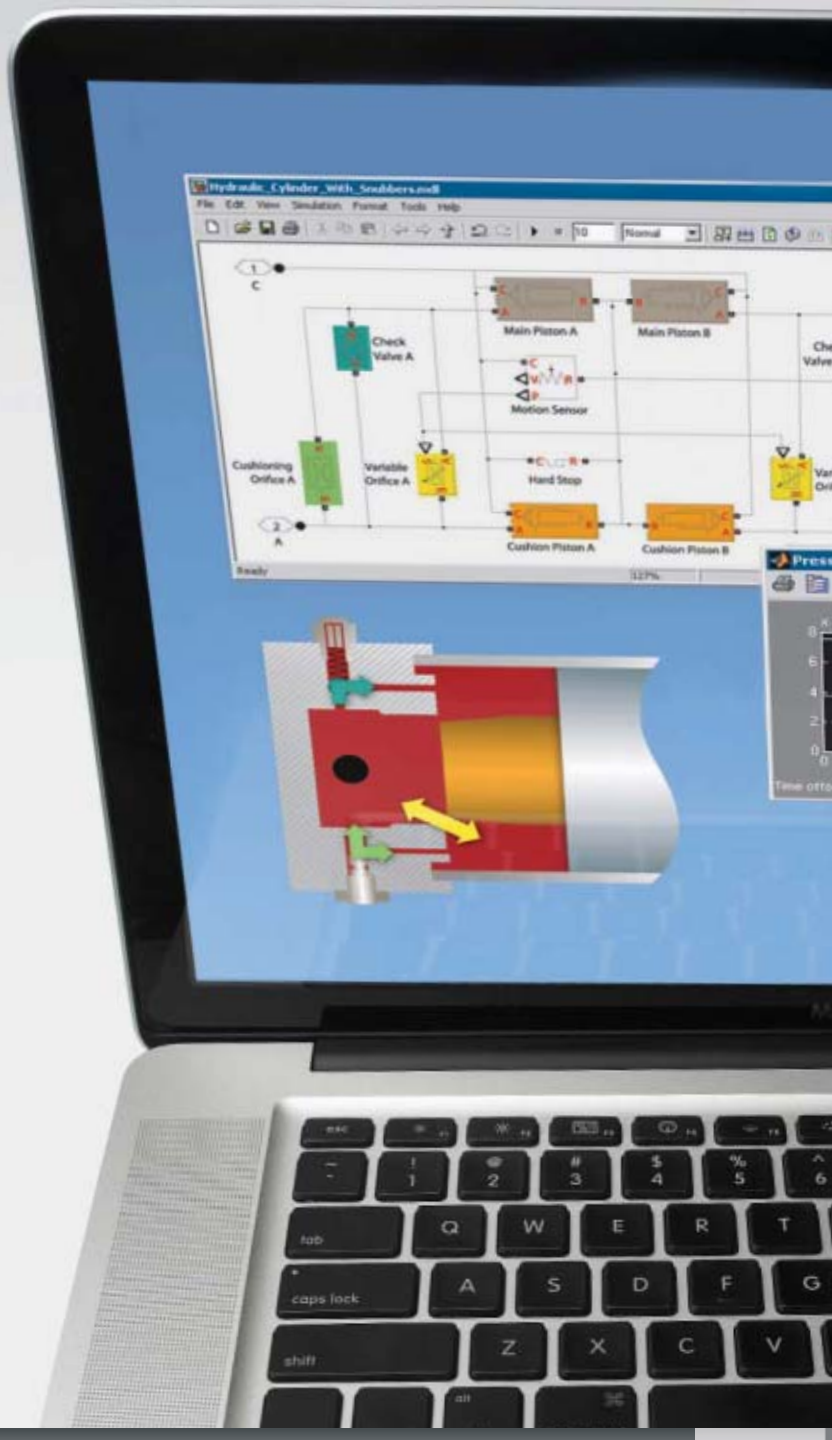

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