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THE MAGAZINE OF TECHNOLOGY INSIDERS
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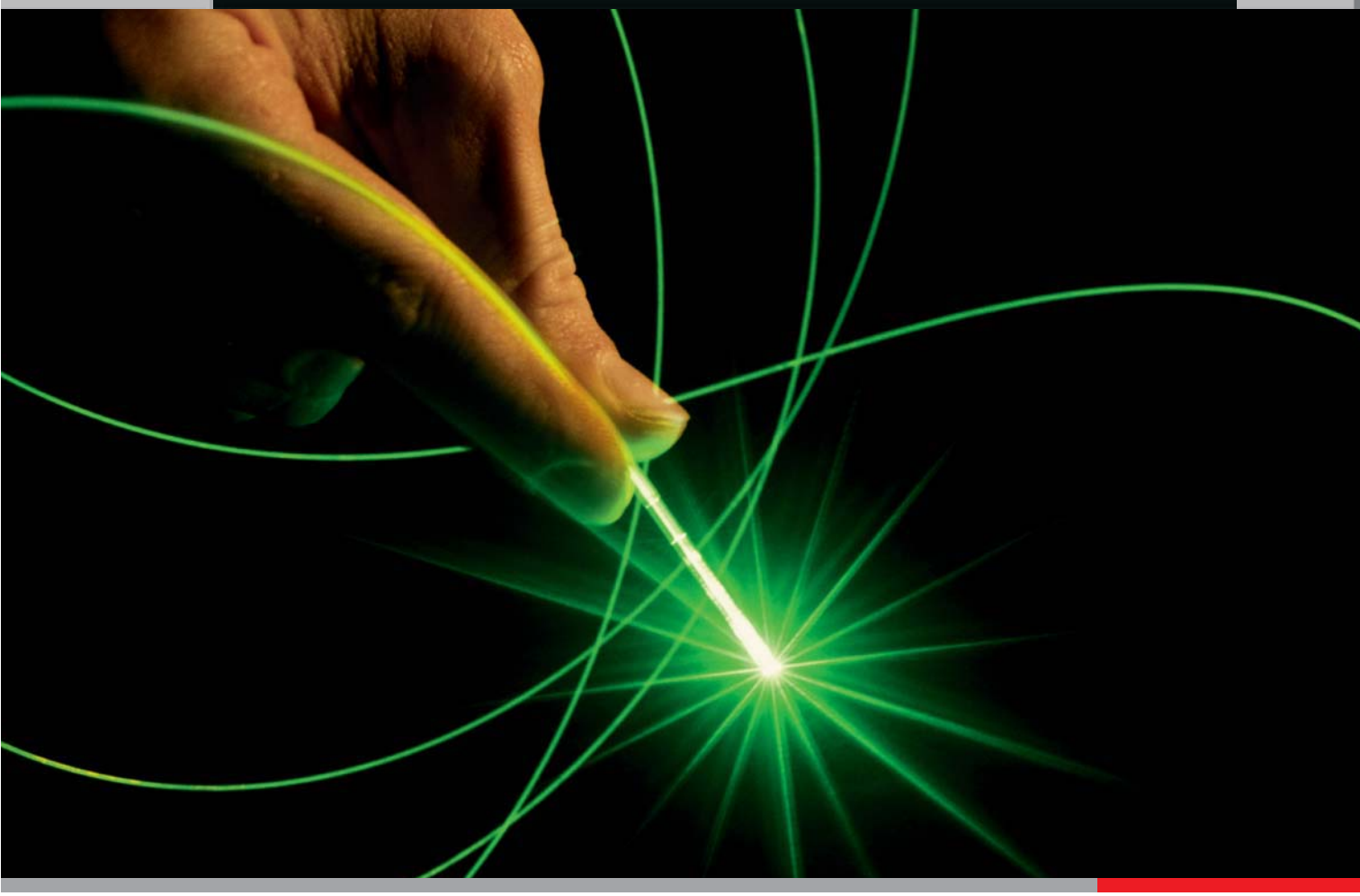

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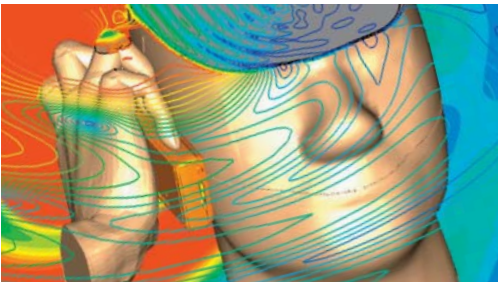

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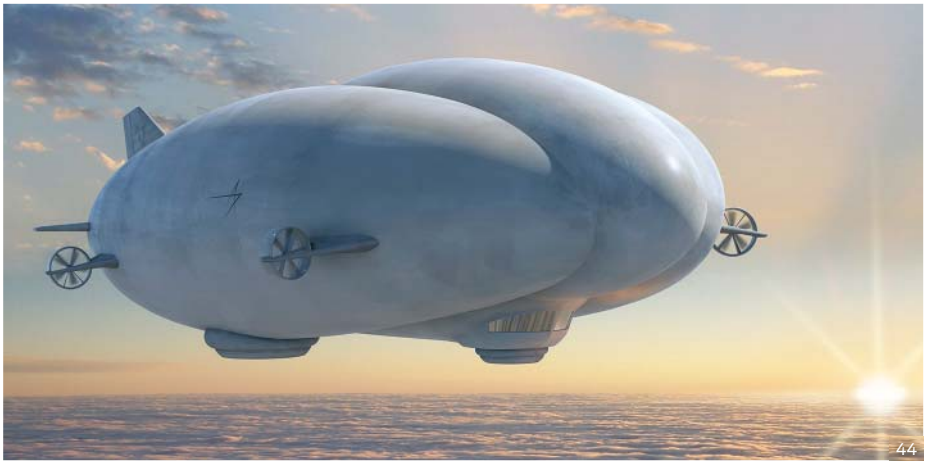


