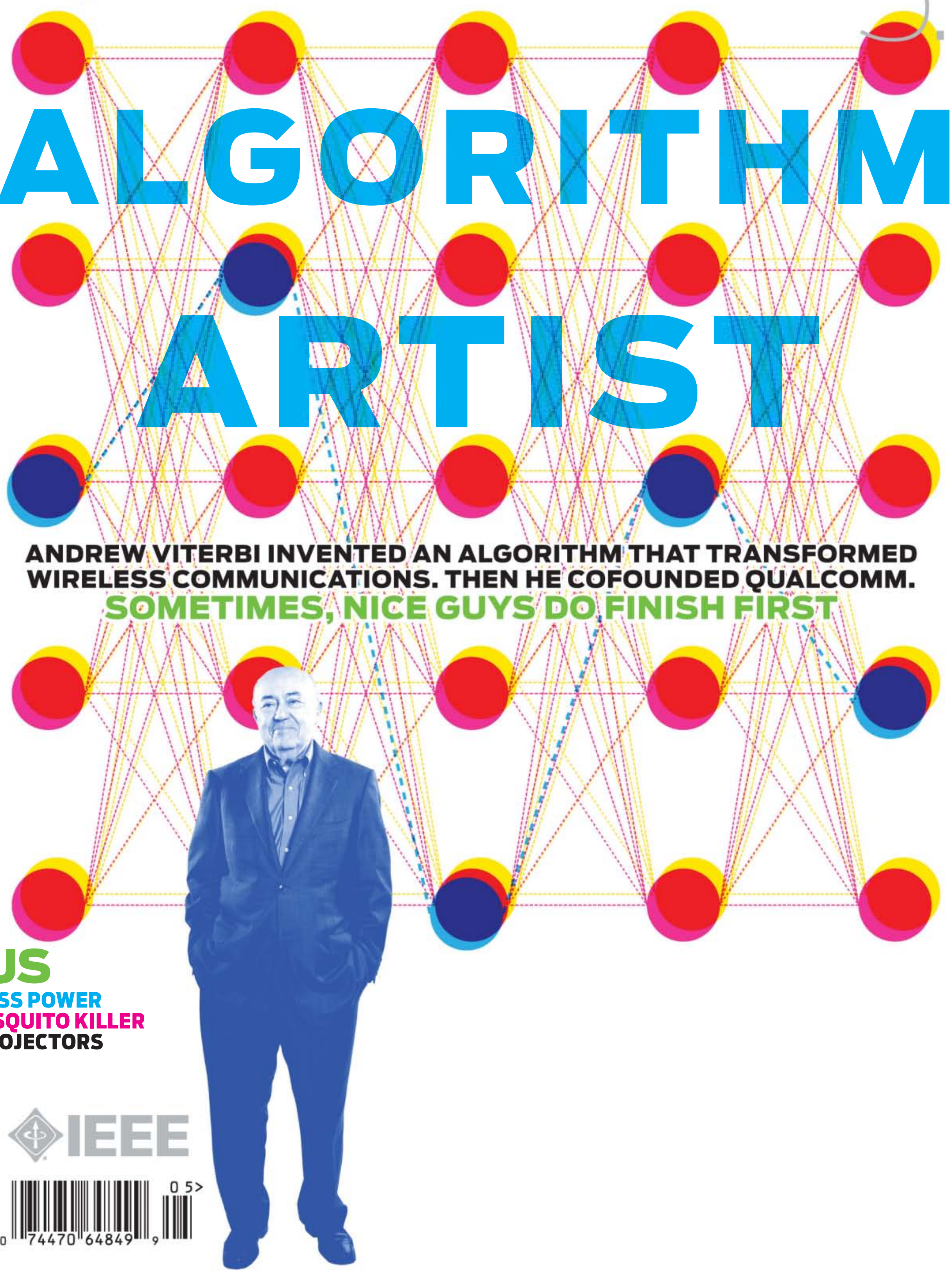
ieee spectrum
THE MAGAZINE OF TECHNOLOGY INSIDERS
5.10

ALGORITHM ARTIST

ANDREW VITERBI INVENTED AN ALGORITHM THAT TRANSFORMED WIRELESS COMMUNICATIONS. THEN HE COFOUNDED QUALCOMM.
SOMETIMES, NICE GUYS DO FINISH FIRST



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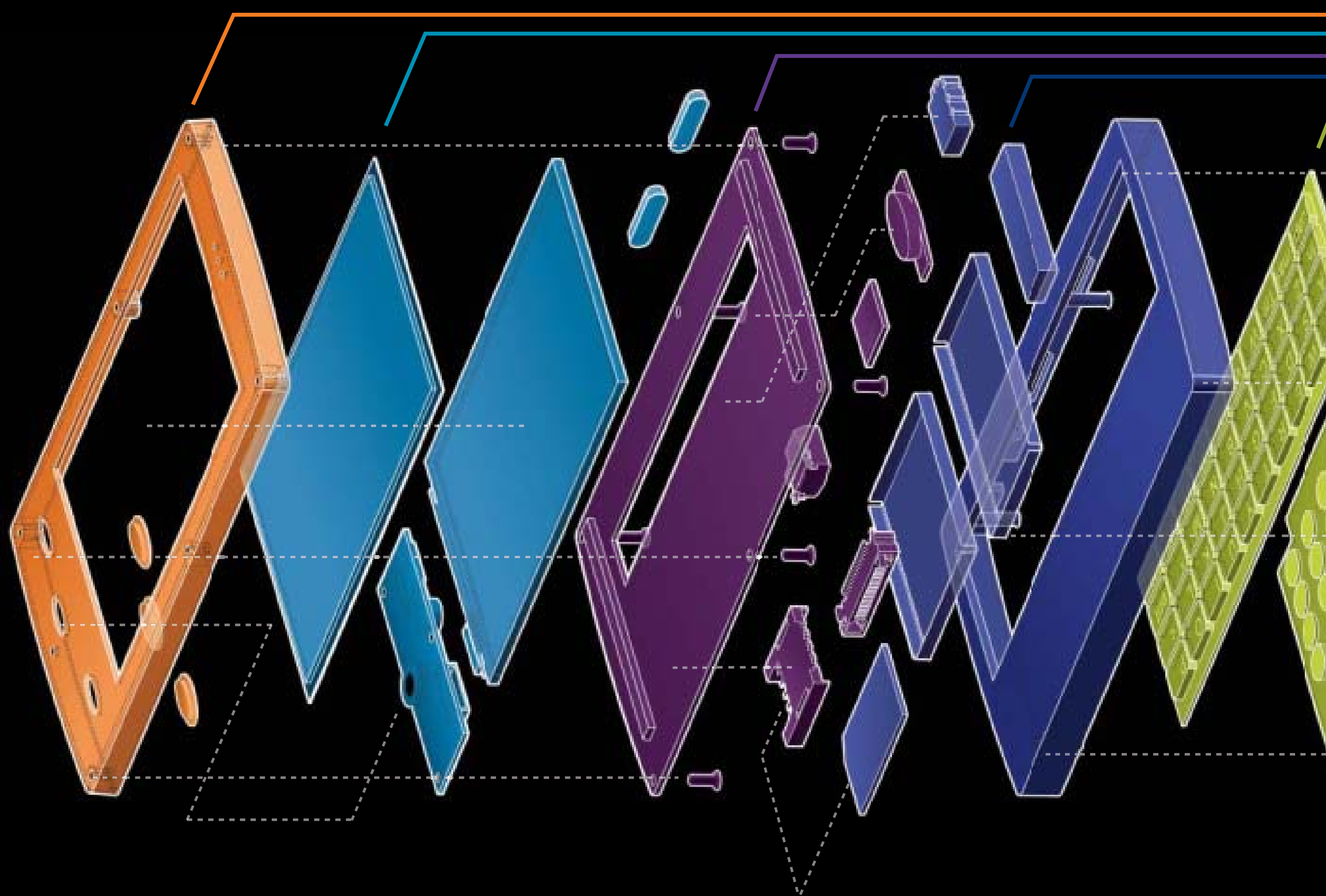


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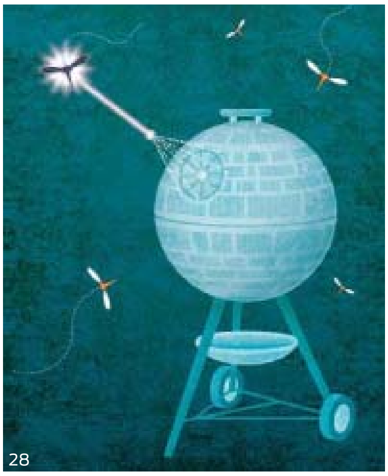
28


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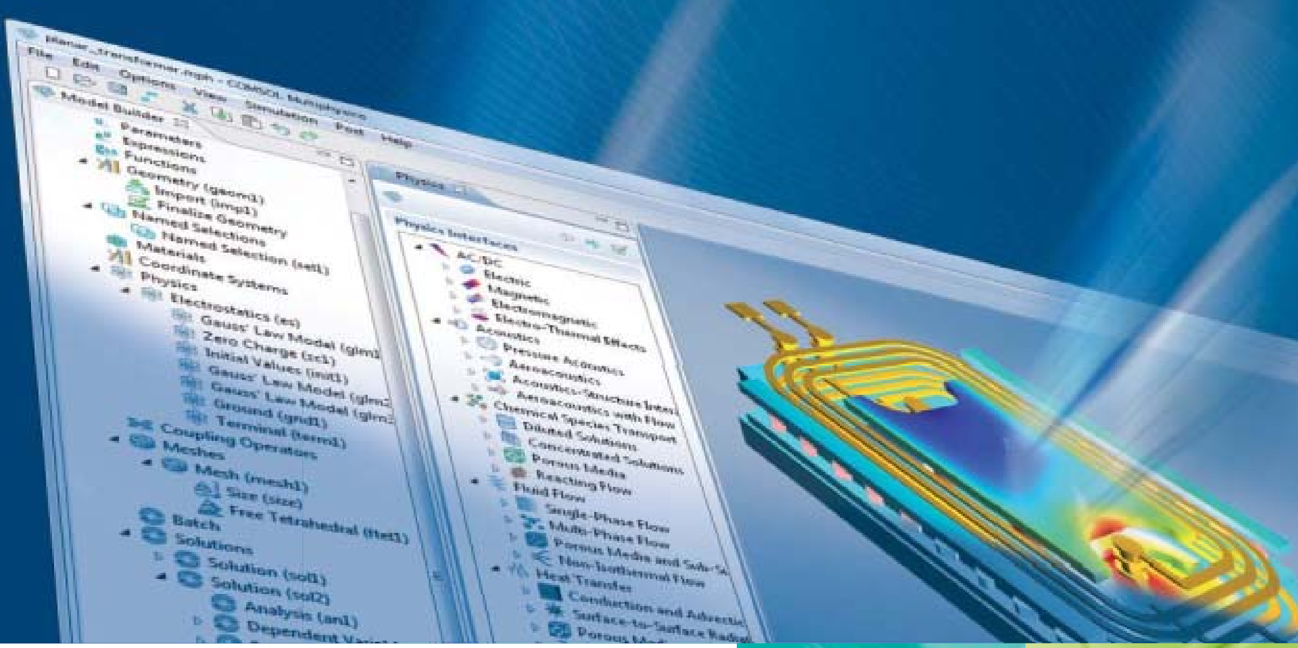
34

BUG BARBECUE: Mosquitoes' tiny brains are no match for our high-tech weaponry [top left]; electrical power can flow even without wires [right]; Andrew Viterbi's life is a modern-day Horatio Alger story.

COVER: PHOTO: BRAD SWONETZ

THIS PAGE, CLOCKWISE FROM RIGHT: HOLLY LINDEM, BRAD SWONETZ, JUDE BUFFUM

COVER STORY



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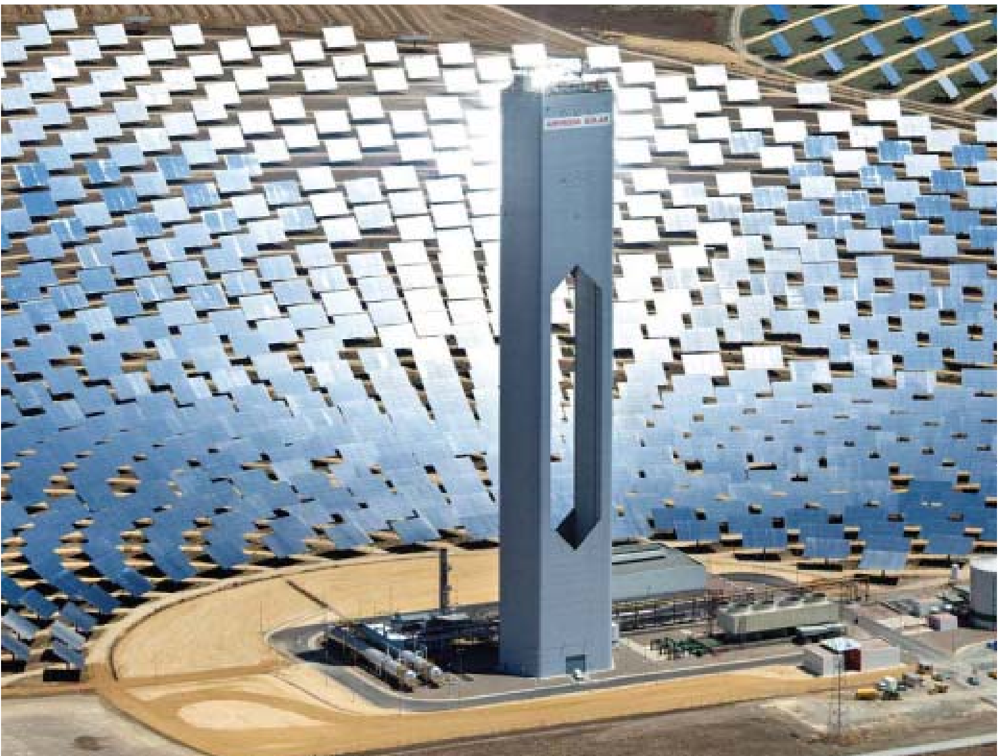

TEMPLE OF THE SUN: The radical design of Abengoa Solar rises near Seville, Spain.

PHOTOS: TOP: PAUL LANGROCK/ZENIT/LAIF/REDUX; BOTTOM: ARMAND VENEZIANO

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AVAILABLE 1 MAY

RENEWABLES ON THE RADIO

Everyone's heard of solar panels and wind turbines. But it's becoming more practical to harness other powers of nature. *IEEE Spectrum* and the U.S. National Science Foundation have produced a radio program with reports from across the globe on such topics as using sensors to create an energy Internet, storing the energy in sunlight as heat in a liquid or gas, making biodiesel from algae, and turning used cooking oil into fuel for driving. Start listening at http://spectrum.ieee.org/energyshow.

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BLAST FROM THE PAST

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IEEE Spectrum editors dug through the archive to find the best cover images in the magazine's history. Take a tour through the online slideshow at http://spectrum.ieee.org/coverslideshow and then discuss your favorites.

IEEE.ORG/THEINSTITUTE

AVAILABLE 6 MAY

STANDARDS FOR CLOUD COMPUTING

As cloud computing gains in popularity, the need for standards to keep it secure has grown. That's why IEEE and the Cloud Security Alliance recently joined forces to ensure that best practices and standards are developed to provide security assurance for cloud computing.

MEMBERS HELP HAITI

In the aftermath of the devastating earthquake in Haiti, IEEE members have been lending a helping hand. Read their stories.

TIPS FOR WOMEN WORKING IN MALE-DOMINATED INDUSTRIES

Roxanne Rivera, author of the new book *There's No Crying in Business*, shares her lessons for succeeding in male-dominated businesses in the webinar "There Is No Crying in Business: How Women Can Succeed in Male-Dominated Industries."

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back story

ERICO GUIZZO

Up in the Air

SEARCH ON "Tesla Street" in Google Maps and you'll come up with five streets in the United States bearing the name of the Serbian inventor who brought us the induction motor and AC power transmission, among other pathbreaking contributions to technology. One of those Tesla Streets is special: It's located in Shoreham, N.Y., on the site of Nikola Tesla's last and only remaining laboratory building.

This turn-of-the-20th-century brick structure, designed by the renowned New York City architect Stanford White, languishes on what is now a Superfund site. A not-for-profit group in the area hopes to turn it into a science museum one day, but for the moment the building remains shuttered, slowly decaying, and surrounded by barbed wire.

Senior Editor David Schneider [left] visited this historic locale, not so much to see the building but rather to examine the remains of something long gone: a tower that once jutted 57 meters into the air. Google's satellite view of this intersection shows vestiges of it—an octagon of concrete and granite measuring more than 20 meters across, which once served as the tower's footing. When he started building the tower in 1901, Tesla planned to use it to project not only radio signals but also useful amounts of electrical power. Alas, it was torn down in 1917, before Tesla could find out if his wildly ambitious vision could ever be more than that.

"What better place to start a story about the prospects for sending electrical power wirelessly—an idea that a century later is again gaining currency?" asks Schneider [see "Electrons Unplugged," in this issue]. Though Tesla never managed to transmit power wirelessly from his tower as he had hoped, companies are now attempting similar feats, albeit at much smaller scales.

What would Tesla think of today's efforts with wireless power? "He thought he could send kilowatts across oceans and continents to power distant airships and automobiles," says Schneider. "He'd probably laugh at engineers who are now working on systems to send a few watts across a room." ❑

CITING ARTICLES IN IEEE SPECTRUM

IEEE Spectrum publishes two editions. In the international edition, the abbreviation INT appears at the foot of each page. The North American edition is identified with the letters NA. Both have the same editorial content, but because of differences in advertising, page numbers may differ. In citations, you should include the issue designation. For example, the first Update page is in *IEEE Spectrum,* Vol. 47, no. 5 (INT), May 2010, p. 9, or in *IEEE Spectrum*, Vol. 47, no. 5 (NA), May 2010, p. 13.

contributors

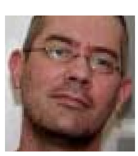
JORDIN KARE, an EE turned astrophysicist, is perhaps best known for his work on propelling spacecraft with laser light. He is now a contributing brain at Intellectual Ventures Management, an idea-making (and -selling) company run by ex-Microsoftie Nathan Myhrvold. When Bill Gates sought new ways to fight malaria, Myhrvold put Kare on the trail of a mosquito death ray powered by lasers. It shot its first bloodsucker out of the sky in 2008. Kare built the system on a shoestring, as he relates in "Backyard Star Wars" [p. 28].

JACQUES LINCOLN, global product manager for consumer projection displays at Microvision, is a 17-year technology industry veteran. He has worked at Advanced Micro Devices, Intel, Motorola Semiconductor, and Microsoft. Microvision's laser-based projection technology, which can be embedded in handheld consumer products like cellphones and media players, is vying with at least four other approaches to ultraminiature projectors, which Lincoln describes in "Little Gizmo, Big Picture" [p. 40].

DANA MACKENZIE is a Ph.D. mathematician and science writer, based in Santa Cruz, Calif. He eagerly agreed to take on The Data, *IEEE Spectrum*'s back page, saying, "I've always been a fan of *Harper's Magazine*'s Index, although I don't like that they present their data in a far-from-unbiased way. It's better if you can let the numbers speak for themselves." In this issue, we publish Mackenzie's initial infographic offering: "Old and New Media" [p. 60]. His first book, *The Big Splat, or How the Moon Came to Be*, was published by John Wiley & Sons in 2003.

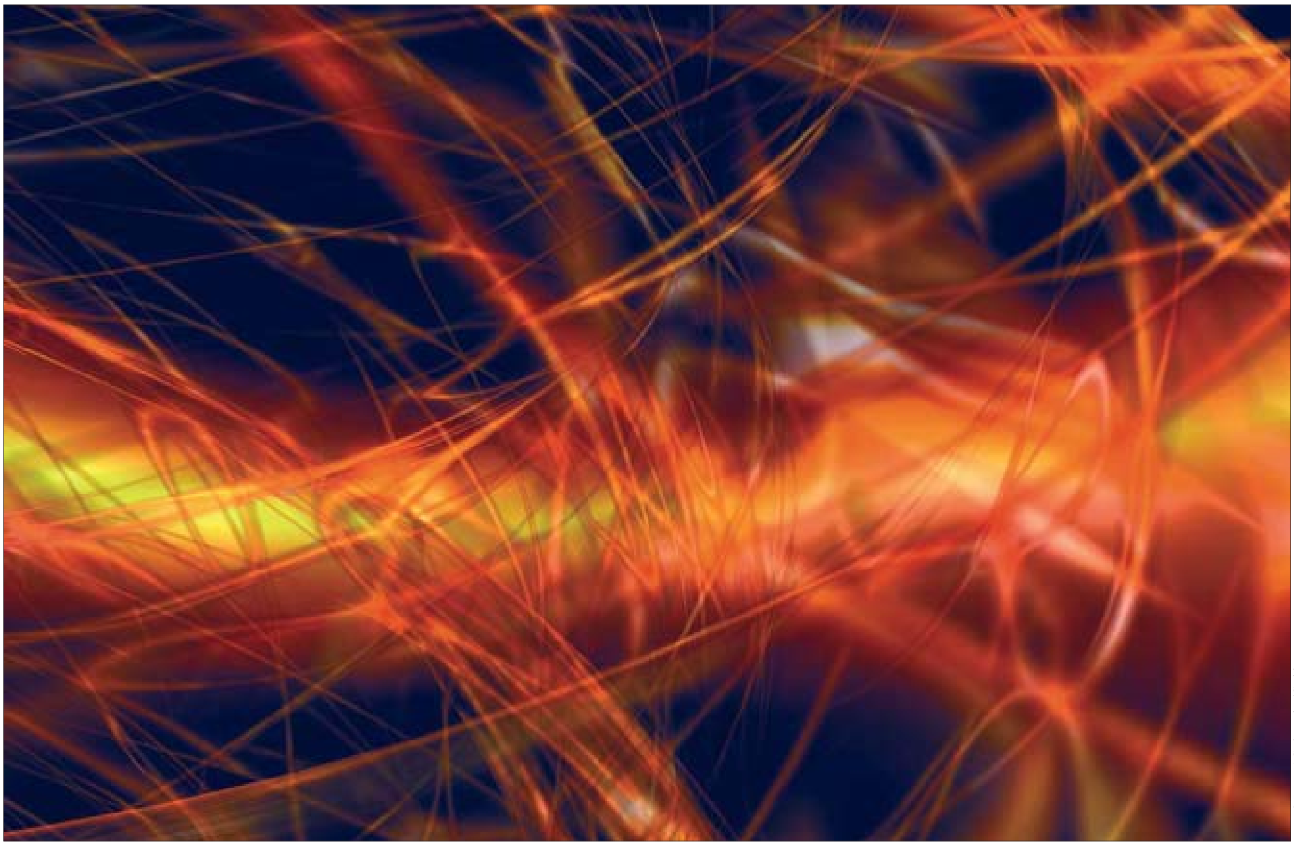
PRACHI PATEL, a *Spectrum* contributing editor, reports that only 7 percent of engineering managers are women, in "It's Lonelier at the Top" [p. 25]. And in Update [p. 18] she writes about advances in flow batteries, which are based on liquid electrolytes. Patel, who holds a master's in electrical engineering from Princeton, has written for *Discover* and the Web sites of *Scientific American* and *Technology Review*. You can also hear her on Spectrum Radio and Public Radio International's "Living on Earth."

BRAD SWONETZ photographed Andrew Viterbi, the 2010 IEEE Medal of Honor winner, for this month's cover story [p. 46]. Swonetz moved to Los Angeles to learn the photography trade after pursuing his passion for surfing and sculpture at the University of California, Santa Barbara. In his work, he loves to show how interesting the seemingly mundane can be.



