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THE MAGAZINE OF TECHNOLOGY INSIDERS

07.08

MACHINIMA'S MOVIE MOGULS

WITHOUT ACTORS, CAMERAS, SETS, OR PROPS, A NEW GENERATION OF GEEKS IS HACKING ITS WAY INTO HOLLYWOOD

IEEE

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CREATURES AND CREATORS: Kiva's founders and their robotic herd; *The Pencil*, one of our 10 favorite tech books; a character from the video game *Halo 3* is now a cinematic star.

COVER IMAGE: PHOTO: MATTHEW MAHON; DIGITAL ILLUSTRATION: SANDBOX STUDIO

THIS PAGE: CLOCKWISE FROM LEFT: JOSHUA DALSIMER; TIMOTHY ARCHIBALD; ROOSTER TEETH

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Forget cameras, actors, and elaborate sets: a new generation of filmmakers relies only on bandwidth and a video game.
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At Kiva's robotic warehouse, machines do all the heavy lifting.
By Erico Guizzo

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By Steven Levy

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LEFT: HARSHA PRAHLAD/ SRI INTERNATIONAL; RIGHT: JASON REEKIE/ ISTOCKPHOTO

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BOTS SCALE NEW HEIGHTS

Engineers are making headway in a new challenge for robots: climbing vertical surfaces. Wall-climbing robots could aid search-and-rescue operations, secretly spy for hours, and inspect aircraft and buildings. The 2008 IEEE International Conference on Robotics and Automation marked the debut of a tank-type robot that uses electrostatic adhesion. Others are making bots inspired by the dry adhesive on a gecko's feet. In this month's featured podcast, *IEEE Spectrum*'s Prachi Patel-Predd reports on where wall-climbing robots are going.

ONLINE FEATURES:

STICKY BUSINESS: Scientists are looking for ways to manage the Casimir effect, the quantum-mechanical phenomenon that makes nanometer-scale MEMS components stick together.

SLIDE SHOW—MOON BUGGIES: Watch engineers test out lunar rovers at Moses Lake.

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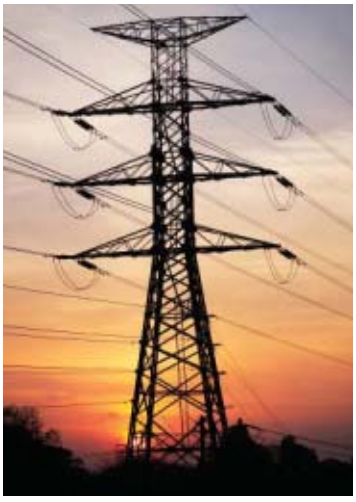

POWER SOCIETY GETS NEW NAME

IEEE's oldest society has a new name. The IEEE Power Engineering Society is now the IEEE Power & Energy Society. The name change reflects the inclusion of emerging technologies.

HEART HACKERS

If you have an implanted heart defibrillator, beware. There's a risk that it may be vulnerable to hacking. Read about recent research, presented at the IEEE Symposium on Security and Privacy, which shows some of these devices that can be hacked to release sensitive patient information.

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DAMIEN DONCK

back story

He's Got A Little List

IN MARCH, while working for his erstwhile employer, *Newsweek*, as senior editor for technology, Steven Levy took home the Apple MacBook Air to review and left it on a pile of papers. He hypothesizes that his wife didn't notice the thing and therefore threw it out, along with the entire pile (a hypothesis his wife disputes). What an illustration of the Air's famously superthin profile—and what a story. Of course, Levy pounced on it himself.

Erstwhile? No, no, it's not what you're thinking. Losing that loaner didn't lead to a layoff. Levy had been weighing a move for some time, and when *Newsweek* foolishly offered fat buyouts to its entire staff, he pounced on that opportunity too. Now he's at the tech mag *Wired*.

It's good we got to him just when we did, because *Wired*'s a bit of a competitor of ours, although the folks over there would prefer to reverse the syntax. But it certainly would have been hard for Levy to resist our invitation to write on a subject even closer to his heart than technology: technology books. In this issue he reviews his 10 favorite nonfiction titles and throws in three novels, just for fun.

Levy's written five tech books himself, as well as one on true crime. He began in 1984 with *Hackers: Heroes of the Computer Revolution*, now in an updated edition (Penguin, 2001). This was the book that acquainted the world with the notion that do-it-yourself software design could be a force for good as well as evil.

His most recent book, *The Perfect Thing: How the iPod Shuffles Commerce, Culture, and Coolness* (Simon & Schuster, 2006), reinforces Levy's reputation as one of the savviest, most plugged-in, and most objective connoisseurs and critics of all things Apple. The criticism part has won both the respect and the ire of Steve Jobs, who once called Levy's home at 11:00 p.m. and launched into a dressing-down—only to be informed that he was speaking not to Levy but to his son. "Well, you sure sound like him," growled Jobs, before slamming down the phone.

So which book has most inspired Levy? "My inspiration wasn't the best technology books per se but the best nonfiction books, period," he says. "[Robert] Caro's books on Robert Moses and Lyndon Johnson, Tom Wolfe's books. Richard Rhodes's *The Making of the Atomic Bomb* is simply great, but I hadn't read it at the time I began writing books." ❑

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. 45, no. 7 (INT), July 2008, p. 7, or in *IEEE Spectrum*, Vol. 45, no. 7 (NA), July 2008, p. 11.

contributors

TIMOTHY ARCHIBALD, based in San Francisco, created the photos for "10 Great Tech Books" [p. 36] with stylist Shannon Amos. The two have collaborated often, several times for *IEEE Spectrum*. Archibald is the author of the book *Sex Machines: Photographs and Interviews*.

SHANNON AMOS, prop stylist, set builder, and prop fabricator, found the perfect setting for the tech books shoot [p. 36]: a home built by real estate developer Joseph Eichler, whose thousands of houses, many in Silicon Valley, epitomize the California modern style. The Northern California site Amos picked had "the best of everything," she says.

DAVID KUSHNER, a *Spectrum* contributing editor, is the author of *Masters of Doom* (Random House, 2003) and *Jonny Magic and the Card Shark Kids* (Random House, 2005). While reporting his article "Machinima's Movie Moguls" [p. 30], he visited the offices of Rooster Teeth Productions, in Austin, Texas, to watch the team in action. The director even let Kushner control one of the onscreen animated characters; sadly, he got blown up.

MATTHEW MAHON shot the cover and the machinima feature [p. 30] photos in the landmark Paramount Theatre, in Austin, Texas. The 1915 building, originally a vaudeville house, is the work of architect John Eberson, who designed numerous movie palaces throughout the United States in the first half of the 20th century.

SCOTT OLDS and his colleagues at Sandbox Studio, in Sterling Heights, Mich., specialize in computer graphics illustrations for such clients as GM and Ford. Departing from automotive imagery for this month's cover and the opening image of "Machinima's Movie Moguls" [p. 30] "stretched our brains," says Olds. The artists made drawings in pencil, then scanned them into the computer alongside photos of the real people. Using Photoshop, they added color and retouched the backgrounds, giving the final product a dramatic finish.

SHERRY SONTAG reviewed Amazon's Kindle and two other e-book readers for this issue [p. 21]. Sontag is coauthor of the best seller *Blind Man's Bluff: The Untold Story of American Submarine Espionage* (Harper Perennial, 1998). She lives and works in New York City.

ROGER ZIMMERMAN reviewed the memoir of renowned acoustics expert Leo Beranek [p. 20]. Zimmerman, an occasional trombonist, works on automatic speech recognition and natural language processing for eScription, of Needham, Mass. He's also an avid amateur brewer: the last beer he helped make had a luscious hoppy bitterness.

CLOCKWISE FROM TOP LEFT: MARK RICHARDS, SANDBOX STUDIO, CHE GRAHAM, DEBRA LAVINE, MATTHEW MAHON, BETH KELLY, SHANNON AMOS

"Man is the only 150-pound nonlinear servomechanism that can be wholly reproduced by unskilled labor" —*Ashley Montagu*

spectral lines

Books in A Networked Age

As a fledgling editor, I was very lucky to work with the celebrated author and anthropologist Ashley Montagu. A prolific writer—he wrote more than 60 books and countless essays and reviews—he was also a prodigious collector of books. I loved books too, and as one of his many editors I always found it great fun to visit him at home in Princeton, N.J., to work on a piece. The house was a lovely garden-surrounded rabbit warren with books simply everywhere, the stairs, the cupboards, the tabletops. I'd roam around looking at his old books, new books, the books he was reviewing, the books he was using for research. And whenever I came across one that I had in my own much more modest library I felt a little secret thrill—great minds thinking alike!

Now it's possible to poke through other people's libraries and compare them with your own by visiting them online. These so-called virtual bookshelves look like library stacks and allow you to post books with reviews and comments for a self-selected circle of friends to see and discuss. Facebook hosts something called the Visual Bookshelf. When I visited in early June, it was claiming that 2 128 143 people were using the app to put 45 916 425 books into their Facebook profiles. There are plenty of other book-sharing sites—if you Google around you'll find Shelfari and BookRabbit and LibraryThing, among many others. So somebody is reading books—when they're not cataloging them!

In this summer reading issue we've given you a chance to peruse someone's library in yet another way—not by visiting him at home but by reading about it in a magazine. In "10 Great Tech Books," noted technology writer Steven Levy gives us 10 of his personal nonfiction (and three fiction) favorites and tells us why they made his list. I agree with many of his choices, but I can think of others I might have included. What about Edward Tenner's *Why Things Bite Back: Technology and the Revenge of Unintended Consequences*? Or Katie Hafner's *Where Wizards Stay Up Late: The Origins of the Internet*? Or Michael Riordan and Lillian Hoddesson's *Crystal Fire: Birth of the Information Age*? Or Douglas Adams's *Hitchhiker's Guide to the Galaxy*? Or anything by Philip K. Dick? And perhaps even Edward Tufte's *The Visual Display of Quantitative Information*. I'm sure you'll have your own quibbles and shoo-ins, and I hope you'll visit our Web site to share them with us [see http://www.spectrum.ieee.org/jul08/booklists].

The migration of books from printed to digital formats has brought pleasure and pain to the publishing community. Digital book sales are up, and devices like the Kindle [see our review in this issue, "Re-Kindling a Love of Books"] make it possible for people to carry several books—or a hundred—without a backpack. Amazon's Jeff Bezos fantasizes about creating the modern equivalent of the Library of Alexandria, with any existing book available in a 60-second download. But others worry about the impact of such an idea on the economics—not to mention the very existence—of book publishing. In the networked book age, what will publishers do when authors and readers can reach each other more or less directly?

But publishers need to recognize that while digitalization and the Web bring challenges, they are also creating new book life-forms, enriched with the immense linked resources of the Internet. And they are getting more people to read and think and talk about reading. The virtual bookshelf communities are proof of that.

As science-fiction writer Ursula K. Le Guin wrote in her trenchant essay "Staying Awake: Notes on the Alleged Decline of Reading," published in this past February's *Harper's Magazine*, books are social vectors. They bind our ideas and our cultures together. Whether these books are composed of glue and paper or pixels and electrons, their importance to our human community will remain intact. —Susan Hassler

SONY

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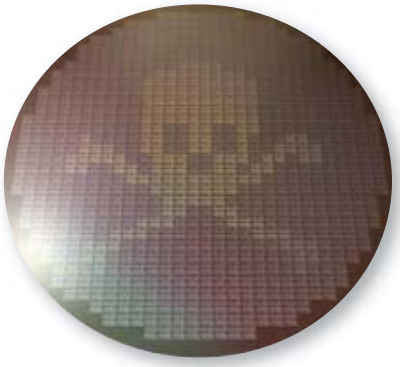

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OVERRIDES COME STANDARD

In "The Hunt for the Kill Switch" [May], Sally Adee describes the threat of outside forces taking control of deployed chips away from military users via remote "kill switches." But that's exactly the purpose of the digital-rights management systems designed to block copyrighted content from playing on unauthorized hardware: publishers want to take control of deployed chips away from media users. When we have an entire industry working hard to build external overrides into electronics, it's no wonder we end up with external overrides built into electronics.

Matthew Skala
IEEE Member
Waterloo, Ont., Canada

IT'S JUST COMMON SENSE

The article by Christensen, King, Verlinden, and Yang, "The New Economics of Semiconductor Manufacturing" [May], implies that the Toyota Production System (TPS) has not been applied outside the automotive industries and that its application to semiconductor manufacturing is novel. The article provides an interesting account of its effectiveness in the case described.

TPS was first described for Western readers by Womack, Jones, and Roos in their book, *The Machine That Changed the World*, published in 1990 (the article claimed by the authors as the first description appeared nine years later). I described it, and explained how its principles could be applied to any engineering manufacturing operation, in my books *The Practice of Engineering Management* in 1994 and *The New Management of Engineering* in 2005.

TPS is really commonsense management, following the principles taught by Peter Drucker and W.E. Deming in the 1950s but applied effectively and uniquely by Japanese industry long before their competitors woke up to the realities. Since the 1980s these principles have been widely applied in other countries and industries. However, the article should stimulate further uptake, particularly by electronics companies.

Patrick O'Connor
IEEE Member
Stevenage, England

HOW GREEN ARE THESE MACHINES?

"Top 10 Tech Cars" by John Voelcker [April] is not acceptable. The article was supposed to value "green" machines' being high-tech. Good idea. So how can you continue to value machines like the Corvette, big sedans, and some SUVs? These cars are ethically unacceptable when you consider that they consume immense amounts of fuel and are driven at speeds that far exceed the limits of most highways. Even valuing biofuel is very controversial—it impoverishes developing countries, and the true energy cost of biofuel is not worth it. Where are the true electric cars? Why not show the serious green cars: ZAP-X, MVS Venturi Fetish, Tesla, SVE Cleanova, or Peugeot's hybrid car with diesel?

Finally, this article values only cars you can find in North America. Here in the United Kingdom, I can see the superiority of French and Italian cars.

Luc Rolland
Preston, England

The author responds: This annual feature appeals to our readers as users of interesting and *commercially available* technology. It is not intended to be an uncritical look at technologies unlikely to penetrate the mainstream market within three to five years. For this article, we define automotive technology broadly and include developments to conventional, combustion-engined cars because that's what almost all our readers are buying.

To address some of Rolland's specific points: we covered the Tesla Roadster in last year's Top 10 and the Venturi Fetish back in 2005. As for the ZAP company, it seems unlikely to ever produce and sell vehicles. Rolland's assertion that our list is U.S.-centric is simply incorrect. Of the eight production cars on the list, three *cannot* be purchased in North America (they are the Tata Nano, Mazda2/Demio, and VW Polo BlueMotion), four more are globally available (Jaguar XF, Nissan GT-R, BMW X6, Chevrolet Corvette ZR1), and only one (Lincoln MKS) is specific to North America. We will probably include Peugeot's diesel hybrid in our Top 10 if it becomes commercially available.

Finally, we cover green machines regularly. Our May issue, for example, featured a Toyota Prius that had been converted into a plug-in hybrid electric vehicle with a 48-kilometer electric range. ❑


MVS Venturi Fetish

TOP: JAMES ARCHER/ANATOMYBLUE; BOTTOM: VENTURI AUTOMOBILES

update

more online at http://www.spectrum.ieee.org

KEEP OUT: This dump in Clive, Utah, is the focal point of an international scheme to import nuclear waste into the United States.
PHOTO: DOUGLAS C. PIZAC/AP PHOTO

U.S. Critics Hope to Halt Nuclear-Waste Imports

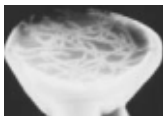
Utah firm wants Italian isotopes

An American company's application to import 18 150 metric tons of low-level radioactive waste (LLRW) from Italy into the United States has set off a firestorm of controversy. In just four months, the proposal has elicited over 2000 comments on the U.S. Nuclear Regulatory Commission's Web site, a federal lawsuit, and a bill in the U.S. Congress that would ban the importation of all "foreign-generated" low-level nuclear waste. Because the case touches on issues related to the Bush administration's plans for international radioactive materials trade, the outcome of this relatively small case could set a precedent with far-reaching consequences.