COVER: TAVIS COBURN
THIS PAGE, CLOCKWISE FROM TOP LEFT: DAN PAGE; TAVIS COBURN; LOCKHEED MARTIN

COVER STORY

38 GREEN SUPERCARS

Frugal with fuel, gentle on the greenhouse gases, and brimming with power: Meet the new beasts of the autobahn. *By Lawrence Ulrich*

26 THE GREAT SPECTRUM FAMINE

The hunger for wireless links to the Internet is fast exceeding what the airwaves can provide. *By Mitchell Lazarus*

32 SOFTWARE V. SOFTWARE

Computer forensics tools can help sort out even the toughest cases of software copyright infringement. *By Bob Zeidman*

44 AIRSHIPS AHOY

The oldest aviation technology is reborn in new designs for high-altitude, long-endurance, and heavy-lift airships. *By Ron Hochstetler*

UPDATE

OPINION

DEPARTMENTS

NI LabVIEW

Limited Only by Your Imagination

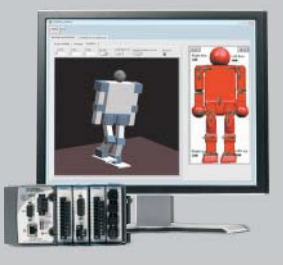
RF

Medical

Robotics

Multicore

LabVIEW graphical programming software and modular NI hardware, such as CompactRIO and PXI, are helping engineers develop fully autonomous robotics systems, including unmanned vehicles designed to compete in DARPA Grand Challenge events.



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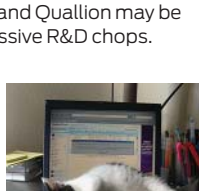
Video: Searching for Europe's Banned Bulbs

Across Europe, nighttime looks a little different these days. That's because the European Union is phasing out incandescent lightbulbs in favor of more energy-efficient compact fluorescent models. Not everyone is happy with the change. Before the 2009 ban on 100-watt and frosted incandescent bulbs went into effect, many consumers complained, and there were even some reports of hoarding. *IEEE Spectrum* investigates whether the ban has worked by scouring Berlin for the forbidden bulbs.

GREEN TECH PATENT SCORECARDS

IEEE SPECTRUM has partnered with 1790 Analytics to bring you our annual patent scorecards. On 15 October, we'll debut our patent scorecards for green tech. We'll tell you who has the most valuable patent portfolios in batteries, clean coal, fuel cells, and more. Some companies, like General Electric and Siemens, will be familiar. Others like ThioSolv and Quallion may be new, but they've shown some impressive R&D chops.

GADGETS ARE A CAT'S BEST FRIEND



CATS AND TECHNOLOGY— two things that go great together. *Spectrum* searched the Web to bring you some of the cutest photos of cats and their favorite devices. Pictured here is Dai-chan, who proclaims, "You will obey my wishes." (And dog lovers, fear not! E-mail your favorite dog-and-tech photos to r.silberman@ieee.org for a chance to be featured in an upcoming slideshow.)

CLOCKWISE FROM TOP: THOMAS KIENZLE/AP PHOTO; ISTOCKPHOTO; ANDREEAINJAPAN/FLICKR; DAVID MCNEW/GETTY IMAGES

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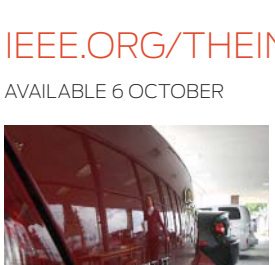

IEEE RELEASES NEW BLACK BOX STANDARD FOR CARS

As millions of drivers face ongoing automotive recalls for electrical and onboard computer issues, motor vehicle event data recorders, also called black boxes, are becoming increasingly important.

USING SOCIAL MEDIA TO ATTRACT NEW CLIENTS

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back story

Up in the Air

During Ron Hochstetler's sophomore year at Purdue University, the Goodyear Blimp came to campus. "The lights were shining up on this big silvery airship, floating just 2 feet off the ground," he recalls. "I thought, Oh, my gosh, this thing is flying all the time! Unlike an airplane or helicopter, which has to exert all this effort to clamber into the clouds, an airship is always flying, as if it belongs in the sky."

Hochstetler, who describes recent advances in airship technology in "Airships Ahoy" in this issue, went on to get a B.S. in aviation technology as well as a Federal Aviation Administration aircraft mechanic's license. "I knew I didn't want to go work in a big airplane factory," he says. Airships, on the other hand, "looked like the last unexploited aviation arena," but jobs in that industry are always scarce.

He got his first big break when he went to work as a mechanic for aviation pioneer Frank Piasecki, inventor of the tandem rotor helicopter. Piasecki was leading a project in New Jersey to build an experimental 105-meter-long hybrid airship-helicopter, called the Helistat [see photo]. "We'd take it out on the tarmac, and the sun would heat it and the helium inside would expand, which would cause these huge air valves to crack open a little," he says. "As the air escaped, it was like the reed of a clarinet vibrating, and the ship would sing."

Sadly, the Helistat was doomed. During a 1986 flight test, it crashed shortly after takeoff, killing one of the pilots. By then Hochstetler was no longer working for Piasecki, but he's spent much of his career since then in the airship industry. Currently, he is director of lighter-than-air programs for Science Applications International Corp., in McLean, Va.

Having witnessed several boom-and-bust cycles in the airship business, he admits it's not for the risk averse or the easily discouraged. "I know people who've wrecked their lives because they can't get airships out of their systems," he says.

The last few years, though, have seen the kind of "slow and steady growth that builds a solid base," he says. The technology has vastly improved, he notes, and "there are sober people in serious positions who don't laugh at using lighter-than-air vehicles for applications where their capabilities exceed those of airplanes and helicopters." ❑

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 Data is in *IEEE Spectrum,* Vol. 47, no. 10 (INT), October 2010, p. 60, or in *IEEE Spectrum*, Vol. 47, no. 10 (NA), October 2010, p. 68.