HARRY TEASLEY, a longtime contributor to *Spectrum*'s blogs, has been developing video games professionally for nearly 20 years. A graduate of the Maryland Institute College of Art, he never touched a computer before getting a job on the debut version of the classic game *Civilization*. He has subsequently worked on such blockbuster games as *Half-Life* and *Halo*. Teasley's need for massive data storage led him to the Pogoplug 2, which he reviews in "Your Very Own Cloud" [p. 22].

CLOCKWISE FROM TOP LEFT: INTELLECTUAL VENTURES; JOEL PREDD; ANNA SWONETZ; HARRY TEASLEY; KAY MACKENZIE; MICROVISION



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Could String Theory Be the Long-Sought "Theory of Everything"?

One of the most exciting scientific adventures of all time is the search for the ultimate nature of physical reality. The latest advance in this epic quest is string theory—known as superstring or M-theory in its most recent versions. Based on the concept that all matter is composed of inconceivably tiny filaments of vibrating energy, superstring theory has potentially staggering implications for our understanding of the universe.

In **Superstring Theory: The DNA of Reality**, you explore this intriguing idea at a level deeper than that available in popular articles. Your guide is Dr. S. James Gates Jr., the John S. Toll Professor of Physics and Director of the Center for String and Particle Theory at the University of Maryland at College Park. Throughout these 24 lectures, he explains the concepts of superstring theory and mathematical ideas like hidden dimensions, dark matter, and black holes—all at the level of the nonscientist. He also draws on the illustrative power of graphics and animations to enhance your understanding and take you to the heart of these cutting-edge ideas.

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Liberty or Safety? Both—or Neither

On 12 January, Google announced that it had been a victim of sophisticated cyberattacks originating in China. Suspecting that the Chinese government had at the very least been turning a blind eye to the problem, the company announced that it would no longer censor its Chinese search results. This tiff between the biggest country and the biggest Internet company affects 1 billion people, tens of thousands of companies, and hundreds of research institutions. It also sets a problem before the rest of the world: Many countries, including the United States, are now grappling with the question of how to balance freedom and security in the Internet age.

In the United States, Republicans and Democrats took a brief time-out from tearing one another apart over health-care reform to praise Google for its principled stand. Secretary of State Hillary Clinton gave a rousing speech declaring Internet freedom to be a pillar of U.S. foreign policy. Lawmakers called on the Obama administration to do more—and yes, spend more money—to support activists fighting censorship around the world.

Those seeking more government funding for cybersecurity are suddenly enjoying unprecedented support from Congress and U.S. government agencies. Funding may be tight for a lot of things in Washington, but not, it would seem, for anything tagged with "cybersecurity" or "Internet freedom."

The problem is that efforts to advance one of these goals can easily conflict with or cancel out the other. For example, Internet freedom requires anonymity—people need to be able to post or access whatever they want without fear of reprisal. But anonymity works against security, because it allows cybercriminals to hide. So that tension raises a couple of questions: Who is in charge of anticipating conflicts and working to avoid them? Who will be the final arbiter as conflicts inevitably arise?

As a free-speech activist, I'm delighted that the U.S. government wants to support technologies that will enable dissidents and whistle-blowers to use the Internet anonymously and securely all over the world. It gives me hope that as the Internet's architecture and technical standards continue to evolve, the possibility of individual anonymity and privacy may not be obliterated—despite the headaches that these freedoms cause for banks, businesses, and law enforcement.

IN MEMORIAM: Flowers outside its Beijing office mark Google's decision to shunt its Chinese traffic to Hong Kong.

What worries me, however, is that based on the congressional hearings I've attended and conversations I've had with people in different parts of the U.S. government, there is no political consensus whatsoever on how to coordinate the conflicting interests and policy goals. Since 2006, Google had gone along with China's demands that it block access to sites that China's government disapproved of. But in late March, Google announced it would move its Chinese-language search service to Hong Kong and cease censorship. Two days later, a bipartisan group of senators launched something called the Global Internet Freedom Caucus. The idea, according to Democrat Ted Kaufman of Delaware, is to "provide bipartisan leadership within the Congress supporting robust engagement by the public and private sectors to secure digital freedoms throughout the world." Sounds great. Who could be against that?

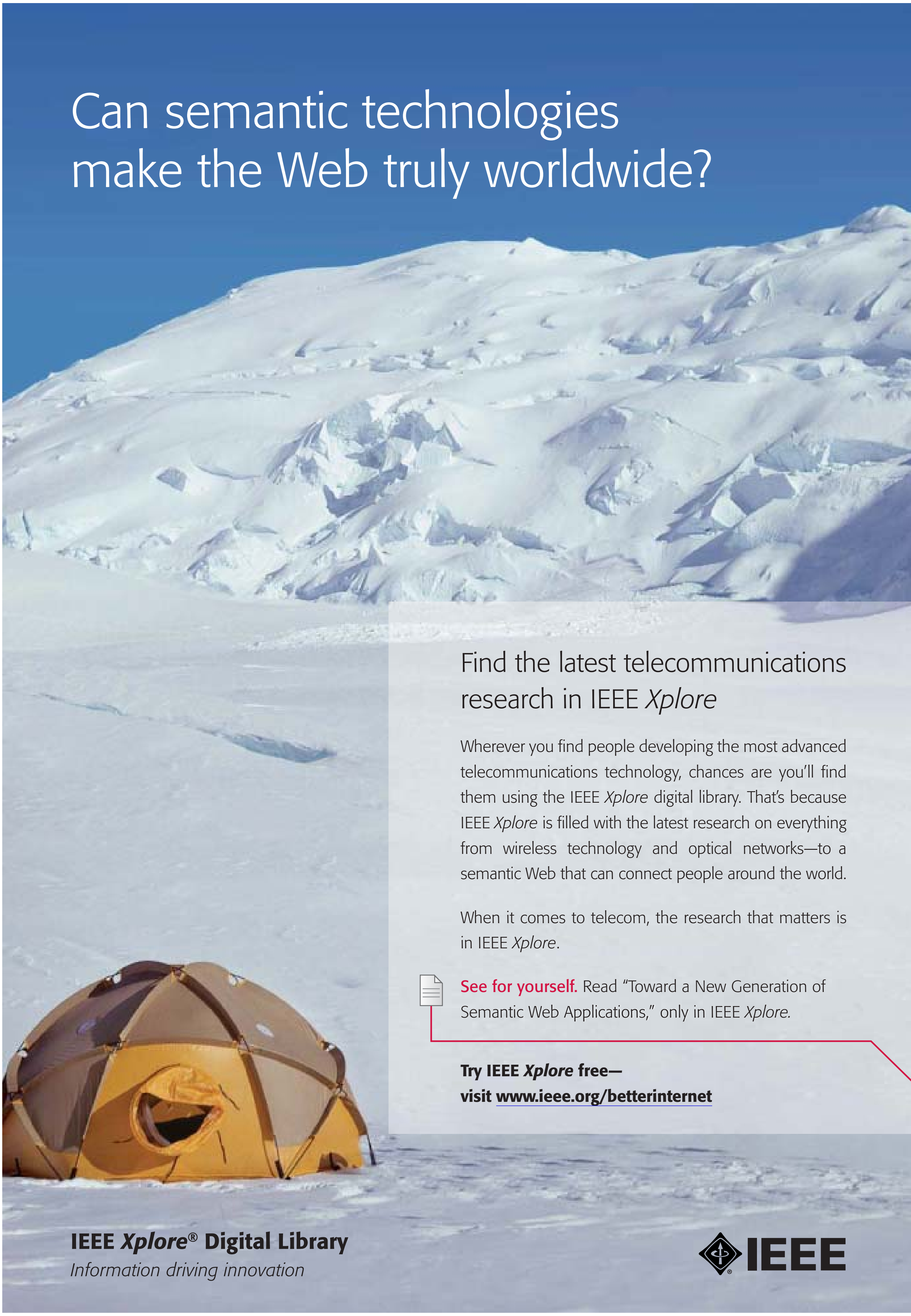
The problem is that in Washington, the phrase "global Internet freedom" is like a Rorschach test, in which different people look at the same ink splotch and see very different things.

U.S. politicians all agree that the concept of global Internet freedom should apply to prodemocracy activists in foreign dictatorships. But not many of them seem to have considered the possibility that the rights of their own constituencies to hear unpopular viewpoints also need protection. So, therefore, if we want to expand global Internet freedom for the long haul, we have to set the priorities. Do we fund software engineers who build censorship-circumvention tools? Or do we engage in the much more difficult work of ensuring that the Internet's technical standards, protocols, regulations, governance practices, laws, and business norms will maximize freedom and minimize the potential for abuse everywhere?

As I sat in the front row listening to Senator Joe Lieberman speak at the launch of the Global Internet Freedom Caucus, I had to bite my lip when he said, "The United States has both a strategic interest and a moral imperative to ensure that the Internet works to empower people everywhere to secure their inalienable human rights—rather than allow the dictators who hope to use new technologies to achieve greater control and stifle dissent." This is the same person who in 2008 demanded that YouTube take down hundreds of videos by extremist Islamic groups. You can't have it both ways, Joe. As Benjamin Franklin said, "Those who would give up Essential Liberty to purchase a little Temporary Safety, deserve neither Liberty nor Safety." That's why China has neither. —Rebecca MacKinnon

Rebecca MacKinnon is a visiting fellow at Princeton's Center for Information Technology Policy, cofounder of Global Voices Online, and a founding member of the Global Network Initiative. She is writing a book about the future of freedom in the Internet age.

LI XIN/AFP/GETTY IMAGES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PAPER OR PHOTONS?

I'VE BEEN reading news stories and technical articles about e-book readers—but I'm reading them in magazines, newspapers, and on the Internet [Spectral Lines and "Lite, Brite Displays," March]. Print publications have a convenience that the Internet doesn't—durability. If I go to the beach and drop my paperback in the water, I can dry it out and read it afterward. If I hike the Appalachian Trail, I can read my book by candlelight, lantern light, or sunlight. It never dies due to a lack of power. When I finish reading my book, I can put it on a shelf, take it down 20 years later, and reread it if I am so inclined. Where will my e-book be in 20 years? In a landfill, probably.

ALEXANDER F. JASZEK
IEEE Life Member
Needham, Mass.

LIVING THE DREAM

I ALWAYS READ with interest the Dream Jobs articles [February]—they're so refreshing. Now I have my own dream job! I've been a Corvette groupie ever since I saw the 1963 Corvette Sting Ray concept car at the New York Coliseum as a very young child. A few years ago, Chevrolet resurrected this car and brought it to a Corvette event at Carlisle, Pa., where I was able to examine, sit in, and generally just drool over this historic vehicle. Being a knowledgeable Corvette player, after my unintended "retirement" from the Silicon Valley tech world after 9/11 I was able to secure a number of contracts creating Web sites for some significant Corvette-related businesses. Talk about a dream job. Life's a trip when you're a single guy with gas money!

ROBERT T. WARDELL
IEEE Member
Ft. Collins, Colo.

WHAT MOTHER DIDN'T TELL YOU

I'M A woman who owns an electrical consulting business specializing in construction drawings, and I employ as many women as men. There are a number of reasons why fewer women than men go into engineering, and some of those reasons arise from misconceptions about engineers. I believe that if more women knew the following things about engineering, more would choose it as a career. Here are a few:

1. Engineering can provide both a nice income and adequate leisure to enjoy a high standard of living. It's a myth that women engineers don't bask in the sun, get pedicures, wear makeup and jewelry, live in nice houses, and drive stylish cars. (Okay, my Prius is no longer trendy, but I do enjoy all of those other things.)

2. Engineering can allow women to work part time. I know several consulting engineers who dropped from full time to part time when they started families.

3. Engineering is a helping career. For example, IEEE and other engineering organizations can make a difference in the countries that suffered damage from the two recent major earthquakes.

4. Engineering can offer a lot more variety than many other fields. There is drama and there are heroes, and the puzzles are at least as good as the ones on the TV series "House."

NAME WITHHELD UPON REQUEST
IEEE Member
Lafayette, Ind.

CORRECTIONS

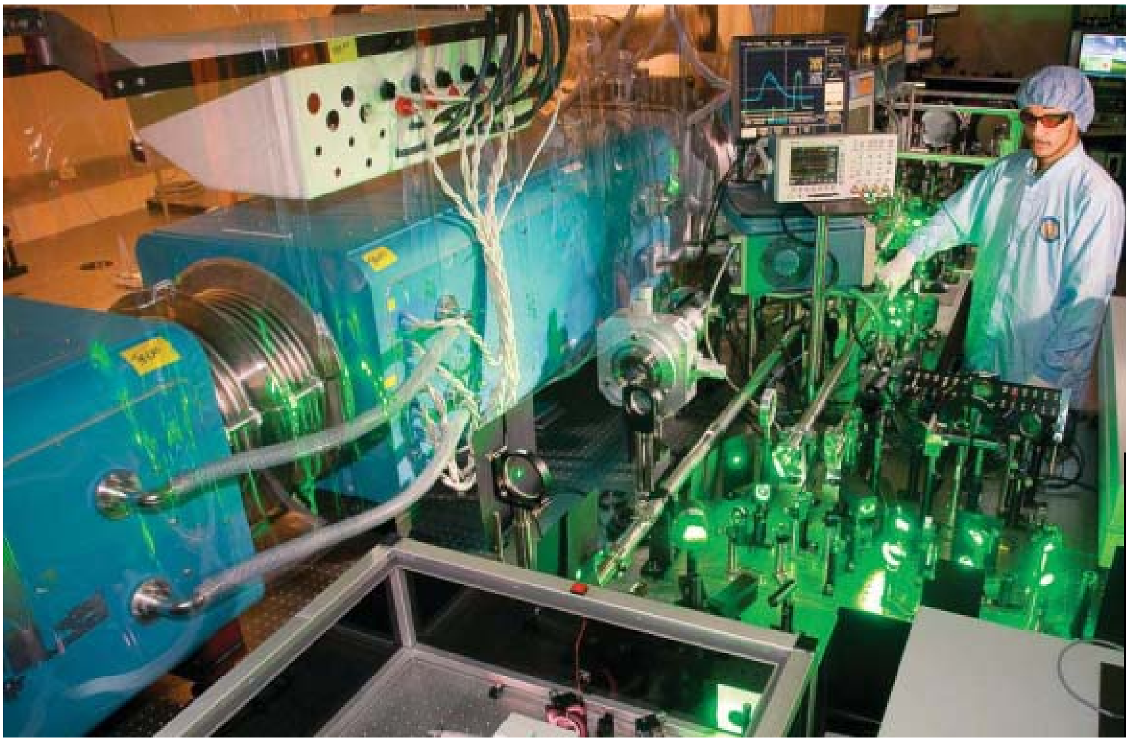
Several readers pointed out that following the wiring instructions in "The Smart Power Strip" by James Turner [Hands On, March] would create a dangerous condition. One wrote: "I was absolutely appalled that James Turner switched the neutral connections (white wire) to the outlets instead of the hot (black wire) connections." Says Turner: "I was absolutely wrong to switch the neutral rather than the hot. The issue is easily fixed, as several readers suggested, by swapping the inputs to the two bus bars so that the hot leg goes into the switches and current monitors and the neutral runs straight to the plugs. Thanks to everyone who pointed out the problem."

The authors of "Vice Over IP" [February] acknowledge their error in referring to a "32-bit-per-second codec." The correct capacity is 32 kilobits per second.

We would like to acknowledge Samuel M. Goldwasser's Web site, Sci.Electronics.Repair FAQ (http://www.repairfaq.org), as the source for the green laser illustration in "Lasers Get the Green Light" [March].

update

more online at spectrum.ieee.org



PETAWATT POWER: The world's highest-power laser delivers nearly 200 joules in less than 200 femtoseconds.

PHOTO: THE TEXAS CENTER FOR HIGH INTENSITY LASER SCIENCE

The Laser at 50

It's the golden anniversary of this fundamental technology

FIFTY YEARS after the first beam of coherent light shone out of a ruby crystal, lasers have expanded in every direction, ranging from as big as three football fields to as small as a few layers of atoms, producing wavelengths from deep in the X-ray regime to far into the infrared. Engineers are pushing the technology ever further, and here are some of the records they have set.

—NEIL SAVAGE

LONGEST WAVELENGTH IN A DIODE LASER

Terahertz radiation, in the infrared spectrum just short of microwaves, is the specialty of the quantum cascade laser—a semiconductor inscribed with a ladderlike series of quantum wells that confine electrons to desired energy states. An electron entering a well creates a photon and a lower-energy electron, and then the electron tunnels to another well and repeats the process. Qing Hu of MIT shaped the wells to achieve long wavelengths, then used a magnetic field to further control the electrons, getting an output of 0.68 terahertz, or 440 micrometers—long enough to serve as an investigative tool in biochemistry and explosives detection.

SHORTEST WAVELENGTH

X-ray wavelengths of 0.15 nanometer, in coherent pulses lasting just 100 femtoseconds, come out of the Linac (for linear accelerator) Coherent Light Source, at Stanford University. The 3-kilometer-long Linac takes short pulses of electrons and accelerates them to nearly the speed of light, then runs them through alternating magnets that jerk the electrons back and forth, making them emit X-ray photons. Physicists use the device to investigate the structure of matter.

FASTEST PULSES

An attosecond is to a second what a second is to the age of the universe. Pulses of X-ray laser light lasting 80 attoseconds—fast enough to take snapshots of quantum-level events, such as the motion of electrons in an atom—have been produced by scientists at the Max Planck Institute of Quantum Optics, in Munich. They fire a femtosecond laser into a neon gas, where extreme nonlinear effects upshift the photons from visible light to X-rays. The process of combining X-rays into a coherent beam shortens the pulse to tens of attoseconds.

HIGHEST ENERGY

One megajoule—enough energy to boil about three quarts of water—is the current record energy output of what is also the largest laser in the world: the 192-beam setup at the National Ignition Facility, in Livermore, Calif. In January, NIF produced that much ultraviolet light in just a few nanoseconds; ultimately it will provide 1.8 MJ. Later

update

this year, scientists expect to shine the combined beams on test capsules containing deuterium and tritium, in the hope of igniting thermonuclear fusion. Project director Ed Moses expects to reach scientific breakeven—when more energy comes out of the system than what goes in—within a couple of years.

HIGHEST POWER

The laser with the highest peak power in the world—1.1 petawatts, about 2200 times the power output of the entire U.S. electrical grid—is run by the University of Texas at Austin. The laser starts with a short, low-energy laser pulse and stretches it to 10 000 times its length, amplifies it to 186 joules, then recompresses it to 167 femtoseconds. The laser provides scientists with enough power to study thermonuclear fusion as well as to examine the nature of plasmas and the properties of dense matter in brown dwarf stars.

SMALLEST LASER

A particle of gold in a silica shell only 44 nm across is the smallest laser yet devised. Scientists from Cornell, Norfolk State, and Purdue universities designed the laser, which exploits surface plasmons—oscillations of electrons that occur where a metal touches an insulator. The laser emitted light in the green spectrum at a wavelength of 530 nm, far larger than the laser itself, which is tiny enough to place on a computer chip or attach to a cancer cell. ❑

Downsizing Nuclear Power Plants

Modular designs rely on "economies of multiples" to make small reactors pay off big

A STANDARD NUCLEAR power plant generates a gigawatt or more of low-carbon power, a boon in this age of anxiety over climate change. The problem is getting the thing built in the first place: At US $7 billion to $10 billion apiece, nuclear plants are tough for even the largest utilities to finance.

President Obama proposes to handle the problem by tripling federal loan guarantees to such plants, to $54 billion. But now a more economical solution is coming under scrutiny: downsizing nuclear plants from gigawatt scale to more affordable units that can be built by the dozen. "Size matters. In this case, small size," says Andrew Kadak, a professor of nuclear science and engineering at MIT.

Small modular reactors, or SMRs, of 70 to 210 megawatts are under construction in China and Russia, and a mix of start-ups and established nuclear technology firms, such as Westinghouse Electric Co., General Atomics, and the Babcock & Wilcox Co., are shopping similarly modest designs in the United States.

This strategy overturns the drive toward economies of scale that has pushed nuclear designers toward ever-larger reactors since the industry's inception. Now the designers may instead rely on the "economies of multiples" that accrue to the mass production of everything from cars to iPhones.

"We want to manufacture in a plant with supply-chain management. This enables you to drive down cost and control the schedule," says John Parmentola, senior vice president for energy and electromagnetic systems at General Atomics. That means building modules, including reactors, that

MULTIPLE MEGAWATTS: Engineering firms are hoping that many smaller reactors will be easier for utilities to finance than a few large ones. *ILLUSTRATIONS: CHINERGY CO.*

are small enough to be shipped on a truck or railcar and designed so that they can be snapped together on-site. "It's almost Lego-style assembly," says Kadak.

These innovators hope to avoid the sprawling construction sites required to build today's gigawatt-plus reactors, which are prone to quality problems and delays. For example, in 2005 France's Areva boasted that its flagship 1.65-gigawatt pressurized water reactor, the EPR, would be completed by 2009. Now the company is admitting that faulty materials and planning snafus have set the completion target back to 2012 and raised the project's estimated cost by 66 percent, to a budget of €5.3 billion ($7.2 billion).

Proponents of SMRs admit that their installation costs may turn out to be as much as or even more than that of today's behemoths, but they argue that the lower risk involved should make SMRs the better deal anyway. Christofer Mowry, CEO of Babcock & Wilcox's Modular Nuclear Energy subsidiary, leads the development of a 125-MW SMR called mPower that he estimates will cost about $600 million in parts and labor. That's comparable to Areva's Olkiluoto plant on a per-megawatt

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3.5 TRILLION ELECTRON VOLTS The level of energy to which each proton was accelerated in the inaugural run of the Large Hadron Collider, outside Geneva, on 30 March.

MODULAR DESIGN: Chinergy Co. plans small pebble-bed nuclear reactors.

basis, but because mPower could be built in bite-size chunks with a relatively modest overhead investment, using the same reliable light-water reactor technology, it's much more likely to work and to start working on schedule. That means the cost of financing and insuring the project should be much lower. "You could have 10 to 20 percent cheaper electricity," says Mowry.

Jack Baker, vice president for energy and business services at Washington state–based Energy Northwest, sees mPower as a clean and economically viable way to meet a 250- to 350-MW increase in demand for base-load capacity. His public power cooperative is taking extra care in assessing investments, having defaulted on $2.25 billion in bonds in 1983 thanks to an overly ambitious reactor construction plan.

Firms are also developing other concepts for small-scale reactors. Take Beijing-based consortium Chinergy Co., which just launched construction of a 210-MW SMR using a pebble-bed reactor, so-named for its 6-centimeter-wide fuel pellets. Protective carbon sheaths encapsulating the pellets' fissile fuel cores allow pebble-bed reactors to operate at double the temperature of a large reactor, at which point they can generate at up to 50 percent higher efficiency and sell waste heat to industrial processors. The fuel's design also ensures that if the cooling system should fail, the reactor will shut itself down passively, rather than melt its way down. Chinergy's permit application seeks permission to build up to 18 of the pebble-bed SMRs at its site in Shandong, where coal-fired chemical industries produce some of China's dirtiest air.

General Atomics, meanwhile, sees an advanced SMR design that breeds and burns its own fuel as the answer to the nuclear waste quandary, which has been heightened by the cancellation of the Yucca Mountain repository. General Atomics' reactor should be able to go 30 years before refueling, about 20 times as long as light-water reactors can go.

Large-scale breeder reactors analogous to General Atomics' Energy Multiplier Module, or EM2, have so far proven unwieldy and uneconomical. France's 1250-MW Superphénix breeder cost €9 billion and ran just 174 days before being shuttered in 1998 [see "Nuclear Wasteland," *IEEE Spectrum*, February 2007, http://spectrum.ieee.org/nuclear-wasteland]. However, EM2's modularity makes it safer and more economically viable, says Parmentola. Microsoft's Bill Gates recently endorsed that view by investing in Bellevue, Wash.–based TerraPower, which is talking up a similar breeder SMR.