Last September, EnergySolutions, a nuclear waste treatment and disposal company based in Salt Lake City, filed an application with the Nuclear Regulatory Commission (NRC) to import the low-level radioactive waste. LLRW is a definition by exclusion: it is anything that is not spent fuel and may include tools, radioactive lumber, steel, clothing, and concrete. Angered by the plan, Representative Bart Gordon (D.–Tenn.), chair of the House Science and Technology Committee, introduced a bill in March that would ban the Italian waste and any other foreign-generated LLRW. "No other country in the world is accepting nuclear waste from other countries," Gordon says. "The United States is putting itself in a position to become the world's nuclear dumping ground."

Most nuclear countries keep their LLRW on-site at reactors or, like Finland, in underground storage. In the United States, LLRW goes to three regional dumps. Gordon worries that a precedent for accepting foreign-generated nuclear waste could compromise U.S. storage capacity.

EnergySolutions spokesman Mark Walker disagrees. The company's 2.6-square-kilometer waste disposal facility at Clive, Utah, he says, "has enough capacity to dispose of [the LLRW from] all 104 [commercial] U.S. nuclear reactors and still have over 50 million cubic feet



"We believe it's the world's smallest ramen bowl, with the smallest portion of noodles inside, although they are not edible"—University of Tokyo's Masayuki Nakao telling the Associated Press about this bowl, a little over 1 micrometer in diameter, that his lab made and filled with carbon nanotubes

update

[about 1.4 million cubic meters] of capacity to spare." Walker adds that because the EnergySolutions facility is a private nuclear waste disposal site, the company's plans would not affect federally mandated LLRW sites.

But analysts question some of the fundamental points of EnergySolution's application. And Utah residents have reason not to trust the company, says Vanessa Pierce, executive director of HEAL, a Utah nonprofit opposed to the company's plan. In 2006, the company was known as Envirocare. The name change resulted from the company's acquisition of two other firms and a desire by the new CEO to distance EnergySolutions from an extortion and bribery scandal associated with the previous owner, which involved more than US $600 000 in real estate, Swiss bank account transfers, and gold coins. "Gold coins!" Pierce exclaims. "It's like a bad movie." Despite the name change, much of the original leadership remains intact.

"We are not excited about being home to the world's largest for-profit nuclear waste dump," Pierce adds.

The waste has to go somewhere, counters Walker. "We are taking only the lowest level of radioactive waste," he says. U.S. regulations separate LLRW into subclasses—named A, B, and C—based on the level of radioactivity. Class A is the lowest, in some cases no more radioactive than a smoke detector. High-level waste will go to France or the UK, he says. "Only Class A waste will be shipped to the United States."

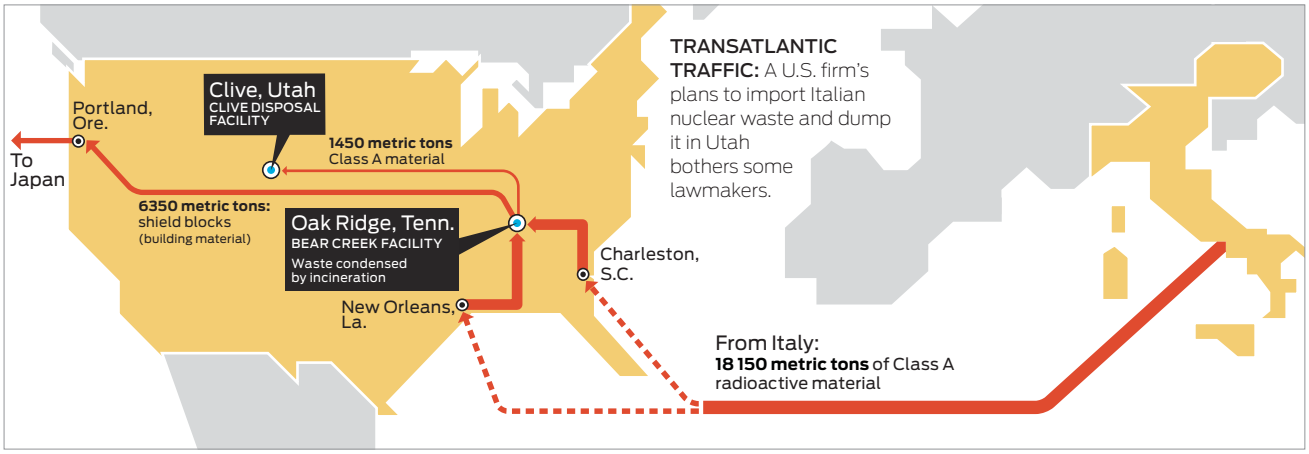
But an analysis of the NRC documents contradicts Walker's claim, argues Arjun Makhijani, a nuclear-fusion engineer with the Institute for Energy and Environmental Research, a think tank based in Takoma Park, Md. Makhijani examined the NRC license application, which lists the amounts and types of radioactive elements intended for the Italy shipments, including transuranics like plutonium. "If they import all the transuranics they say they're going to, then they are importing Class C waste," Makhijani says.

According to EnergySolutions' NRC application, the plan for the Italian waste is to first classify the waste in Italy and then ship the LLRW to the United States for processing at its Bear Creek facility, in Oak Ridge, Tenn., which is licensed to accept Class B and Class C wastes. After processing and separation, 6350 metric tons are to be recycled for use as specialty building materials and shipped to Japan. Walker says the company's waste treatment processes are capable of a 200-to-1 volume reduction. The remaining waste, about 12 000 metric tons, will then be condensed into about 1450 metric tons and sent to EnergySolutions' LLRW dump in Clive, Utah.

"You cannot take 20 000 tons of this waste, incinerate it, reduce it by volume, and end up with Class A waste," says Makhijani. Its radioactivity would have to increase.

At press time, Representative Gordon was gathering cosponsors for the bill banning imports. "If there is not a legislative change, it means these license applications have to be fought case by case," says a congressional aide in Gordon's office.

But Ivan Oelrich, a nuclear physicist with the Federation of American Scientists, thinks that Gordon's bill, if passed this year, could risk being vetoed by President Bush. "It's because of the precedent it would set to ban importing nuclear waste," Oelrich says. The president's plan for resumption of spent fuel reprocessing and recycling in the United States requires a global transfer of plutonium and other transuranics under a program called the Global Nuclear Energy Partnership (GNEP). Any law that would isolate the United States from international nuclear waste trade would signal a lack of political support for the GNEP. —Sally Adee



NAKAO HAMAGUCHI LABORATORY/UNIVERSITY OF TOKYO/AP PHOTO

Crimeware Pays

Adware, phishing, and spam are a strange—and big—business

ANNA DEMIAN

As recently as five years ago, online crime—malware, Trojan horses, phishing—was still a kid's game, dominated by grandstanding cliques of hackers. But today, according to new industry studies, "crimeware" has become an emerging worldwide business. Often based in former Soviet bloc countries like Russia and Romania, where Internet access is high but policing low, burgeoning syndicates regularly launch attacks on users around the world. The first comprehensive analysis of crimeware business models finds a multitude of ways to make money. Of them, phishing is the fastest-growing sector, but adware is the steady moneymaker.

Adware is code secretly installed by a Web site that generates pay-per-click advertising on a user's computer. As frustrated users try to click their way out of a sudden flurry of pop-up ads, each ad's owner must send money to the adware supplier. (Generally, the advertiser is unaware that malicious adware is involved.)

One Russian Web site, iFrameCash.biz, exploited a Microsoft Windows security hole in late 2005, generating thousands or perhaps millions of dollars in adware revenue, notes David Cole, director of consumer products at Symantec, in Cupertino, Calif. Cole coauthored a chapter on crimeware business models in the new book *Crimeware: Understanding New Attacks and Defenses* (Addison-Wesley Professional) with his Symantec colleague Sourabh Satish. Although Microsoft promptly patched the security hole that iFrameCash took advantage of, many computers around the world remained unpatched and vulnerable for months. A similar attack on MySpace users in 2006, exploiting the same hole, resulted in more than a million infected computers. Cole estimates that each infected computer could net 20 to 30 U.S. cents for the Russian perpetrators.

The fly-by-night nature of the crimeware business makes tracking overall industry revenues difficult, says Cole, although the *costs* of computer crime are reported annually by the U.S. Federal Bureau of Investigation and the Computer Security Institute, a private membership organization of IT security experts.

According to the 2007 CSI Computer Crime and Security Survey, computer crime is on the rise—costing each CSI member bank, company, or organization an average of US $345 000, up 105 percent from 2006. But those costs are far from those incurred during the boom years of 2001 and 2002, when CSI member organizations (whose firewalls and security measures were still comparatively unsophisticated) reported an average annual loss of $3.1 million and $2.1 million, respectively.

The aggregate revenue generated by computerized fraud and crime, says Ross Anderson, professor of security engineering at the University of Cambridge, in England, is "surely in the billions of dollars" from the United States alone. And the fastest growing sector, he adds, is phishing—the spam that tries to coax naive users into giving up access to their bank accounts.

The biggest difficulty with phishing, he says, is that banks—the primary targets of phishing e-mails—are extremely secretive. And that has left the industry exposed to phishing attacks that could be thwarted with better cooperation between banks' IT departments. In 2006, for instance, UK banks lost £35 million (currently about $68 million) to phishers, but 93 percent of that was from a single attack on Barclays. "From the point of view of every other bank in 2006, that wasn't their problem," Anderson says. "That was Barclays' problem."

Phishing and adware have straightforward business models, but the crimeware industry has its quirks. For instance, the going rate for access to a good *World of Warcraft* avatar is $10 or more on Internet black markets, says Cole. On the other hand, he adds, "You can buy a [real person's] stolen identity for anywhere from $1 to $2. That includes name, social security number, mother's maiden name, address—all the things you need to actually open up a [credit card] account."

Cole says this pricing disparity reflects the ease and immediacy with which real-world cash can be wrung from the respective stolen goods. Setting up phony credit cards takes effort and exposes the thief to prosecution. On the other hand, rogue *World of Warcraft* trading Web sites offer quick cash. And no one is likely to complain "to the FBI that they lost their magic sword to someone in China," he says. —Mark Anderson

update

Ocean Power Catches a Wave

Europe and New Zealand to install commercial generators; U.S. lags

SEA MONSTER: A Portuguese utility plans to install wave-power generators like these.

THE FIRST commercial ocean energy project is scheduled to launch this summer off the coast of Portugal. Three snakelike wave-power generators built by Edinburgh's Pelamis Wave Power will deliver 2.25 megawatts through an undersea cable to the Portuguese coastal town of Aguçadoura. Within a year, another 28 generators should come online there, boosting the capacity to 22.5 MW. That may be a trickle of power, but the project represents a new push into wave and tidal power as governments eye the oceans as a way to meet their renewable energy targets.

Engineers have come up with a variety of schemes to harness the power of waves, the flow of currents, and the motion of the tides. The Pelamis generators, part of a class of wave-energy converters called linear absorbers, each comprise three long canisters that look like giant oxygen tanks. Hinged joints link the canisters; when the waves change the segments' positions relative to one another, the joints push hydraulic rams, which pump high-pressure oil through turbines inside the canisters.

Though Portugal may be the site of the first commercial installation, the UK—Scotland in particular—leads in the research and development of ocean energy and is expected to end up with the most installed capacity in the coming years, say experts. Pelamis's generator was first tested at the European Marine Energy Center (EMEC), which is located amid the Orkney Islands off Scotland's northeastern coast.

The UK created EMEC with an eye toward making renewables 20 percent of its energy mix by 2020. The government-financed Carbon Trust estimates that Britain could someday meet as much as one-fifth of its electricity demand using ocean energy alone. For its part, the Scottish government is awarding the annual US $20 million Saltire Prize to the creator of the most innovative marine renewable-energy technology deployed there. "Scotland has a huge renewable-energy potential—enough to meet its demand for power almost 10 times over," says its energy minister, Jim Mather. Scotland is estimated to be home to 25 percent of Europe's tidal power potential and 10 percent of its wave-power potential.

On the other side of the globe, New Zealand already gets 60 percent of its electric power from renewables but wants to raise that figure to an amazing 90 percent by 2025. Among the ocean-power projects under consideration is an array of 200 tidal turbines that would be anchored to the seafloor across the mouth of the 900-square-kilometer Kaipara Harbor near Auckland. Crest Energy, the project's Auckland-based backer, estimates that the turbines would yield 200 MW, or 3 percent of the country's energy demand. Getting ocean-power projects going in New Zealand was made easier thanks to an initiative introduced in October 2007, says Anthony J. Hopkins, codirector of Crest Energy. It places a 10-year moratorium on the construction of new fossil fuel power plants by state-owned utilities and creates an emissions-trading scheme. "This levels the playing field quite a bit," says Hopkins.

Despite growing momentum for ocean power elsewhere, the tide hasn't turned in the United States, where environmental regulatory tangles and a preference for wind and solar energy have left most ocean-energy schemes at the research stage. Though ocean energy could offset as much as 10 percent of national electricity demand, "it will be around 2020 before any [U.S.-based] commercial projects come online," predicts Roger Bedard, the lead ocean-energy researcher at the Electric Power Research Institute in Palo Alto, Calif. The Energy Department has requested only $3 million for ocean energy for the 2009 fiscal year, compared with $156 million for solar energy. And, says Bedard, unlike the UK, where a single agency has jurisdiction over all ocean-energy projects, the United States has as many as 20 agencies from which developers have to gain approval—even for a pilot project. —WILLIE D. JONES

PELAMIS WAVE POWER

Mixing Memory To Speed Solid-State Drives

Korean researchers find that a little ferroelectric RAM goes a long way

THE PRICEY MacBook Air you covet, with its small, lightweight, shock-resistant solid-state drive (SSD), may have a secret. Despite their advantages, solid-state drives suffer not just from enormous price tags but also from slow performance during certain key operations. Now Korean engineers report that through a clever mix of two types of memory, they can give solid-state drives a boost without also jacking up their price.

Unlike a traditional hard-disk drive, which can write new data directly over recorded data, the NAND flash memory that makes up solid-state drives requires free memory space in which to write. That's usually not a problem when you have to write large chunks of sequential data, such as a video clip. But it is a problem when you have to make frequent small additions and changes to existing data. If, for instance, you need to update a file, the original data must be copied to a fresh memory block so that the first block can be erased. The new data can then be merged with the original and written back to the first block.

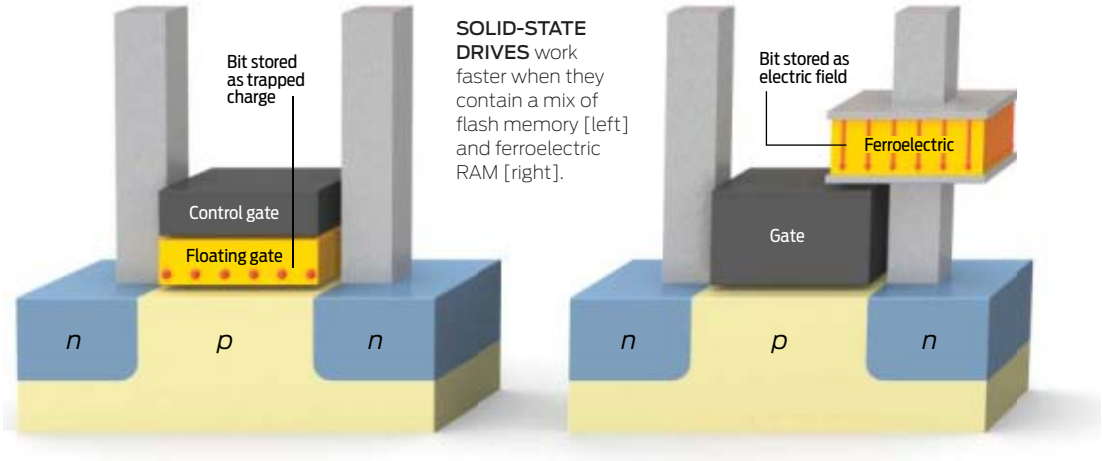
But as engineers at Seoul National University in South Korea report in a recent issue of *IEEE Computer Architecture Letters*, there's a better way. They developed a prototype solid-state drive, dubbed Chameleon, that employs a small amount of ferroelectric RAM (FRAM), a comparatively expensive niche nonvolatile memory, to more efficiently deal with such small data changes. "Our motivation was to combine the benefits of NAND and FRAM so as to create a high-performance SSD," says Sang Lyul Min, a professor in the department of computer science and engineering at Seoul National University who jointly led the drive's development with professor Yookun Cho.