COURTESY OF RON HOCHSTETLER

contributors

TAVIS COBURN, based in Toronto, draws inspiration from printed materials of the 1920s to the 1960s, including Russian avant-garde posters and classic comic books. He began creating illustrations by hand with paint and silk screen. Now he achieves similar effects with digital tools. For the retro-style images of classy cars accompanying this month's cover story, "The Greening of the Supercar" [p. 38], Coburn says he strove to "exude the excitement and optimism of the auto industry's golden era" using a digital process "that's very similar to old-school low-fi printing."

MICHAEL DUMIAK is a science and technology reporter based in Berlin. This summer, in Belgrade to interview heart-imaging engineer Nenad Filipovic for the profile "Coronary Calculus" [p. 23], he wondered how this corner of Europe became a source of predictive software that visualizes the plaques that cause heart attacks. But, he says, it all made sense after a few meals. "Serbian cooking is...robust. This guy's going to have a lot of patients."

CHAD HAGEN, who illustrated the futuristic concept of "spimes" for Technically Speaking [p. 25], has been a graphic designer and art director for 16 years. Based in Minneapolis, he has created infographics for popular magazines, including *Fortune* and *More*. Recently, he took on a creative challenge, joining the Flickr group "Make Something Cool Every Day," for which he created an original image each day for a year.

MITCHELL LAZARUS is a partner in the Washington, D.C.–area law firm of Fletcher, Heald & Hildreth, which specializes in telecommunications law and regulation. In addition to a law degree, he holds two degrees in electrical engineering and a doctorate in experimental psychology. During the 1970s, while working on mathematics education reform, he wrote on the subject of math anxiety. His article on the looming crisis in wireless broadband, "The Great Spectrum Famine" [p. 26], nevertheless takes an unblinking look at the numbers.

LAWRENCE ULRICH explores an unorthodox trend in high-end power cars in "The Greening of the Supercar" [p. 38]. And he came to auto journalism by an unorthodox route: rock music. The native Detroiter worked in the 1980s as a rock musician, playing keyboard as far afield as Europe before becoming a business writer in the early 1990s, then a car writer. He lives in Brooklyn, N.Y., and regularly writes for *The New York Times* and *Automobile*.

BOB ZEIDMAN, who wrote "Software v. Software" [p. 32], is the president of Software Analysis and Forensic Engineering Corp., the leading provider of intellectual-property analysis software. He holds seven patents, two bachelor's degrees—in physics and electrical engineering—from Cornell, and a master's in EE from Stanford. He is also the inventor of the Silicon Valley Napkin, a cocktail napkin printed with a simple form for creating a business plan, which when completed can be presented to a venture capitalist as a funding pitch.

CLOCKWISE FROM TOP LEFT: TAVIS COBURN; MITCHELL LAZARUS; RANDI SILBERMAN KLETT; CARRIE ZEIDMAN; SHELLY DIXON; SARAH MARTIN

spectral lines

DIY as an Extreme Sport

FLASHBACK: The front panel of Bill Buzbee's handcrafted Web server [left] evokes the late 1960s or early '70s. Residing within it are some two hundred 74-series ICs, painstakingly wire-wrapped together [right].

Lots of people know that you can construct a Web server at home without great difficulty. Get a PC, load it with Apache, do some port forwarding on your router, and you're good to go. Or if you think that's too mundane, you could build a tiny Web server out of an Arduino microcontroller by adding an Ethernet accessory board. Thousands of people, I'm sure, have hacked systems like that together for various purposes. But I've recently discovered, much to my pleasure and amazement, that one home brewer has set up a DIY Web server that's far more impressive than any of those. Indeed, he's taken "do it yourself" to a whole other level.

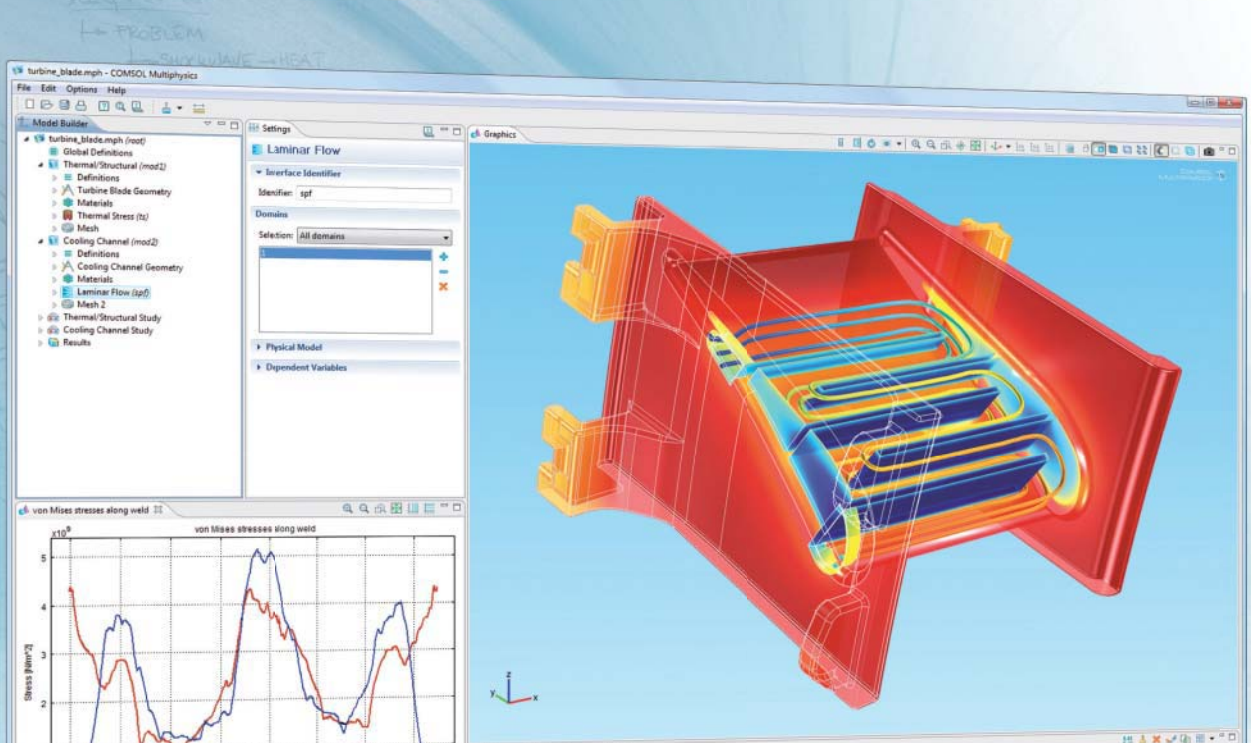
Bill Buzbee, of Half Moon Bay, Calif., has built himself a Web server entirely from scratch. *Scratch* is, of course, a relative term. No, he didn't draw the copper into wires or slice the silicon into wafers. But he did construct his home-built CPU, called Magic-1, by meticulously wire-wrapping together some two hundred 74-series TTL chips. They reside on five printed-circuit boards, which are housed in a cabinet whose front panel is replete with dozens of LEDs and paddle switches. It thus has, as he intended, the distinctive look of the mini- and microcomputers of the late 1960s and early 1970s. Buzbee claims that it sports the performance of an Intel 8086 (a close cousin of the 8088, the CPU found in the original IBM PC) making it a decade or so ahead of its nonchronological time. It's a DIY masterpiece. But Buzbee is self-deprecating in advertising his creation: On his Web site, at http://homebrewcpu.com, which is served up, of course, by Magic-1, he says, "I'm continually amazed that the damn thing runs at all, much less runs as well as it does."