However, there are political objections to SMRs. Precisely because they are more affordable, they may well increase the risk of proliferation by bringing the cost and power output of nuclear reactors within the reach of poorer countries.

Russia's first SMR, which the nuclear engineering group Rosatom expects to complete next year, is of particular concern. The *Akademik Lomonosov* is a floating nuclear power plant sporting two 35-MW reactors, which Rosatom expects to have tethered to an Arctic oil and gas operation by 2012. The reactor's portability prompted Greenpeace Russia to call this floating plant the world's most dangerous nuclear project in a decade.

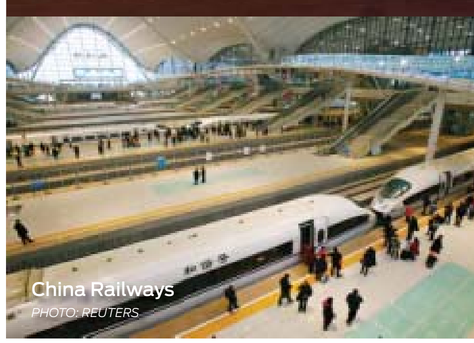
SMRs may be smaller than today's reactors. But, politically at least, they're just as nuclear. —PETER FAIRLEY

update

Tech in Sight

Three ways to move people—fast, faster, fastest

Segway/General Motors EN-V
PHOTO: GENERAL MOTORS



China Railways
PHOTO: REUTERS

Boeing X-51
ILLUSTRATION: BOEING

HERE WE ARE in the future, yet we're still wasting time stuck in traffic and trussed in a pressurized cabin for long hours in flight. For the speed boost that was promised us in so many futuristic movies, look to these three technologies.

SEGWAY/ GENERAL MOTORS EN-V

The Segway Personal Transporter was billed as revolutionary, but you still don't see lots of people riding to work on them. The commuter version of the machine has a top speed of 20 kilometers per hour (12.5 miles per hour), faster than walking, but still too slow to get you across town. So how about making the Segway more like, um, a car? The scooter maker collaborated with General Motors to design a concept vehicle called EN-V, for electric networked-vehicle. This two-person vehicle uses a Segway-like drivetrain, but it can achieve twice the speed: 40 km/h (25 mph). Oh, and it has a roof, so rain won't be a problem.

CHINA RAILWAYS WUHAN-GUANGZHOU TRAIN

The world's fastest rail line, the new China Railways Wuhan-Guangzhou service, opens this year. The Hexie Hao, or Harmony Express, reaches 350 km/h (217 mph), beating the current record speed of 320 km/h set by France's TGV. In a trial run, the Chinese train reached nearly 400 km/h (250 mph)—faster than a Formula 1 racing car. The service will cover the 1000-km route between Wuhan and Guangzhou in 3 hours, a journey that takes half a day by car or regular rail. The Harmony Express is part of China's massive rail effort, which aims to build 30 000 km of railways in the next five years.

BOEING X-51 HYPERSONIC AIRCRAFT

Imagine boarding a plane in New York City and stepping out just 3 hours later in Sydney—a trip that would normally take an entire day. A supersonic aircraft flying at 10 times the speed of sound—Mach 10—could do it, but as the demise of the Concorde showed, the economics of supersonic travel are no breeze. Still, there's hope. Sometime this year, the X-51, developed by a consortium that includes the U.S. Air Force, NASA, and Boeing, will test its air-breathing scramjet—or supersonic combustion ramjet—engine to achieve Mach 7, which is 10 times as fast as a conventional airliner. Unfortunately, the missile-shaped X-51 is still more like a missile than an airplane: After this flight it will plunge into the ocean. So wannabe hypersonic travelers will have to wait for a future model. —ERICO GUIZZO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update

BACKUP POWER: Batteries with flowing electrolytes could be key to smoothing out intermittent wind and solar power. *PHOTO: ZBB TECHNOLOGIES*

Batteries That Go With the Flow

Flow batteries promise to even out fluctuations in solar and wind power

If we're ever to run our electric grid on the on-again, off-again power that wind and sun provide, we're going to need better batteries. About half a dozen types of batteries are now grid-ready, but a 30-year-old technology known as a flow battery could be the best bargain.

In place of the solid electrodes of a conventional battery, flow batteries use two liquid electrolytes that react when pumped through a cell stack. The battery is broken down into a cell stack and two large electrolyte tanks; as the electrolyte flows past a porous membrane in each cell, ions and electrons flow back and forth, charging or discharging the battery. Recharging simply means putting in fresh electrolyte; to increase the energy storage, you merely need to make the tanks larger.

Such batteries are already used for backup power at factories and cellphone towers. Now manufacturers are attracting millions of dollars in venture capital to develop the batteries for grid-level systems. The U.S. Department of Energy (DOE) has poured in US $31 million in Recovery Act funds to jump-start five utility-scale projects.

Cost is critical for grid storage, and this is where flow batteries deliver. Some zinc-bromine devices in the works could store energy for less than $500 a kilowatt-hour, a third as much as for lithium-ion batteries and about three-quarters as much as for its toughest competitor, the sodium-sulfur battery.

The inherent architecture of flow batteries makes them particularly safe, says Craig Horne, CEO of flow-battery start-up EnerVault, in Sunnyvale, Calif. "With a flow battery you can have megawatt-hours of energy stored [in the electrolyte tanks], but only a small fraction of the volume is in the stacks at any instant," Horne says. "It's simple to shut off the electrolyte supply."

There are many chemical reactions around which such a battery can be designed, but those involving vanadium and zinc-bromine are the most familiar. Vanadium systems have been tied to the grid to reduce peak loads and store wind energy, mostly in Japan by Sumitomo Electric Industries. In the United States, ZBB Energy Corp., in Menomonee Falls, Wis., and Premium Power Corp., in North Reading, Mass., sell trailer-transportable zinc-bromine systems that store megawatt-hours of energy. ZBB tested its 2-megawatt-hour system in California for reducing peak loads in 2007, while Premium Power will test seven 2.8-MWh systems for three years with DOE-allocated Recovery Act money.

Many other grid-ready flow-battery systems will be on the market within five years. Beijing-based Prudent Energy is likely to be a major player. And start-ups such as Primus Power, EnerVault, and Deeya Energy are working on newer chemistries.

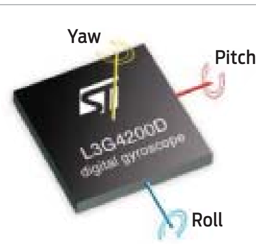
Sodium-sulfur batteries have one edge over flow batteries: They've been tested extensively in the field. The only manufacturer, Tokyo-based NGK Insulators, has sodium-sulfur storage in Japan capable of producing 270 MW. Utilities in the United States have installed 9 MW of capacity, with projects of an equal amount on the way.

However, the advent of the smart grid could make these distinctions moot. Utilities are now looking for a mix of energy storage technologies, flow batteries included.

"The technology is well understood," says Dan Rastler, an energy-storage expert at the Electric Power Research Institute. "The biggest challenge is adapting to utility scale and doing complete system integration, which also involves power electronics and controls." In the next two to three years, he adds, flow-battery technology will get plenty of opportunities to prove its mettle. —Prachi Patel

news briefs

Three Axes in One Device



STMICROELECTRONICS

To orient themselves properly, smartphones require not just GPS capability but also an electronic compass, an accelerometer, and increasingly, digital gyroscopes, which can sense changes in an object's axis of rotation. Up until now, gyroscopes measured movement around the three axes with three sensors—one for pitch, one for yaw, and another for roll. But in February, STMicroelectronics unveiled a 4- by 4- by 1-millimeter gyroscope whose single sensing structure tracks all three angular motions. The device draws only 6 milliamps; two years ago, each one of ST's single-axis devices drew 5 mA. —*Willie D. Jones*

SMALLEST SUPERCONDUCTOR A nanometer-wide sheet of four pairs of molecules showed no resistance to electric current at 10 kelvins, according to scientists at Ohio University, in Athens.

Light at the End of the Chip

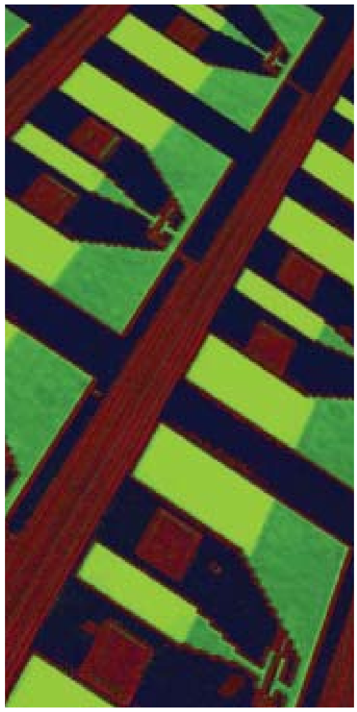
IBM's low-power germanium photodetectors may bring optical interconnects to microprocessors

A BETTER PHOTODETECTOR could bring optical data transfer between computer chips closer to reality, according to the IBM researchers who created the device. Such an advance could overcome a looming speed limit—the rate at which data can move between a processor's cores, or from one chip to another, over copper wire.

The detector is built from a germanium crystal that amplifies signals tenfold, operates at 40 gigabits per second, and consumes one-twentieth the power of previous efforts while producing less noise. Solomon Assefa and his colleagues at IBM's T.J. Watson Research Center, in Yorktown Heights, N.Y., reported on their work in the 4 March issue of *Nature*.

"The idea is to build all the different components we need to replace copper wires," Assefa says. The photodetector "was basically the last piece of the puzzle." Niche applications for the detectors may come soon, he adds, but it may be as long as 10 years before they can be used in high-end computing.

Germanium is attractive because it's compatible with silicon and is already used in complementary-metal-oxide semiconductor manufacturing. But a germanium avalanche photodiode, which amplifies a signal by using an incoming



GERMANIUM JUXTAPOSED: IBM integrated nanoscale germanium-based avalanche photodetectors on a silicon chip.
IMAGE: IBM

photon to create a cascade of electrons, produces too much noise to differentiate the signal. In 2008, Intel came up with a solution that used a layer of germanium to detect the photons and a layer of silicon to do the amplification, but the sheer size of the device, about a micrometer thick, limited signal speed to about 10 Gb/s.

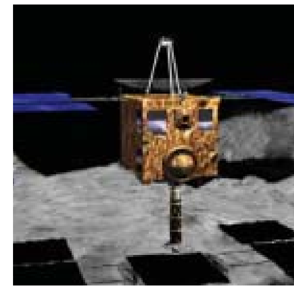
The IBM team overcame the limits of germanium by controlling the characteristics of electric fields in the device over a distance of just a few nanometers. They placed a series of tungsten plugs in a thin layer of germanium and attached lines of copper to the plugs. The close spacing of the plugs, 200 nanometers apart, combined with the thinness of the germanium, 150 nm thick, created very strong electrical fields in the germanium, which sped up the electrons. It also narrowed the range of energies of the charge carriers—both electrons and holes—which reduced the noise by as much as 70 percent.

Generally engineers deposit germanium on silicon through epitaxy, but because the two elements have different crystalline structures, strain between the materials causes defects. The IBM group used a rapid-melting growth technique instead.

The researchers started with a strip of silicon that would later act as a waveguide. On top of that they deposited a thin layer of silicon oxynitride that would isolate the silicon from the germanium so that the charge carriers wouldn't pass between them in the finished device. They made a tiny hole in the oxynitride to expose a bit of the underlying silicon, then put down a thin layer of germanium on top to match the waveguide underneath. After adding another layer of oxynitride to encapsulate the germanium, they then heated the whole thing up until the germanium melted. Because the germanium was touching the still-unmelted silicon through the hole, as it cooled, the silicon acted as a crystalline seed, imprinting its structure onto the germanium, which formed a single crystal.

These are the first detectors that can amplify the input tenfold and work at 40 Gb/s, "which will be extremely important for on-chip interconnects," says Franz Kaertner, an electrical engineer at MIT, who was not involved in the project. Though integrated germanium photodetectors have been demonstrated before, none performed the amplification in the germanium layer itself, and none operated at such low voltage. "In that context it is unique," he says. The challenge now, he adds, is to reduce the current that runs through the device in the absence of an input of light, a type of noise called dark current. —NEIL SAVAGE

J.R.C. GARRY



news briefs

Fetching a Piece of Heaven
A small, severely damaged spacecraft named Hayabusa, launched by the Japan Aerospace Exploration Agency, is limping back to Earth with a jury-rigged ion drive that would have made *Star Trek*'s Scotty proud. Already seven years into its planned five-year mission to retrieve soil samples from an asteroid, the probe faces one last round of hazards before its midnight landing in Australia with a sample canister sometime in June. Even if the canister turns out to be empty, the probe will still have brought back useful scientific observations, demonstrated the technology, and provided an inspirational example of ingenuity and perseverance. —*James Oberg*

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the big picture

VEHICULAR VENDING MACHINE

They say that the difference between men and boys is the size of their toys. Here's the man-size version of the Matchbox car garage, which turned legions of lads into gearheads. It's one of two 60-meter-tall glass towers connected by an underground tunnel to Volkswagen's vehicle production facility in Wolfsburg, Germany. Each tower stores 400 cars. A European car buyer, having chosen to pick up a new vehicle at the factory, can watch as a robotic arm snatches the car from a shelf and brings it to the ground. The car arrives without being driven so much as a meter.

PHOTO: SEAN GALLUP/ GETTY IMAGES

tools & toys

Pogoplug 2
Cloud Engines; US $129
http://www.pogoplug.com
PHOTO: CLOUD ENGINES

YOUR VERY OWN CLOUD

Cloud Engines' Pogoplug is a $129 device that puts up to four storage drives on the Internet

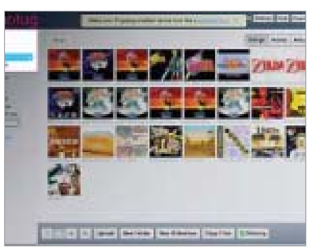
As WIRELESS Internet connectivity gets better, cloud storage—storing your data "out there," on Internet servers—seems more reasonable. But which cloud? It seems risky to store all your personal information on someone else's server. The company could go bankrupt, get hacked, or leak your data through sheer incompetence. Then there's the expense, usually in the form of a monthly fee. Meanwhile, storage drives are cheap, and home networking is easy. Why not set up your own cloud?

Cloud Engines, a 2007 start-up in San Francisco, has come up with a remarkably simple way to do just that. Its Pogoplug 2, a box about the size of a Wi-Fi router, connects to your home network with an included Ethernet cable. Plug one or more storage drives into its four USB ports, register your Pogoplug on the company's Web site, and you're now officially running a file server. It's that easy.

You can access the drives via your Web browser or with an application that runs on Windows or OS X. Even better, there's an iPhone app. By default, files are accessible only to you, but you can give anyone permission to read, and also write, any file or folder. You can also set up the Pogoplug to back up the computers on your home network just by specifying the folders. When files in those folders change, Pogoplug copies them.

If you can access your data from anywhere, can others as well? They may be able to if you don't change the password for the root account, which by default is the same for every Pogoplug. Anyone comfortable with a Unix terminal interface and a log-in utility like SSH could connect and gain root access, if the Pogoplug has a routable IP address or if it's on an accessible wireless network. (Cloud Engines says that SSH will be turned off by default in an upcoming software update.) You can easily change the password, but not via the Web page or applications: You, too, need to be comfortable with a Unix terminal interface. Changing the Pogoplug's root password from its settings Web page is a sorely needed option.

At least you don't have to worry about accessing your device if Cloud Engines goes out of business. A copy of the Pogoplug's source code is in an escrow account, to become open source in that event.



REMOTE ACCESS: The Pogoplug [above, in pink] lets you put photo albums [left] and other files online.
PHOTO: CLOUD ENGINES

The Pogoplug does more than simple file sharing. You can be on the other side of the planet and stream any songs, photos, and videos that were copied to the device (so long as the videos aren't encoded with copy protection). To be sure, the music-playing interface is noticeably bare bones if you're used to the power and flexibility of iTunes. And for video, your outbound bandwidth from home needs to be excellent, or streaming will be unacceptably slow. My home DSL connection in Massachusetts wasn't up to the task. I was able to watch a movie after using some included software that reprocesses video into a more streaming-friendly version, but it takes about a day to process a standard-length motion picture. Pogoplug does much better with photos—the included software lets you quickly create slideshows and share them with anyone.

Strictly speaking, the Pogoplug isn't a cloud—at least, not in the sense that if your house burned down your data would be safely in the ether. But if you need to access your data from anywhere, the Pogoplug is about as easy as it gets. This is a file server you could direct your parents to, if you have files you need to send them. In fact, this is a file server your parents could run themselves.

—Harry Teasley

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MIND OVER MATTER

A $199 headset controls objects via brain waves

IT WAS a typical technology product party—a swank Beverly Hills hotel, loud music, and tiny sausages on sticks. Then partygoers started zooming around in mind-controlled electric carts.

Yes. Mind-controlled electric carts.

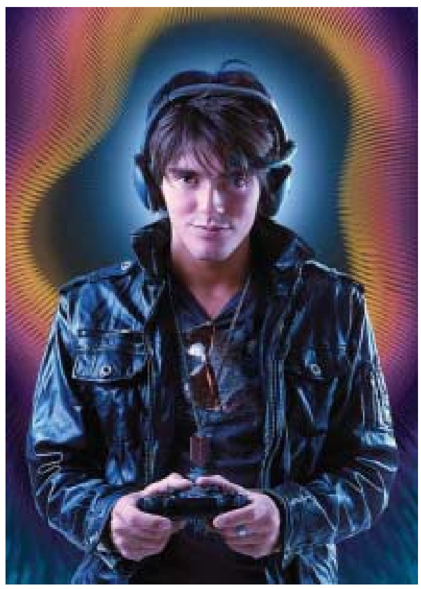
The drivers were wearing NeuroSky MindSet headsets. The devices were launched last July, but they were being introduced at this October party as a prelude to a possible TV game show where contestants might use their minds to ignite or levitate various objects. A show hasn't materialized yet, but since the beginning of this year, NeuroSky's technology has been used in toys from Mattel, Roll 7, and Square Enix. Players use the power of their minds to float an actual ball through perilous mazes, explode on-screen objects, or reveal hidden avatars.

It's not all fun and games, though. Initially marketed as both a game and a meditation tool, the MindSet is being deployed in studies that attempt to improve the focus of children with attention-deficit, sleep, and post-traumatic stress disorders, as well as the memories of patients with Alzheimer's disease. It may soon be used in the automotive and medical industries.

The US $199 headset is a simplified version of an electroencephalograph. Scientists have long understood that different EEG waves are linked with different mental states: Alpha waves, at 8 to 12 cycles per second, are associated with a restful, meditative mind, and beta waves, at 13 to 30 cycles per second, with an alert, engaged mind. Primitive biofeedback machines that emit different sounds for each wave have been used since the 1970s to help meditators increase their alpha wave activity.

The MindSet detects changes in brain-wave patterns via metal sensors at the front and back of the head and at the earlobes. A chip digitizes and transmits that information wirelessly via Bluetooth or RFID to a computer or PDA, which in turn translates it into commands that go back to the device.

Concentrating on an object or thought produces different patterns of brain waves; after the headset calibrates itself to the individual, its algorithms detect those characteristic patterns. As the electric cart drivers, for example, increased their focus on a point ahead or thought of moving forward, the carts moved faster in a straight line. The first person to reach the finish line won.



MIND THE GAP: MindSet wearers can control games and race carts using brain waves.

PHOTOS: TOP: NEUROSKY; BOTTOM: COURTESY OF "THE DOCTORS" AND CBS TELEVISION DISTRIBUTION

Cart racing is just a start. NeuroSky's sexiest future app is an actual thought-controlled "smart" car. This is no pipe dream, says the company; it's working with unnamed automakers, although not for any mission-critical tasks like steering. Potential applications include mental control of the car's temperature and song selection.

EEGs are normally taken in quiet, low-lit labs with minimal electromagnetic noise that can interfere with getting a clear signal. NeuroSky has already developed electronic filters that cancel out electronic signals from light, muscle movement, and the surrounding environment. The San Jose, Calif.–based company now must adapt those filters to cars so they pass safety certifications.

"We've also had inquires from cellphone companies," says CEO Stanley Yang, who was born in Taiwan and earned an EE degree from the University of California, Berkeley, in 1986. "They are interested in the levels of distraction caused by using a cellphone while driving."

The big bucks may lie in the video-game industry, though probably not right away. Last year a San Francisco company, Emotiv Systems, launched a $300 headset for computer-based games; its 14 saline sensors also read brain waves that correlate to your facial expressions. *IEEE Spectrum* reviewed the device in January 2009 and found it wanting.

For its part, NeuroSky is working with several game platforms on a suite of mind-controlled console games. The company also anticipates that developers will release mind-game iPhone apps by August.

"We're expecting this approach to be a game changer—no pun intended—by taking interactivity to a new level in that industry," says NeuroSky marketing director Tansy Brook. "Imagine actually being able to cast a spell or kill a monster using just your thoughts. Harry Potter would be proud." —SUSAN KARLIN

education

Making Engineers Smart—and Savvy

A new MIT leadership program grafts social skills onto problem solvers

PUSHED BY an entrepreneurial alumnus, MIT is determined to retire the stereotype of the antisocial engineer.

Come June, the Bernard M. Gordon–MIT Engineering Leadership Program will graduate its first class. The program is designed to give budding engineers skills that go beyond the technical—risk assessment, decision making, interpersonal relations, resourcefulness, and flexibility. Gordon, a successful inventor, made it all possible by donating US $20 million.

"Bernard's complaint—shared by many industry professionals—is that engineering students he's hired from top colleges have been very smart and can solve difficult problems but don't have the perspective and street smarts needed to solve customers' problems, bring in a project on budget and on schedule, and motivate others," says Joel Schindall, an MIT professor of electrical engineering. Schindall, who has a 35-year aerospace and telecommunications industry background, runs the program with Edward Crawley, a professor of aeronautics, astronautics, and engineering systems.

Schindall says that new areas of physics and engineering, such as quantum mechanics and nanotechnology, require faculty with stronger scientific backgrounds, and the new hires have come at the expense of practicing engineers. That trend has drained the universities of role models. Meanwhile, social media have an egalitarian effect that's transforming the way organizations operate. "Today's students tend to do things by consensus and don't appreciate the strengths of a hierarchical system for deciding things," says Schindall. "You're deemed too bossy if you try to direct things. But projects go downhill because [the students] haven't organized them well." The result is an entire generation of managers who don't know how to get the most out of their engineers and engineers who don't know how to make their innovative voices heard.

That was never a problem for Gordon himself. The MIT-trained electrical engineer developed the first fetal heart monitor and some of the earliest high-speed analog-to-digital converters. He founded and led Analogic Corp., an airport security and medical imaging firm in Peabody, Mass., and more recently founded the medical imaging firm NeuroLogica Corp., in Danvers, Mass. The money he gave MIT to start the leadership program is but a fraction of some $300 million he has committed to philanthropic and charitable causes.

THE DECIDERS: A new engineering leadership program at MIT teaches risk assessment, flexibility, and decision making. PHOTO: BRUCE MENDELSOHN

Before the program rolled out in September of 2008 with an initial class of 16 (to be expanded to 30) competitively chosen juniors, Gordon, Crawley, and Schindall spent a year honing the curriculum with the help of professionals from industry, academia, and the military. The students, now seniors, spend roughly 12 hours a week with industry mentors and on in-class exercises that develop initiative, responsibility, decision making in the face of uncertainty, negotiation, advocacy, and ethics. One example: creating and executing a team plan to move a (mock) radioactive object from one side of a room to another without touching it. Less intensive versions of the course are available to other students.