Like flash memory, FRAM retains its data after the power is switched off; unlike flash, it can overwrite existing data. The mixed-memory prototype improves performance by more than 20 percent compared with an all-flash SSD in a standard suite of tests that included starting up Windows XP and loading applications. The FRAM also speeds the drive's own boot-up time by two orders of magnitude, to less than 7 milliseconds.

Flash memory stores its bits within transistors that are connected to each other serially. So though NAND flash is compact, it cannot easily overwrite itself. An FRAM cell takes up more space because it stores its bits as an electric field within ferromagnetic capacitors, but its arrangement allows for random overwriting.

Much of the performance gain comes from the way the FRAM handles maps and other information that keeps track of the data. Solid-state drives need these maps to make themselves appear to a computer to be a real hard-disk drive. The maps are frequently subject to small random updates, something FRAM is good at but flash is not.

Min and his colleagues are now working with SSD maker Mtron Storage Technology, located near Seoul, to bring a product to market. —JOHN BOYD



SOLID-STATE DRIVES work faster when they contain a mix of flash memory [left] and ferroelectric RAM [right].

EMILY COOPER

news brief

NANO-FLOWERS

These sunflowers, which took first place in the 2008 Materials Research Society's Science as Art competition, are actually bundles of silicon oxide nanowires. The flowers' centers are tightly packed clusters, while the petals are looser clusters. Researchers from the Chinese University of Hong Kong added color to the image with graphic software.

IMAGE: S.K. HARK/MATERIALS RESEARCH SOCIETY

NASA Touches Down In Moses Lake

Field test vets new moon-worthy technology

MOVE OVER, BEN HUR: Chariot, a lunar truck prototype designed at the Johnson Space Center, has six double wheels that can be steered independently in any direction and a tanklike turret that rotates 360 degrees.

NASA may not return to the moon for another 10 years, but that's not stopping the U.S. space agency from conducting lunar expeditions.

In June, research teams from seven NASA centers gathered at Moses Lake, in central Washington state, to test prototypes for new moon-worthy robots, vehicles, and spacesuits. During the two-week-long field test, the teams and their machines replicated logistical and scientific operations that might be carried out on the moon.

It was the first time that all the centers were involved in such a test, which gave the teams a chance to see how well the equipment they'd designed played with others.

The field test also offered a "much broader area to stretch your legs," says Bill Bluethmann, a robotics engineer at NASA's Johnson Space Center, in Houston, who served as the expedition's leader. Moses Lake boasts 1200 hectares of sand dunes, popular with the off-road crowd. NASA liked the spot, too, because the loose sand and treeless horizon roughly simulate the lunar surface.

Among the vehicles fielded was a gold-toned, six-wheeled lunar truck called Chariot. Intended to carry up to four suited astronauts, Chariot has an active suspension that lets any part of the truck be lifted and lowered independently. "If one wheel fails, we can just pick it up and continue the mission," says Lucien Junkin, the vehicle's chief engineer. Chariot was designed and built in just 12 months. Under such a compressed schedule, he says, the team became experts at "5-minute design reviews."

Also on hand was a four-wheeled lunar prospecting robot called Scarab, which can operate in daylight as well as at night. Built by the Robotics Institute at Carnegie Mellon University, in Pittsburgh, the robot totes a 1-meter-long drill for taking geological samples.

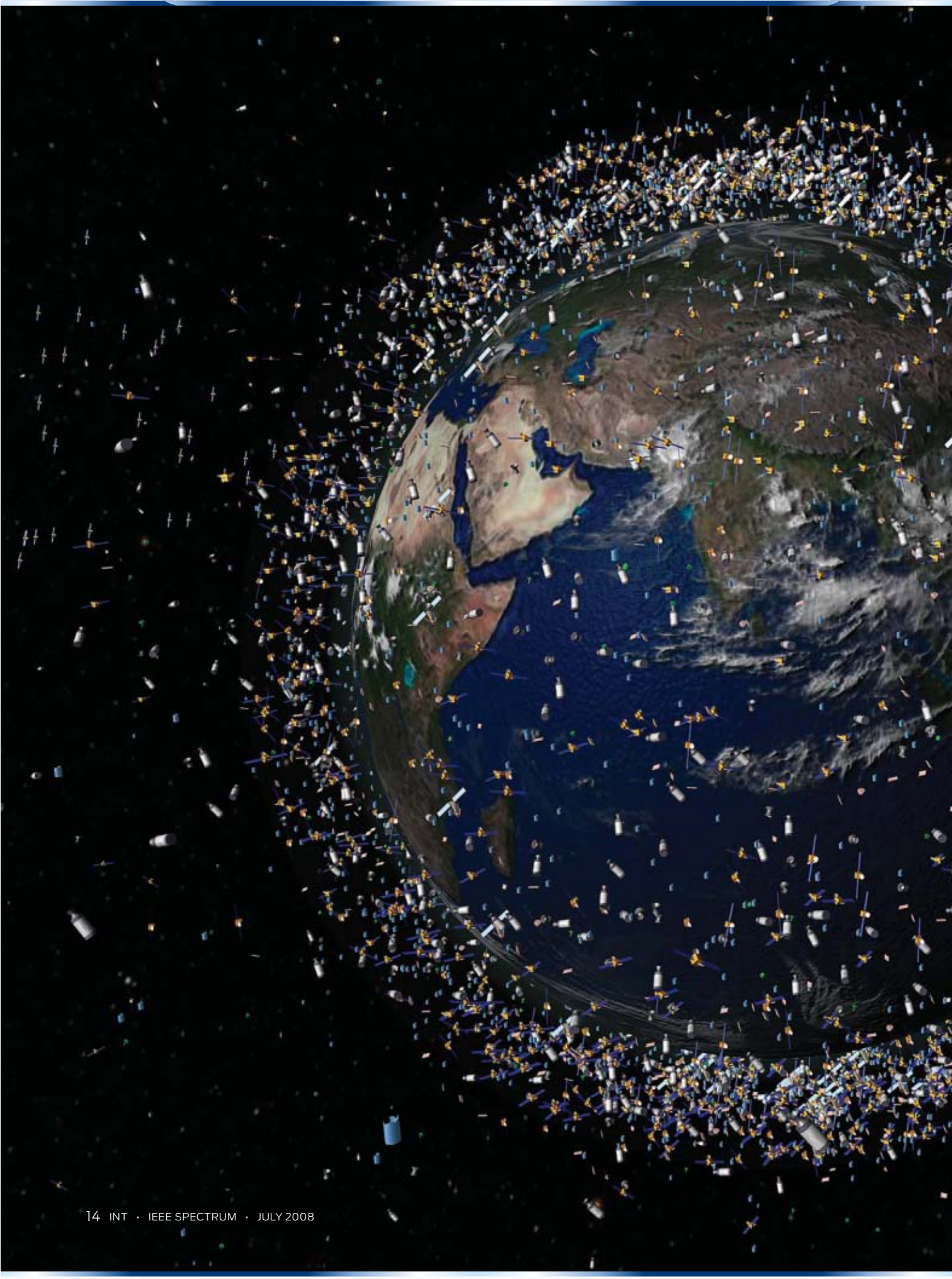
During the field test, the teams replicated remotely controlling the robots from Earth by sending commands from a cockpit at the Johnson Space Center.

Talk of a U.S. return to the moon raises the inevitable criticism: been there, done that. But this time will be different, NASA's Bluethmann says. Unlike the Apollo era's quick trips, the manned and robotic missions NASA envisions will extend over months or even years. That will mean constructing a lunar infrastructure to support personnel and equipment, as well as a reliable, reusable means for shuttling cargo and crew.

Of course, NASA may not have the place all to itself by then. China plans an unmanned lunar landing as soon as next year and a manned mission by 2017. India is also contemplating a manned mission in 2020. The Google Lunar X Prize, meanwhile, is offering US $30 million to whomever can land a robot on the moon, drive 500 meters, and beam data and images back to Earth; so far, 14 teams have registered to compete.

But the moon isn't an end in itself, at least for NASA. The agency's current plan calls for a manned Mars mission by 2031. "We're going to practice on the moon, develop the technology, learn firm lessons about how humans and machines operate on a remote surface, and then apply them to Mars," says Bluethmann. "The nice thing about the moon is that it's comparatively close." —Jean Kumagai

NASA



the big picture

SNOW GLOBE
Instead of floating inside an orb, these flakes, some of the solar system's newest ornaments, dance around it. The dusting comprises active satellites and tens of thousands of space scraps—including wrenches left behind after extraterrestrial home-repair projects, bits of long-abandoned satellites, and actual trash bags stuffed with the detritus of manned space flight. The number of pieces of junk in this orbiting garbage dump, which circles Earth at speeds up to 7800 meters per second, is multiplying; when the particles collide, they break into smaller pieces that some believe could eventually make it too risky to put satellites into orbit or even to explore outer space.

IMAGES: EUROPEAN SPACE AGENCY

BY ROBERT W. LUCKY

Zero Privacy

ALMOST A DECADE AGO Scott McNealy, chairman and cofounder of Sun Microsystems, famously told reporters, "you have zero privacy anyway. Get over it."

Maybe McNealy wishes he hadn't said that, or at least that people like me wouldn't keep bringing it up. When you're famous, reporters tend to write down random things you say, and sometimes they don't come out quite right. Of course, McNealy had a point, and if there was little privacy at the end of 1998, there is even less of it today. Technology has only one direction—toward more power and capability—and it goes that way no matter whose interests are injured. It is up to society to adapt to the inevitable changes that are wrought. The problem is usually that society and technology run on different clocks.

In the past decade, camera phones have proliferated, GPS has become ubiquitous, sensor networks have become a popular research topic, the skies have filled with drones that have all-seeing eyes, and RFID tags have been attached to our cars and other big-ticket products. Now researchers are developing microbots with embedded cameras and sensors.

Not only can electronic systems collect far more information than they could 10 years ago, but they can put it all together in new ways. Memory has gotten much cheaper, processing capability has increased by a factor of about 64, and the algorithms for data mining and social-network analysis have become much better.

Information leakage from one domain to another exacerbates the problem. Every time some online merchant tells me that "other people who bought what you bought also bought such and such," I'm reminded that the merchant is making inferences about me based on my apparent membership in a particular group of people. This is, of course, a simple example, but there is great power in the analysis of networks of apparent or induced connections.

On top of all this new technology are the social trends based on it, as illustrated by the meteoric rise of Facebook, MySpace, and YouTube. Although there are many clear ways in which these technologies and social trends have weakened privacy, it would seem that there are no ways in which they have strengthened it.

Furthermore, technological attempts specifically designed to protect privacy have been unsuccessful. While encryption techniques have been a celebrated theoretical achievement, they have not proved to be a social panacea. Digital-rights-management technology is a model that could be applied in the privacy domain, but so far it has not achieved wide market acceptance.

The argument about privacy seems to have two polarized extremes with a vast, indifferent middle ground. Almost all my engineering friends appear to be in that middle ground, saying that they would gladly give all their private information to the government in return for saving 10 minutes in airport security lines. They seem to reason that since their privacy isn't worth anything, these 10 minutes of their life will be restored to them at no cost every time they fly.

At one extreme there is a group of pioneers, or exhibitionists (take your choice), who flout their state of virtual zero privacy, putting their entire life on the Net for all to see. A small group of self-styled "cyborgs" view the world continuously through head-mounted, networked cameras. A larger group of people install webcams that broadcast their everyday life at home, while still others put all their "life bits" on their Web sites. I sometimes wonder who watches all this stuff, but incredibly, there seems to be quite a number of voyeurs who would rather watch someone else's life than live their own.

At the other extreme stands a group of passionate civil libertarians who view the rise of Big Brother capabilities as a dire threat to humanity. They maintain that there should be laws prohibiting the government from collecting or processing social information. In their defense, it should be said that historical examples of government abuses are not encouraging.

So there is quite a dilemma. Is the privacy genie out of the bottle? What should we do about it? Alas, no one seems to have the answer.

Maybe McNealy was on to something after all. ❑

BRIAN STAUFFER

careers

YOUR MENTOR AND YOU

Getting the most from career counselors

You face an important decision in your career and don't know what to do. You're in a difficult work situation and are under a lot of pressure. Your confidence is low, and encouragement from others just doesn't cheer you up. Your world seems to be coming to an end. You need a mentor.

A mentor is someone who shows you the ropes. He or she is usually a bit older than you and in a more senior position, perhaps in your organization or in your professional society network. A mentor can even be a close friend or relative. I've benefited in my career from a half-dozen mentors, including Bud (at work), Kim (an alum, still a mentor), and my Uncle Joe (who helped me buy my first car and my first house).

Mentors listen to you and give you advice you couldn't get elsewhere. They talk with you, review your résumé and work situation, help you do your "SWOT"—identifying your internal strengths, weaknesses, opportunities, and threats—and help you think through career options and goals and develop action plans.

Don't be shy: start by contacting a person you feel good about. Most likely the person knows who you are, but on some occasions it may be a stranger, in which case you'd have to explain how you came to call. But don't ask, "Do you want to be my friend?" This is not about making friends. Instead, ask directly if the person's willing to give you career advice from time to time, even to meet with you regularly, say, for lunch.

Remember that this is a long-term relationship and a two-way street: you get advice, and your mentor gets the chance to pass on wisdom. Therefore, never regard your mentor as merely someone to network with. Forcing the person into a not-so-hidden agenda can disrupt the building of a trusting relationship.

Mentors should be easy to find, and you probably already know a handful of people who may fill the bill. Write down their names and see which one(s) you feel comfortable getting closer to.

Determine whether your organization or professional society has a formal mentoring program. I've been a mentor for 10 years in a transportation society and am matched with "apprentices" who have between 5 and 10 years' experience. A mentor within your organization gives the added benefit of understanding your corporate culture and can advise you on which career moves would be valuable. He or she may also understand the people with whom you may be having some difficulty.

With a mentor providing support, you won't be alone when you're facing a difficult situation or frozen with indecision at an important career opportunity. You'll get objective feedback from a more experienced professional who has your best interests at heart and who may be able to suggest approaches you hadn't considered. And you're making another professional friend. Many of my dozen former apprentices have kept up our relationship, albeit at a less intense level, which has been very personally satisfying as I've watched their careers develop.

You have to make the first move, and that can be the biggest hurdle. Go out and find yourself a mentor in the next few weeks. Then make the most of this relationship to help you advance your career. —Carl Selinger

DIAMOND SKY/GETTY IMAGES

mini-profile

By Susan Karlin

JACKIE MARTLING: JOKE MAN

Jackie Martling has made a career out of telling jokes, most of them off-color, notably on "The Howard Stern Show" and now on "Jackie's Joke Hunt," on Sirius Satellite Radio 101. But he's a closet geek, with a mechanical engineering degree from Michigan State University, and he's learned the hard way that engineers make the toughest audience. His worst show ever was at a technical college in Philadelphia in 1981, where he'd wowed the crowd the year before. This time, though, people complained that he told the same jokes both years. "Of course I did," he remembers. "I still tell a lot of the same jokes every night. But no one remembers them. Except those engineers that night at the tech college." For a sampling of his humor, go to http://www.jokeland.com.

PHOTO: JANINE MARTEL

tools&toys

Let 'Er Rip

Audio-Technica's USB turntable spins '70s vinyl albums into MP3 gold—and I don't even have to leave my desk

"Goodbye to Paris, goodbye to the past, we live in shadows..." Oh, excuse me. I'm listening to my favorite vinyl album—Southside Johnny's *The Jukes*—for the first time in decades, using the Audio-Technica USB stereo turntable, through my laptop speakers. Now Southside and Blondie and Dan Fogelberg are going into my iPod. And then maybe I can finally say good-bye to the vinyl of my past—and pick up a little closet space.