That one person could construct a Web server starting from little more than stone knives and bear skins—and doing it all in his spare time—is just stunning. But Buzbee's accomplishment doesn't end with putting together the hardware. "I've had to write an assembler and linker from scratch, retarget a C compiler, write and port the standard C libraries, write a simplified operating system, and then port a more sophisticated one," he says. It helps that Buzbee develops software for a living. "It also helps that as far as my wife knows, I'm actually doing paying work on the laptop and not just screwing around with my hobby projects."

Still, that somebody would take on such a challenge—and purely for the entertainment and educational value—must inspire anyone's admiration. And it warms the hearts of us middle-aged technophiles to see this tribute to the kind of technology that got us first acquainted with computers. I'd urge other geeks of the baby-boom generation who want a good soaking in nostalgia to drop in on Magic-1 over the Internet. If browsing Buzbee's Web site seems too modern for you, Telnet in and play the original *Adventure* game or perhaps have a soothing session of ELIZA. Consider it therapy for dealing with the frustrations of modern computing hardware. You can also take pleasure in knowing that the signals you're creating in the depths of Magic-1's circuitry will be flowing through wires lovingly connected by one pair of human hands.

—David Schneider

BILL BUZBEE/HOMEBREWCPU.COM



TURBINE STATOR BLADE. A stator blade in the turbine stage of a jet engine is heated by the combustion gases. To prevent the stator from melting, air is passed through a cooling duct in the blade. The resulting temperature gradients introduce significant stresses.

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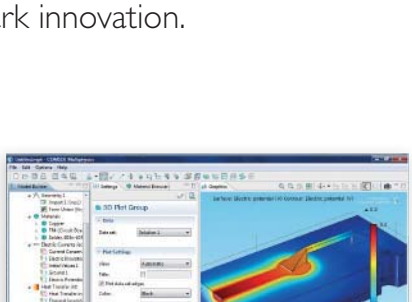

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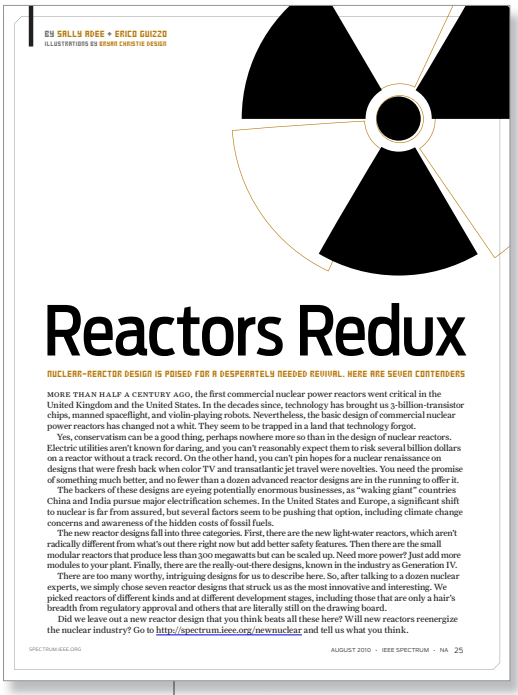

BY SALLY ADEE + ERICO GUIZZO
ILLUSTRATIONS BY BRYAN CHRISTIE DESIGN

Reactors Redux

NUCLEAR-REACTOR DESIGN IS POISED FOR A DESPERATELY NEEDED REVIVAL. HERE ARE SEVEN CONTENDERS

MORE THAN HALF A CENTURY AGO, the first commercial nuclear power reactors went critical in the United Kingdom and the United States. In the decades since, technology has brought us 3-billion-transistor chips, manned spaceflight, and violin-playing robots. Nevertheless, the basic design of commercial nuclear power reactors has changed not a whit. They seem to be trapped in a land that technology forgot.

Yes, conservatism can be a good thing, perhaps nowhere more so than in the design of nuclear reactors. Electric utilities aren't known for daring, and you can't reasonably expect them to risk several billion dollars on a reactor without a track record. On the other hand, you can't pin hopes for a nuclear renaissance on designs that were fresh back when color TV and transatlantic jet travel were novelties. You need the promise of something much better, and no fewer than a dozen advanced reactor designs are in the running to offer it.

The backers of these designs are eyeing potentially enormous businesses, as "waking giant" countries China and India pursue major electrification schemes. In the United States and Europe, a significant shift to nuclear is far from assured, but several factors seem to be pushing that option, including climate change concerns and awareness of the hidden costs of fossil fuels.