Ultimately, Gordon, Crawley, and Schindall hope MIT can inspire such training at other universities, leading to more competitive products and the United States' regaining its technical edge. Gordon has also started similar programs at the Technion–Israel Institute of Technology, in Haifa; the University of California, San Diego; and Tufts and Northeastern universities, in Massachusetts.

Even before the first class departs for the world of work, the students have become more effective, fulfilled, and mature. "Reports from employers with whom students interned this past summer were staggering," Schindall says. "One student, whose company raved about the new idea that she proposed and implemented, told us that without this program, she wouldn't have had the courage to speak up about her ideas." —SUSAN KARLIN

TO PROBE FURTHER For more information about the Bernard M. Gordon–MIT Engineering Leadership Program, see http://mit.edu/gordonelp.

careers

HUGH KRETSCHMER/GETTY IMAGES

IT'S LONELIER AT THE TOP

Seven percent of engineering managers are women, but things are looking up

Betty Shanahan remembers often being the only woman in a meeting room. Someone would curse and then immediately look at her and say, "Sorry, Betty." "They were doing it as a nice gesture," says Shanahan, now the executive director of the Society of Women Engineers, in Chicago. "But the subtle message is 'Oh, I can't swear because Betty's here.' " It's a trivial example, she admits, but add up enough incidents like this one and it says you don't belong.

For women, leadership roles in engineering can be isolating. The U.S. numbers are typical—and daunting. Female undergraduate engineering majors are outnumbered by men four to one. When they join the workplace, the ratio gets only more dismal: 9:1. Move up the ladder into management and it's 14:1. Yes, according to the U.S. Bureau of Labor Statistics, in 2006 just 7 percent of engineering managers were women. And although ever more women are becoming engineers, it will take years for them to rise through the ranks.

It's not that males treat their female peers with less respect than they do colleagues of their own gender, says Shanahan; you just happen to be different from everybody else and can feel out of place. The comparison is more pronounced in electrical engineering firms, because EE lags other engineering disciplines when it comes to recruiting women.

Even other women in the workplace can have an unconscious bias, believing that managers and executives should be stereotypically masculine: aggressive, dominating, and decisive. The belief in the corresponding female stereotype—that women are collaborative, nurturing, and team oriented—starts at an early age, according to Pat Heim, CEO of the Pacific Palisades, Calif., consulting firm The Heim Group and an expert on gender issues in the workplace. As a result, Heim says, men are comfortable with hierarchy and know where they fit, while women want to share power equally.

Not that there's anything wrong with that, says Sharon Nunes, vice president of IBM's Big Green Innovations program. Most women engineers she knows do in fact fit the stereotype. "They're much more collaborative—let's figure out a way to do this so that everybody wins," she says. Even five years ago, management style was much more "top-down, military," where bosses made decisions and gave orders. "Corporate America is much more about collaboration these days," she says. The result is that women are more welcome in executive circles.

Besides, Nunes says, being different can also be a good thing. People will ask for your feedback and pay attention to what you have to say. "If you're one of three or four women out of a hundred, then people recognize you," she says. "I look at it as an opportunity to make my voice heard."

It's not only companies that are changing, but also husbands. They're much more willing to see their wives take on big jobs outside the home. Chris Coon says that when she was promoted to a vice president position in national operations at Denver-based Qwest Communications, her husband took early retirement.

Technology helps, too. Running a meeting or making a presentation remotely is now easier, as is staying home with a sick child or watching a kid's soccer match—BlackBerry in hand, of course. Both men and women have benefited from that, Coon says.

Another surprising boon for women engineering managers could be the free market's obsession with share prices. Catalyst, a New York City–based nonprofit aimed at advancing women in business, recently ranked Fortune 500 companies by participation of women in top management levels and found that the more diverse those circles, the better the company's financial results.

Shanahan of the Society of Women Engineers says the difference isn't just financial. "Particularly in engineering, you get better results if you have diversity," she says. "You make better products, you make better decisions." —Prachi Patel

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books

Two Beautiful Minds, One Perfectly Rendered

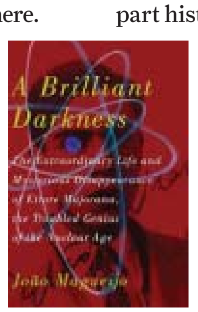
A new biography of geometry genius Grigory Perelman is enjoyable, but not as successful as one of unheralded physicist Ettore Majorana

ON THE evening of 26 March, 1938, a young Italian nuclear physicist boarded a ferry in Palermo, Sicily. At the time, Ettore Majorana—a working colleague of nuclear pioneer Enrico Fermi, a friend to uncertainty principle developer Werner Heisenberg, and an undisputed genius in his own right—seemed poised to shake up or even revolutionize physics. Instead, he was never heard from again. Some believe Majorana committed suicide. Others suspect he slipped away to start a new life elsewhere.

Less eerily but no less strangely, in December 2005, Russian mathematician Grigory Perelman quit his job at the Steklov Mathematical Institute in St. Petersburg. The preeminent genius who two years earlier proved the Poincaré conjecture, one of the greatest problems in mathematics, simply stopped working. He reportedly hasn't done any math since and today lives with his mother.

New biographies of these renegade "beautiful minds" are now on bookshelves. Like their subjects, both books are idiosyncratic.

A Brilliant Darkness: The Extraordinary Life and Mysterious Disappearance of Ettore Majorana, the Troubled Genius of the Nuclear Age by João Magueijo, in fact, carves out its own subgenre. Rarely can the phrases "page-turning mystery" and "creative introduction to modern physics" be uttered about the same tome. Part thriller, part biography, part history, part scientific primer, *Darkness* is a remarkable book because of Majorana's singular nature and incredible story, but also because Magueijo is a superb storyteller and, as a theoretical physicist at Imperial College London, an ideal biographer of Majorana. (In the interest of full disclosure, this reviewer once worked on a television pilot about cosmology hosted by Magueijo, for the Science Channel.)



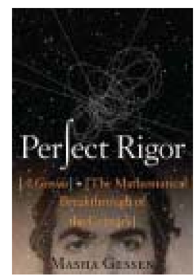
A Brilliant Darkness: The Extraordinary Life and Mysterious Disappearance of Ettore Majorana, the Troubled Genius of the Nuclear Age
By João Magueijo; Basic Books, 2009; 280 pp.; US $27.50, ISBN: 978-0-465-00903-9

From its first pages, *Darkness* grabs the reader with the grand mystery at its core—that strange night in 1938. It's no spoiler to say that it never finds a definitive answer; Magueijo captivates the reader by navigating the tale's historical, scientific, and biographical currents—at turns contemplative and brooding like its subject, acerbic and cheeky like its author.

Not so surprisingly for people working in such highly abstract fields, both biographical subjects suffered from personality disorders that probably put them somewhere on the autism spectrum. Rendering such characters sympathetic is no easy task. But Magueijo makes Majorana, as well as the physics he pioneered, approachable and engaging.

In *Perfect Rigor: A Genius and the Mathematical Breakthrough of the Century*, author Masha Gessen does not similarly succeed. Although her subject never gave her an interview, she clearly talked with nearly everyone else in his puzzling life, and her reconstruction of Perelman makes *Perfect Rigor* an enjoyable narrative. But all too often she skips over the mathematics in favor of gumshoe reporting.

Core subjects—topology, geometry, and Jules Henri Poincaré (1854–1912)—are outlined sparingly and in soft focus. So the chapters that discuss Soviet-era mathematics as a kind of ersatz samizdat for would-be dissidents offer no fascinating historical digressions but merely teasers that leave a reader yearning for more. As a nonmathematician, I came away with an unsatisfied curiosity about the very thing that makes Perelman fit for a biography: the mathematical brilliance of his proof.



Perfect Rigor: A Genius and the Mathematical Breakthrough of the Century
By Masha Gessen; Houghton Mifflin Harcourt, 2009; 256 pp.; US $26.00; ISBN: 978-0-15-101406-4

To be sure, Gessen elegantly sets the stage, revealing the Poincaré conjecture's lineage from Euclid to modern-day topology. But even here, there's not a single diagram or illustration to help make sense of the many abstruse (but still geometrical!) underlying concepts. Ultimately, I learned more about the Poincaré proof from a Wikipedia entry.

Near the end of *Perfect Rigor*, mathematician Jim Carlson addresses the book's author about Perelman's oftentimes murky proofs. "There were many methods and ideas," Carlson says. "It's always hard to communicate these to a general audience, but I hope you can do that when you write your book."

In the final analysis, *A Brilliant Darkness* fulfills Carlson's conjecture, while *Perfect Rigor* does not.

—MARK ANDERSON

 BY ROBERT W. LUCKY

The Ephemeral Now

RIGHT NOW, things are happening out there. I know, because I can hear the buzz of terabytes in the ether. If I listen closely, I can hear the singing of flying tweets, and if I squint I can see the haze of raging blogs. There is a melody and a dance there that I might discern, and if I could, I would know what is happening right now.

I confess that I used to be a futurist. I would predict things, and people would sometimes pay attention as if I really knew something about what would happen in technology. I was seldom right. But in the futurism business you're rarely found out, because by the time the future arrives, people have forgotten your misguided predictions. Still, I gave up on futurism. Talking about the past, when you've lived there as a kind of technological Forrest Gump, is a lot more legitimate and easier.

However, through the years I have gradually come to appreciate that the really important predictions are about the present. What is happening right now, and what is its significance? The Internet's progression from static to streaming—and solitary to social—has not only made predicting the present possible, it has redefined the whole concept of what we mean by "right now."

A century ago, "now" lasted about a week. There was a lot of lag in the system. More recently, but before the Internet, we were content with one or two daily updates from the morning newspaper or the evening news. Paradoxically, our world of technology was even slower—our leading magazines and journals were often a year behind, and even word of mouth from meetings and conferences lagged by months.


DAN PAGE

How the world has changed! In the few moments since you began reading this, terabytes have flowed across the global grid. If we listen we can hear the cries from the void, the tears and laughter, the sorrows and the joys. All that noise can be processed and distilled, and we can search for keywords and phrases and apply tools such as automated sentiment and social-network analysis. We can analyze query data and track locations in real time. We can study patterns and look for correlations. It's an immense trash pile, but there's a pony in there somewhere—lots of them, in fact.

What subjects are being discussed most frequently? How is Twitter feeling today? What Web links are particularly busy? What videos are going viral? What are the instant polls telling us? What trends are appearing? Which individuals seem to be the opinion leaders at this moment?

Governments can look for signs of impending revolution and social unrest. Companies can track the real-time popularity of their products and learn where their brands are weakest. Analysts can use query behavior as a leading indicator of home sales. Social experiments can be conducted by changing a few HTML codes.

As the evanescent "now" slides by and becomes the recent past, all this distillation is available for instant retrieval and response. The feedback loop gets tighter and tighter and the delay in the system gets ever shorter. As engineers, we should be leery, perhaps, knowing what can happen to systems with feedback as the gain is increased. But here we are dealing with an immensely complicated system. Some even believe that a "global brain" is evolving, in which we individuals serve merely as neurons with no comprehension of what the brain itself is thinking. Some praise this amassed heterogeneous input as the "wisdom of crowds," while others warn of a dangerous, ever-growing herd mentality.

More than half of all U.S. Web users are on Facebook, for example, and they spend an average of 7 hours a month on the site. The connectivity of the global network, its speed, and its instantaneous nature continue to increase.

I've just been checking on some of the Web sites that monitor what's happening out there. So I know exactly what is happening right now. Oops! That knowledge just slipped into the past. I no longer know what is happening now. Just give me a minute here... ❑

A long time ago, in a suburb far, far away...

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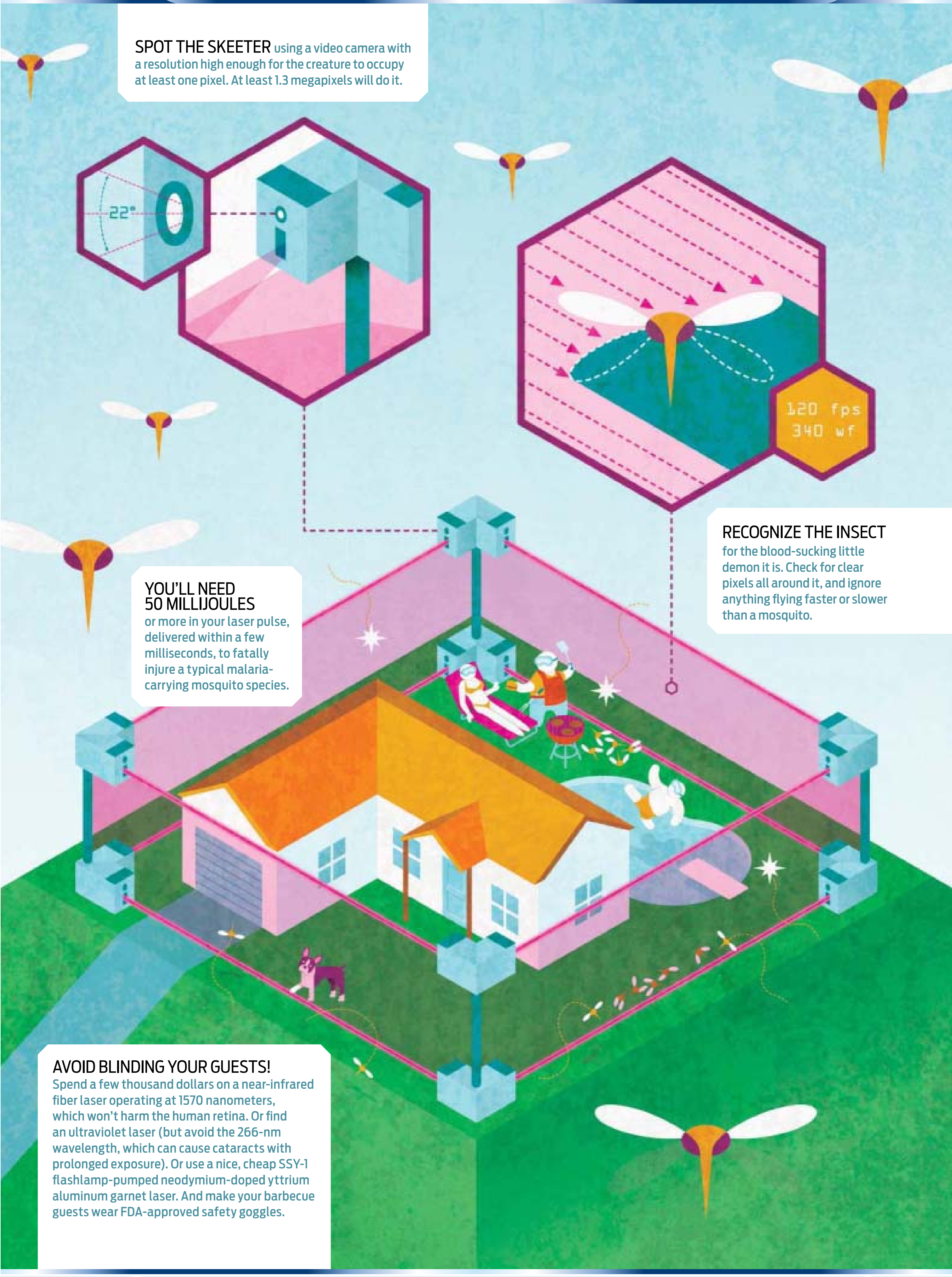
BACKYARD STAR WARS

BUILD YOUR OWN PHOTONIC FENCE TO ZAP MOSQUITOES MIDFLIGHT

BY JORDIN KARE // ILLUSTRATIONS BY JUDE BUFFUM

"So, how would you kill mosquitoes with a laser?" Nathan *Myhrvold asked us.* Lowell Wood, Rod Hyde, and I smiled. *The three of us were meeting* with Myhrvold in the fall of *2006, in an office* at Intellectual Ventures Management, *a company* in Bellevue, Wash., that he founded in 2000 *to create and invest* in inventions. We smiled because we *had just spent* the afternoon arguing over that very question, *scribbling ideas* and calculations on a whiteboard, *and had come up* with what we thought was a pretty *good answer: a* "photonic fence" in the form of a row of *vertical posts* that would use optical sensors and lasers *to spot, identify,* and zap bad bugs on the wing.



SPOT THE SKEETER using a video camera with a resolution high enough for the creature to occupy at least one pixel. At least 1.3 megapixels will do it.

RECOGNIZE THE INSECT for the blood-sucking little demon it is. Check for clear pixels all around it, and ignore anything flying faster or slower than a mosquito.

YOU'LL NEED 50 MILLIJOULES or more in your laser pulse, delivered within a few milliseconds, to fatally injure a typical malaria-carrying mosquito species.

AVOID BLINDING YOUR GUESTS! Spend a few thousand dollars on a near-infrared fiber laser operating at 1570 nanometers, which won't harm the human retina. Or find an ultraviolet laser (but avoid the 266-nm wavelength, which can cause cataracts with prolonged exposure). Or use a nice, cheap SSY-1 flashlamp-pumped neodymium-doped yttrium aluminum garnet laser. And make your barbecue guests wear FDA-approved safety goggles.

THE IDEA OF BUILDING a high-tech defense against disease-carrying pests had come up in discussions that Myhrvold and Wood had been having with Bill Gates, who was Myhrvold's boss when he was chief technology officer at Microsoft in the 1990s. Through the Bill and Melinda Gates Foundation, Gates has been trying to improve living conditions in some of the world's poorest countries and in particular to come up with ways to eradicate malaria, a mosquito-borne disease that sickens about a quarter billion people a year and kills nearly a million annually, including roughly 2000 children a day (see Web-only sidebar, "New Techniques Against a Tenacious Disease").

Wood, a veteran of advanced weapons development at Lawrence Livermore National Laboratory, in California, and one of the scientists behind the Strategic Defense Initiative (otherwise known as "Star Wars"), had suggested trying a similarly high-tech approach against malarial mosquitoes—to take advantage of inexpensive, low-power sensors and computers to somehow track individual mosquitoes and shoot them out of the air. If it could be done cheaply enough, this might offer the first really new way in many years to combat malaria, as well as other diseases transmitted by flying insects, such as West Nile virus and dengue fever.

Hyde and I had worked with Wood at Livermore. Hyde now manages Intellectual Ventures' stable of staff and consulting inventors, and he assigned me the challenge of making the idea work—or showing why it couldn't.

Three years later, my colleagues and I at Intellectual Ventures have now worked out many of the trickiest aspects of the photonic fence and have constructed prototypes that can indeed identify mosquitoes from many meters away, track the bugs in flight, and hit them with debilitating blasts of laser fire. And we did it without a multimillion-dollar grant from some national Department of Entomological Defense. Nearly everything we used can be purchased from standard electronics retailers or online auction sites.

In fact, for a few thousand dollars, a reasonably skilled engineer (such as a typical IEEE Spectrum reader) could probably assemble a version of our fence to shield backyard barbecue parties from voracious mosquitoes. We therefore present the following how-to guide to building a photonic bug killer, in five parts: selecting an appropriate weapon, spotting the bugs, distinguishing friends from foes, getting a pest in your sights, and finally shooting to kill.

CHOOSE YOUR WEAPON

Why build a fence? You could try to lure bugs to one spot and kill them, but more will just keep arriving. For all practical intents, the supply of mosquitoes is infinite.

You could build a system that scans your entire yard for bugs. But as any infantryman knows, the first step in defense is to establish a perimeter; it's much more effective (and safer) to concentrate your firepower in a narrow zone. Mosquitoes generally don't spend their whole lives in your backyard, unless you live in a swamp. They fly back and forth from their breeding grounds, so to get to you they have to cross your laser-guarded perimeter. A few may fly over the fence, but not many. The average flying altitude varies among mosquito species but is usually only about 2 meters. They will fly over obstacles when necessary—even into an upper-story window—but if your virtual fence is 3 to 5 meters high, it can catch almost all mosquitoes that fly by.

Of course, there are any number of ways to build a fencelike barrier. You could detect mosquitoes acoustically, with radar, or with ultrasonic sonar. You could shoot them down with tiny bullets, break them apart with sonic pulses, or cook them with microwaves. We considered these and many other possibilities, but it's hard to beat the range, precision, and literally lightning-fast response of optics. Good digital cameras and powerful diode lasers are relatively affordable and easy to find. So for us, photonic technology is the way to go.

GETTING A BUG IN THE CROSSHAIRS

To detect mosquitoes, you'll need several video cameras—four per fence post for a full-coverage fence (two at the top and two at the bottom facing the two adjacent fence posts—see "Spot the Skeeter"). The cameras don't have to be sharp enough to take a good photo of a mosquito many meters away, but they should have a resolution high enough so that a distant insect will at least fill up most of one pixel. If the bug occupies several pixels in the frame, that's even better, as this will allow you to find its center.

LIGHTS, CAMERA... Here's some of the equipment needed to image a tiny bloodsucker flying at up to 1 meter per second.

RYAN SMITH/INTELLECTUAL VENTURES

A 1.3-megapixel (1280- by 1024-pixel) camera turned sideways can cover a 4-meter-high fence post with pixels 3 millimeters on a side. If you're economizing, you could even try VGA-resolution (640- by 480-pixel) cameras.

The speed of your cameras matters as much as the resolution. It's no good if the bug is already through the fence by the time your system registers its presence. Mosquitoes fly up to a meter per second, so if the active zone is 10 centimeters wide, the frame rate must be more than 10 frames per second. Standard video cameras supply 30 frames per second, but the frames are interlaced—odd and even rows of pixels are delivered separately, 1/60 second apart—which will make it hard to follow a small moving object. So you'll want to use noninterlaced cameras, or at least units on which you can disable the interlacing.

You're interested only in a narrow vertical strip of image, less than 100 pixels wide, so you can drastically cut down the amount of data your cameras produce if you capture only that strip. Many digital video cameras allow you to do this by selecting a rectangular "region of interest." Using less than the full frame may also let you increase the frame rate.

Next you need to get all those pixels into a computer. Not only do you need a high data rate but also low latency—as little delay as possible between the moment the pixels are captured and when they're available for processing. USB connections are probably too slow; we've found that IEEE 1394 (FireWire) or gigabit Ethernet interfaces work fine. (Best of all would be to create a custom image-processing chip and integrate it directly into the camera. But that's a different project.)

Mosquitoes are dark and typically fly at dusk, so they're hard to see by reflected light. It's much easier to pick out their silhouettes against a bright background. Fortunately, in a fence, we can use one post as the background, as seen from the next post in line.

Put a light source next to each camera and aim both the light and the camera at an adjacent fence post. Cover the target post with retroreflective tape, which will reflect the incoming light directly back toward the camera, much as a highway sign does. We often use 3M's Diamond Scotchlite material, which reflects 3000 times as much light back toward the source as a matte white surface does. Other "safety marker" retroreflective materials should work too.

Single-color LEDs or diode lasers are good choices for the light source, because you can put a filter on your camera to block out stray visible light from the sun or nearby lamps. Infrared LEDs work better if you'd rather not attract insects, pets, or curious children to your fence; if you prefer a high-tech look, you can use red LEDs. You can add lenses or reflectors to focus the light at the target post, so that as little is wasted as possible.

Now that you have streaming video of bug shadows, the next step is to track the bogies. In simplest form, this just means generating a list of darker-than-usual pixels and grouping sets of adjacent dark pixels into objects. More sophisticated software might calculate the geometric center, or centroid, for each object, to achieve much better than single-pixel accuracy, or it could match up objects from one frame to the next, thus generating flight paths and measuring velocity. Extrapolate a track into the future and you can even predict where an insect will be—at least until its next zig or zag.