I could have done this conversion without the Audio-Technica AT-LP2D-USB LP-to-Digital Recording System, or any of the other USB turntables you can now find for between US $90 and $300. All I really needed was a $15 adapter—to convert two RCA jacks (standard for audio equipment) to a single miniplug—and some software. But going this route would have meant crawling behind the audio equipment in the family room, unplugging various cables, and sitting there the entire time with one hand on the speed switch of my old, failing turntable, which doesn't always hold its position by itself. Way too much trouble. I was willing to tackle my pile of vinyl albums only if conversion was easy and mostly automatic.

The Audio-Technica system lists for more than $200 but is available at retail for about $100. It includes cables for connecting to powered speakers, traditional stereo systems, computer audio, and USB inputs. There was something thrilling about unpacking the USB turntable; it really was a trip down memory lane. Slip the rubber mat over the spindle, pull the safety cover off the needle, and remove a mysterious round black plastic gizmo. (It was, of course, the adapter for 45-rpm records. Now I just have to find my old 45s.)

It took me less than 15 minutes to unpack and assemble the turntable, find the right cable, plug the USB cord into my Apple PowerBook G4, and get the included Audacity software loaded and set up. The instructions were clear, simple, and left little out; hats off to Audio-Technica for the best user manual I've read in ages. Within the hour I was back to reading e-mail, this time with Blondie blasting through my computer speakers. Unlike digital copying, vinyl ripping happens only in real time—plus another 45 seconds per track for me to chop up the file into tracks and save them in MP3 format. Fortunately, most of this happens in the background, so you can listen while you rip.

I'd used Audacity before—to handle voice files—so I knew a few shortcuts, like zooming way out on the sound wave image that represents the data. You want a bird's-eye view that lets you see the breaks between tracks without a lot of scrolling.

All the track titles ended up with the same name, reflecting either a problem with Audacity or with the way I used the software. Renaming the tracks is easy. On the plus side, iTunes filled in most of the cover art automatically. Sound quality was fine; there was an occasional pop that reminded me that this was a vinyl track, but even through headphones it was more nostalgic than annoying. (I could have used Audacity to clean up the noise.)

Does Audio-Technica's USB turntable make converting old LPs so easy that I'll actually do it? Yes, it does, if only for financial reasons. On average, an album costs about $10 to download from iTunes, so the system can pay for itself in just 10 albums. Or 12 or 13 albums.

I'm going to hand the whole project off to my kids, who would probably rather rip vinyl than wash windows to earn a little extra spending money. —Tekla S. Perry

AUDIO-TECHNICA

On Time And Under Budget

Keith Bayern won *IEEE Spectrum*'s clock-making contest with brains, elbow grease, and a lot of solder

BAYERN BUILT his clock with transistors, not ICs—"that was the fun of it," he says. Watch his presentation at http://www.spectrum.ieee.org/videos. PHOTO: BRIAN SMALE

IF IT took him, on average, 10 seconds to set up and solder one thing to another, then Keith Bayern must have gripped his solder gun for a total of 7 hours while building his all-transistor wall-mountable digital clock.

"That's 2700 solder joints," he told an openly impressed visitor to his demo in the *IEEE Spectrum* booth at Maker Faire, the science fair for adults sponsored by *Make* magazine. This year it was held in May in San Mateo, Calif.

Bayern was flown there from his home in suburban Seattle as part of his prize as the winner of *IEEE Spectrum*'s contest for making the best possible clock with generally available components that cost no more than US $100. (A steak dinner was the other part of the prize.) He'd built such a thing quite recently, after turning the idea over in his mind for a few years, always following the principle of using as little modern stuff as possible and, above all, avoiding integrated circuits. Except for 1970s-vintage LEDs, he says, every component was available back in the 1960s.

The contest's guidelines emphasized accuracy, usability, attractiveness, and the cool factor. Bayern's clock won because it was at or near the top in every category; the timepiece's only arguable weakness is its dependence on the timing provided by the 60-hertz signal from the wall socket.

One runner-up entry, from Randy Heisch, an engineer in Austin, Texas, also takes its time from the wall socket, but it presents the result in a beautiful analog display, which uses a rapidly moving rotor with synchronized LEDs to paint concentric rings of light showing the seconds, the minutes, and the hours. It is, however, rather delicate and a little hard to set. A second runner-up, made by Joe Sousa, an engineer in Lowell, Mass., supplies its own time and displays it with Nixie tubes, but it's encumbered by a clunky old U.S. Army power unit.

Bayern's clock won out in the end for the geeky beauty of its 194 transistors and many, many other components, all clearly presented for scrutiny. Solid and reliable, it's mounted on an eminently hangable wooden panel and now greets all visitors to the *Spectrum* office in New York City. You can see how Bayern made it and buy a kit from him, if you like, by going to his site, at http://www.transistor-clock.com.

Bayern, 49, is married and has four children. He got his bachelor's in electrical engineering from Montana State University and worked at Dana Corp. for 7 years, Hewlett-Packard for 16, and Honeywell for 7, with a year of self-employment thrown in. As he moved into management—especially after earning an MBA—he found himself drifting away from hands-on technical work, and so he compensated by redoubling the hobby work he's done since he was a kid. "I've been immersed in solder fumes since I can remember," he says, chuckling.

Late last year he moved to SAIC, an engineering consulting company, where he is a senior principal digital and analog engineer. Now he's got a lot more technical meat on his plate than he's had in a long time. —PHILIP E. ROSS

books

An Exquisite Ear

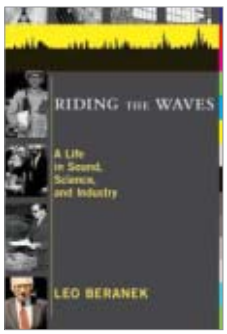
The memoir of BBN cofounder and acoustics pioneer Leo Beranek

THIS MEMOIR, by a pioneer of psychoacoustics, is a salient reminder of how business and social collaboration can drive technological innovation. For sure, people skills aren't enough; you also need an understanding of the underlying science to judge which contracts to accept, never mind with whom it is best to collaborate. It is the rare individual who has all the qualities needed to succeed at all these things. Indeed, Leo Beranek's character, as much as his talent, is the (usually understated) leitmotif of this book.

After his Depression-era upbringing in a financially pressed Iowa family, a chance encounter with a well-connected Harvard alumnus set the stage for Beranek's move to Cambridge, Mass., for graduate school. There, during World War II, Beranek and his Harvard colleagues worked under contract for the U.S. military on a project to reduce cockpit noise so that pilots could communicate during flight and battle. This research constituted foundational work not only in noise reduction but also in the intelligibility of speech, and it required marshaling the talents of engineers, technicians, and psychologists.

Later, at the Cambridge consulting firm Bolt, Beranek and Newman (now BBN Technologies), Beranek and his colleagues shifted their focus from noise control to architectural acoustics, a decision which now seems natural and obvious, but which required imagination and courage at the time. There were triumphs, such as improvements to the Tanglewood Music Shed, and there were also qualified failures, such as the saga of Philharmonic Hall (now Avery Fisher Hall) at Lincoln Center, which the author goes to some length to analyze. This section of the book is primarily about business and social relationships, including encounters with famed musicians such as the conductor Herbert von Karajan and the violinist Jascha Heifetz.

The discussion of architectural acoustics, however, is disappointing, at least to this reader; I found it too abstract and marred by gaps. It proceeds as if the Sabine reverberation formula (developed by Wallace C. Sabine in the 1890s), in combination with Beranek's pathfinding work on the acoustical absorption characteristics of building materials, were all that is known about concert hall acoustics. It gives scant attention to the research of Yoichi Ando and Manfred Schroeder on the directionality of echoes and their effect on the cross-correlation of signals at the two ears. Still, it is clear that Beranek's knowledge and love of music informed his engineering efforts, and this synthesis certainly contributed to concert hall successes.



RIDING THE WAVES: A LIFE IN SOUND, SCIENCE, AND INDUSTRY
By Leo Beranek;
MIT Press, 2008;
256 pp.; US $25.95;
ISBN: 978-0-262-02629-1

This is a memoir, not a treatise, and you will not find in it a deep explanation of acoustics and its application as an engineering discipline. But if you are looking for a fascinating glimpse into a time unique in American industrial history and into a life well-lived in pursuit of the rewards offered by that era, you could do worse. It is the spirit of Leo Beranek that shines throughout this book—a spirit of confidence, open-mindedness, and intellectual adventure. —ROGER ZIMMERMAN

Playing With Cyc

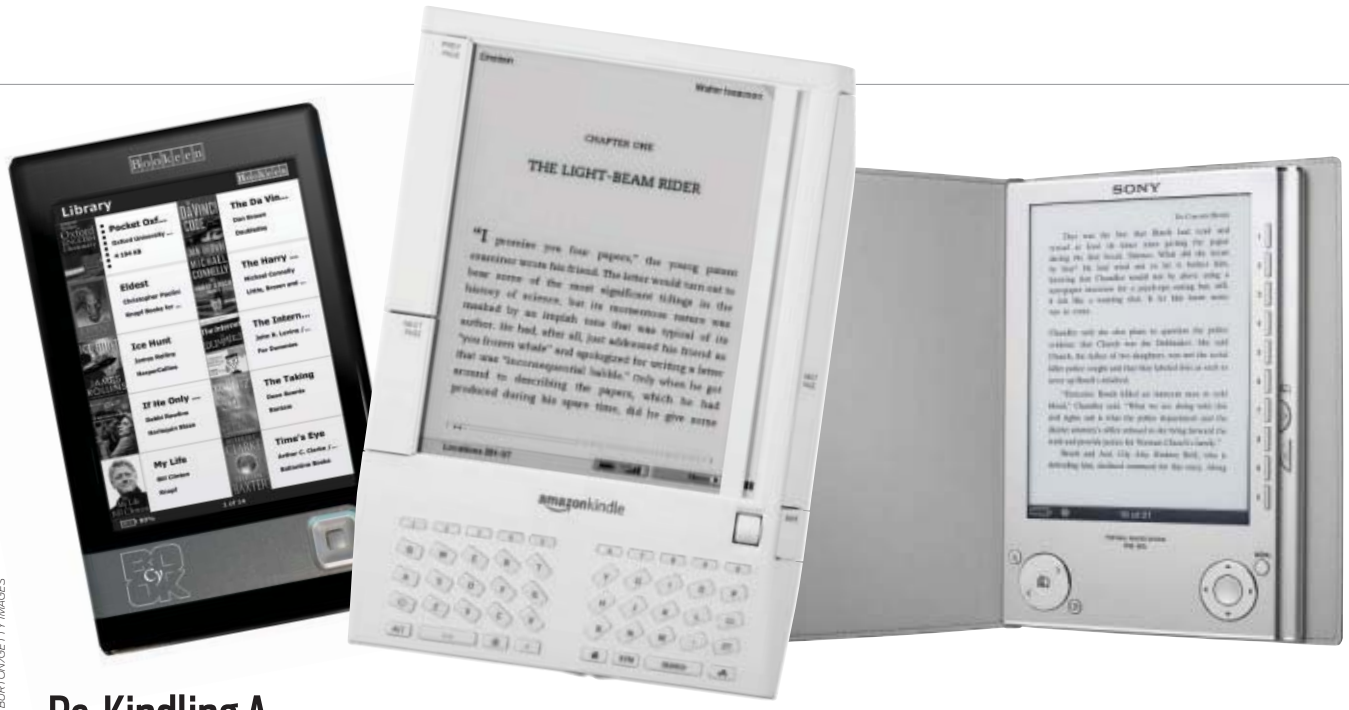
One of the world's oldest AI projects needs your help

For more than 20 years, researchers at Cycorp, in Austin, Texas, have been developing an artificial-intelligence system to apply a modicum of common sense about the world around us. Last year the company made part of the system available in an open-source format, so I downloaded the half-gigabyte-plus compendium of facts, inference methods, documentation, and customized Web server and started poking around.

And you know what? Half a gigabyte isn't nearly enough to emulate the brain.

Cyc contains masses of information on subjects as varied as cats and *Anna Karenina*, linked thematically in hierarchical ontologies, formal specifications of how the concepts in a given area relate to one another. For instance, it might specify that a cat's feet are at the bottom, its head and tail at opposite ends, and so on. Cyc also packs a host of tools for reasoning about the subjects, some formal, others heuristic. OpenCyc is a stripped-down version.

OpenCyc's knowledge is good on some things but not on others. For instance, it "knows" about the different kinds of tactics terrorists use, that blowing things up and taking hostages are different kinds of events but that both are actions that terrorists perform. On the other hand, although it knows that William Shakespeare was a poet, a dramatist, a human being, and the title character of the comic film *Shakespeare in Love*, it can't give you a list of his plays.



TOP, FROM LEFT: BOOKEEN; AMAZON; SONY; BOTTOM: JANE BURTON/GETTY IMAGES

Re-Kindling A Love of Books

We compare three e-books and find that Amazon's Kindle lights our fire

OKAY, I admit it. I think Amazon's Kindle is beautiful. All white, all plastic with big next-page/previous-page buttons, this wireless reading device performs a magic trick: it melts away, leaving only the words behind.

At only 292 grams (10.3 ounces)—lighter than most paperbacks—the Kindle has a glare-free "e-ink" screen that is readable for hours on end. Here's the best part: Say your flight is stuck on the tarmac and you've finished your book. You can get trapped in a 2-hour conversation about the weather, or you can use Amazon's free wireless service to sample a new best seller and then buy it for less than half the cover price.

I pitted the Kindle against its two main rivals, the Sony PRS-505 and a Bookeen Cybook Gen 3. They're all priced about the same, between US $300 and $400, and they all use the same e-ink technology.

Sony's offering—an ultra-modern marvel with a spiffy metallic case—is sleeker than the Kindle, but I had to look at its controls when I wanted to do something, whereas on the Kindle turning the page quickly became an unconscious flick of a thumb. The Kindle's clunkiness is actually a plus: because it's wider on one side, a little like a book, you can wrap your hand around it more comfortably.

Paris-based Bookeen is an admirable, pioneering e-book company and the only one of the three companies that's marketing a reader internationally. Its reader is also sleeker than the Kindle, and what's more, it's the only one of the three that allows multiple formats of copyrighted material. But, like Sony's machine, it requires a computer. The Kindle does not.

That's one reason ours is a three-Kindle family. I can e-mail books directly to my technophobic mom and my kid's babysitter without their having to turn on a computer. Up to six Kindlers can share books, and my 11-year-old nephew is sufficiently enamored with it to hint that he'd give up his Nintendo DS to be our fourth.

Why such an emotional reaction to a machine? Perhaps it isn't an attachment to a machine at all. For my own part, the Kindle has helped me rediscover an old and deep love of books, something I had lost in writing my own best-selling book, raising two little boys, working my day job, and worrying about the looming deadline for my next book.

The Kindle can't buy me the time to read, but it makes it easy to carry a book or two—or 200, and 1000 more on a secure digital card—wherever I go. It lets me adjust text size for my tired middle-aged eyes. It can be read one-handed when wrangling said kids.

Hi. My name is Sherry, and I'm a Kindleholic. —SHERRY SONTAG

However, if you just wanted to add real-world intelligence to your software—say, for a computer game or spam-recognition software—a knowledge base like OpenCyc would be a good place to start.

—*Paul Wallich*

THREE ENGINEERS, HUNDREDS OF ROBOTS, ONE WAREHOUSE

Kiva Systems wants to revolutionize distribution centers by setting swarms of robots loose on the inventory

BY ERICO GUIZZO

NO HANDS: Machines do the heavy lifting at a Staples Denver facility.

"THE BEAUTY OF OUR SYSTEM," Raffaello D'Andrea says as he paces across the warehouse, "is that you don't have to walk over to the shelves to get things—the shelves come to you." With that, he motions toward some 200 blue plastic racks sitting at the center of the building. A mechanical whir fills the room. And then the robots appear.

Two dozen squat machines, like orange suitcases on wheels, scurry on the floor. They park underneath the man-high racks and start pirouetting; the spinning is part of the mechanism that jacks the racks off the ground. One robot hauls shelves with 12-packs of Mountain Dew; another carries bottles of Redken shampoo. They move along straight lines and make 90-degree turns, maneuvering just 15 centimeters from each other. It's a bit like Pac-Man.