The new reactor designs fall into three categories. First, there are the new light-water reactors, which aren't radically different from what's out there right now but add better safety features. Then there are the small modular reactors that produce less than 300 megawatts but can be scaled up. Need more power? Just add more modules to your plant. Finally, there are the really-out-there designs, known in the industry as Generation IV.

There are too many worthy, intriguing designs for us to describe here. So, after talking to a dozen nuclear experts, we simply chose seven reactor designs that struck us as the most innovative and interesting. We picked reactors of different kinds and at different development stages, including those that are only a hair's breadth from regulatory approval and others that are literally still on the drawing board.

Did we leave out a new reactor design that you think beats all these here? Will new reactors reenergize the nuclear industry? Go to http://spectrum.ieee.org/newnuclear and tell us what you think.

SPECTRUM.IEEE.ORG AUGUST 2010 · IEEE SPECTRUM · NA 25

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TIME FOR THORIUM?

THE ARTICLE "Reactors Redux" [August] on possible "new" nuclear power reactors is interesting, but it left out an entire class—the molten-salt reactors. MSRs were developed between 1954 and 1974 by Eugene Wigner, Edward Teller, and Alvin Weinberg of Manhattan Project fame. The Oak Ridge National Laboratory actually ran a 7.4-megawatt MSR for five years. MSRs were designed to be safe, nonexplosive, efficient, and compact. However, the government stopped funding them because MSRs couldn't make plutonium for Cold War bombs. Now we need them, and other countries are doing R&D on them while we've been snoozing for 40 years. Combining an MSR with fluorinated thorium as the input fuel leads to a liquid fluoride thorium reactor, which solves most nonproliferation and waste issues and uses 100 percent of its input fuel, as opposed to current solid-fueled reactors, which use less than 10 percent of their supply of enriched uranium. All fissionable elements are maintained in the molten salt until destroyed; there is no refueling and no spent fuel to store for millennia.

ALEXANDER CANNARA
IEEE Life Member
Menlo Park, Calif.

SAFETY BY REMOTE

I FOUND THE ARTICLE "Beyond the Black Box" [August] interesting but severely lacking in information, history, and references on the use of real-time remote black boxes on aircraft.

I have U.S. Patent No. 5890079 for the remote aircraft flight recorder, or RAFT. The patent was awarded to me in 1999. While the patent was pending, I presented a paper at the 1998 Digital Avionics Systems Conference on the remote control of black boxes. I also spoke at the National Transportation Safety Board's International Symposium on Transportation Recorders in May 1999. Both of these papers are available online, as are a number of other IEEE papers and presentations I have written on this subject over the last 12 years.

The Safelander remote piloting system (U.S. Patent No. 7099752) was the result of a paper I presented at a symposium of the International Aviation Safety Association in New York City in November 2000. There, approximately a year before 9/11, I spoke on the remote aircraft flight recorder and how to use the data in real time in order to prevent terrorist and hijacking attacks as well as decompression crashes.

SEYMOUR LEVINE
IEEE Life Senior Member
Culver City, Calif.

TO TELL THE TRUTH

I READ WITH INTEREST Mark Harris's article ["Liar!," August] about my company's MRI-based lie-detection technology and compared this account with Harris's earlier story for *The Sunday Times* of London. There Harris admitted we were correct on our findings that he lied about overclaiming on his expenses. Yet, strangely, in the *IEEE Spectrum* article he states, "For the record, I never pad expense reports."

JOEL HUIZENGA
CEO, No Lie MRI
San Diego

The editors reply:
We thank Joel Huizenga for pointing out the contradiction. After consulting with Mark Harris, however, we stand by the statement he made to us and to our readers that he hadn't overstated business expenses, which means that No Lie MRI's findings on that particular question were indeed wrong.