If you have more than one camera looking at the same target area, you can experiment with stereo imaging to estimate the range of each insect. The OpenCV software library (http://opencv.willowgarage.com) has many prebuilt functions for tracking and ranging.

WHO FLIES THERE—FRIEND OR FOE?

Let's assume you don't want to shoot down bumblebees, scare off hummingbirds, or freak out the neighbor's cat while annihilating mosquitoes. How do you pick out the pests? The first test is size: Anything bigger than, say, 2 centimeters is not a mosquito (except perhaps in Minnesota, where the mosquito is reputed to be the state bird).

Another useful check is whether the target is isolated, with clear pixels on all sides. This test will rule out fingers, tree branches, or other objects that are thin but long. It should also prevent your fence from shooting at anything that's too close to a large object, like your neighbor.

You may want to tune your system to reject things flying too fast (any more than 1 meter per second, unless there's a breeze) or too slow. And anything moving vertically downward is more likely to be a raindrop or a falling leaf than a mosquito.

Simple filters such as these may be sufficient for backyard use. Although you don't want to wipe out beneficial insects wholesale, it is probably okay to shoot gnats, flies, and small moths that attempt to crash your barbecue. Certainly the fence will inflict no more damage on the local ecology than an insecticide spray or an electric bug zapper. For large-scale malaria control, though, we need to be more selective (and more energy efficient), and so we have one more filter: We check how fast an insect beats its wings (see Web-only sidebar, "Hold Your Fire Until You Hear the Beat of Their Wings"). This allows us not only to accurately identify the mosquitoes but also to tell in a split second whether they're male or female. That way we can conserve power by sparing the lives of the males, which do not suck blood.

READY, AIM...

An insect has now wandered, unsuspecting, into the forbidden zone, and your program has decided it's a bad bug. It's time to point your death ray at it.

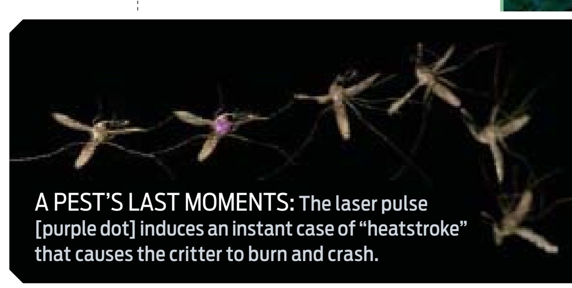
How fast and accurate your aiming system needs to be, and how large your killing pulse is, will depend on the geometry of your fence. As an example, if you want to be able to place a lethal pulse of energy anywhere within a target zone that's 4 meters high and 10 centimeters wide (at a distance of 10 meters), then your beam must be able to swing 22 degrees up and down and about half a degree from left to right.

The most common way to steer a laser beam is to use galvanometers. A galvo is essentially a simple motor with a mirror mounted on the shaft. Drive a current through the galvo and the mirror will rotate by an amount proportional to the current. A built-in encoder feeds back the mirror position for closed-loop control. Individual galvos are often mounted in pairs to provide *x*-*y* motion.

High-quality galvos are carefully matched to their drive circuits and tuned by the manufacturer to provide maximum speed without overshoot or oscillation. They can be expensive: The Scanlab units we use—designed for laser marking and micromachining systems—cost upward of US $10 000 new. We managed to find some at an online industrial auction for about $500 each (although we then had to buy a controller card for close to $2000). But lower-cost galvos, designed for laser light shows, are widely available.

You can also experiment with other beam-deflecting techniques. Acousto-optic modulators deflect narrow laser beams over small angles (up to a few degrees) at high speed. Yet another approach is to rotate a pair of prisms relative to one another.

Whatever strategy you choose, keep in mind that the laws of diffraction will limit how well you can focus your killing laser. So the smaller the spot you want to produce, the wider the beam must be before it enters the focusing optics.



A PEST'S LAST MOMENTS: The laser pulse [purple dot] induces an instant case of "heatstroke" that causes the critter to burn and crash.

RYAN SMITH/INTELLECTUAL VENTURES

If, for example, your kill laser is an 808-nanometer infrared laser diode (with a high-quality single-mode beam), then a 4-mm-wide beam will remain nearly constant in diameter over 10 meters and will illuminate a 4-mm spot on

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ELECTRONS UNPLUGGED

Wireless power at a distance is still far away **BY DAVID SCHNEIDER**

THE OYSTERMEN must have been puzzled by what they saw going up near the north shore of Long Island in New York state at the turn of the 20th century. Nikola Tesla, a Serbian immigrant from what is now Croatia, had set up a laboratory in the midst of potato fields and erected behind it a tower almost 60 meters (200 feet) tall. Tesla said he intended to use it to communicate wirelessly around the world.

The idea was ambitious but not unreasonable, Guglielmo Marconi having just sent the first tentative signals across the Atlantic in 1901. But the Long Islanders living next to the huge tower would have been more shocked—perhaps literally—if Tesla had carried out his second plan, which was so audacious he hid it initially even from J.P. Morgan, the financier who was bankrolling the operation. Tesla wanted to use the tower for wirelessly transmitting not just signals but also useful amounts of electrical power. His strategy for accomplishing that feat was vague, but it seems he had notions of sending power wirelessly to such things as airships in flight and automobiles on the move.

HOLLY LINDEM

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POWER TOWER: In the early 20th century, Nikola Tesla planned to use this immense tower to send power wirelessly. *PHOTO: TESLA WARDENCLYFFE PROJECT*

Tesla never did quite finish the enormous tower—Morgan got fed up and cut off funds. Tesla abandoned the lab, which fell into disrepair, and in 1917 the tower was unceremoniously demolished.

Decades later, Tesla's laboratory was turned into a factory for photographic paper, an operation that left enough toxic waste on the grounds to have the property qualify as a Superfund site. Today the elegant brick lab building is abandoned once again. Plywood covers its windows. All that remains of the tower is its huge octagonal footing, now overgrown with trees.

Scientists and engineers these days, of course, appreciate Tesla's enormous if rather quirky brilliance—he invented the induction motor, for one thing, and he championed alternating current when Thomas Edison would have none of it, for another. So it's no surprise that some of Tesla's admirers are seeking to preserve his old laboratory.

"To think that Tesla walked here, walked on this ground, and had his vision and his dream," says Jane Alcorn as she surveys the laboratory. Alcorn heads a not-for-profit group dedicated to turning the now-derelict site into a science museum. She knows full well what great things Tesla imagined for the place. "The transmission of power without wires will very soon create an industrial revolution and such as the world has never seen before," Tesla wrote in a 1906 letter to George Westinghouse.

While Tesla's vision may appear ludicrous today, things were different before power poles and high-tension lines became a part of the industrialized landscape. Tesla had demonstrated his ability to send power wirelessly over modest distances at a laboratory he had set up earlier in Colorado Springs. But he failed in his grand attempt to scale up the effort. And by the time his power tower came crashing down, people were too busy stringing electrical cables to worry very much about how to do away with them. Recently, though, some hardheaded scientists and engineers have been thinking very carefully about how to do just that.

IN 2006, exactly 100 years after Tesla laid off his employees on Long Island, another immigrant from Croatia surprised America with a proposal for sending power through the air. Physicist Marin Soljačić, along with several of his colleagues at MIT, performed a theoretical analysis of a system for projecting useful amounts of power wirelessly using electromagnetic induction, a phenomenon that's been well known since Michael Faraday first described it in the early 19th century.

BRIGHT IDEA: Intel's wireless-power system [top] was inspired by MIT's [bottom]. *PHOTOS: TOP: INTEL; BOTTOM: MARIN SOLJAČIĆ/SCIENCE*

In 2007, Soljačić's team went further and published an article in the prestigious journal *Science* describing hardware that could light up a 60-watt incandescent lamp using power transferred between two coils separated by a little more than 2 meters. Images of that bulb spookily lit up from afar sparked considerable buzz in the press. But the physics at work was really not so very different from what goes on in any electrical transformer. There, AC current flowing in one coil of wire, the primary, creates an oscillating magnetic field, which in turn induces an AC voltage in another coil, the secondary. In a typical transformer, the magnetic lines of force that link the primary and secondary are channeled through iron, maintaining a tight coupling that keeps power losses to a minimum. If you separate the primary and secondary coils by a distance that's filled with nothing but air, those losses mount and the transfer becomes inefficient.

"Resonance enables efficient energy transfer," says Soljačić, describing the basic strategy his team used to get significant amounts of power to flow. It's not a new idea: Tesla's eponymous coils use that very same principle.

A good way to understand why resonance helps is to imagine the mechanical analogue. Suppose you wanted to transfer mechanical energy across a room, but all you had coupling the power source with the load was a long and very weak spring. You'd have to pump the end of the spring you were holding vigorously, moving it back and forth as fast and as far as you could until sweat poured down your brow. It wouldn't be very efficient, but only with such effort would the far end of the spring wiggle a bit.

To make life easier, you could attach your end of the spring to a pendulum swinging in a wide arc, for instance. Now your arm wouldn't hurt so much, and the far end of the spring would still wiggle. But another difficulty would appear when you tried to attach that far end of the spring to a mechanical load. If you weren't careful, you'd find the waves of energy being sent down the spring weren't being absorbed—most of what little energy that got to the far end would just bounce back. To solve this new problem, you could attach the far end of the spring to a second pendulum, one that was built exactly like the first. Now, all you would need to do is give the first pendulum some gentle rhythmic shoves until the amplitude of its swinging became large enough to get the far end of the spring wiggling in time with it. And those little wiggles would in turn have the right timing to get the second pendulum swinging. Despite having only a weak spring as the conduit, you would have transferred power across the room. Then you could do something useful with it—maybe smash a window.

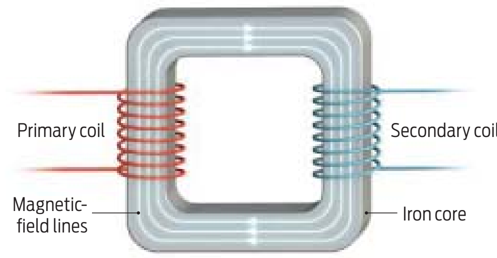
This mechanical analogy may seem a bit loopy, but in fact it provides a very good parallel for what goes on between the coupled resonant electrical oscillators used to transfer power inductively. The mechanical version even shows some of the subtleties of wireless-power systems—for example, that the coupling between the primary and secondary oscillators gives rise to a second, higher frequency of resonance. More important, this thought experiment helps to illustrate a fundamental challenge: As the frequency and amplitude of the oscillations increase, the primary starts to experience significant losses of power. Air resistance would sap the energy of a swinging pendulum, to take one example. For electrical oscillators, most of the losses arise just from the resistance of the wires.

So when Soljačić calls his system "efficient," he's speaking in relative terms. The actual plug-to-bulb efficiency in his demonstration would make an environmentalist cringe—it was only 15 percent. Nevertheless, Soljačić and his colleagues were so enthusiastic about the prospects of using such inductive systems to charge cellphones and laptops at a distance that they founded a start-up to commercialize the technology. Dubbed WiTricity Corp., the company, which is located in Watertown, Mass., now has about 20 employees.

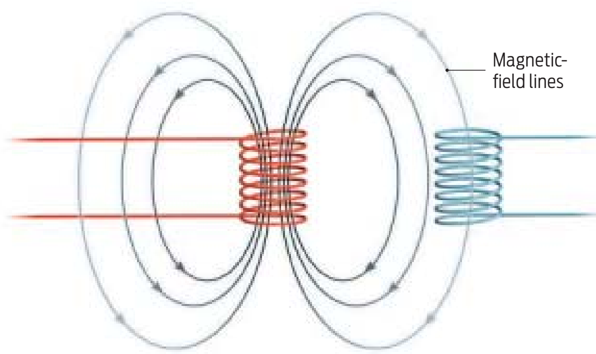
Strangely enough, even before Soljačić's work appeared in print, others at MIT had been looking into the problem of how to send power wirelessly over short distances. Jeff Lieberman,

TRANSFORMING A TRANSFORMER

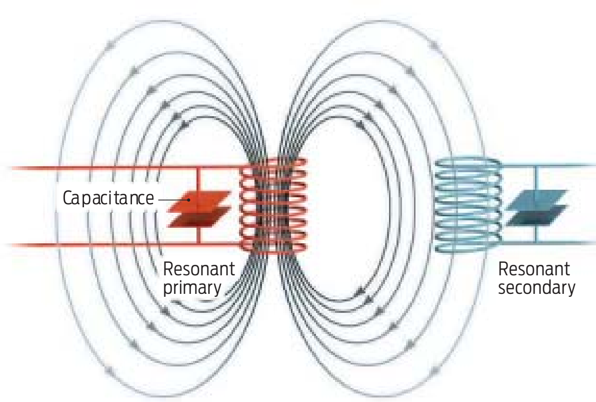
A wireless-power system operates much like an ordinary transformer—but with only air between the coils



AN ORDINARY TRANSFORMER (shown schematically above) contains two coils—a primary and a secondary—which are wound around different parts of a steel frame. The steel has high magnetic permeability and channels magnetic-field lines within it, so virtually all of the magnetic field created by powering the primary coil passes through the secondary. This tight magnetic coupling allows power to flow from primary to secondary with high efficiency.



IF THE PRIMARY AND SECONDARY COILS do not share a common steel core and are instead separated by nothing but air, the magnetic linkage becomes far more tenuous. Only a small fraction of the magnetic-field lines generated by the primary will pass through the secondary coil. The power source would then have to drive very large currents in the primary to transfer the same amount of power. But those larger currents would give rise to larger losses.



ADDING CAPACITANCE to the primary circuit causes a resonant oscillation, with energy shifting back and forth between the magnetic field surrounding the coil and the electric field within the capacitor. In this way, high currents can be attained within the primary without suffering losses within the source powering it. Adding capacitance to the secondary so that it resonates at the proper frequency further boosts the efficiency of the power transfer.

EMILY COOPER

then a graduate student in MIT's Media Lab (and now the host of the Discovery Channel show "Time Warp"), wasn't aiming for anything practical; he merely wanted to create an intriguing piece of art—a levitating lightbulb that lit up. So he confronted the same challenge that Soljačić and his colleagues faced: getting power to something without attaching wires to it. Lieberman's solution differed from Soljačić's in detail, but the fundamental approach he took was the same.

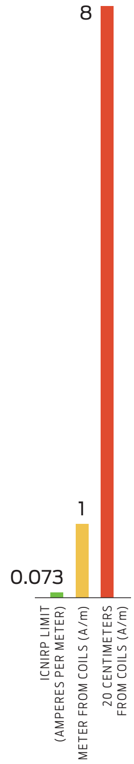
"I knew the principles of inductively coupled resonant systems had been around," says Lieberman, who went as far as consulting notes that Tesla had recorded at his Colorado Springs laboratory. After much experimentation, and with the help of Joseph Stark III, another MIT graduate student who wrote his master's thesis on wireless power transmission, Lieberman succeeded in building a floating, glowing bulb in 2005. But he remained unaware of Soljačić's work in the physics department until the professor's scholarly articles on the subject came out.

Those articles brought Soljačić's group, and later their spin-off company, much attention outside of MIT. And why not? The name WiTricity is, of course, a play on Wi-Fi. It brings to mind images of transmitting power wirelessly throughout homes and offices in the same way that Wi-Fi radios spread Internet access around. A page on WiTricity's Web site certainly plays on that image, showing an artist's rendering of a compact transmitting coil positioned in a living-room ceiling, sending power to a wall-mounted television, various lamps, and a laptop poised on a coffee table.

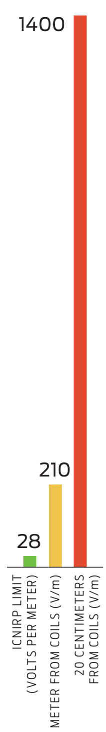
Such thoughts also got Intel to explore the prospects for wireless power at its Seattle labs, where researchers developed something they call the Wireless Resonant Energy Link. "We were inspired by the MIT paper," says Joshua R. Smith, the Intel engineer who heads the effort. But the system Intel first demonstrated in 2008 uses flat coils rather than the corkscrew coils Soljačić and his coworkers had described the year before. "We didn't want to use a helix, which is hard to fit into a laptop," says Smith.

It turns out they didn't have to. The underlying reason for Soljačić's helical coils is that they provide not only inductance but also capacitance by virtue of the separation between their adjacent loops. So at radio frequencies these coils resonated without separate capacitors. The advantage, Soljačić figured when he designed them, was that there would be no losses from capacitors, a worry that may have been exaggerated. WiTricity, like Intel, has moved away from Soljačić's original helical coil design, because the bulky corkscrew form would be awkwardly constraining. "If you're going to power a device, you want the capture coil to be *in* the device," says WiTricity's chief technical officer, Katie Hall.

Another constraint appears to be less well known, however—or at least it's less discussed. It comes from the strength of the electromagnetic fields being generated and how they compare with the levels that people would willingly expose themselves to.



OUTER LIMITS: Magnetic-field values [above] and electric-field values [below] for the MIT wireless-power system [yellow and red] exceed ICNIRP limits [green] by a wide margin.



HOW ELECTROMAGNETIC FIELDS affect health is a rich subject, both for what is known about it and what isn't. The latter category includes many possibilities that may seem more or less reasonable, depending on your perspective. But at radio frequencies, some of the effects are indisputable.

"Exposure to very high RF energy will heat you—there's no question about that," says Richard Strickland, who runs the consultancy RF Safety Solutions. He points out that RF exposure guidelines differ from place to place. In the United States, for example, many follow IEEE's C95.1 standard, whereas Europeans generally adhere to the somewhat stricter guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Consideration of those limits should be sobering to anyone hoping to send significant amounts of power using electromagnetic fields. Take the ICNIRP guidelines for RF fields at 10 megahertz, the frequency of the system Soljačić and his MIT colleagues built. For this frequency, those guidelines indicate that the general public should not be exposed to magnetic fields in excess of 0.073 ampere per meter, or to electric fields greater than 28 volts per meter. Were this RF energy radiated from a distant antenna, you could apply either the magnetic or the electric-field limit alone, because the ratio of the fields would be a fixed quantity. But inductive power transfer of this kind takes place in what is known as the near field of the antenna (the coil), so the relationship between the electric and magnetic fields is not so simple.

According to their 2007 *Science* paper, Soljačić and his colleagues measured a magnetic field of 1 A/m at the halfway point between transmitting and receiving coils—almost 14 times the ICNIRP limit. The electric field was 210 V/m, which tops the ICNIRP limit by a factor of 7.5. Things get even worse if you consider the fields closer to the coils. Twenty centimeters away, the magnetic field was more than 100 times—and the electric field 50 times—the ICNIRP limit.

"They are not going to be able to fill a room with fields and not come up with issues," says Grant Covic, a professor in the department of electrical and computer engineering at the University of Auckland, in New Zealand. He should know: Covic and his Auckland faculty colleague John Boys have been working for two decades on the engineering of such systems, which, despite having garnered little publicity, are in fact used widely for a variety of applications where power cords would be problematic.

One such application is materials handling. Daifuku Co., based in Osaka, Japan, for example, has licensed patents from the University of Auckland to build tracked conveyor systems with moving platforms that are powered wirelessly. These systems, which make up a significant fraction of Daifuku's US $2.5 billion in yearly sales, don't generate the fine particles that would contaminate sensitive processes like chipmaking, as brushed electrical contacts tend to do. Such conveyances are useful in other industrial settings, too. Audi and BMW, for example, both use inductively pow-

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ered carts on their assembly lines, these systems proving more robust than ones that rely on brushed contacts.

Another well-established application is the charging of electric vehicles. More than a decade ago, GM's ill-fated EV1 was charged using an inductive paddle, instead of actually plugging it into an outlet. In the ancient port area of Genoa, Italy, you'll find electric buses that charge themselves wirelessly at the whopping rate of 60 kilowatts for 10 minutes each hour, by parking over flat charging coils built into the road surface. The system was built by Conductix-Wampfler of Weil am Rhein, Germany, which has also licensed patents from the University of Auckland.

These systems have long ago proved themselves able to move power wirelessly, often a lot of it, and with good efficiency. That's possible because they transfer the power for only a short stretch through the air—a few tens of centimeters at most—nothing like the distances WiTricity and Intel are shooting for. The key question is whether engineering improvements will make greater separations practical.

"I'm skeptical about sending [power] over distances that are larger than the coil diameter," says Menno Treffers, who works for Royal Philips Electronics and serves as the head of the two-year-old Wireless Power Consortium, which is aimed at establishing industry standards for the wireless charging of consumer electronics. Right now you can get wireless charging pads if you buy a Dell Latitude Z laptop or a Palm Pre smartphone. BlackBerry and iPhone owners can get this feature too, if they purchase special aftermarket charging sleeves.

The idea the Wireless Power Consortium is pushing is that eventually you'll be able to buy a single charging pad that will recharge whatever device you place on top, regardless of brand. Treffers is keen to bring such interoperability to what he sees as a blossoming consumer technology, but he doesn't expect it to get to the point where you can recharge your mobile gizmo while using it. "It's not like you can charge your BlackBerry while sitting on the couch," he says.

Eberhard Waffenschmidt, a Philips electrical engineer working with Treffers, has examined the question of what distances are possible for resonant inductive charging. His calculations suggest that the prototype systems that Intel and WiTricity have demonstrated are pushing the limits of what can practically be done without efficiency plummeting to ridiculously low levels. And even if poor efficiencies could be tolerated, the RF field levels required to send truly useful amounts of power over even modest distances would be above what you could reasonably expose people to. "All the journalists had missed this," says Waffenschmidt, adding that "[charging] pads don't have this problem."

Is there no way then to increase the distance you can send power wirelessly? Of course there is, but not inductively. If you have a clear path, you could use microwaves or laser beams, as has been demonstrated many times. Or just keep it simple. "Sunlight is excellent for long-distance power transfer," quips Treffers.

TODAY'S WIRELESS POWER

Wireless-power systems are still limited to short ranges. But even so, they are becoming increasingly popular

WIRELESS CHARGING: Electric buses in the ancient port area of Genoa, Italy, are recharged inductively.
PHOTO: CONDUCTIX-WAMPFLER

CHIP TRIP: Materials-handling equipment used in semiconductor manufacturing is often powered inductively.
PHOTO: DAIFUKU

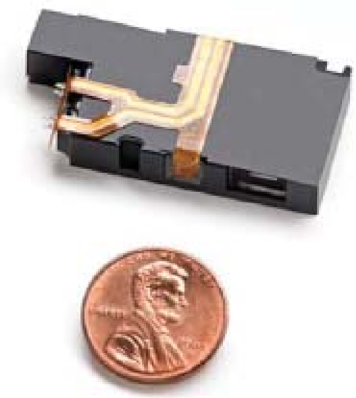
NO-CORD CHARGING: Wireless charging pads are becoming widely available for consumer electronics, including the Dell Latitude Z laptop [top], the Palm Pre smartphone [center], and various smartphones equipped with Powermat charging sleeves [bottom].
PHOTOS, FROM TOP: DELL; PALM; POWERMAT

EVEN IF RESONANT INDUCTION ends up being limited to short distances, it may yet have a great influence, particularly for the future of transportation. "We now [have the means to] charge a car safely and efficiently over gaps of 20 to 40 centimeters, and we believe we can build that into a roadway system," says Covic. "That's probably a decade away, but you've got to have a vision, and ours is roadway-powered systems."

A small step in that direction is taking place at Berlin-based Bombardier Transportation, which is gearing up to offer an electric streetcar that is inductively powered through the roadway. Although there are other ways to avoid a streetcar's hard-to-maintain cables [see "Fuel Cells Could Power a Streetcar Revival," *IEEE Spectrum*, September 2009], Bombardier's system, called Primove, avoids many of the problems that some of the competing solutions face.