This is the demonstration facility of Kiva Systems, a start-up in Woburn, Mass., just north of Boston, that wants to reinvent the centuries-old warehouse business. Kiva's idea is simple: by making inventory items come to the warehouse workers rather than vice versa, you can fulfill orders faster. A computer cluster keeps track of all robots and racks on the floor, and resource-allocation algorithms efficiently orchestrate their movement.

WEIGHT LIFTING: Kiva's standard robot can lift 454 kilograms; its bigger model [below] can hold three times as much, or 1362 kg.
PHOTO: JOSHUA DALSIMER

"When you see these things moving, you think, 'Oh my goodness, they're going to hit,'" D'Andrea says. "But of course they never do."

D'Andrea should know. He wrote the robots' control algorithm. An engineering professor formerly at Cornell University and now at ETH, the Swiss Federal Institute of Technology, in Zurich, he joined Kiva after meeting Mick Mountz, a graduate of MIT and the Harvard Business School, who conceived the idea of using mobile robots to manage inventory. The third founder is Peter Wurman, an expert in multiagent systems and a former professor of computer science at North Carolina State University, in Raleigh.

Raff, Mick, and Pete, as they're known, form a triumvirate of sorts. D'Andrea and Wurman, who are called engineering fellows, oversee system architecture and algorithm development; Mountz, the CEO, drives the business. "They're a well-oiled machine," says one engineer at the company.

After four years perfecting its system, Kiva now faces the challenge of convincing potential customers to switch from conventional warehouse technologies to a fleet of mobile robots. Today's most automated distribution centers rely on vast mazes of conveyor belts, chutes, and carousels. Human operators stand along the conveyors, near inventory shelves, grabbing products and putting them into boxes or totes rolling past them. It's the assembly-line approach that most warehouse managers are used to, and it hasn't changed much in the past 100 years. In fact, for many of them the idea of handing over their inventories to robots is a big departure, if not a crazy proposition.

"Kiva has an inherent degree of flexibility that a lot of the more traditional storage and picking technologies don't," says William L. Vincent, a principal with Tompkins Associates, a supply-chain-technology consultancy in Orlando, Fla. "But many customers are scared of the latest whiz-bang toys and prefer to wait until they get a little bit more history."

Maybe that's one reason Kiva avoids the label of "robotics company." "We invented a solution for fulfillment," Mountz insists. He says that the Internet has made shopping effortless for consumers and now it's time for the back end to catch up. Kiva claims that its system makes it easier to set up and manage a warehouse and that it can boost order-fulfillment speed to three times that of conveyor-based operations. "We turned what is normally a serial process into a massively parallel process," he says.

Mountz's pitch appears to be working. Since 2004, Kiva has amassed US $18 million in funding from Bain Capital and other investors. It has also signed up three heavyweight customers. The office supply giant Staples uses 500 Kiva robots at its 30 000-square-meter fulfillment center in Chambersburg, Pa., and has equipped an entire warehouse in Denver with the robotic system. Walgreens, the drugstore chain, is using hundreds of Kiva robots at a distribution center in Mt. Vernon, Ill., to prepare cases with inventory to restock stores. And Zappos, the online shoe store, is adding Kiva robots to part of its massive fulfillment center in Shepherdsville, Ky., which began operation three years ago and now houses 4.2 million shoes, handbags, and clothing items.

"If I'd known about Kiva back then," says Craig Adkins, vice president of fulfillment operations at Zappos, "I'd have built the entire building with nothing but Kiva."

D'Andrea says that this is the first time hundreds of autonomous robots have been put to work together on a commercial application. He probably knows more about the orange, wheeled machines than anyone else, but with a hectic travel schedule, he's one of the few Kivans—as the staff calls itself—who has never seen the robots in action at a customer's site. "As soon as we have an installation with over 1000 robots," he says, "I'll be one of the first there."

PREVIOUS SPREAD: JOEL EDEN PHOTOGRAPHY/KIVA SYSTEMS

SQUAT AND SMART

Kiva's robots have more than 900 parts, from off-the-shelf dc motors to custom-made ball screws. Here's how the robots' main systems work. *PHOTOS: JOSHUA DALSIMER*

LIFTING MECHANISM
A large screw turns to raise racks of inventory 5 centimeters from the ground. At the same time, the wheels make the robot rotate in the opposite direction to keep the rack motionless.

NAVIGATION SYSTEM
A camera facing upward reads bar codes placed under inventory racks to identify them. Another camera located at the bottom of the robot views bar codes on the floor. This location information is combined with readings from other navigation sensors, such as encoders, accelerometers, and rate gyros.

POWER SYSTEM
Four lead-acid batteries power the motors and onboard electronics. When batteries run low, the robot automatically drives to a charging station.

COLLISION-DETECTION SYSTEM
Infrared sensors and touch-sensitive bumpers stop the robot if people or objects get in its way.

DRIVING SYSTEM
Two brushless dc motors control independent neoprene rubber wheels, moving the robot at 1.3 meters per second.

Kiva's Woburn facility is a typical technology start-up. Engineers park their bicycles in their cubicles, take breaks at a Ping-Pong table, and spice their talk with such industry jargon as "eaches" (individual items) and "sortation" (separating inventory into groups). They don't name their robots but simply call them "drive units." If you hear that one "needs a drink," that just means it's going to get a battery recharge.

But to understand what the company does, you have to step into the warehouse, where Kiva has set up its 1000-square-meter demo facility. When I visited this past February, D'Andrea gave me an overview of the system. The robots, he explains, navigate the warehouse by pointing cameras at the floor that read two-dimensional bar-coded stickers laid out by hand 1 meter from each other, in a grid. The robots relay the encoded information wirelessly to a computer cluster that functions both as a dispatcher and a traffic controller. It instructs, for instance, robot No. 1051 to bring rack No. 308 to worker No. 12—without colliding with robot No. 1433, which is crossing its path.

To fulfill an order, a human operator stands at a pick-and-pack station on the perimeter of the warehouse. Robots crisscross the floor—they even use elevators to get to a mezzanine—and find specific racks to carry to the station. When the first robot positions itself in front of the worker, a laser pointer on a metal pole shines a red dot on a product. Once the worker has retrieved the item, the robot departs and another one takes its place.

In a typical conveyor-based operation, a worker can pick 200 to 400 items per hour. The Kiva robots can present a new item to a worker every 6 seconds, leading to a base rate of 600 picks per hour, with Walgreens reaching a rate of more than 700. Kiva says a large warehouse performing 200 000 picks a day would require two 75-person, 8-hour shifts if it used conveyors. With Kiva's technology, just 25 people a shift would be enough to get the job done. The company says equipping a 10 000-square-meter facility costs between $4 million and $6 million, which is less than what a conveyor system would go for.

D'Andrea says that setting up a warehouse becomes much easier with the robots. Building a conveyor system can take 12 to 18 months for a large warehouse; a Kiva deployment, by contrast, takes weeks rather than

HOW KIVA'S ROBOTIC WAREHOUSE WORKS

1. A worker ready to fill an order stands at a picking station with empty cardboard boxes.

2. A computer running resource-allocation algorithms dispatches robots to pick up inventory racks and carry them to the picking station.

3. Robots with the requested racks line up at the picking station, and the first unit positions itself in front of the worker.

months. Last year, when Staples had to relocate its Kiva operation from one end of the building to another, the engineers simply placed bar codes on the hallway leading from the old to the new site and told the robots to do the rest.

A Kiva warehouse, D'Andrea adds, can also self-organize. The computer cluster tracks high- and low-selling products and stores them accordingly. It directs the robots to park racks that contain popular products near the pick-and-pack stations and place less popular ones at the back of the warehouse.

It's fun to watch the robots, but the human workers filling the orders are also impressive: they watch for the laser dot, pick a product, scan its bar code, throw it into a box, and start over. The humans are rather robotic themselves. I ask D'Andrea: Why not automate this job too? Why not run a warehouse like a semiconductor fab, with everything untouched by human hands? He says that because products vary so much in size and shape and because of the way they sit on shelves, robotic manipulators still can't beat real arms and hands.

"They factored what robots are good at compared to what people are good at, and they realized you don't have to stop with one robot—you can have thousands of robots," says Rodney Brooks, a professor of robotics at MIT and cofounder of iRobot, the maker of the Roomba vacuum cleaner. "These guys are really farseeing in bringing all those mind jumps together at once."

Robots are not new to warehouses. Traditional material-handling vendors, as well as a handful of start-ups, offer self-driven forklifts, pallet-manipulator arms, automated storage-and-retrieval shelves, and other systems. Why has it taken so long for robots like Kiva's to appear?

"Technologically, there's no reason why Kiva couldn't have happened 10 or 15 years ago," says Scott Friedman, CEO of Seegrid, a start-up in Pittsburgh that developed pallet-carrying robots guided by an advanced vision system. "However, labor costs and labor scarcity have made it more appealing to put together some old tech in a new way now."

D'Andrea disagrees. "If that was the case, Kiva would have been invented a long time ago in Europe, where labor costs are normally much higher." More important, he adds, was the emergence of powerful but inexpensive electronics—wireless systems, guidance sensors, embedded processors—and the recent development of novel algorithms in the fields of multiagent systems and control theory. "To architect the whole system," he says, "it took us many, many late nights."

KIVA'S TECHNOLOGY began in early 2002 as a bunch of diagrams and queuing-theory equations on a dry-erase board at Mountz's one-bedroom apartment in Palo Alto, Calif. Mountz stood for hours in front of that board, looking for new ways of speeding up the pick-and-pack queues of warehouse operations.

His obsession grew out of his experience at the Internet grocery store Webvan. Despite its adoption of the latest warehouse technologies, Webvan's cost of fulfilling orders ran three times as high as what the business plan had estimated. In 2001, the company became an infamous casualty of the dot-com bust.

"I thought, let's start fresh," Mountz recalls. "How could any item in an inventory become available to anybody in the warehouse at any time?" The answer, he figured, was that items had to "walk and talk on their own." But how to do that?

He brainstormed the possibilities. If labor were really cheap, he could pack a warehouse with, say, 5000 people, each holding one object. "I'd shout, 'Toothpaste!' and a person would bring it to me," he recalls thinking one day. Another possibility, suggested by a friend, was transforming the warehouse into a gigantic air-hockey table and have products gliding around the place. Those ideas were clearly too far-out, but they helped Mountz zero in on a promising concept: motorized trays to ferry products throughout the warehouse. What he needed, he finally realized, were mobile robots—lots of them.

Before building any prototypes, Mountz called up Peter Wurman, an old MIT roommate then at North Carolina State University, to find out what kind of software would be able to orchestrate so many robots. He flew several times to Wurman's home in North Carolina, where they'd retreat to Wurman's office in the attic. "We'd spend the weekend scribbling ideas and drinking a lot of coffee," Mountz says.

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They eventually focused on the idea of a central computer that would wirelessly command all the robots in real time, so that the human operators would never stand idle. There was just one problem. A large warehouse would involve dozens of workers, hundreds of robots, and thousands of products. Finding the best way of organizing the inventory and mobilizing the robots would be really difficult. In fact, it's a type of problem that mathematicians call NP-hard: solving it exactly is often impractical.

Mountz and Wurman came up with methods to cut corners. They won't reveal all the details, but they offer some hints. Instead of relying on a single piece of software that centralizes all the decisions, they envisioned software agents that could run on the central computer, on the robots, and on PCs at the picking stations. The agents would exchange information but act independently, each trying to optimize its own tasks. They also adopted heuristic methods, like greedy algorithms that can make good—but not always the best—decisions to perform tasks such as assigning racks to stations.

Mountz hired a contractor to prepare computer simulations of the system. The results stunned him. His robotic warehouse looked as if it could operate better than any real one. On 15 July 2002, he filed U.S. Patent No. 6950722, which described a "real-time parallel-processing order fulfillment and inventory management system." It had a crude drawing of the robots, which looked like short trash cans on wheels. He called his business Distrobot Systems.

THE ROBOTIC TRAYS Mountz envisioned had their problems. For one thing, they would occupy too much space in a warehouse. They would also be too costly, because each would need its own motors, batteries, controllers, and communications module. To solve these issues, he decided that the trays could be stacked up to form shelves, and a handful of mobile robots could be used to move the shelf units around.

He began Googling, looking for projects involving mobile robots, and became fascinated with videos of RoboCup, the international robotic soccer championship. One day in the fall of 2003, he mentioned the videos to another MIT friend, Marjolein C.H. van der Meulen, now a professor of mechanical and aerospace engineering at Cornell, who promptly said, "You have to meet this RoboCup guy at Cornell!" The colleague in question was Raffaello D'Andrea, who had led the Cornell team to no less than four RoboCup world championships.

That year, D'Andrea had just begun a sabbatical at MIT, and Mountz arranged to meet him for half an hour on campus. They talked for three hours. They met the next day, and again the following weekend. D'Andrea was hooked. "Mine was probably the shortest-lived sabbatical of all time," he quips.

In late 2003, Wurman and D'Andrea officially joined Distrobot. The company set up shop in a small warehouse in Burlington, Mass., not far from iRobot. In fact, they had chosen the Boston area because of the robotics expertise found there. The warehouse was just a big empty space, which they heated as little as possible to keep costs down. "It was so cold we kept our drinks in a little side room," D'Andrea recalls.

The founders hired two engineers and one computer scientist and got to work. The first weeks consisted mostly of brainstorming. Progress was slow. One day, Mountz gathered everybody and said, "Stop doing stuff on the whiteboard. You guys should do less thinking and more coding." He wanted to see something actually *doing* something.

D'Andrea and Wurman, on the other hand, were wary of a rushed design that could lead to problems in the long term. "From this tension we arrived at an engineering philosophy that lasts to this day," Wurman says. "We do rapid prototyping and demonstrations, and then a cycle of deep thinking and major improvements."

To build the first prototypes, Mountz hired some of his MIT fraternity brothers who worked in robotics. The initial models were metal boxes on wheels, the kind used in motorized wheelchairs. They had no navigation system and no collision-detection capability. The machines could move only from one point to another and often sent boxes flying off racks.

D'Andrea and his team set out to redesign the robots entirely. They modified the rack-lifting mechanism, optimized the wireless module, added safety and power-management features, and most important, came up with a totally new navigation and control system.

4. A laser pointer hanging from above on a metal pole shines a red dot on the product to be retrieved.

5. The worker grabs the product from the rack and scans its bar code to verify that it is the correct item.

6. The worker places the item into a cardboard box, which also receives a shipping label.

7. The robot at the front of the line drives away, and the one behind it takes its place. When the order is completed, the cardboard box travels to the shipping area on a conveyor or is carried by a robot.

PHOTOS: JOSHUA DALSIMER

STEP UP: Kiva's founders [from left], Peter Wurman, Mick Mountz, and Raffaello D'Andrea, envision thousands of robots in warehouses. *PHOTO: JOSHUA DALSIMER*

Their innovation was to put barcode stickers on the floor and equip the robots with cameras to read them. As the robots move, they read the encoded information to learn their coordinates in the warehouse. At the same time, the robots' control systems determine how far off their bodies are from the center of the stickers. If, for instance, a robot is a bit off to the right, the control system nudges it to the left.

The control system also reports its readings to the computer cluster to share that information with other robots. This distributed-control approach improves their navigation capabilities. Say a robot sees certain stickers off to the left. Instead of simply correcting its course by turning to the right, the robot first checks what other robots see—what the "wisdom of the crowd" is. If most of them see centered stickers, the robot figures that the stickers are in the right place and that the shift in position is due to inherent imperfections with its own hardware—its camera may be off center or its wheels misaligned. The robot then adjusts its own control parameters to navigate more accurately. In fact, the machines drive so meticulously that their rubber wheels leave precisely aligned tracks on the warehouse floor.

The greatest advantage of this approach is that the robots are mechanically simpler, and therefore cheaper. Rather than equipping the robots with expensive, high-precision parts to ensure they drive in straight lines, Kiva lets the control software take care of the variations and imperfections in the hardware components. "We don't have to buy the best motors, the best gear boxes to make the robots reliable," says Dennis Polic, one of the electrical engineers. "The control system takes care of that."