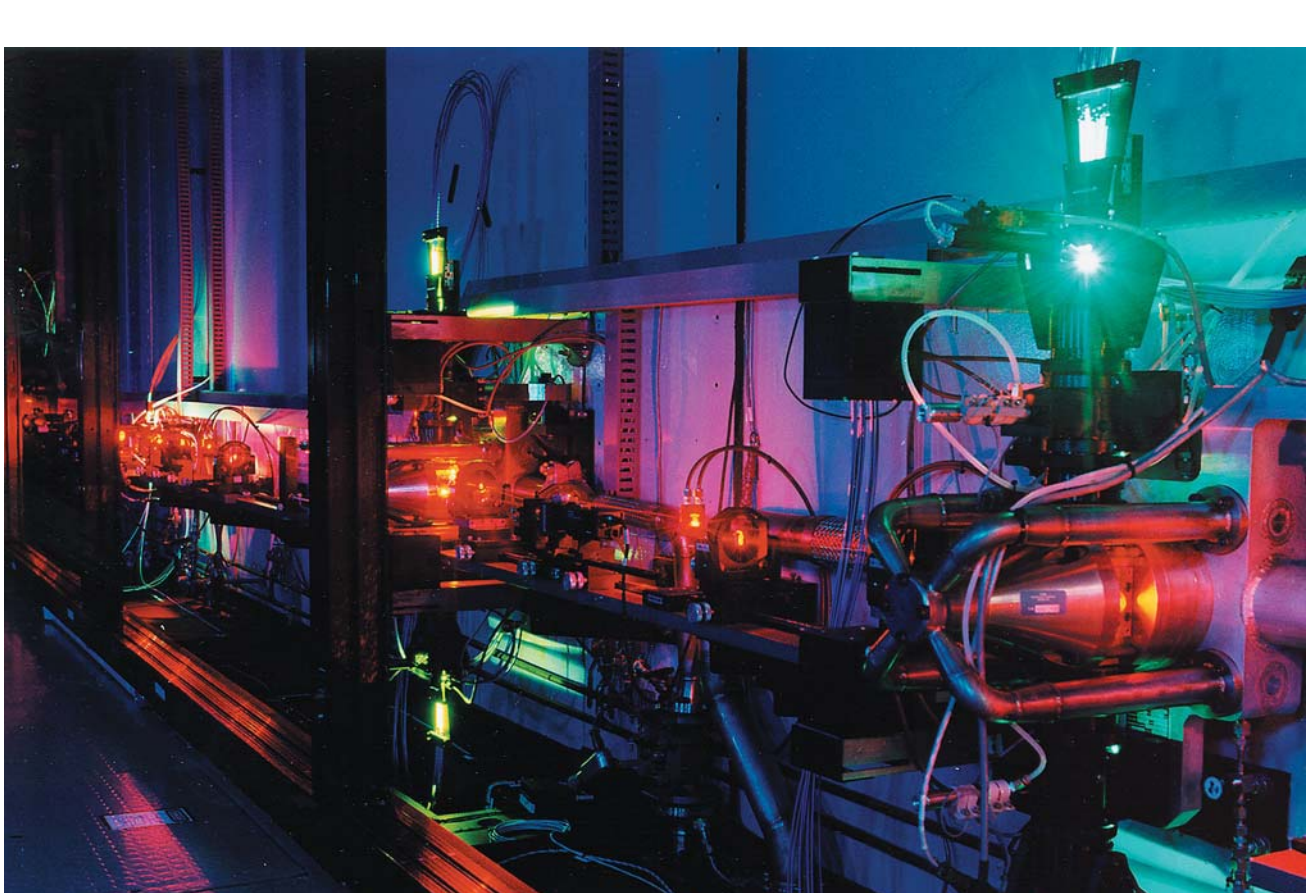
NO ROSE-COLORED GLASSES

AS A MEMBER of the Theatre Historical Society of America, I note that Mark Anderson's special report, "3-D in the Home" [Tools & Toys, August], perpetuates the myth that theatergoers of the 1950s viewed 3-D movies using glasses with anaglyphic (colored) lenses. With rare exceptions, 3-D movies of that era were projected using linear polarized light onto silver screens, hence requiring glasses with polarized (colorless) lenses, the same principle used by some of today's theatrical 3-D systems.

JOSEPH ZOLLNER
IEEE Member
West Allis, Wis.

update

more online at spectrum.ieee.org



Laser Uranium Enrichment Makes a Comeback

The controversial technology poses proliferation risks, but nuclear firms press on

TWO TECHNOLOGY GIANTS, GE and Hitachi, are betting big on a nuclear renaissance. The companies formed an alliance in 2006 to push for a global expansion of nuclear power. But selling new reactors is only half the game. The joint venture is also aggressively pursuing a controversial technique for making nuclear fuel using lasers, a method they hope to commercialize by building the world's first industrial-scale pilot plant in 2012. Regulatory agencies are worried that laser enrichment of uranium could lead to the proliferation of nuclear weapons.

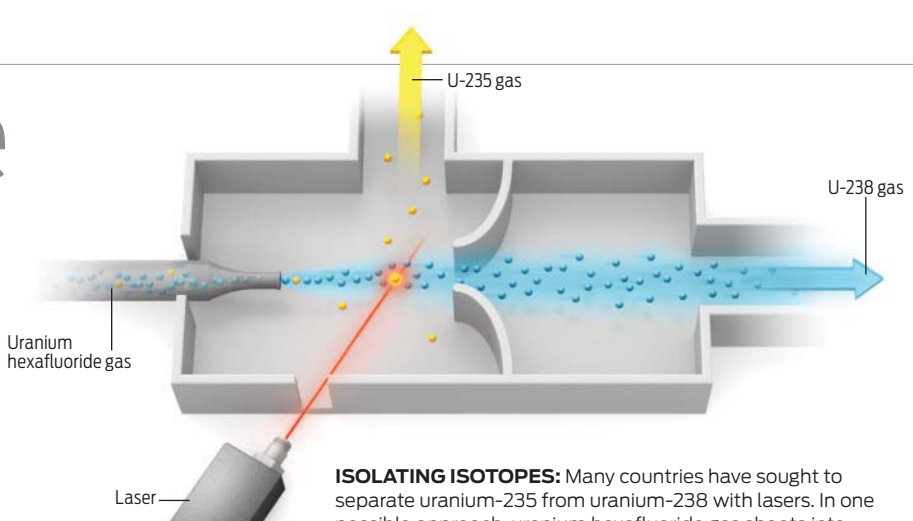
GE has called the laser method a "game-changing technology" and along with Hitachi and Cameco Corp., a Canadian nuclear fuel provider in Saskatoon, Sask., is devoting hundreds of millions of dollars to developing it and building the plant near Wilmington, N.C. The technology in question was licensed from Silex Systems, an Australian company that's been quietly conducting enrichment research at a small facility near Sydney for the last quarter century.

But many experts are skeptical. Allan Krass, a retired U.S. State Department official and a physicist

DANGEROUS DEVICE? Lawrence Livermore National Laboratory's plan was among many doomed laser uranium enrichment schemes. Will GE and Hitachi succeed where so many others have not?

PHOTO: LAWRENCE LIVERMORE NATIONAL LABORATORY

update



ISOLATING ISOTOPES: Many countries have sought to separate uranium-235 from uranium-238 with lasers. In one possible approach, uranium hexafluoride gas shoots into a chamber at supersonic speeds. A precisely tuned laser intercepts the stream, causing the molecules containing U-235 to absorb a photon. Those molecules then undergo a series of brief events that propel the U-235 to the outside of the gas stream. A barrier separates the core of the stream from the rim, which now has a higher concentration of U-235.

SOURCE: JEFF W. EERKENS AND JAEWOO KIM

who visited Silex's laboratory in 2000, says GE and Hitachi "are betting that there will be an upsurge of nuclear power plant construction—that's a huge and extremely risky bet." He adds that laser enrichment has been held back by substantial technical hurdles.