If this approach for powering streetcars catches on, perhaps wider-ranging electric buses will be next. It's not unreasonable to think that some decades from now private electric cars may also be able to draw at least some of their power wirelessly from suitably equipped roadways. Who knows? Maybe the early adopters of today's electric cars will be able to retrofit their rides to get such a boost while cruising. Then even the people who bought their Tesla Roadsters in the 2010s could zoom along inductively powered highways of the future. Such a thing would surely please that roadster's visionary namesake. ❑

SLIDESHOW *For more on Tesla's wireless-power tower, go to* http://spectrum.ieee.org/tesla-tower.



LITTLE GIZMO, BIG PICTURE

The latest video projectors can fit inside tiny cameras or cellphones yet still produce big pictures

By JACQUES LINCOLN

MORE THAN EVER BEFORE, we are flocking to a gaggle of tiny devices for entertainment. We watch movies on iPods and use our mobile phones to show our family photos and to watch live TV. We bump shoulders as we crowd around the minuscule screens, fumble for reading glasses, and tilt the displays back and forth to find workable viewing angles. If we're old enough, we pine for the good old days of drive-in movies, with their vast screens.

We love multimedia content, and we also love the convenience of enjoying it wherever we are and whenever we want. But can we continue to put the two together without turning into perennial squinters?

We sure can! Behold the ultraminiature, or "pico," projector. From now on, the dimensions of the device in your hand will no longer dictate the size of the viewing screen.

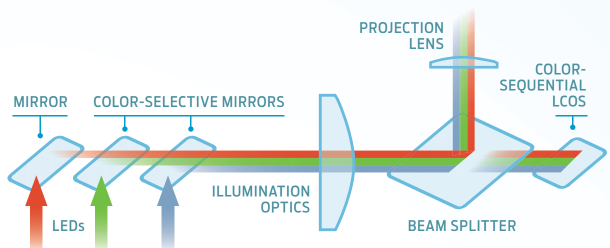
The first generation of pico projectors hit the market in 2008. They weren't much—clunky little boxes that produced low-quality images and had to be cabled to a computer or PDA. Very few people bought them.

Turns out that what people really want is a mobile phone, music player, laptop, or camera that projects big, bright, and sharp images—or an extremely tiny plug-in projector compatible with all those devices. This year, they're going to get what they want. We're just now starting to see the next generation of pico projectors, and besides being in smaller stand-alone devices, they're coming embedded in cameras, media-storage devices, and a few smartphones—about 100 individual products so far. Over the next few years they'll be popping up in more products and are likely to be the hottest new feature in mobile devices since the cellphone video camera. In fact, market research firm Insight Media forecasts shipments of embedded pico projectors—in consumer electronics, cars, industrial applications, and medical equipment, as well as in cellphones—to reach 30.8 million units in 2014, up from about 1 million units in 2009.

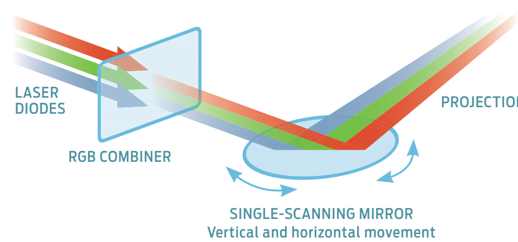
DAN SAELINGER

PETITE PACKAGE: Inside this pico projector [top] from Microvision is a silicon mirror about the size of the head of a pin. *PHOTO: MICROVISION*

MORE THAN ONE WAY TO PRODUCE A PICO



FLASH FOCUS: In color-sequential liquid-crystal-on-silicon (LCOS) displays, red, green, and blue LEDs or laser diodes flash sequentially to illuminate an image created by an LCD. The image then reflects out to the projection surface, where it appears in full color.



MIRROR IMAGE: Scanning-mirror projectors send laser light to one [as in illustration] or two silicon mirrors. The power of the lasers adjusts to determine the color of each pixel. The mirrors tilt to direct that light to an external surface.

What a pico projector does is simple: It takes a digital image and sends it out as a beam of light, creating an image that's much bigger than the originating device. Aim that beam at, say, the tray table nestled into the airline seat in front of you and you've got a miniature movie theater. Or aim it at a dark ceiling and you've got a display with a diagonal of some 60 inches or larger.

To do this, every pico projector needs chips to process and decode the image data for the hardware; a light source, typically LEDs or laser diodes; and mirrors and optics, to direct and focus the image.

Pico-projector technologies differ in how they turn light into the pixels that make up a video image. The battle between plasma and LCD for dominance in flat-screen television was heated and confusing (LCD won, if you missed it). The battle for the heart of the pico projector is shaping up to be much more complicated, because to date there are three vastly different technologies—liquid-crystal-on-silicon (LCOS) microdisplays, digital light-processing (DLP) devices, and scanning-mirror systems (also called laser-beam steering systems, or LBS)—and there are even significantly different design approaches within these three categories. Some of the leading players in this game so far are Aurora Systems, Himax Technologies, Light Blue Optics, Micron Technology (through its acquisition of Displaytech), Microvision, Syndiant, Texas Instruments, and 3M. With an estimated market of US $1.1 billion at stake by the year 2014, according to market research firm In-Stat, we're going to see a good old-fashioned consumer-electronics footrace.

TWO OF THE FIRST TECHNOLOGIES to make it into commercial pico projectors were LCOS and DLP. But their hold is anything but secure: The scanning-mirror systems are about to mount a serious challenge.

LCOS was developed in the late 1990s by JVC, which used it for large-screen projection televisions. In LCOS, liquid crystals sit directly on a silicon chip that has been coated to act as a mirror. The liquid crystals change their orientations in response to an electric field; as their orientations change, so does the polarization of light that travels through the liquid-crystal layer and reflects off the coating. A polarizing beam splitter at the front of the LCOS imager, acting like a goalie of sorts, either allows light to pass straight through or redirects it. When the crystals align with the polarizing beam splitter, the beam splitter lets the light through to reflect off the chip, where it bounces back to create an "on" pixel. When the crystals are out of alignment, the beam splitter blocks the light to create an "off" pixel. And in between on and off states, the crystals can allow different intensities of light to reflect. Refreshing the individual pixels on the chip dozens of times per second creates a moving image.

In projection TVs and digital cinema, designers use three LCOS chips. A beam of red light is aimed at one chip, green at another chip, and blue at a third. The three resulting images are sent through lenses to combine them into one full-color image on the screen.

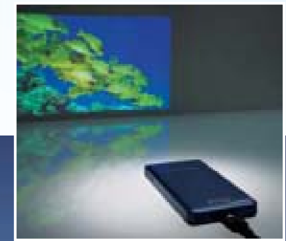
At pico-projector sizes, however, there just isn't enough room for three LCOS chips, so designers had to come up with another way to separate an image into its three primary color components. Actually, they came up with two ways: color sequential and color filtering.

Color-sequential LCOS is the more common method. Red, green, and blue LEDs or laser diodes—one of each—flash sequentially at a single LCOS panel, which adjusts how much of each color for each pixel is projected. When the device uses LEDs, a reflective cone surrounds each light, directing it to the LCOS panel in the same way a flashlight directs its beam of light forward. When the device uses lasers, direction isn't an issue; instead, lenses in between the lasers and the panel spread the tightly focused beam of light to cover the entire panel. In both LED and laser LCOS projectors, the light, after bouncing off the panel, travels through a set of lenses that enlarge and focus the final image.

Aurora, Micron, and Syndiant all use the color-sequential approach in the pico-projector modules they sell to consumer electronics companies. Himax is now developing a module for a color-sequential projector intended for consumer products.

Color-filtering LCOS uses a single white LED as the light source, creating color by sending that light through red, green, and blue filters. The light follows the same path as in color-sequential LCOS—reflecting from the panel and then passing through enlarging and focusing lenses on the way out of the device. The filters, however, make for a more complex LCOS panel, because each of the three subpixels requires an independent electrode to control its status: on, off, or somewhere in between.

POCKET THEATER: About the size of an iPhone, Microvision's US $550 laser-based ShowWX projector plugs into portable devices. *PHOTO: MICROVISION*



PICO INSIDE: The Nikon Coolpix S1000pj, at US $430, is the first camera with a built-in projector. It uses color-filtering liquid-crystal-on-silicon technology to create the image and LEDs to project it. *IMAGE: NIKON*

On the plus side, product designers can fit color-filtering LCOS into a small space, because they have only one light source to deal with. On the minus side, the filters reduce the amount of light that gets to the screen by up to two-thirds, and some of the colors bleed together, reducing color quality. Plus it's difficult to get good manufacturing yields; the three subpixels mean that the chip design is three times as complex.

Aurora, Himax, and Micron are producing or will soon produce color-filtering pico projectors, and Nikon has built the technology into its Coolpix S1000pj compact digital camera, already in stores.

Like LCOS, DLP technology came to the pico-projector world from projection television (perhaps just in time for DLP's survival in the mass market, as market research firm International Data Corp. predicts that rear-projection TV sales will plunge to nearly zero by next year). DLP chips, invented by Texas Instruments in 1987, each contain a rectangular array of up to 2 million hinge-mounted microscopic mirrors. You can fit five of these mirrors across the width of a human hair. These micromirrors create pixels by tilting toward the light source (on) or away from it (off) as red, green, and blue light alternately shines onto them.

Because of the complexity of the chip, it tends to be a little more difficult to manufacture than its competitors. But the technology is relatively stable. And because DLP is used in digital projectors in movie theaters, it has already had its high-resolution shakeout, a challenge that's still in the future for most of the other pico-projection technologies.

UNLIKE DLP AND LCOS, which were both adapted from television, scanning-mirror systems originated from contracts with the U.S. military for development of head-mounted displays that project an image directly onto the eye, a concept on which work still continues. Their imagery is extremely sharp, has the highest contrast of the three technologies, and potentially could be produced in the smallest package. The main drawback, however, is that, at least in the short term, they are more expensive than the competition, for they rely on three separate high-frequency lasers as the light source, and the light source makes up at least a third of the cost of the product.

Let's take a closer look at those laser components. In a full-color laser system, you need red, green, and blue laser-light sources. Red diodes are readily available—they're in all consumer CD players. Blue—actually, almost violet—laser diodes were first developed by Shuji Nakamura at Nichia Chemical Industries in 1997. Today they're used in Blu-ray DVD players, so they're also widely available and can be adapted for mobile projectors. True green-laser diodes, however, are not yet commercially available. But companies like Corning, Osram (a Siemens subsidiary), and others have come up with a mechanism that bounces laser light in a cavity between two crystals and doubles its frequency. With this technology, an infrared laser can produce a suitable green to meet current demand. Next-generation green lasers are likely to be simple green-laser diodes, with size and price advantages. While this new crop of green-laser diodes should come to market within the next year or two, both technologies will coexist for the foreseeable future.

Why go through all this hassle to use three lasers? For one, laser-based systems don't have to struggle with filters that dim the light or with other means of generating multiple colors from a single light source. Because laser light is inherently tightly focused, laser-based systems don't need a movable lens for focusing. And scanning laser systems also dispense with the expansion lens needed for laser-lit physical arrays, whether they're LCOS or DLP. Lenses introduce losses, distortion, color changes, and other aberrations. But the real advantage is package size. Mobile-device makers value every cubic millimeter. A smaller size and reduced complexity are precisely the characteristics needed to crack that huge mobile phone market. The

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pure light of lasers also allows these systems to produce a huge range of colors—twice that of broadcast television—and very high contrast ratios, as much as five times those of DLP and LCOS projectors. A downside of laser-based systems is a phenomenon called laser speckle, which occurs when the beams of light scatter randomly off imperfections in the projection surface and interfere with one another to create patterns of light. It can look a bit like someone tossed a handful of glitter on the screen. For the most part, the speckle is down to an acceptable level, but developers are still trying to eradicate it.

So all scanning-mirror systems start with three lasers. The red, green, and blue beams change power, going from totally off to barely on and all the way to fully on, depending on the color of the pixel being displayed. Unlike the three colored lights in color-sequential LCOS, the lasers often shine simultaneously, not sequentially. To display purple, for example, both the red and the blue lasers shine at once.

Each laser sends its beam through lenses that direct it to the center of a mirror (or mirrors). These mirrors are microelectromechanical devices manufactured on silicon, similar to computer chips. Now here's where the scanning-mirror systems diverge into two types: single scanning and dual scanning. In a single-scanning mirror system, one mirror directs the laser beam, painting horizontal lines back and forth to create a frame of the moving image. At the end of each line, the beam shifts vertically, and then, when the screen image is complete, the beam zips back to the top and starts again for the next frame. In a dual-scanning mirror system, one mirror directs the laser light back and forth along a horizontal path and then sends it to another mirror that adjusts the vertical position of that horizontal line, moving it down the virtual screen.

All mirror systems send the image back out through lenses that correct for distortion introduced by the curve of the mirror (or mirrors). Two-mirror systems create less distortion to correct, but the second mirror has to catch the spread-out beam of the first mirror. If the mirror is out of alignment, the effect on the final image can be dramatic.

Late last year, Microvision began shipping a product called ShowWX, based on a single-scanning mirror. (Full disclosure: The author is a product manager at Microvision.) Maradin Technologies, in Israel, is also developing a single-scanning mirror system and aims to have a commercial product in a few months. The Nippon Signal Co. and the Israeli company bTendo have publicly demonstrated two-mirror systems.

Some pico-projector designers are trying to combine the low cost and durability of LCOS technology with the rich colors and tight focus of laser light in a technology known as holographic laser projection. The underlying concept is pretty complicated (see sidebar, "A Projector of a Different Color") but remarkably effective. In brief, instead of producing the image in the time-honored way—as a grid of pixels—the technology recalculates the image into a set of diffraction patterns, or holograms. The holograms appear sequentially on an LCOS display and, when a laser light shines on the display, the holograms create an image projected on a surface.

Light Blue Optics, in Cambridge, England, is the first company to announce a commercial product using this technology. The company demonstrated a reference product, Light Touch, at the January 2010 Consumer Electronics Show, in Las Vegas, that turns a flat surface into a 10.1-inch touch screen. The images produced are clean and crisp, and the technology avoids the speckle of other laser-based technologies, but so far the device is bigger than those using competing technologies.

A word about eye safety: All of the commercial projection technologies are considered "eye safe" by international standards bodies. But these organizations recognize varying levels of eye safety. The LCOS approaches, which diffuse the laser beams before they leave the projector, are rated Class 1—safe under all conditions of normal use. The scanning-mirror technologies, to date, are rated Class 2—safe because the normal blink response limits exposure.

IN THE END, THERE WILL BE ROOM for more than one technology. Some pico projectors will be plug-in, stand-alone devices, intended for use with a laptop computer, an iPhone, an iPod, or even an iPad. For these, size and power consumption won't matter as much as brightness and overall image quality. Others, intended for use in smartphones, will have to be tiny, extremely power efficient, have decent image quality, and be affordable enough to justify the incremental cost of adding the projector. Right now, the size of the projector package ranges in overall volume from 5 to 18 cubic centimeters. With green-laser diodes coming to market, scanning projectors and some engines could shrink to 3 cm^3.

And there's the size of the projected image. In general, the shorter the distance needed for the projector to produce a large image, the better—up to a point. In the case of an embedded pico projector inside a multimedia player, a 1:1 distance-to-image-size ratio (a projection angle of 53 degrees) is probably sufficient for most applications. The first products on the market have projection angles in the range of 30 to 45 degrees; holographic technology claims a theoretical projection angle of 90 degrees and greater.

Brightness counts too, of course. The brighter the better, right? Not exactly. A very bright source means high power consumption and therefore short battery life. And that's bad for mobile devices. Depending on the way they are designed into products, the current pico-projector technologies deliver between 2 and 20 lumens of brightness, which can mean a projected and readable image that measures diagonally anywhere from 2.5 to over 250 cm.

The pico projectors available now have resolutions as high as 800 by 600 pixels, equivalent to the SVGA (Super Graphics Video Array) standard. Some projector designers are now working on high-definition resolutions—either 720 by 1280 or 1080 by 1920 pixels, in the wide-screen format of Hollywood movies. None of the contenders has an obvious edge at the moment, but with consumers getting used to high resolution content in other venues, new developments are likely to be announced here soon.

A PROJECTOR OF A DIFFERENT COLOR

LIGHT TOUCH: This projection system creates a picture from holograms, then uses lasers [above] to project an interactive image onto a tabletop [left].

PHOTO: LIGHT BLUE OPTICS

HOLOGRAMS have always been a fascinating oddity, a crowd magnet at any science museum. Yet their path to commercial adoption has been slow. One company, however, is betting on holograms having a big impact in the soon-to-be-booming pico-projector market. Whether or not the bet pays off, again, the idea captures the imagination.

My company, Light Blue Optics, in Cambridge, England, has developed what it calls Holographic Laser Projection (HLP) technology, a technique that uses the principles of holography to project 2-D rather than 3-D images. In January, the company introduced the first example of a product using the technology: Light Touch, a pico projector that creates a virtual touch screen. The company isn't planning to sell products to the consumer but is working with more established companies to bring this, or products like it, to market.

HLP takes the image data that typically instruct pixels to turn on and off and recalculates them into a set of diffraction patterns, or holograms. It then displays a series of these holograms on a ferroelectric liquid-crystal-on-silicon display while shining red, green, and blue lasers at it. (Ferroelectric liquid crystals respond faster than other liquid crystals.) The holograms modulate the light coming in from the lasers, steering it instead of selectively blocking it—an efficient use of energy.

While researchers have understood how to create images from holograms for almost 50 years, none had overcome the main challenge to commercialization—the amount of computational power necessary to calculate the interference patterns in real time. Traditionally, methods for calculating holograms work by exhaustive optimization, revising the interference pattern multiple times to get the best image possible. This works for simple static patterns, but it's too slow for video. By not trying to create the best possible hologram for each individual frame of video, Light Blue Optics has developed holographic algorithms that are fast enough for standard video and can be built into a low-power chip.

Instead, the algorithms generate multiple holograms for each video frame, each of which roughly approximates the image. Individually, each would create a noisy image. However, as these images display in quick succession, the eye averages out the noise and perceives a single high-quality image. Because each hologram is phase-independent, the resulting image tends not to show speckling.

The Light Touch is intended to sit on a tabletop and project down onto the surface. This makes the virtual screen size an unchanging 10.1 inches in diagonal. The device turns that virtual screen into a touch screen with a fan of low-power infrared laser light superimposed over the projected image and infrared sensors that detect scattering.

—*Edward Buckley*

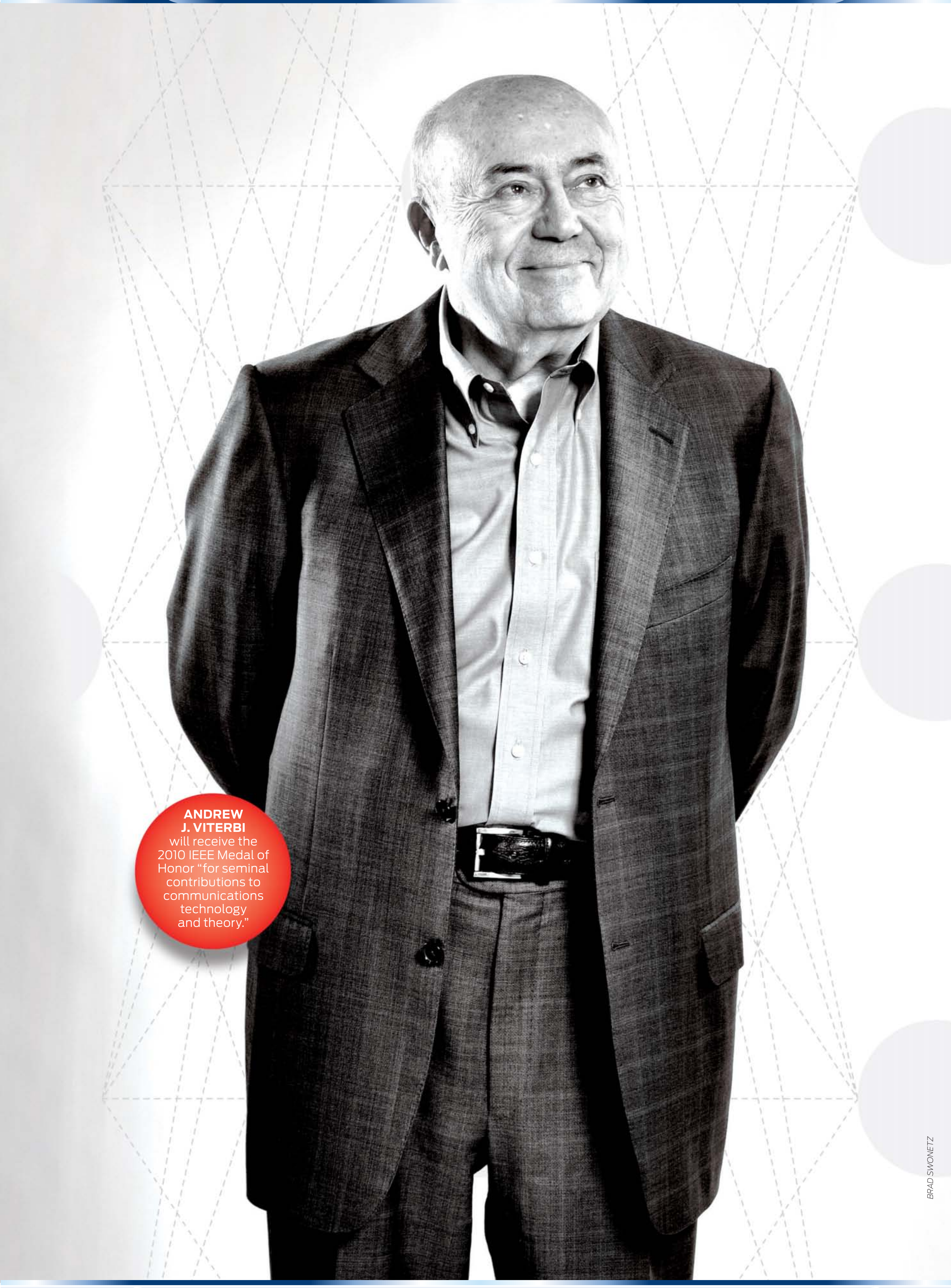
EDWARD BUCKLEY is responsible for worldwide business development activities at Light Blue Optics.

Spoiled by high-quality LCD screens, we've come to take rich, vivid colors for granted. And most pico projectors, using either lasers or LEDs for light sources, can project them. But contrast also affects picture quality. Contrast is the dynamic range of a display, from the whitest white to the blackest black. Good contrast is the difference between crisp, dramatic-looking images and washed-out ones. Technologies that use three LEDs or lasers rather than a single light source are tops here, because they simply turn the light source off when it isn't needed.

Pico projectors will make their first impact in portable consumer electronics. But they won't stop there. By 2012 we could start seeing them in cars, both in rear-projection video systems and driver head-up displays. Microvision and Light Blue Optics are trying to push laser-based pico projectors into these niches. Lasers are bright enough to overcome daylight. They also have the flexibility to be very dim at night and very bright during the day. Plus, the lasers can be turned off when pixels are not needed, for better nighttime driving visibility. LCDs, on the other hand, are problematic for nighttime driving because the backlight leaches through the liquid crystals, creating a halo effect and reducing contrast.

Further in the future, maybe 3 to 10 years from now, we'll start seeing pico projectors in eyeglasses and visors, overlaying graphical information on real-world images. For example, with geotagging and location-based services, you might have information about buildings appear as you look at them.

Pico projectors are going to become commonplace. Six or seven years from now, we'll look back and marvel that people must have been crazy back when they huddled around 3-inch screens. ❑



ANDREW J. VITERBI will receive the 2010 IEEE Medal of Honor "for seminal contributions to communications technology and theory."