The control system also takes care of another nagging issue: keeping the rack stable while the robot lifts it off the ground. This is necessary because the lifting mechanism consists of a ball screw that rotates to raise the rack above it. It's an intricate piece of machinery—a threaded shaft 30.5 centimeters in diameter with a nut assembly filled with ball bearings, custom-machined from hard-anodized aluminum at an undisclosed shop in Massachusetts. One dc motor turns the screw, raising the rack about 5 cm into the air. To prevent the rack from rotating while the screw turns, the control system causes the robot to rotate in the opposite direction at the exact speed required to keep the rack motionless.

The current production model can lift 454 kilograms and travel at 1.3 meters per second. Kiva builds the machines at its warehouse. Assembly takes just a few hours. Then comes a series of tests. Designed to last 10 years, the robots must drive on a floor scattered with 1-cm-thick plywood squares while carrying half a ton of patio paving stones. "They bounce and rattle quite a bit," says Brett Anderson, a senior mechanical engineer. "It's like an off-road course."

In other test protocols—designed more for fun than for technical reasons—the team aligned a dozen robots and made them oscillate like a sine wave while engineers "surfed" them. To evaluate a stronger robot capable of lifting three times as much weight, or 1362 kg, a dozen employees climbed on top of the robot as it went about its business. And during the holidays last year, a Kiva intern got two dozen robots to dance to the score of Tchaikovsky's *The Nutcracker*.

Running the robots in real warehouses has shown Kiva how customers can push its system to the limit. One client posted a lower price for a product on its Web site by mistake, attracting hordes of shoppers—and sending the Kiva robots after the same few racks, which had to be replenished over and over. Another time, workers at a customer site started driving forklift trucks through a section restricted to the robots. Eventually, a robot was hit and nearly destroyed. As engineers, D'Andrea and his team expect such problems to crop up, he says. "More late nights, I guess."

EARLY DAYS: Clockwise from left: Peter Wurman prepares inventory for a 2005 trial at Staples; Raffaello D'Andrea wrestles with robot prototypes in early 2004; the first production units await a firmware update in March 2005. *PHOTOS: KIVA SYSTEMS*

Kiva has evolved significantly since its first days. In 2005, it moved to its much larger home in Woburn. It also got rid of the Distrobot name—"People were thinking we're building humanoids to carry boxes," Mountz says—to become Kiva. That year, it also signed up its first customer, Staples, followed by Walgreens in 2007 and Zappos this year. The company now has 80 employees, a number expected to nearly double this year.

This past April, Kiva shipped its 1000th robot. It says several potential clients that want to remain anonymous are currently testing its system. D'Andrea is confident that more and more Kiva robots will make it into warehouses. "We've simulated huge warehouses with thousands of robots," D'Andrea says. "I can just imagine 10 years from now—people will start writing papers about PDE [partial differential equation] fluid models of Kiva robots, just as it was done with highway traffic."

And he adds that although Kiva is not about "cool robots," he enjoys spending time with them. "To me, it's just beautiful. It's like a dance," he says. "That's really what motivates me. To be able to make something like this—it's human achievement. It's a look-what-we-can-do sort of thing." ❑

TO PROBE FURTHER To see videos of the Kiva robots in action, go to http://www.spectrum.ieee.org/jul08/kiva.

MACHINIMA'S MOVIE MOGULS

A NEW BREED OF FILMMAKER IS BYPASSING THE ACTORS, ELABORATE SETS, AND EVEN THE CAMERAS IN FAVOR OF A COUPLE OF DECENT COMPUTERS AND A VIDEO GAME. THEIR MOVIES MAY SURPRISE YOU

BY DAVID KUSHNER

IT'S A WARM JANUARY AFTERNOON in Austin, Texas, where another movie is being shot. That's not so unusual; with its laid-back pace and funky vibe—the city's motto is "Keep Austin Weird"—this university town has become a hive of independent filmmaking over the past decade, sparked by the success of local directors Richard Linklater and Robert Rodriguez. Both directors built their reputations in part on their willingness to experiment with low-budget digital animation and special effects.

But even by Austin's anything-goes, do-it-yourself standards, today's shoot is notably bootstrapped. For one thing, it's being made above the Pita Pit sandwich shop, overlooking a busy downtown street. The movie studio here at Rooster Teeth Productions consists of a tiny windowless room at the end of a hallway, in what used to be the restroom of a Wendy's burger joint. "We had to run 30 gallons of bleach in here to get out the smell," says Michael "Burnie" Burns, a stocky 34-year-old in a T-shirt and beat-up jeans who cofounded Rooster Teeth five years ago.

The aroma of disinfectant may have dissipated, but the place still suggests more slacker hangout than filmmaking enterprise. The only pieces of equipment in sight are three Microsoft Xbox 360 video-game consoles, assorted Xbox controllers, a 3-gigahertz Hewlett-Packard Blackbird desktop computer, and the obligatory lumpy couch. There's no sign of the usual trappings of Hollywood moviemaking: no actors, no stylists, no catering table. Also missing are sets, costumes, and props. That's because at Rooster Teeth, the cinematic process occurs almost entirely within that HP computer.

Burns and the four other young geeks intently twiddle their Xbox controllers, moving their video-game characters on screen in carefully choreographed moves. Technically, all five are playing the science-fiction shooter game *Halo 3*, but they're also making a movie. As the players put the characters through their motions, the computer records all the action, which will then be edited and paired with dialogue and a soundtrack into a short animated video.

PHOTO: MATTHEW MAHON; ILLUSTRATION: SANDBOX STUDIO

POP ART: Rooster Teeth's Gus Sorola, Matt Hullum, and Mike Burns [from left] have turned do-it-yourself filmmaking into a business. PHOTO: MATTHEW MAHON

It's a new genre of filmmaking called machinima, and it's one of the brashest DIY developments to hit moviemaking since Roger Corman pointed a camera at a guy in a rubber monster suit and catapulted himself into B-movie history. What's making it possible is the latest crop of popular video games and Internet environments, like *Halo 3*, the human-simulation game *The Sims*, and the virtual world *Second Life*. These products all have deeply immersive environments powered by sophisticated real-time three-dimensional graphics engines, and they usually come with free video-editing software and other tools that let players modify the games' characters, environments, and sound and then create and record their own scenarios. Machinimators exploit those free tools to produce animations that span the gamut of film types, including short comedic riffs, serial sitcoms, and even 2-hour feature-length films.

Machinima (a mashup of "machine" and "cinema," pronounced muh-SHIN-ah-muh or mah-SHEEN-ah-muh) isn't intended for the silver screen; most of the films get downloaded or streamed via the Internet and watched on a computer monitor. And they're cheap to make: instead of pouring millions of dollars and many months into a film, Rooster Teeth may spend US $5000 and a week's time on a 5-minute video—and that covers everything from the first-draft script to the final formatting and uploading of the finished film to the Web.

Who makes machinima? High school kids getting together in basement rec rooms, adults blowing off steam on weekends, and a few scrappy start-ups like Rooster Teeth. Nobody knows exactly how many machinimators are out there, but as a group, they are incredibly prolific, churning out hundreds of thousands of animated films over the last decade. In recent years, machinima has blossomed into a tech-centric international subculture. With little more than a video game, a computer, and some imagination, anybody can create machinima.

For most machinimators, it's more a labor of love than a moneymaking venture. But as video-game animation technology aims for Pixar-like quality, machinima is now finding a broader audience. Episodes of the popular TV series *South Park* and *CSI: New York* have featured machinima scenes. This May, the cable channel Cinemax premiered a machinima shot entirely in *Second Life*, reportedly paying the director, Douglas Gayeton, $200 000 for the broadcast rights. This fall, the grandiosely named Academy of Machinima Arts & Sciences, a group that nurtures the new genre and its practitioners, will host its biggest-ever film festival.

Of all the start-ups making a commercial go of machinima, Rooster Teeth seems to be the most highly regarded and may be the only one that generates consistent profits. It all started about six years ago, when Burns and a few buddies started making an improbably funny series based on *Halo* called *Red vs. Blue,* or *RvB,* as it's known to fans.

In the show, two teams of hapless soldiers stuck in a kind of wartime purgatory consider their existential place in the universe as they battle each other and the occasional alien. From the first episode in April 2003, the program proved an instant cult hit, and it ran for five seasons. Hundreds of thousands of fans worldwide eagerly awaited the uploading of each new 6-minute episode to the company's Web site.

At the end of May, fans rushed to the site once again, as Rooster Teeth debuted a follow-up series, *Red vs. Blue: Reconstruction*. "We wanted the next phase of *RvB* to have more of a 'movie' feel to it," says Rooster Teeth cofounder Matt Hullum. And so it does: the editing and pacing are crisper, the scenes and sound effects are more sophisticated, and the action and dramatic tension get kicked up a notch. But the trademark absurdist banter that made the original series a huge hit is still there.

Rooster Teeth is privately held and won't release financial details, but Burns says it now makes enough from DVD sales of *Red vs. Blue* and other productions, as well as commercial work for video-game companies, to support a full-time team of six. Their work has appeared on network and cable TV and at New York City's Lincoln Center, and the company's community site now boasts 650 000 registered members and about 750 000 video downloads each week. Rooster Teeth was even commissioned in 2004 to create a short introductory video for a speech

that Bill Gates gave to Microsoft employees.

"They are the pioneers," says Paul Marino, himself an accomplished machinima producer and now the executive director of the Academy of Machinima Arts & Sciences. "They not only made this a pastime, they made it a business."

IN THE ROOSTER TEETH STUDIO on this January afternoon, two guys move their *Halo* soldiers around on screen as a voice actor in a nearby sound booth reads from a script. Today's project is a short instructional video on how to play Grifball, a multiplayer game that Burns invented to run inside *Halo 3*. Think rugby, except with gravity hammers and energy swords. Burns, who wrote the script, also directs the take. "Give me some more hoo-hahs at the end of the last line," he tells the voice actor after one take.

Halo's software and development tools don't allow for an enormous range of expressiveness. The soldiers' faces are entirely covered by face masks, so each player indicates that his character is talking by bobbing its head up and down roughly in time with the dialogue. "It's like puppeteering," explains Hullum.

Today's how-to video features two of the main characters from *Red vs. Blue*. Although the plots are sometimes punctuated by more or less random violence, the characters' sardonic banter is what separates Rooster Teeth's work from the competition. In one memorable episode, the Red and Blue teams call a truce and then stand around in an uncomfortable circle, guns at the ready, debating the absurdity of their situation:

Grif: "So now we're forced to work together? How ironic."

Simmons: "No, that's not ironic! Ironic would be if we had to work together to hurt each other!"

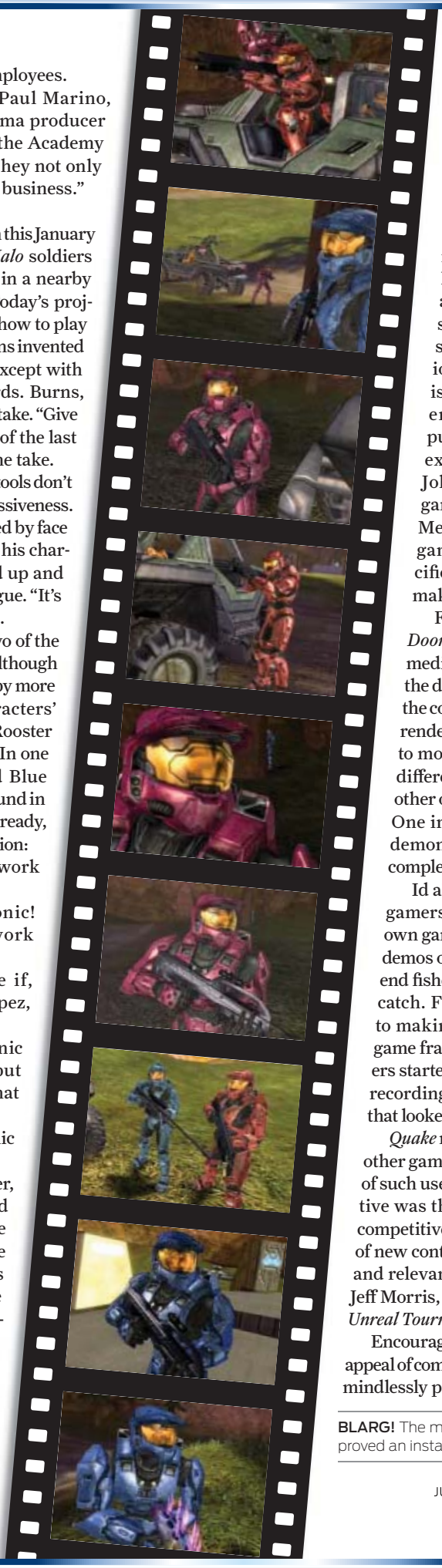
Donut: "No, ironic would be if, instead of that guy kidnapping Lopez, Lopez kidnapped him."

Sarge: "I think it would be ironic if our guns didn't shoot bullets but instead squirted a healing salve that cured all wounds."

Caboose: "I think it would be ironic if everyone was made of iron!"

The scene then cuts to 2 hours later, which finds the soldiers still locked in their semantic standoff. Blue team leader Church, in a deliberate and slightly testy voice, attempts to sum up the consensus: "OK. We all agree that while the current situation is not totally ironic, the fact that we now have to work together is odd in an unexpected way that defies our normal circumstances. Is everybody happy with that?"

When the series' second season premiered to a sold-out crowd at Lincoln Center in 2004, Graham Leggat, then director of communications for the Film Society of Lincoln Center, called it "truly as sophisticated as Samuel Beckett."



RvB, like most machinima, sprouts from the desire to reach inside a video game and manipulate it into something personal, or at least more original or funny—the same urge that compels car enthusiasts to pimp their rides and fashionistas to accessorize. That desire isn't new to the gaming world: players have been hacking into computer games for at least 25 years. For example, in 1991, John Romero and John Carmack started a legendary game company called Id Software, in Mesquite, Texas, and the two, former game hackers themselves, made specific concessions to gamers in order to make such modifications easier.

For Id's 1993 first-person shooter game *Doom*, Carmack created a subsystem of media files called WADs, for "where's all the data?" The WADs were separate from the core engine, the chunk of software that renders the 3-D objects and tells them how to move around. WADs let players swap different images of characters, props, and other objects without damaging the engine. One industrious player tweaked *Doom*'s demons from hell to re-create *Star Wars*, complete with Death Star.

Id also included a function that allowed gamers to record clips, or demos, of their own game play. Users soon began swapping demos of their death matches, just like weekend fishermen trading snapshots of their big catch. From there it was only a small step to making movielike clips. When Id's next game franchise, *Quake*, debuted in 1996, gamers started modifying the content of the game, recording the action, and creating scenarios that looked like little movies.

Quake machinima quickly proliferated, and other game developers began to see the benefit of such user-created content. Their main incentive was the only one that really matters in a competitive industry: money. "A steady stream of new content keeps the game on store shelves and relevant even years after its release," says Jeff Morris, producer of the multiplayer shooter *Unreal Tournament 3*, from Epic Games.

Encouraging machinima can also broaden the appeal of computer games, often dismissed as being mindlessly passive. Eric Lempel, director of Sony

BLARG! The machinima series *Red vs. Blue* proved an instant cult classic. IMAGES: ROOSTER TEETH

PlayStation Network Operations, says, "With games, we now have the opportunity to open up the experience to players and allow them to get creative in their own way."

Michael Gartenberg, an analyst with JupiterResearch, a research firm based in New York City, views the machinima craze as part of the larger trend in user-generated content. "The ability for users to generate their own content is becoming a standard part of the equation," says Gartenberg. "It's not something everyone will do, but for a lot of users it becomes an important way to differentiate [themselves] from competitors. You're not just playing but participating in the game."

To create machinima, Rooster Teeth does essentially no coding. Some machinimators do call upon more advanced special-effects techniques, such as motion capture, and on such dedicated machinima tools as Moviestorm, iClone, and Antics3D. Others hack into the video-game engines to get them to do what they want. But you don't have to. Rooster Teeth takes the purist approach, refusing to modify the graphics with anything other than what's bundled with the game engine.