If approved, the pilot plant will be the first large-scale attempt to use photons to separate the desirable uranium-235 isotopes from the more abundant but nonfissile U-238 isotopes found in natural uranium. Experts generally believe that a laser facility would be both smaller in size and have much lower energy demands than existing enrichment plants. Those features are excellent from the perspective of improving the economics of nuclear power plants, but they also present a major headache for the International Atomic Energy Agency (IAEA) and other nuclear watchdog groups attempting to spot clandestine enrichment plants, largely from satellite imagery.

At least 20 countries have attempted—and, at one point or another, failed—to use lasers to economically separate uranium isotopes since the 1970s. "Everyone was looking for this magical elixir, the best way to do this," recalls Dennis Garratt, who was director of R&D for Cameco from 1989 to 1996.

So what's different this time? And will this version of laser enrichment somehow be proliferation proof? When contacted by *IEEE Spectrum*, GE-Hitachi, Silex, and the IAEA wouldn't say. But some hints can be found in the technology's history.

Of the many government-sponsored laser enrichment programs, most were shut down in anticipation of a 1993 agreement between the United States and Russia, known as the Megatons to Megawatts Program, which flooded the market with cheap uranium scavenged from Russia's nuclear arsenal. The engineers and physicists working in those laboratories tend to argue that they were on the verge of success when their projects were discontinued.

In essence, all those programs made use of the unique frequencies at which atoms and molecules vibrate. A laser tuned to the precise vibrational frequency of a U-235 atom or a molecule containing U-235 can cause that isotope to behave differently from the heavier U-238.

Broadly, in the method that Silex explored, called molecular laser isotope separation, enrichment begins with uranium hexafluoride gas—in which each uranium atom is surrounded by six fluorine atoms—mixed with an inert gas that dilutes the uranium. The gas is cryogenically cooled and shot out of a nozzle at supersonic speeds. Rapid-fire pulses from an infrared laser penetrate the gas, increasing the vibrational energy in the U-235 molecules' chemical bonds.

That higher vibrational energy causes each U-235 molecule to react more quickly with a third substance in the gas stream, explains Garratt. In one version of the process, a new molecule forms around the U-235. The new molecule lasts for less than a microsecond before breaking apart, and the repelling force from that event pushes the U-235 to the edges of the stream, where it can then be siphoned off.

Though the precise mechanics of Silex's process may differ, the underlying logic is that illuminating a gas with a laser would require only a fraction of the energy needed by the two methods used now to enrich uranium—spinning the gas in a series of centrifuges or repeatedly forcing it through a porous membrane.

At least that's the theory. In practice, several obstacles have kept the technology in the lab. "These lasers are unlike any other in the world—basically, if you need a laser, you've got to go invent one," says Bruce Warner, a laser physicist who led Lawrence Livermore National Laboratory's enrichment program, in Livermore, Calif., until the program's demise in the late 1990s.

According to several laser enrichment experts, Silex's approach likely begins with a 10.8-micrometer carbon dioxide laser that pulses hundreds of times per second. The infrared pulses travel through elaborate optics that tune their wavelengths to the needed 16 μm. Each pulse must contain about one joule of energy and be repeated fast enough to expose as much gas as possible. And if the laser doesn't pulse fast enough? Add more lasers! In short order you can wind up with an expensive and

EMILY COOPER

7 °C The temperature increase needed to rescue computers controlling the GOCE gravity-mapping satellite. The troubled €350 million (US $455 million) satellite was unable to send data down to Earth from 8 July until the fix in September.

complex assembly of staggered pulsing lasers, each with its own set of tuning optics.

The optics themselves are also difficult to engineer, says Einar Ronander, the CEO of Klydon, a South African firm that grew out of that country's laser enrichment program and sold Silex its lasers. The laser-tuning process uses a hydrogen gas whose aerodynamics can be finicky. Bouncing shock waves in the gas can disrupt the beam, diminishing the laser's overall efficiency. And that's no good, says Ronander, because the energy cost of photons adds up fast.

The difficulties don't end there. Skimming off the enriched material is troublesome too. In the system Cameco built in the early 1990s, the entire laser apparatus had to be shut down to collect the enriched uranium. "We had ideas of how to solve this, but we never had the chance to try them," Garratt says.

GE-Hitachi wouldn't say if it has solved these issues—or has faced entirely different ones.

Either way, whether the venture even gets to work out the kinks in laser enrichment is now a question for the U.S. Nuclear Regulatory Commission (NRC). That agency is charged with assessing the safety of nuclear facilities but is unaccustomed to weighing the proliferation risk of new technologies.

The extent of this particular risk, of course, is open to debate. Jeff W. Eerkens, an independent physicist who has worked on laser enrichment as long as lasers have existed, recognizes the threat and suggests tracking sales of the optics, which are uncommon. Other experts think there's no imminent danger; they say that countries interested in clandestine enrichment will continue building centrifuges because that technology's comparatively simpler designs have already eluded proliferation controls. But Charles Ferguson, the president of the Federation of American Scientists, cautions that as more niche laser applications emerge, laser enrichment will eventually seem less exotic.

The NRC is expected to rule on GE-Hitachi's building license by the end of 2011. Should it deny the license, though, laser enrichment is unlikely to disappear. As Krass, the state department physicist, wrote in a 1977 review of laser enrichment in the journal *Science* (paraphrasing J. Robert Oppenheimer), "It would be a mistake to underestimate the great desire of scientists to achieve something 'technically sweet'... and worry about the consequences later."

—Sandra Upson

DANIEL HERTZBERG

An Easy Smart-Grid Upgrade Saves Power

Trimming voltage trims power consumption, and consumers needn't lift a finger

Less is more when it comes to beef on the bun (at least according to your doctor), and the same now appears to be true for AC voltage. Research by the Electric Power Research Institute (EPRI), in Palo Alto, Calif., is confirming that many electrical devices work equally well and use less energy at lower voltages, and that offers utilities a big conservation opportunity. By trimming the voltage they deliver, distribution utilities in the United States could slim the nation's power appetite by 3 percent—the equivalent of unplugging every refrigerator in the country—according to an August 2010 analysis from the Department of Energy's Pacific Northwest National Laboratory (PNNL).