BRAD SWONETZ

Medal of Honor

Andrew Viterbi's

Fabulous Formula

HIS DISCOVERY LED TO 3G CELLPHONES, WI-FI, AND A HOST OF OTHER TECHNOLOGIES

BY TEKLA S. PERRY

THE RANKS OF FIRST-RATE INVENTORS are chock-full of characters who are brash, egotistical, and temperamental. And for quite a few, even those adjectives are stretched to their euphemistic limits.

So meeting Andrew J. Viterbi can be something of a shock. He speaks softly, responds patiently. It's not that he's shy; it's a soothing kind of quiet, the kind that makes a guest comfortable. He's dressed nicely—in gray slacks and a dress shirt—but not formally; he rarely wears a tie. He's mostly bald, with a round face and eyes that crinkle when he smiles, which is frequently. He looks like someone's grandfather (which indeed he is; he has five grandchildren).

"Success comes to all kinds of personalities," says Viterbi's friend Carver Mead, the Caltech professor, integrated circuit pioneer, and oft-quoted tech visionary. "But it sure is nice when it comes to people like Andrew, who aren't just in it to beat their own chests."

It's not easy to reconcile the mild-mannered Viterbi with the tech titan who made fundamental contributions to Wi-Fi, 3G cellular and digital-satellite communications, speech recognition, and DNA analysis. Who cofounded Qualcomm. And, oh yeah, came up with one of the most important mathematical concepts of the 20th century: the Viterbi algorithm, a means of separating information from background noise. It's that last one, the algorithm, that was singled out in the citation for the IEEE Medal of Honor, Viterbi's most recent accolade.

Viterbi's tale isn't one of an aggressively ambitious engineer trying to shake up the world, make a fortune, or claw his way to the top of his profession. It's the story of an unusually bright and hardworking professor who wanted to explain a difficult concept in clear and simple terms in order to better teach his students.

THE SON OF JEWISH-ITALIAN immigrants, Viterbi did well in both math and English at the venerable Boston Latin School. His father, a doctor, encouraged him to be an engineer, remembering the impact electrical power had made when it first came to Bergamo, the Italian town where Andrew was born. Viterbi won a scholarship to MIT and graduated with bachelor's and master's degrees in electrical engineering in 1957. His father's medical practice was struggling, and the family needed Viterbi's financial support, although he wanted to go on to a Ph.D. and teach.

He had enjoyed working at Raytheon as a co-op student, but deplored the way engineers were treated. "Engineers were not people trusted to make any decisions," he recalls. He'd heard that things were different on the West Coast, where some engineers even got private offices. So he applied for and got a job at the Jet Propulsion Laboratory, in Pasadena, Calif. Signing on with a lab that was affiliated with a university seemed like the next best thing to the academic career he really wanted.

At JPL, he started off working on telemetry for guided missiles, helping develop a then-new device called the phase-lock loop, which tunes into a carrier signal in spite of surrounding noise. After the Soviet launch of Sputnik and the beginning of the space race, Viterbi's efforts shifted to space communications systems, but the underlying focus on signals and noise didn't change. Simultaneously he worked on his Ph.D. at the University of Southern California.

BRAD SWONETZ

Andrew J. Viterbi

DATE OF BIRTH
9 March 1935

BIRTHPLACE
Bergamo, Italy

FIRST JOB
Soda jerk in a drugstore

FIRST JOB IN TECHNOLOGY
Co-op student, Raytheon

PATENTS
Six, but inspired hundreds

HERO
Claude Shannon

MOST RECENT BOOK READ
Skeletons at the Feast *by Christopher A. Bohjalian*

FAVORITE MUSIC
Light classical, opera, music of the '40s and '50s

COMPUTER
Lenovo laptop, several Dells

FAVORITE RESTAURANT
Il Tinello, New York City

FAVORITE MOVIE
Casablanca

BIGGEST WORRY
Nuclear proliferation

LANGUAGES SPOKEN
English, Italian, French, German

ORGANIZATIONAL MEMBERSHIPS
IEEE, National Academy of Sciences, National Academy of Engineering, Jewish Community Foundation of San Diego, Mathematical Sciences Research Institute

In the fall of 1963, doctorate in hand, Viterbi finally made it to academia, joining the University of California, Los Angeles. Teaching classes in communications and information theory, he couldn't have been happier.

Then came the algorithm.

IT WAS MARCH 1966. Viterbi was struggling with yet another class of graduate students, who just couldn't grasp a key set of concepts in information theory. The troublesome algorithms, known as sequential decoding of convolutional codes, extracted data from a signal corrupted with noise. Essentially, the algorithms decided if a bit was a 0 or a 1 by looking down a decision tree. When it became clear that the data had been corrupted, the software would go back one or more steps and try a different path.

The students didn't get it. Viterbi decided that the reason the algorithms were so hard to understand was that the proof of the theorems was too complex. So he set out to find a simpler proof.

After several months of obsessing over the problem, it hit him: It wasn't the proof that needed to be simplified; it was the algorithms themselves. Instead of going down a tree over and over again, Viterbi envisioned a trellis, in which the software considers the bits surrounding a particular bit in question to decide whether that bit is a 0 or a 1. The software assigns a probability of the accuracy of its decision to each bit based on the voltage of the received signal that conveys that bit. Based on the probabilities, the algorithm then decides whether that particular bit is a 0 or a 1. Unlike the earlier convolutional code algorithms, the software needs to keep track of only the paths leading up to a limited number of states, typically more than four but not more than 1000, a far more effective method than following each path until it dead-ends. Viterbi published his results in the *IEEE Transactions on Information Theory* in 1967, and his paper became a classic.

"After you see this approach, you wonder why nobody thought of it before," says Robert G. Gallager, an MIT professor emeritus and an eminent scholar in communications theory. "But that's what the best inventions are. After you see them, they are obvious."

The algorithm did what Viterbi wanted—it simplified the course material for his students. But he sensed it could do a lot more—for example, enabling the extraction of weaker signals from noisier environments. That in turn could mean lower-power transmitters, smaller antennas on the receiving end, or both. But to be useful, it would require both computer memory and processing power to calculate and track all the probabilities. Extracting the weakest signal from the greatest amount of noise would mean keeping track of about 1000 states at once; to do that, you'd need the processing power of a mainframe computer.

Viterbi and his colleagues did some further tinkering with the algorithm. They discovered that by keeping track of just 64 states, you could create a device that was four times as good as an uncoded transmission, or twice as good as coding systems in use at that time. That meant that the transmission power could be one-fourth the strength, or the receiving dish one-fourth the size, or the range twice as far, as similar uncoded systems. Within a few years, the falling price of electronic components made possible devices that tracked 256 states.

In 1968 Viterbi joined two engineers from his JPL days—Irwin Jacobs, then at the University of California, San Diego, and Leonard Kleinrock, then at UCLA—and started consulting on applications of his algorithm. They called their firm Linkabit.

The company worked on various defense and commercial satellite modems and terminals. It also built a satellite signal scrambler called Videocipher for the cable channel HBO; the technology continued to be used to scramble pay-TV signals until the end of 2008. In 1973, Viterbi left UCLA and joined Linkabit full time. Seven years later, M/A-Com acquired the company and eventually sold off its various pieces. Viterbi and Jacobs stuck around until 1985, when they decided to start all over with a new business they named Qualcomm. They weren't exactly sure what this company would do, just that it would be something in commercial communications.

Then, recalls Viterbi, "along came this interesting fellow, Allen Salmasi." With backing from a rich uncle in Paris, the Iranian émigré had founded a company called OmniNet. Salmasi envisioned a mobile satellite network that would let trucking dispatchers track trucks in real time and send messages to the drivers. He hired Qualcomm to build it.

The time was right. A number of companies had launched satellite TV businesses, but the service wasn't catching on, so they were eager to lease their transponders. There was just one problem: Those satellite downlinks were licensed for fixed reception, not mobile use. The only way around the rule was if the mobile application did not interfere with fixed services.

Qualcomm's solution was to use spread-spectrum communications. The engineers figured that if they combined their signal with a broader signal that looked like noise, the fixed satellite networks would ignore it. They then used the Viterbi algorithm to help extract the original signal from the noise. The Federal Communications Commission gave Qualcomm an experimental license to try out the idea.

In 1988, Qualcomm was in the midst of testing the system with 600 trucks when Salmasi's company started falling apart. Viterbi and his colleagues, rather than letting the effort fold, decided to acquire OmniNet in 1988. Within three years, the trucking system, called OmniTracs, was turning a profit. It's still used around the world by long-haul truckers.

FOLLOWING THE LAUNCH OF OMNITRACS, the scrappy start-up took on the mobile phone industry. In an era when analog cellphones still ruled, the company introduced a digital spread-spectrum network (also based on the Viterbi algorithm, of course) to efficiently extract the right digital bits from a host of simultaneous transmissions in which everything looks like noise. (Today all 2G and 3G digital standards use the Viterbi algorithm.) Viterbi and his colleagues also figured out a way to have each handset and tower analyze the quality of its own signals as well as the other conversations being transmitted around it; the tower would then adjust power usage until the handset was transmitting just enough signal to work.

Qualcomm cofounder Jacobs says that it was a long uphill battle for the company to convince the world that its technology, code-division multiple access, or CDMA, was commercially viable, and even the usually patient Viterbi sometimes got frustrated. "A couple of professors at Stanford were being quoted in the press saying that CDMA violated the laws of physics," Jacobs says. "[Viterbi] did get into a bit of an interchange with one of them." For his part Viterbi recalls those years as intense but "very exciting. Things were happening. Hardware was being built. Maybe we were whistling in the dark, but the technology worked."

His daughter, Audrey, theorizes that this battle was perhaps "the most exciting period of his career. My father is always up for a challenge; that's what motivates him." Eventually, Qualcomm's CDMA won out. In 1993, the Telecommunications Industry Association, a trade group that represents about 600 telecom companies, incorporated it into its wireless cellular standard. Today a form of it is used in 3G cellular systems throughout the world.

Viterbi retired from Qualcomm in 2000, with hundreds of millions of dollars in stock. He now had the time and the resources to do just about anything. And what he really wanted, he decided, was to do more to help up-and-coming engineers.

These days, Viterbi's helping to groom the next generation of tech entrepreneurs through his investment firm, the Viterbi Group, which consists of Viterbi, his daughter Audrey, and an assistant. Not surprisingly, he focuses on communications start-ups, many of which are adapting the fundamental algorithm he discovered to new purposes. He's not trying to control his technology, he explains; it's just the area he knows best. To date, the group has invested in 30 companies and currently has some US $10 million invested in 10 companies.

One of his earliest investments was in VoiceSignal Technologies, which used the Viterbi algorithm for voice recognition systems in cellphones, including the iPhone. Nuance Communications acquired VoiceSignal in 2007. He was also an early investor in Provigent, a company that produces systems for microwave point-to-point transmission; Flarion Technologies, a company with a 4G phone technology that was eventually acquired by Qualcomm; and TransChip, a camera-on-a-chip manufacturer purchased by Samsung. While Viterbi may be a money man for these companies, his technical advice and industry contacts are invaluable to the start-up teams. Rajiv Laroia, Flarion's founder, says that when his company was still just a struggling New Jersey start-up, Viterbi's stamp of approval conferred instant credibility. "He is a god in the field of communications," says Laroia.

Viterbi has also made generous donations to engineering education at USC (where the school of engineering now bears his name); MIT; the Technion–Israel Institute of Technology, in Haifa; Boston Latin School; and two private high schools.

"The future of this nation is scientific literacy," Viterbi says. "What else do we have to sell? We have innovation and we have a lot of bright kids."

Maybe one of those bright kids will grow up, challenge the established way of doing things, and change the world of technology. Just like Andrew Viterbi. ❑

Backyard Star Wars

Continued from page 33

the far fence post. But if you want to focus that beam on a 1-mm spot at 10 meters or on 4 mm at 40 meters, you'll need to start with a beam that's 16 mm in diameter.

In any case, you'll need a beam expander to enlarge the narrow beam produced by your laser, as well as galvo mirrors or other aiming optics big enough to accommodate the beam. Or you can deflect the beam first, then magnify it, which means you'd need to trade smaller galvo mirrors for bigger (but stationary) lenses. In our test system, the large output lens is actually a low-power telescope, which doubles the beam diameter (see photo, "Lights, Camera…").

For the simplest aiming system, use a dichroic (wavelength-selective) beam splitter and arrange the camera and galvo so they share a common optical center. Then you don't need to know the distance to your target; just as if you were sighting along a rifle barrel, what you see is what you hit. You'll still need to calibrate the system to match up the camera and beam-steering coordinates, though. If everything is linear, that's easy; you just need to steer the laser to three different spots and find the corresponding pixels on the camera.

If your camera can't see your laser wavelength, you'll need a way to find where the laser is pointed, such as an infrared-sensitive card, and mark the spot in a way the camera can see. A little algebra will give you the offsets and scale factors you need to point your laser accurately.

Usually, though, life won't be so simple. Either your camera or your pointing system may be nonlinear; for instance, many camera lenses have "pincushion" or "barrel" distortion, which is really a change in magnification with the angle. You can measure the distortion by pointing your camera at a calibration grid and noting the nonlinearities. Or you can just move the beam a few more points, make a table of galvo input versus pixel position, and let your software interpolate between table entries. It's worth the time to set up an efficient alignment process, though, because you'll have to calibrate each camera, and you'll need to recalibrate each time you change your optics or move a laser and camera relative to one another.

If the camera and beam deflector don't share the same pivot point (as in our test system, where the camera lens and beam-output lens are a few inches apart), you'll end up with a parallax error whenever you rotate the line of sight: A bug that shows up in a particular camera pixel will need slightly different laser-beam pointing, depending on how far away it is. I mentioned stereo imagery above as one way to find the range to bug; astute readers will no doubt think of other approaches.

BLAST 'EM!

Now comes the fun part: zapping the nasty little things. How much of a wallop should your laser pack? We've yet to find an engineering handbook—or even a paper in the entomological literature—that specifies the energy that's lethal to mosquitoes. Certainly it must be less than about 2 joules, because that's enough to boil the water inside a 1-milligram bug.

So we at the Intellectual Ventures laboratory have undertaken the world's largest effort to discover what it takes to kill a mosquito using various wavelengths, pulse lengths, and fluxes of light. Our conclusion: For *Anopheles stephensi* (not your typical backyard pest but a close relative of the malaria-carrying strains), a few tens of millijoules, delivered within a few milliseconds, will cause most mosquitoes to expire within 24 hours. The blast gives them a sudden high fever, but not an obvious injury. Even under a microscope it isn't clear what they actually die of. Let's call it heatstroke.

We've shot high-speed video of mosquitoes being zapped with 50 to 100 mJ of light and found that although they keep flapping their wings, they lose attitude control and fall out of the sky. Boost the energy further and wings burn through or fall off, bodies emit puffs of steam, legs and antennae char, and so forth. Yes, it is a waste of laser energy, but revenge is sweet.

For a backyard system, the safest route would be to insist on "eye-safe" lasers, which emit wavelengths that the eye will not focus onto the retina. Alas, there are few inexpensive high-power lasers at eye-safe wavelengths, other than carbon dioxide lasers, whose wavelengths are so long (10.6 micrometers) that they require very large optics to focus over any distance. We have used an eye-safe near-infrared fiber laser operating at 1570 nm to kill mosquitoes, but even with diligent bargain hunting at surplus stores, you're unlikely to find a comparable laser for less than several thousand dollars.

Ultraviolet lasers (shorter than 400 nm) are safe for the eyes, and pulsed UV light seems to be quite good for killing bugs, but they are also expensive. In addition, shorter UV wavelengths, particularly 266 nm (sometimes used for laser machining), can cause severe photochemical damage, including cataracts, even though they aren't focused by the eye.

Therefore, if you can observe safety precautions—particularly wearing goggles at all times if there's a chance of a stray beam—the best option may be a visible or near-infrared diode laser, or perhaps an older flashlamp-pumped laser. (SSY-1 flashlamp-pumped neodymium-doped yttrium aluminum garnet lasers, which can put out about one mosquito-lethal pulse a second, are often available on eBay for around $100.) Of course,making your guests wear FDA-approved goggles may put a crimp in your barbecue, but so would a cloud of thirsty mosquitoes.

We've found it helpful, as we assemble and align all the components, to combine a visible guide beam with the main laser beam, a color-selective beam splitter, or a filter. This makes it much easier to see where the laser will go. If your system has lenses downstream of the galvo, though, you will have a more complicated job aligning everything, because beams of different wavelengths will be steered and focused differently.

Before pressing the big red button, make sure your safety systems are working. Double-check that the kill laser won't fire if there's anything bigger than a mosquito in the way. Cover the optical path with an interlock to keep unauthorized folks away from beam paths (and high voltage, if any) inside.

All ready? Then turn everything on and wait for your first invader to breach the photonic plane. Track! ID! Aim! Fire!

INTELLECTUAL VENTURES developed the photonic fence to help in an epic struggle against malaria and other vicious insect-borne diseases. But this technology could prove valuable in other roles as well, such as protecting crops from airborne pests or simply tallying insect populations rather than reducing them.

We don't really expect many *Spectrum* readers will build a photonic fence for their backyards—although given the number of people whose first reaction to the concept is "How soon can I get one?" we wouldn't be shocked to hear that some of you do. Our compliments: You will be helping to make the world a better place. Or at least a less itchy one. ❏

TO PROBE FURTHER *For an expanded version of this article, including a video of the laser in action and sidebars on fighting mosquito-borne diseases and killing blood-sucking female mosquitoes while sparing harmless males, see* http://spectrum.ieee.org/backyard-star-wars.

Candidates in 2010 Election

THE IEEE BOARD OF DIRECTORS has received the names of the following candidates to be placed on this year's ballot. The candidates have been drawn from recommendations made by divisional and regional nominating committees. In addition, the names include candidates for positions in the IEEE Standards Association, IEEE Technical Activities, and IEEE-USA.

Individuals may petition to be placed on the ballot. Please refer to IEEE Policy 13.7.3. found within the IEEE Constitution, Policies and Bylaws link at http://www.ieee.org/about/corporate/governance/index.html.

For more information on IEEE elections and candidates, please visit http://www.ieee.org/elections or e-mail corp-election@ieee.org.

Ballot packages will be mailed to and electronic ballot access created for all IEEE members eligible to vote on or before 1 August.

To ensure ballot packages are delivered to the proper mailing address, please visit http://www.ieee.org/go/my_account and update your member profile if necessary.

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Joseph V. Lillie

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Cor L. Claeys
Alfred E. Dunlop
Irving Engelson

DIVISION III DELEGATE-ELECT/ DIRECTOR-ELECT, 2011
Stanley L. Moyer
Douglas N. Zuckerman

DIVISION V DELEGATE-ELECT/ DIRECTOR-ELECT, 2011
James W. Moore
Jon G. Rokne

DIVISION VII DELEGATE-ELECT/ DIRECTOR-ELECT, 2011
Saifur Rahman
Cheryl (Cheri) A. Warren

DIVISION IX DELEGATE-ELECT/ DIRECTOR-ELECT, 2011
Anthony K. Milne
José M.F. Moura
Robert (Bob) C. Rassa

REGION 2 DELEGATE-ELECT/ DIRECTOR-ELECT, 2011–2012
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Murty S. Polavarapu

REGION 4 DELEGATE-ELECT/ DIRECTOR-ELECT, 2011–2012
Robert C. Parro
Karen S. Pedersen
Hamid Vakilzadian

REGION 6 DELEGATE-ELECT/ DIRECTOR-ELECT, 2011–2012
Michael R. Andrews
Roy E. (Gene) Stuffle

REGION 8 DELEGATE-ELECT/ DIRECTOR-ELECT, 2011–2012
Jaafar M. Al-Ibrahim
Gerhard P. Hancke

REGION 10 DELEGATE-ELECT/ DIRECTOR-ELECT, 2011–2012
Jose (Joe) B. Cruz Jr.
Toshio Fukuda
Ramakrishna Kappagantu

IEEE STANDARDS ASSOCIATION BOARD OF GOVERNORS MEMBER-AT-LARGE, 2011–2012
Karen Bartleson
Victor Berman

IEEE STANDARDS ASSOCIATION BOARD OF GOVERNORS MEMBER-AT-LARGE, 2011–2012
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Glenn W. Parsons

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Frederick C. Mintzer

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Marc T. Apter
James M. Howard

IEEE-USA MEMBER-AT-LARGE, 2011–2012
Mauro G. Togneri
John R. Twitchell

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TU WIEN
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Vienna University of Technology, Faculty of Electrical Engineering and Information Technology, Austria, invites applications for the faculty position of a **full professor** in **Energy Systems Engineering**.

Candidates should have an excellent scientific background and strong expertise in at least one of the following research areas: power plant design and electrical energy transmission, architecture and numerical simulation of complex electrical energy systems, congestion management and energy system protection. Applications are expected until June 18, 2010. More information concerning the requirements for this position is available at

http://eeg.tuwien.ac.at/announcement/.

Please, send your application along with your scientific CV and list of publications to: TU Vienna, Faculty of Electrical Engineering and Information Technology, Dean's Office, Gusshausstrasse 27-29, 1040 Vienna, Austria.

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Los Alamos National Laboratory

Agnew National Security Postdoctoral Fellows

Los Alamos National Laboratory (LANL) addresses national security needs through cutting-edge experimental, theoretical, and computational science, and engineering research using the newest and most advanced facilities in the US and around the world. LANL seeks applications from outstanding candidates to be considered for an Agnew National Security Postdoctoral Fellow appointment. Selected candidates will have the opportunity to perform research aligned with the national security mission of LANL including the following research areas:

- Advanced Engineering Analysis
- Advanced Hydrodynamics
- Computational Astrophysics
- Computational Fluid Dynamics
- Dynamic Material Properties and Shock Physics
- High Energy Density Physics (HEDP) and Inertial Confinement Fusion (ICF)
- High Explosive and Detonator Technologies
- Magneto-Hydrodynamics
- Nuclear Physics and Neutral/Charged Particle Transport
- Plasma Physics
- Radiographic Technology for Hydrodynamic Testing
- Weapons Engineering

For more information regarding the identified research areas access http://www.hr.lanl.gov/JobListing/SingleJobAd.aspx?JobNumber=219144

Required skills – Ability to obtain a DOE "Q" Security Clearance, excellent communication skills, ability to work independently with minimal supervision. Demonstrated success in performing, analyzing, and publishing high quality research in related areas.

Education – Completion of the Ph.D. in fields relevant to the research described above within the last five years or will have completed all Ph.D. requirements by commencement of appointment.

Candidates interested in being considered for one of these appointments should submit a letter describing your research interests, and a CV or resume including list of publications by accessing job # 219144 at http://www.hr.lanl.gov/JobListing/SingleJobAd.aspx?JobNumber=219144. For technical questions, e-mail agnew@lanl.gov. **Deadline for application is June 4th, 2010.**

For general information regarding the Postdoctoral Program, refer to:
http://www.lanl.gov/science/postdocs/

Los Alamos
NATIONAL LABORATORY

www.lanl.gov/jobs

TEXAS TECH UNIVERSITY
Edward E. Whitacre Jr. College *of* Engineering™

Dean of the Whitacre College of Engineering

Texas Tech University invites applications and nominations for the position of Dean of the Whitacre College of Engineering.

Texas Tech University, the flagship institution of Texas Tech University System, is a 1,839-acre award-winning campus located in Lubbock with an enrollment of more than 30,000 students.

The dean of the Whitacre College of Engineering (www.coe.ttu.edu) has responsibility for more than 130 tenured/tenure-track faculty positions, and an annual operating budget of $14 million. The college is home to eight academic departments and offers over 30 degrees to more than 4,700 students, including more than 700 masters and doctoral students. Research funding has grown 40% in the last three years, with research awards totaling $16.5 million in the last fiscal year.