Halo 3 and *Half-Life 2*, another sci-fi shooter, are preferred by many machinamators because the built-in software is so flexible. Bellevue, Wash.–based Valve Corp., creator of *Half-Life 2*, offers a free software development kit called FacePoser, to animate characters' facial expressions, from the droop of the eyelids to the clench of the jaw. There's also a lip-synching function, so that the character actually looks like it's speaking.

With *Halo 3*, the creators at Bungie Software, in Kirkland, Wash., included a powerful new function called Saved Film. As with other games, you can record your game play as a data file for later viewing and editing. But Saved Film also lets you change the camera's point of view after the fact, so you can replay a scene from any angle or perspective—zooming in on an explosion, say, or freezing a scene—and then save that new sequence for later playback and editing. You can also record a scene through one character's eyes, reverse the camera angle, and then play it back through another character's eyes.

Bungie encourages the kind of aftermarket videos that Rooster Teeth produces. "It's a great way for our game franchise to get represented in a whole new light," says Bungie's Brian Jerrard, whose job is to interact with players, including machinimators. "There are people who probably heard about *Halo* for the first time in *Red vs. Blue*."

HOWDY, NEIGHBOR! In Rooster Teeth's *The Strangerhood*, the cast have forgotten who they are.
IMAGES: ROOSTER TEETH

For those games that don't include video-editing tools, machinimators often invent their own. Pawfect Films' San Andreas Studios is a set of tools for shooting films within the ultraviolent action game *Grand Theft Auto: San Andreas*. The original game doesn't allow for much customization of the characters, but with San Andreas Studios you can create new characters on the fly and control an entire cast in real time.

"Games are transitioning away from the movie metaphor into the hobbyist metaphor," says Will Wright, creator of *The Sims* and the upcoming *Spore*, which will enable players to create worlds and creatures from the DNA level on up. "In terms of the editing experience and sharing with other people, it's intensely motivating for people."

Back in Austin, a production break gives the Rooster Teeth guys a chance to effuse about just how easy it has become to make digital movies. They should know: before turning to machinima, Hullum and a few others served time in Hollywood working on big-budget films.

In a typical week, Burns will write up a script on a Sunday night and polish it on Monday. On Tuesday and Wednesday, the team will record the audio; Burns does the voices for several *RvB* characters, including Church and Lopez, while Hullum voices Sarge and a few others. Eighty minutes of audio will be distilled down to a 6-minute episode.

Thursday will be spent "filming" the sequences within a game according to the script. Rooster Teeth uses three Xbox 360 machines that are networked together. One machine is the director's box, which functions as the shoot's "camera"; data files created during the shoot are stored on a nearby PC. The other two Xboxes each run up to four video-game characters—the "actors" in the film. Even this amount of technology is pretty elaborate for machinima, notes Gustavo "Gus" Sorola, Rooster Teeth's designated tech whiz. When the company got started back in 2003, it relied on Burns's old 2.6-GHz Pentium 4 computer with 1 gigabyte of RAM. "All you really need is a computer and a video capture card," Sorola says.

Again, creating machinima at Rooster Teeth is not a matter of slinging code; it's simply a group of players

running through sequences in a multiplayer game that they've modified into a production set. On a real set, actors follow tape marks on the floor that indicate where they should stand. In a machinima game, the director may fire lines of bullet holes into the ground to show the characters where to go.

Once all the filming is done, the piece is edited using Adobe Premiere. The finished piece may run to about 3 GB of data, which gets compressed down to a more palatable 10 megabytes for online downloading and viewing. To facilitate playback, the film gets encoded in three formats: Flash, Windows Media, and QuickTime.

Keeping the many fans satisfied means more than just cranking out new films. Rooster Teeth also has to maintain a robust infrastructure that can support the downloading of about 500 terabytes of data each month. The site previously ran off of file servers in Sacramento, Calif., and Washington, D.C., but recently the company moved its servers to Austin to give Sorola easier access to the hardware. At one point, he had to rebuild the disk array—the servers' storage system of disk drives—because heavy traffic on the site had slowed download rates to a crawl. "It's a problem that few people have," he says.

But Rooster Teeth vastly prefers that fans use its site—or better yet, buy its DVDs—rather than viewing its videos on public sites like YouTube. In fact, the company fights a constant battle against the free distribution of its videos by others, regularly sending requests to YouTube to take the videos down. In any event, many gamers seem to prefer the DVD format, because it lets them watch several machinima videos at a time, offers behind-the-scenes footage, and carries translations in French, German, and Spanish.

AS MACHINIMA MATURES and its popularity grows, game companies are beginning to set some rules on just what filmmakers can do with their products. Last year, for instance, both Microsoft and Blizzard Entertainment, the powerhouse developer behind the massively multiplayer online franchise *World of Warcraft*, released restrictive new guidelines aimed at machinima creators.

In exchange for a "personal, nonexclusive, nontransferable license to use and display Game Content and to create derivative works based upon Game Content," Microsoft now prohibits machinimators from, among other things, reverse-engineering their titles, creating anything Microsoft might deem obscene, or selling the machinima works. (Rooster Teeth is one of the few machinima developers not bound by Microsoft's ban on profits, having cut a deal early on to use *Halo* for the *Red vs. Blue* series.) Blizzard, based in Irvine, Calif., similarly prohibits the sale of machinima and requires that content reflect the equivalent of a T (for Teen) rating.

The upshot is that despite the DIY nature of machinima, the medium is not as freewheeling as traditional filmmaking. It's hard to imagine Sony setting rules on what kinds of scenes directors can shoot with its high-definition cameras, for instance, but that's exactly what the game companies are doing to machinimators. To circumvent the intellectual property issues that arise from using video games, a few software developers have come up with specialized programs for creating machinima. With the Moviestorm package, for instance, created by the Cambridge, England, company Short Fuze, the user can produce a machinima-style film from start to finish, including writing a script, developing characters, and choosing shots and camera angles.

Some machinimators view the video-game restrictions as an odd form of flattery or as a validation of their work—they've now moved sufficiently above the radar that mainstream companies are taking notice. But even long-time machinima creators say it's a necessary step. "Before there was a potential liability because, if you read the user license agreements, they said you could only play a game," not modify it, says Marino of the Academy of Machinima Arts & Sciences. "Now people can create legally."

MACHINIMA SPROUTS FROM THE SAME URGE THAT COMPELS CAR ENTHUSIASTS TO PIMP THEIR RIDES AND FASHIONISTAS TO ACCESSORIZE

AS A LONG DAY OF FILMING at Rooster Teeth comes to a close, the entire team is tired and cranky. Making machinima can be as tedious as shooting a live-action film, as the sequences are filmed over and over again to capture just the right look and feel. Moving the characters around is hampered by the fact that they weren't exactly programmed to be emotive actors. Just to get a *Halo 3* soldier to lower his weapon, the puppeteer must perform a contortionist combination of moves, holding down so many buttons on the controller that he has to use his nose to make it all work. (Try this at home: simultaneously hold down the left and right bumpers, the left stick, the d-pad, and the A button for 2 to 3 seconds.)

Just as they're shooting the final sequence, an errant soldier wanders into the background on screen. The character isn't under the control of anyone at Rooster Teeth, so it's assumed to be an admirer who somehow found his way into their private online game room and decided to see what was up. It's the machinima equivalent of the annoying bystander who waves and mouths "Hi, Mom!" as the camera pans a crowd scene.

"Um, we have a fan who made it onto the production set," Hullum says wearily.

"We'll have to kill him," Burns replies. With that, he discharges his video weapon into the fan's character, who hits the ground in a splat. The character is gone for now, but the moment this video goes online, that fan will almost certainly be waiting, searching for his moment in the sun.

Although their art form has been around for more than a decade, for Rooster Teeth and other machinimators, it's still the beginning. "As real-time rendering approaches photo-realism, it will get crazier and crazier," predicts Burns. It's just a matter of time before machinima supplants carbon-based performers, he says. "Who wants an actor that gets old?" ❑

TO PROBE FURTHER A complete archive of Red vs. Blue *and new episodes of* Red vs. Blue: Reconstruction *are on the Web site http://rvb.roosterteeth.com. (Note: The videos contain lots of profane existential banter and some violence.) And if you'd like to try your hand at machinima, start with* Machinima for Dummies, *by Hugh Hancock and Johnnie Ingram (Wiley, 2007).*

ISTOCKPHOTO


2
THE PENCIL
HENRY PETROSKI

HERE ARE THE FAVORITES OF VETERAN TECHNOLOGY WRITER **STEVEN LEVY**, WHO WAS TOO MODEST TO INCLUDE ANY OF HIS OWN SIX BOOKS ON THE LIST

10 GREAT TECH BOOKS

Any great nonfiction book combines education with entertainment. In drafting my A-list of general-interest books about technology, I considered impact and significance but gave still more weight to the reading experience. This is a collection where lay readers can appreciate each entry—and engineers, programmers, and other tech professionals can't afford to miss a single one.

PHOTOGRAPHY BY TIMOTHY ARCHIBALD

The Pencil: A History of Design and Circumstance

Henry Petroski (Knopf, 1989)

Early in his exhaustive study of the invention, refinement, production, and commercial history of this humble and indispensable writing implement, Henry Petroski claims, "It is by trying to understand simple ideas and principles in terms of the most complex of examples and issues that we tend to feel overwhelmed.... What might seem to be the secrets of engineering are in the common as well as in the uncommon, in the small as in the large, in the seemingly simple as in the indubitably complex." *The Pencil* justifies this contention. Though the lead-pointed device seemingly sprang out of nowhere (it is first mentioned in a 1565 book on fossils), Petroski traces its origins and skillfully follows its progress from early appearances to a product of the emerging age of assembly-line industries. He is less interested in the cultural history of the pencil than in its steady evolution. The cast of characters is not necessarily the most colorful bunch. A notable exception is Henry David Thoreau, whose name is associated not only with Walden Pond but also the leading 19th-century pencil-making operation in America. The star here is really the stick of cedar and graphite we take for granted. Every aspect of the pencil—the graphite, the eraser, the shape, the color—is examined thoroughly. Maybe a little too much so, as Petroski can be long-winded and might have benefited from a more liberal application of an eraser. Nonetheless, *The Pencil* never loses sight of its point. ❑

Mirror Worlds; or, The Day Software Puts the Universe in a Shoebox...How It Will Happen and What It Will Mean

David Gelernter (Oxford University Press, 1991)

William Gibson, in *Neuromancer*, introduced the concept of "cyberspace as place." And another sci-fi writer, Neal Stephenson, in *Snow Crash,* took pains to explain how a computer-based world might work [see sidebar, "Favorite Fiction"]. But the prize for prescience goes to computer scientist David Gelernter, who in *Mirror Worlds* outlined how an alternative universe that reflected and interacted with physical reality would emerge. Though he knew that the picture he drew had elements of the cyberpunk to it, he bristled at the idea that his vision could be viewed as another version of Gibson's matrix or Stephenson's metaverse. "There is nothing science-fictionish about these programs," Gelernter wrote. The book was written before the Internet exploded, and parts can seem dated. But time has proven it correct: our current connected state—always on, perpetually blogged, and geo-tagged—is beginning to look a lot like one of these mirror worlds. Consider this thought: "When you switch on your city Mirror World, the whole city shows up on your screen, in a single dense, live, pulsing, swarming picture." Sound familiar? While assessing the direction of open services like Google Maps and Facebook, I keep returning to *Mirror Worlds* as the best way to understand how computational reality coexists and merges with the physical world. ❑

A New Kind of Science

Stephen Wolfram (Wolfram Media, 2002)

Stephen Wolfram was more or less a traditional particle physicist when he came across the mathematical backwater of cellular automata, or CAs—artificial, grid-based systems that "behave" according to a set of rules that provide a sort of local physics. Sensing that CAs would be helpful in answering some of the bigger questions he was pondering, he shifted his scientific work to the field. Meanwhile, he built a successful computer software business around a dazzling program that performed complicated math. Using his own software and funding his research with his commercial bounty, Wolfram produced *A New Kind of Science*, a 1200-page behemoth claiming that the lessons we can learn from CA provide (as the title implies) no less than a new, computation-based way to understand natural phenomena. His key point is that very simple cellular automata systems, using just a few basic rules, can often display stunningly complex behavior. That's the basic melody running through Wolfram's symphony of findings and claims, and variations on it lead him to explore the relevance of his computer-based CA experiments in fields ranging from biology to social sciences. He even speculates that "underneath all the complex phenomena we see in physics there lies some simple program which, if run long enough, would reproduce our universe in every detail." Whether or not you buy this, the book is a lushly illustrated and clearly written immersion into the mind and theories of a brilliant iconoclast. ❑

Gödel, Escher, Bach: An Eternal Golden Braid

Douglas R. Hofstadter (Basic Books, 1979)

Though best-seller lists seem all too often dominated by celebrity memoirs, diet books, and partisan political rants, every so often there's a marvelous exception that defies prediction. And what could be more unlikely than a philosophical ramble on the nature of computation and the possibilities of artificial consciousness built on the mathematical theories of Kurt Gödel, the intricacies of Bach's fugues, and the graphic ambiguities of artist M.C. Escher—punctuated by a series of dialogues in the spirit of Lewis Carroll? What makes this a technology book is that while its soul

PROP AND WARDROBE STYLIST: SHANNON AMOS; HAIR AND MAKE-UP STYLIST: MEAGANNE MCCANDESS. ADDITIONAL BOOK COVER PHOTOGRAPHY BY RANDI SILBERMAN

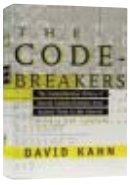
is ineluctably human, *Gödel, Escher, Bach* is also a romance about what the computer has helped us uncover—a larger way of viewing who we are, fueled by the questions raised by universal computation. If this sounds complicated, that's because it is, but Douglas R. Hofstadter is relentlessly instructional. (Digging out my old copy of *GEB* to reacquaint myself with it, I found it stuffed with scratch paper on which, 25 years ago, I worked out his various challenges.) As with James Joyce, Hofstadter's ideal reader is one willing to devote massive energy to decoding his book. And as with Joyce, that energy is rewarded. ❑

The Soul of a New Machine
Tracy Kidder (Little, Brown, 1981)

At the time Tracy Kidder was collecting his National Book Award and Pulitzer Prize for this blow-by-blow account of the building of a Data General minicomputer, *The Soul of a New Machine* was heralded as a must-read for anyone who wanted to understand those strange and scary machines called computers. Indeed, in addition to the sharp portraits of the designers, engineers, and managers who burned the midnight fluorescent light to create the Eclipse MV/8000 (code-named Eagle), Kidder walks his readers through a series of painlessly embedded tutorials on how such machines work. Typically, these are scenes where our avatar, Kidder, is receiving a lecture from one of the designers or micro-coders. In 2008, *The Soul of a New Machine* works as a fascinating snapshot of a suddenly distant past. In Kidder-land, Massachusetts Route 128 is the white-hot center of the digital action, time-sharing is king, and the concept of personal computers is worthy of but a single clause in one sentence. What hasn't changed, though, are the corporate pressures and personal dramas that accompany almost every major project. By sticking to his narrative and rendering it in elegant prose, Kidder proves that unveiling the specific is still the best way to illuminate the bigger picture. It's no accident that, long after Data General and the Eagle team's ultimately undistinguished computer have faded into obscurity, the ultimate compliment to any book that chronicles a project is, "This is *The Soul of a New Machine* of..." ❑

The Design of Everyday Things
Donald A. Norman (Basic Books, 1988; paperback reprint, 2002)

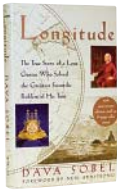
Design guru Donald A. Norman's devastating critique of how engineers fail to make their creations comprehensible was originally called *The Psychology of Everyday Things*, a moniker he felt was clever, in that it was thought-provoking and acronymic (the first letters of each word spell out *poet*). For the paperback edition, his editors suggested the current title. Norman at first opposed it, but he changed his mind when the equivalent of a user study found that the original title was misleading (people thought it might be a self-help book). It was a great example of one of his big themes—creators should understand that their users are not necessarily the same as themselves. Writing at a time when such concepts were barely known to the general public, Norman, a world-class crank, instructively eviscerates the product design of doors, telephones, air-traffic systems, and computers by describing their design flaws and how those flaws found their way to market. Then he outlines how to solve those problems. In the two decades since this book's appearance, Norman's point of view has become widely adopted. Yet bad design still persists, and this book should still be read both by those who design products and those who use them. ❑