The successful applicant will have an earned doctorate in engineering, computer sciences, or a closely related discipline and a record of scholarly accomplishments that merits appointment as a tenured full professor in one of the college's departments.

A full position description and further details can be found at www.coe.ttu.edu/deansearch. The salary and other benefits are competitive and are based on experience. Apply for the position online at http://jobs.texastech.edu. Search Postings for Requisition No. 81078.

Screening will begin upon the receipt of applications and will continue until the position is filled. Candidates names will not be made public until the final stages of the search. To nominate a colleague for this position, visit www.coe.ttu.edu/deansearch. Nominations can be made anonymously.

Questions about the Dean of the Whitacre College of Engineering should be directed to:
Dean Search Committee | Texas Tech University | Whitacre College of Engineering
Box 43103 | Lubbock, Texas 79409-3013
engineeringdean.coe@ttu.edu | 1.800.528.5583

Texas Tech University | Whitacre College of Engineering
1.800.528.5583 | www.coe.ttu.edu/deansearch
An Affirmative Action/Equal Opportunity/Americans with Disabilities Employer

Portland State
UNIVERSITY

Portland State University invites applications for a tenure track position as Assistant or Associate Professor of **Energy Systems in Electrical & Computer Engineering Department,** commencing fall 2010.

An earned doctorate and a proven research record in electrical/computer engineering is required, as demonstrated by archival publications, and evidence of successful research funding at the associate professor level. The successful applicant will be expected to contribute to undergraduate and graduate programs, and to develop a sustainable externally funded research program in energy systems, (e.g. alternative/renewable energy, smart grid technologies, or more traditional areas,) in collaboration with existing campus and departmental faculty, and local industry. PSU is situated in downtown Portland, in the heart of the Silicon Forest, where sustainability and alternative energy have been identified as civic and State priorities. The Portland region hosts a wide range of high-tech electronics and power companies, e.g. Intel, Tektronix, PGE, PacifiCorp, SolarWorld, and Vestas, with Energy Systems R&D centers at Bonneville Power and the Pacific Northwest National Laboratory. Salary is competitive and dependent on qualifications and experience. PSU offers an excellent benefits package including fully paid healthcare, reduced tuition rates, and a generous retirement package.

Applications must be submitted on-line at
http://ece.pdx.edu/EnergySystemsPosition.php,

where detailed information on the position, the Department, and the campus can also be found. PSU is an AA/EO institution and welcomes applications from diverse candidates and candidates who support diversity. Application reviews will begin immediately and continue until finalists are identified.

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Faculty Position in Aerospace Engineering

at the Ecole polytechnique fédérale de Lausanne (EPFL)

The Institutes of Electrical and Mechanical Engineering at EPFL invite applications for the position of **tenured full or associate professor** in the area of **Aerospace Engineering.** As a faculty member of the School of Engineering, the successful candidate will be expected to teach and conduct cutting-edge research in fields such as space systems, aviation, aerospace materials or aeronautics. This is a broad search in all areas of aerospace technologies.

The successful candidate will also be expected to assume the role of **Director of the Space Center EPFL.** This partnership of government and industry has the goal to foster, promote and federate space technology across science, education and industry both within Switzerland and with international partners. Unique within Switzerland, the Space Center EPFL aggregates equipment and coordinates space-related research across several institutes, serving as a platform to facilitate cross-disciplinary research. In collaboration with its partners, the Space Center EPFL recently launched its first flagship project, the SwissCube satellite.

Candidates should have an outstanding academic record, as well as exceptional leadership, communication and management skills. The EPFL will provide the means to attain the objective of establishing world-class leadership in education and research. The EPFL, located in Lausanne, Switzerland, is a dynamically growing and well-funded institution fostering excellence and diversity. It has a highly international campus at an exceptionally attractive location boasting first-class infrastructure. As a technical university covering computer & communication sciences, engineering, environment, basic and life sciences, management of technology and financial engineering, EPFL offers a fertile environment for research cooperation between different disciplines. The EPFL environment is multi-lingual and multi-cultural, with English often serving as a common interface.

The Search Committee invites letters of nomination, applications (complete CV with list of publications, research and teaching vision statements, and the names of at least 5 referees), or expressions of interest. Applications must be uploaded in PDF format to the web site **http://sc-search10.epfl.ch.**

Evaluation of candidates will begin in September 2010.

Enquiries may be addressed to:
Prof. Claude Nicollier
Search Committee Chairman
E-mail: sc.search@epfl.ch

More information on EPFL, the School of Engineering and the Space Center EPFL can be found at **http://www.epfl.ch, http://sti.epfl.ch and http://space.epfl.ch**

EPFL is committed to increasing the diversity of its faculty, and strongly encourages women to apply.

Professor in Antennas, Propagation & Radio Networking

AALBORG UNIVERSITY

Applications are invited for a position at the level of Professor at the Faculties of Engineering, Science and Medicine, Department of Electronic Systems (position number 60031). The position is available from September 1st 2010.

Research areas will be within:

- Dynamic radio channel modelling and characterization
- Modelling and characterization of antennas
- Physical layer workability of short range (UWB, RFID etc) as well as cellular (2G,3G,4G..) wireless communication systems
- Multi-element antenna system design in terms of communication performance
- Multi-element radio channel sounding principles
- Design of probing antenna systems
- Dosimetry aspects of biological effects of wireless systems
- EMC aspects

In order to apply for this position, all applicants must read the complete job notice at: **http://stillinger.aau.dk/**

Deadline for applications is: **June 5th 2010**.

The mission of Aalborg University (AAU) is to ensure high quality in higher research and education within the fields of Engineering, Natural Sciences, Medicine and Social and Human Sciences. With an annual budget around DKK 2 billion, more than 15,000 students, 600 Ph.D. students, more than 2,000 employees and strong ties to industry and business life, Aalborg University has established its position as a considerable force within higher research and education both nationally and internationally.

THE UNIVERSITY OF HONG KONG

Post-doctoral Fellows and Research Assistant Professors for the Area of Excellence Project (Ref.: 20100118)

Applications are invited for appointments as Post-doctoral Fellows (PDF) and Research Assistant Professors (RAP) in Emerging Electronics for the AoE Project, from as soon as possible for one to three years, with the possibility of renewal.

Applicants should possess a doctoral degree in Physics, Chemistry or Electric Engineering, with strong experience in Computational Science and Engineering. Successful candidates will join a multi-institutional interdisciplinary project on modeling and simulation of emerging electronics in Hong Kong to develop a suite of multi-scale electronic devices and automation software tools. Details can be found at http://www.physics.hku.hk/~fczhang/AoE/AoE.html.

Applicants who have responded to the previous advertisement (Ref.: RF-2009/2010-435) need not re-apply.

A highly competitive salary commensurate with qualifications and experience will be offered. Annual leave and medical/dental benefits will be provided. The appointments of RAPs for two years or more will attract a contract-end gratuity and University contribution to a retirement benefits scheme, totalling up to 15% of basic salary.

Interested candidates should send a cover letter, C.V. and 3 recommendation letters to Ms. Anna Wong (**e-mail**: annaylw@hkucc.hku.hk). **Review of applications will continue until the posts are filled.** Candidates who are not contacted within 3 months from the date of their applications may consider their applications unsuccessful.

The University is an equal opportunity employer and is committed to a No-Smoking Policy

Georgia Tech Research Institute

Solutions for the Real World

Researchers at the Georgia Tech Research Institute interact with colleagues across Georgia Tech and the national research and development communities to advance technology supporting National Security. Our researchers work in a team-oriented environment, developing innovative solutions and taking their ideas from the white board through analysis, modeling and simulation, prototype, integration, and test and evaluation. GTRI is also involved in training through extensive professional education programs.

Successful candidates should have a BS/MS/PhD in a relevant engineering, mathematics, or physics discipline.

Missile Defense Radar Engineer/Systems Engineer • System of systems engineering, radar systems engineering, phased array antenna systems analysis, digital beamforming, electronic protection, track and sensor fusion algorithms, modeling and simulation, test and evaluation of complex systems

Antenna Design Engineer/Electromagnetic Phenomenology • Antenna design and analysis, novel antenna concepts, conformal and wideband antennas, antennas for radar and communications systems, antenna measurements, antenna calibration, advanced techniques • Electromagnetic propagation, EMI/EMC, advanced sensing techniques and phenomenology exploitation

Electronic Attack/Protection Research Engineer • RF EA/EP techniques development, algorithm development and evaluation, hardware development, test and evaluation, data analysis, modeling and simulation

Algorithm Developer/Radar Systems • Algorithms for moving target detection and SAR, through-the-wall sensors, aerospace radar systems for ISR and/or fire-control, advanced concepts, radar payloads and technology prototyping

RF Systems Engineer • Embedded computing and real-time software applications for radar system development, radar signal processing, hardware-in-the-loop simulation, integration and test • High power microwaves

Ground Tactical Radar Engineer • Weapons location radar, CRAM, next-generation systems, technology insertion, test and evaluation

Intelligence Analysis • Analyze threat systems, threat system simulators, FME • Future threats, foreign systems analysis

Electronic Warfare Research Engineer • Perform modeling, simulation, analysis and concept development of RF electronic warfare systems • Develop analytical tools using MATLAB and similar programs to support analysis and development programs

Real-Time Embedded Software Developer • Develop application software used for defensive avionics and related testing, training, and instrumentation • Integrate aircraft and ground systems using MIL-STD-1553, Ethernet, and Tactical Data Links

Candidates interested in the GTRI postings listed above should send their resume and statement of interest to hiring coordinators, Ms. Melanie Scoville, melanie.scoville@gtri.gatech.edu, Voice 404-407-7915 and Mr. Joe Brooks, joe.brooks@gtri.gatech.edu, Voice 404-407-7144.

Due to the unique nature of our work, US Citizenship is required for employment. Current collateral or elevated security clearances are especially desirable. Georgia Tech is an equal opportunity employer.

Georgia Tech Research Institute
www.GTRI.gatech.edu

Oregon State University OSU College of Engineering

Oregon State University Department of
Nuclear Engineering & Radiation Health Physics

The Department of Nuclear Engineering and Radiation Health Physics invites applications for a Full-time, 12-month research faculty position. The successful applicant will work in developing and characterizing radiation detectors, digital pulse processing algorithm, and radiation transport modeling to detect radioactive noble gases through beta/gamma coincidence measurements. For complete position details and qualifications and to apply, go to
http://oregonstate.edu/jobs/
and submit your application packet.

The Hong Kong Polytechnic University
香港理工大學

The Hong Kong Polytechnic University is the largest government-funded tertiary institution in Hong Kong, with a total student headcount of about 28,655, of which 15,350 are full-time students, 8,485 are part-time students, and 4,820 are mixed-mode students. It offers programmes at Doctorate, Master's, Bachelor's degrees and Higher Diploma levels. The University has 27 academic departments and units grouped under six faculties, as well as 2 independent schools and 2 independent research institutes. It has a full-time academic staff strength of around 1,400. The total consolidated expenditure budget of the University is in excess of HK$4 billion per year.

DEPARTMENT OF BUILDING SERVICES ENGINEERING

The Department of Building Services Engineering is one of the constituent departments of the Faculty of Construction and Land Use. It offers a full range of programmes leading to the awards of Doctor of Philosophy, Master of Philosophy, Master of Science and Bachelor of Engineering. It has an undergraduate student body of over 400 full-time students, over 200 part-time students and a postgraduate student body of over 350. There is a total full-time academic staff establishment of 29 engaging in a wide range of active research areas including but not limited to HVAC, Building Environment, Electrical and Lighting Systems, Facility Management, Fire and Safety. The University and the Department highly encourage a multiple culture environment concerning both staff and student mix. Please visit the website at http://www.bse.polyu.edu.hk for more information about the Department.

Associate Professor / Assistant Professor in Electrical Services

The appointee will be required to (a) undertake teaching activities at both undergraduate and postgraduate levels in Electrical Services and related subjects; (b) be an active researcher concerning quality publications, external research grants and applied research; (c) supervise undergraduate and postgraduate research/design projects; and (d) provide leadership in developing a programme, a subject discipline, or a research programme, etc.

Applicants should have (a) a PhD degree in an appropriate discipline related to Electrical Engineering; (b) a proven track record in research publications and scholarly activities; (c) preferably a professional qualification in a recognised and relevant professional body; and (d) several years of research experience in an electrical discipline, preferably related to application in buildings.

Applicants with a high level of achievement, and an outstanding level of knowledge of and extensive experience in a related discipline will be considered for the post of Associate Professor.

A start-up package will be provided for initiation of a new research programme or research area.

Remuneration and Conditions of Service
Salary offered will be commensurate with qualifications and experience. Initial appointment will be made on a fixed-term gratuity-bearing contract. Re-engagement thereafter is subject to mutual agreement. Remuneration package will be highly competitive. Applicants should state their current and expected salary in the application.

Application
Please submit application form via email to hrstaff@polyu.edu.hk; by fax at (852) 2764 3374; or by mail to **Human Resources Office, 13/F, Li Ka Shing Tower, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong**. If you would like to provide a separate curriculum vitae, please still complete the application form which will help speed up the recruitment process. Application forms can be obtained via the above channels or downloaded from http://www.polyu.edu.hk/hro/job.htm. **Recruitment will continue until the position is filled**. Details of the University's Personal Information Collection Statement for recruitment can be found at http://www.polyu.edu.hk/hro/jobpics.htm.

For further details about the University, please visit www.polyu.edu.hk/hro/job.htm

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IRIS PASSCAL Program Manager

The Incorporated Research Institutions for Seismology (www.iris.edu) seeks a dynamic and forward-looking scientist or engineer with managerial and instrumentation experience to serve as Program Manager for the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL). The preferred candidate will have an advanced degree or equivalent experience in engineering or science and ten or more years experience leading research or facilities programs in academia, related government agencies or industry.

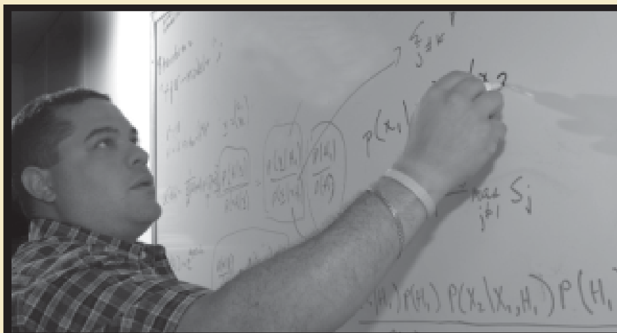
The PASSCAL facility based at New Mexico Tech (www.passcal.nmt.edu) is managed by the IRIS Consortium and is funded primarily by the National Science Foundation. This facility provides access to a broad range of portable seismic instruments, field training and support, and data services to assist seismological research on earthquakes and Earth structure. The PASSCAL Program Manager provides leadership and technical advice in the development, operation and evolution of PASSCAL, including oversight of the subaward for facility operation at New Mexico Tech.

The successful candidate must demonstrate vision and an ability for sustained leadership, and be capable of managing in a challenging, dynamic and highly rewarding scientific and technical environment. Significant travel is required. The position will be located in Socorro, New Mexico or Washington, D.C.

IRIS offers competitive salaries, an excellent benefits package and a collegial work environment. IRIS is an equal opportunity employer and welcomes a diverse pool of candidates. Consideration of applications will begin in early May, and the position will remain open until filled. Additional information on the position can be found at www.iris.edu/hq/employment.

Please e-mail vitae with a cover letter including names of references and salary requirement, preferably by May 15, 2010, to: HR@iris.edu.

IRIS



Discover the satisfaction of innovation and service to the nation

MIT Lincoln Laboratory applies advanced technology to problems critical to national security in the areas of communications, space surveillance, advanced electronics, air and missile defense, network security, integrated sensing and decision support, and homeland protection.

Unless otherwise noted, the following positions require a PhD in Electrical Engineering, Applied Mathematics or Physics. In lieu of a PhD, a MSEE with 3-5 years of directly related experience will be considered.

Senior Integrated Circuit Test Engineer (872)

Lead a team of approximately four that serves all testing needs of the Advanced Silicon Technology Group. Will be responsible for a large VLSI digital tester capable of 1 GHz, an automated parametric tester, and many discrete instruments, and have access to an extensive microwave lab capable of 100 GHz. Our custom circuits often require custom analog and digital test equipment, developed by the person in this role. Develop test plans and procedures, write test programs for both commercial and custom test equipment, debug programs and the IC's being tested. Requires MSEE and Familiarity with Agilent (now Verigy) 93000 VLSI tester programming and data extraction.

Digital Systems Engineer (220)

Develop digital signal processing hardware and firmware, including FPGA-based algorithms, for use in wireless communications systems. Plan architecture of wireless communications systems; design communications systems based on high-level specifications; and manage a team of developers. Must be able to develop implementation architectures from requirements documents.

Algorithm Development/Surface Surveillance Radar Staff (218)

Conduct algorithm development for surface surveillance radar programs for moving target detection, synthetic aperture radar (SAR), as well as moving target imaging or inverse synthetic aperture radar (ISAR). Digital signal processing expertise is required.

Algorithm Development/Surface Surveillance Radar Staff (230)

Research and development on advanced signal processing techniques for mitigation of complex interference sources. Expertise in adaptive and statistical signal processing, electronic protection and detection is essential. Candidate must be able to perform data-driven algorithm development using experimental data.

All positions are located in Lexington, MA.

Please visit our website at **www.ll.mit.edu** for more information on these and our many other opportunities.

LINCOLN LABORATORY
Massachusetts Institute of Technology

Technology in Support of National Security

As an Equal Opportunity Employer, we are committed to realizing our vision of diversity and inclusion in every aspect of our enterprise. Due to the unique nature of our work, we require U.S. citizenship.

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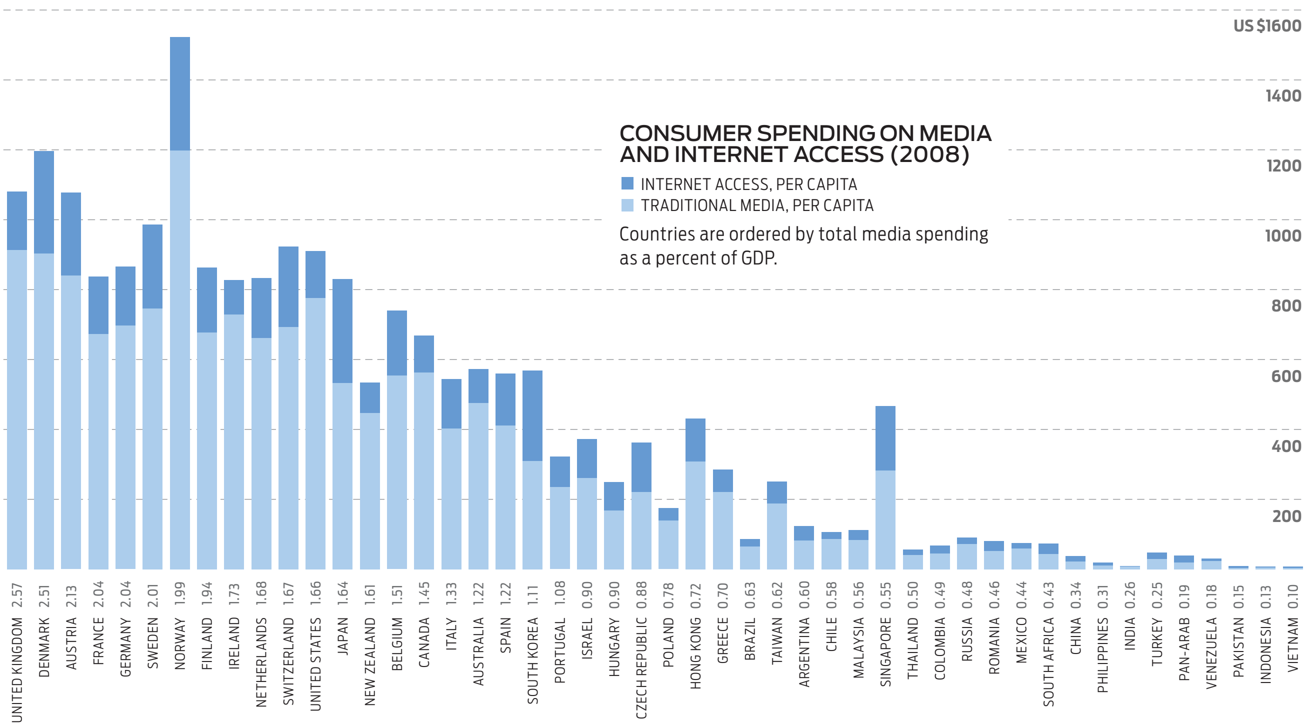


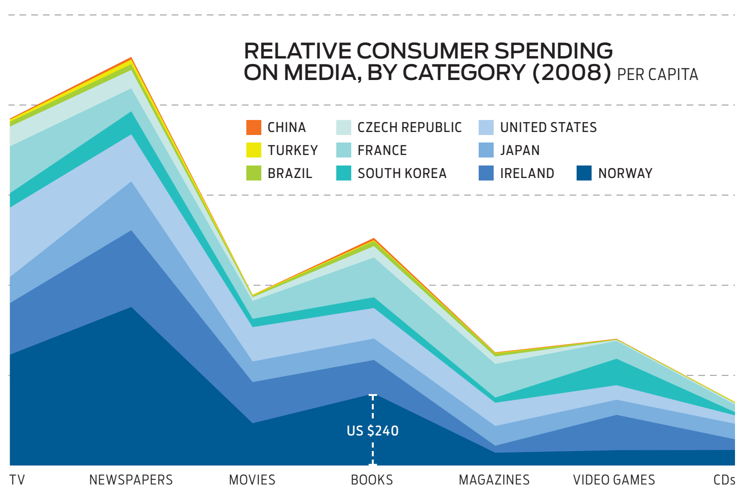
Old and New Media

HOW MUCH are you willing to spend to be entertained and informed? If you live in Norway, quite a lot. In 2008, Norwegians spent US $1522 per capita on media and Internet access, according to a recent study by PricewaterhouseCoopers. On the other hand, the average Chinese person spent about as much that year ($38) as a Norwegian did in nine days. (To be sure, China's 2008 per capita GDP was just about one-tenth Norway's; the gap in disposable-income spending is presumably narrower.)

When it comes to traditional media—including newspapers, magazines, books, movies, television, video games, and CDs—the top 15 countries in per capita spending are all in North America and Western Europe; the leading non-Western country is Japan, in 16th place. Elsewhere, consumers may be turning more to the Internet for their entertainment. Japan ranks second in per capita spending on Internet access, South Korea fourth, and Singapore tenth; the average Czech spends more on Internet access ($141) than does the average American ($133).

Westerners spend at least three times as much on traditional media as on Internet access. In non-Western countries, a ratio of less than 2:1 is not uncommon. In Vietnam and Pakistan, consumer spending for Internet access actually exceeds purchases of traditional media. (It's worth remembering that a DVD of the same movie, for example, can cost far less in some countries than others.)

Who spends the most per capita on recorded music? That would be the Japanese. For magazines, the leader is Finland, followed closely by Greece and Switzerland. The Irish spend the most on video games. In most other categories Norway leads. Partly, that's due to its high cost of living. But they also seem to love media—especially books, at $240 per year per person. Must be those long winter nights! —*Dana Mackenzie*



SOURCES: PricewaterhouseCoopers, "Global Entertainment and Media Outlook: 2009–2013"; U.S. Census International Data Base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Over one million people around the world speak MATLAB.
Engineers and scientists in every field from aerospace and semiconductors to biotech, financial services, and earth and ocean sciences use it to express their ideas.
Do you speak MATLAB?
Saturn's northern latitudes and the moon Mimas. Image from the Cassini-Huygens mission.
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MATLAB®
The language of technical computing