The Codebreakers: The Story of Secret Writing
David Kahn (Macmillan, 1967; revised edition, Scribner, 1996)

Writing a comprehensive history of cryptography would have been a daunting task even if much of the information had not been sequestered as national security secrets. But to do so while trying to dislodge the knowledge from the grip of the United States' zipped-tight National Security Agency (NSA) must have seemed almost impossible. Yet in the mid-1960s, David Kahn, a newspaper editor with an interest in history, persisted in writing what will forever be the most authoritative account of cryptology. It's also a rip-roaring read, starting with ancient times and following the field through the medieval Vatican catacombs to the age of electronic cryptography, including its crucial role in the world wars; the revised

edition continues the narrative into the Internet era. His explanations of various codes are sound and expansive; the cryptosystems almost become characters in their own right. And his chapters on the NSA itself were groundbreaking. Published during the height of the Cold War, *The Codebreakers* provided such a wealth of information that the U.S. government attempted to suppress the book. (As a sign of the shift toward the public discussion of crypto that he helped set in motion, decades later Kahn served a stint as a visiting historian at the NSA.) *The Codebreakers* will make you an armchair expert in cryptography—while delivering the thrills normally found in a top-notch spy novel. ❑



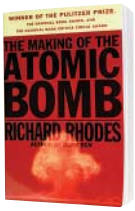
Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time
Dava Sobel (Walker, 1995)

Dava Sobel's straightforward and charming account of how "a lone genius...solved the greatest scientific problem of his time" (as the subtitle

Hackers & Painters: Big Ideas from the Computer Age
Paul Graham (O'Reilly, 2004)

When I first discovered the amazing cohort known as computer hackers over 25 years ago, what impressed me most was their unfettered way of thinking. In order to come up with the coolest and most innovative programs, a hacker must sweep away preconceived notions to come up with something new. This way of thinking also offers a powerful way of approaching the larger world, one that has charmed and instructed me as I continue to interview and understand these wizards. Paul Graham's small but power-packed collection of essays provides an inside view of that ultrainnovative mentality. Graham, a self-described computer nerd who made his fortune by writing the first Web-based application and selling it to Yahoo at the height of the first Internet boom, is blessed with an ability to analyze his own mind-set and explain it to outsiders. To paraphrase a sentence in the book: even though he is the water, he can see the wave. Graham is so unabashedly geeky that, though he is a natural writer, he can't help but express himself in metaphors drawn from what he calls "his native land, hacking." (Typical sentence: "When you damp oscillations, you lose the high points as well as the low.") The book really sings when he analyzes nonprogramming problems (building a business, understanding great design, mastering human interaction) through his hacker's eye. ❑

immodestly puts it) inspired copycat publishers to issue numerous brief narratives of other history-of-technology tales with similarly momentous consequences. But none surpasses Sobel's unexpected best seller on the achievements of Englishman John Harrison (1693–1776). He was an autodidactic clockmaker whose brilliant timekeeping machines proved to be the breakthrough to the biggest challenge of the world's economies—the lack of a reliable method for navigating the seas, specifically in determining a ship's longitude. Latitude, in contrast, is easy because the imaginary horizontal lines that band the Earth can be located by the interaction of the sun and Earth's rotation. In outlining early attempts to solve the problem, Sobel ushers in Renaissance superstars Galileo, Cassini, Newton, and Hooke. But the real drama begins with Harrison and his attempts to convince the Board of Longitude—an elite committee formed by Parliament to award a lucrative prize to the first person who solved the problem—that his seaworthy clocks provided a flawless means to determine location. In the hands of a more scholarly historian, this might have been a messier tale; Harrison might have been a less saintly protagonist, and the motives of his eternal foe, Royal Astronomer Nevil Maskelyne, might have been portrayed as less vile. Sobel wryly acknowledges that her narrative vessel lists toward caricaturization, noting that "a story that hails a hero must also hiss at a villain." But her research is sufficiently sound to keep her storytelling on course. ❑

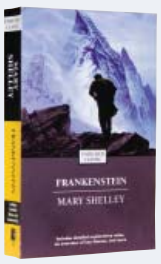


The Making of the Atomic Bomb
Richard Rhodes
(Simon & Schuster, 1986)

The creation of the world's most fearsome weapon—perhaps the ultimate tale of how pure brainpower fused with engineering can lead to earth-shattering consequences—deserves no less than epic treatment. Richard Rhodes provides just that in a magisterial account whose first paragraph whisks us inside the head of physicist Leo Szilard, waiting in the rain at a stoplight outside the British Museum, as he grasps the possibility of a nuclear explosion. "A way to the future," he mused, "death into the world and all our woe, the shape of things to come." Then comes a painstakingly explicit account of the carnage that would follow. The narrative is sweeping but never sprawling, taking almost 300 pages to step through the advances in theoretical physics that made possible the desperate effort to build a bomb. Another 400 pages race through the development itself. Not many 700-page books can be called riveting, but this one can. By fully developing dozens of key figures—Bohr, Rutherford, Oppenheimer, Teller, von Neumann—and often focusing on their inner conflicts between the excitement of discovery and the dread cast by the knowledge of its consequences, Rhodes casts an operatic spell. His deft handling of the political and military circumstances surrounding the effort is spliced with sound science. In my edition, five Nobel winners endorse the author's understanding. In an audacious pitch to pen the definitive account of a massively important development, Rhodes succeeds. ❑

Favorite Fiction

Frankenstein; or, The Modern Prometheus
Mary Shelley
(First published, 1818; Penguin Classics edition, 2007)



Technology's original sin is the reckless drive to invent despite the inevitability of unintended, and often disastrous, consequences. Born from a parlor game among the elite literary figures of the early 19th century, *Frankenstein* remains the definitive treatment of that subject. It also became the mythic legacy of Mary Wollstonecraft Shelley, wife (and soon after writing this, widow) of the poet Percy Bysshe Shelley. The monster of the story is now generally regarded as sort of an animated Halloween costume, embodied by the bolt-necked, grunting beast portrayed by Boris Karloff. (A variation of the movie monster is currently tap dancing on Broadway in *Young Frankenstein*.) But in Shelley's treatment, the creature is an articulate—and ultimately more dreadful—creature whose murderous acts are a direct rebuke to the hubris of its creator. The beast is relentless in calling its creator to task, at one point confronting the young man with a charge that yet reverberates in discussions of today's cutting-edge biotech: "How dare you sport thus with life?" Though the novel is approaching its 200th birthday and bears some of the over-the-top prose trademarks of the Romantic era, it is still compelling and unforgettable. Penguin Classics' new edition is not only meticulous in reproducing and annotating Shelley's text, but its covers and flaps also feature comic-book artist Dan Clowes's cool graphic renderings of scenes from the novel. ❑

Neuromancer
William Gibson (Ace Books, 1984)
Snow Crash
Neal Stephenson (Bantam Spectra, 1992)

A twofer fills this slot—two science-fiction novels on the creation of computer-based alternative worlds. It was *Neuromancer* that introduced the concept of "cyberspace as place," incidentally kicking off a sci-fi genre known as cyberpunk. William Gibson created an iconic character for the digital age: Case, a jaded hacker who literally drops into the computational maw. (He's a postmicrochip version of that classic educated-man's detective, Philip Marlowe.) Gibson's dark *Weltanschauung* has persisted almost to the point of a cliché; movies like *The Matrix* would be unimaginable without him. Yet his hardboiled linguistic panache keeps *Neuromancer* fresh to this day. In *Snow Crash*, Neal Stephenson writes in a looser tone—a mashup of Don DeLillo, Joseph Heller, and old comic books—and takes more pains to explain how a computer-based world might work. His metaverse (where a pizza delivery guy can become a celebrated sword warrior) has become the standard-issue vision of alternative reality. ❑

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It is proposed to make an appointment to the Thales/Royal Academy of Engineering Research Chair of Radio Frequency Sensor Systems, which is supported by Thales UK and the Royal Academy of Engineering.

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For this prestigious Research Chair we seek candidates with a sustained record of carrying out leading edge research, and a demonstrated ability to obtain support, both nationally and internationally, for this level of research work. A record of high impact publications, invited international conference presentations and major involvement in learned society activities is expected. Candidates should have made world-leading contributions to research on the design of radio frequency sensors and associated signal and data processing techniques, particularly in the field of radar or related systems. Candidates should be able to demonstrate an outstanding record of collaboration with industry, including successful translation of their research results into innovative products. A strong record of involvement with government agencies and other end users is desirable. Proven leadership skills and the ability to inspire students, academic and research staff to achieve their full potential are also of great importance to us.

The salary will be negotiable according to experience in the professorial range but will not be less than £55,277, inclusive of £2,649 London allowance.

Further details of the post including how to apply are available at www.ee.ucl.ac.uk/vacancies or from Ms Sara Collins, email: s.collins@ee.ucl.ac.uk, tel: +44 (0) 20 7679 3186.

It is planned for the successful candidate to take up the position from a date to be agreed.

Closing date: 15th July 2008.

We particularly welcome female applicants and those from an ethnic minority, as they are currently under-represented within University College London at this level.

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- **Biomedical Engineering (Assistant or Associate)**
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For detailed descriptions of these positions, please visit:
http://www.ece.ubc. ca/jobpostings

The Department offers a full range of undergraduate and graduate degree programs in Electrical Engineering and Computer Engineering. A number of new initiatives – from new Professorships and Chairs with significant support from local companies to new project-based undergraduate teaching – have created an exciting work environment. The Institute for Computing, Information and Cognitive Systems, partly funded by the Canada Foundation for Innovation (CFI), provides state-of-the-art laboratories for interdisciplinary research in a number of areas. Significant start-up funding to new faculty could be offered through CFI, the Canada Research Chairs Program and other sources. The department currently has approximately 50 faculty members and 375 graduate students; it has undergone a major expansion that has allowed critical masses of researchers to develop in selected areas.

UBC

The closing date for applications is July 31, 2008. These positions are subject to final budgetary approval. For instructions on how to apply, please see http://www.ece.ubc.ca/jobpostings.

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the data

BY SALLY ADEE

Iraq Electricity, By the Numbers

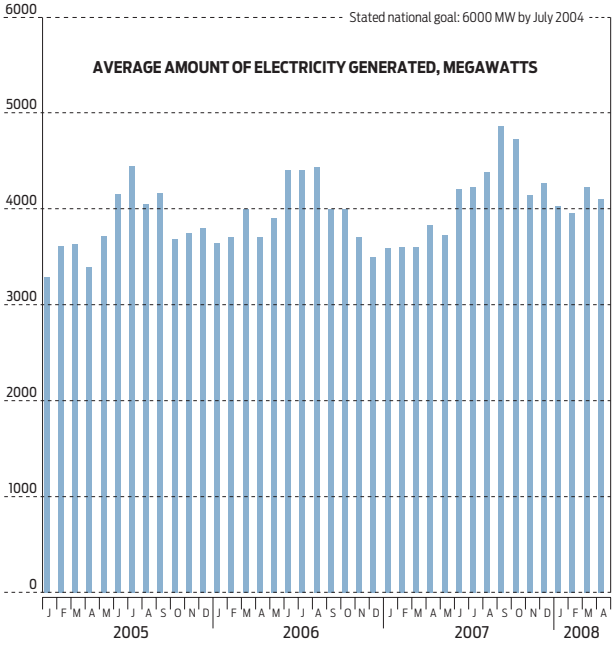
It's July in Iraq, and that means temperatures nearing 54 °C, combined with a maddening talc-like silt that invades eyes and teeth. The air-conditioning works for only about 10 hours a day; in Baghdad province, that number is closer to six.

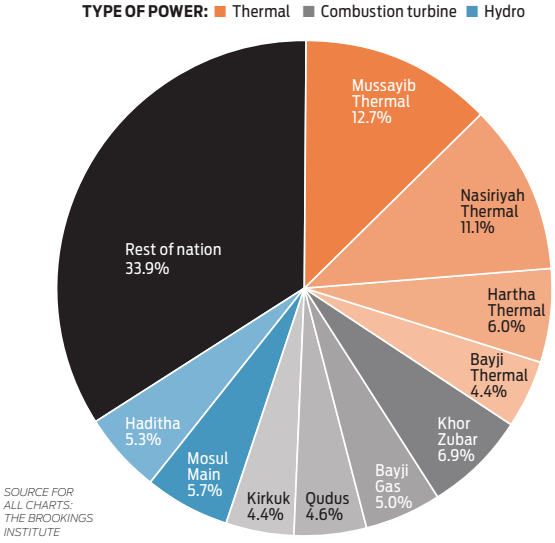
The United States has spent US $4.3 billion to help Iraq's Ministry of Electricity fix the country's power grid, by resurrecting old plants and bringing new ones on line. Nevertheless, the average daily power availability has hardly increased.

In 2005, 173 generating units at 35 power plants were able to reliably produce about 5000 megawatts at peak periods. Another 13 power plants and 262 units later, Iraq still has not reached 6000 MW, the stated goal for 2004.

What's the problem? Insurgent attacks on the electrical grid and a failure of the provincial authorities to cooperate. An electrical grid needs to be balanced: generation needs to keep up with the load, otherwise voltage and frequency will decline. The ministry sheds the load with rolling blackouts.

If provinces shared the load properly, even in midsummer, every province could have as much as 10 hours a day of electricity. But some provinces simply take as much as they can at any given time. The result: more blackouts and more downtime for the already beleaguered electrical system. Attacks on personnel have also chilled progress. In early May, Hassan Kadhum Aziz, the Ministry of Electricity's distribution directorate's advisor, was assassinated. ❑





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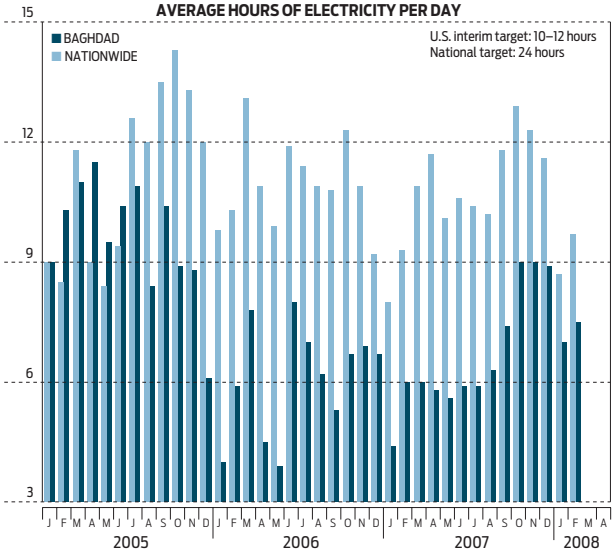

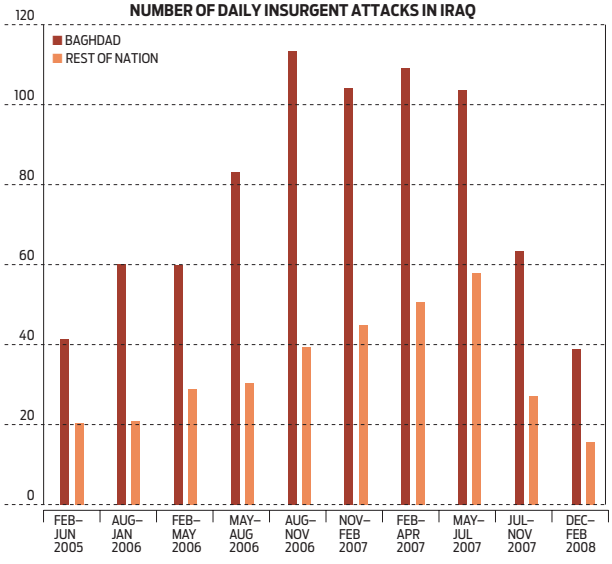

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