Some utilities are facing push-back from consumers disenchanted with smart meters and riled by real-time pricing for electricity. So the best news for utilities is that such conservation voltage reduction, or CVR, should cut energy use without asking consumers to change their behavior.

CVR operates within the wiggle room offered by electrical standards. The standard for the nominally 120-volt AC power in the United States and Canada,

300 gigahertz

New top speed for a graphene transistor. UCLA engineers say such devices should be able to reach terahertz speeds soon.

update

for example, calls for 114 to 126 V. The range is practical, given the ever-shifting power demand on a distribution system. Utilities generally measure and control voltage at their substations and aim for the higher end of the range to avoid browning out customers at the ends of the lines. The result is that, on average, U.S. customers get 122.5-V power.

Until recently, most utilities saw no need to operate differently, assuming that voltage had a negligible effect on power demand. And indeed that assumption is true for some loads. Electric heaters on a lower voltage simply run longer to deliver the same heat, resulting in no savings. But other appliances can get by at lower voltages by doing less work. For example, at the low end of the voltage range, lights dim imperceptibly.

The big-ticket item for CVR appears to be the induction motors in fans, refrigerators, and dozens of other appliances. Motors tend to operate at a lower mechanical load than they are rated to handle. As a result, higher voltages generate stronger magnetic fields than the motors can use, throwing energy away.

Utilities in the U.S. Pacific Northwest began testing CVR's potential in the 1990s. They minimized the voltage delivered by measuring it close to the consumer and adjusting frequently. Voltage is controlled at substations for each feeder line, which generally serves a whole neighborhood. An influential 2008 study by the Northwest Energy Efficiency Alliance, based in Portland, Ore., analyzed the experience of six CVR pioneers and found that on average every 1 percent drop in voltage delivered a 0.7 to 0.8 percent drop in power. And most feeders could safely drop 3 to 4 V.

Bob Uluski, a distribution specialist with EPRI, says many utilities are exploring CVR through pilot projects financed with economic recovery funds, and a few, such as Progress Energy, in Raleigh, N.C., are pushing into full-scale implementation. For those installing smart meters, CVR is a natural, because smart meters provide the real-time voltage readings to guide the voltage trimming: If levels dip too low, many smart meters can send an alert back to the utility. However, even with smart meters, utilities will be adjusting the voltage feeder by feeder, not at the level of the individual house.

Uluski says EPRI is developing more precise tools to help utilities predict how much energy CVR can save them on each feeder. That should help focus CVR investments, according to the PNNL report. The report's model suggests that using CVR on the 40 percent of feeders most responsive to it nationwide would capture 80 percent of the technique's energy-saving potential. EPRI is also quantifying how emerging loads such as plasma TVs and electric cars will respond to CVR.

The biggest obstacle to CVR, however, remains the classic lost-revenue problem that has long stifled utilities' conservation impulse. Utilities that succeed at CVR will sell less power. Tom Wilson, president of CVR system developer PCS UtiliData, based in Spokane, Wash., says this lost revenue problem has made selling utilities on CVR an "uphill struggle."

Wilson says change is coming, as regulators get more creative about rewarding utilities for the "nega-watts" of energy saved through conservation programs. Rather than wait, he says PCS is marketing CVR to large power consumers such as industrial firms and universities. They have the clout to press utilities to implement CVR on their feeders, says Wilson. —Peter Fairley

Powered-Down Appliances

118 VOLTS VS. 122 VOLTS

Appliance	Conserved power (watts)	Conserved power (percent)
INDUCTION MOTOR		
Fan	4.2	6%
DISPLAY		
CRT TV	2.1	4%
LCD TV	0	0%
Plasma TV	–2	0%
Desktop LCD	–0.6	–2%
LIGHTING		
13-W compact fluorescent lamp (CFL)	0.9	8%
20-W CFL	1	6%
LED (low quality)	0.2	6%
75-W incandescent	3.4	5%
42-W CFL	0.8	2%
LED (high quality)	0.1	1%
LED (medium quality)	–0.1	–1%

SERIOUS SAVINGS: Reducing the voltage feeding a variety of appliances from the 122 volts typical at wall plugs in the United States down to 118 V saves power in most cases.

SOURCE: Pacific Northwest National Laboratory

tech in sight

These Humanoid Robots Could Kick Your Asimo

ASIMO

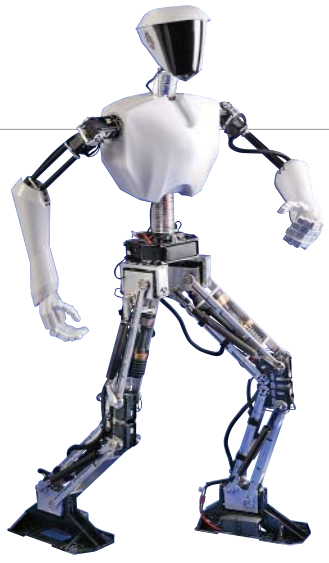
JAPAN HAS long held world dominance when it comes to walking humanoid robots, its most famous emissary being the charismatic, child-size, astronaut-like Asimo, which ambles, runs, and climbs stairs. Until recently, only South Korea had demonstrated full-size humanoids with legs as impressive as those of their Japanese counterparts. Now other countries are trying to catch up. Here's how four robots might take on Asimo in a future robot race.

—ERICO GUIZZO

REEM-B Pal Robotics, BARCELONA

Reem-B was designed to assist humans with everyday tasks, says Davide Faconti, founder of Pal Robotics. The 1.47-meter-high robot can walk at a relatively slow speed of 1.5 kilometers per hour, but thanks to powerful actuators in its legs and arms, Reem-B "is probably the strongest humanoid in the world," says Faconti, boasting that his robot can carry a 12-kilogram payload—say, a big watermelon. Try that, Asimo.

PHOTO: PAL ROBOTICS



CHARLI Virginia Tech's Robotics & Mechanisms Laboratory, BLACKSBURG, VA.

CHARLI (Cognitive Humanoid Autonomous Robot with Learning Intelligence) is the first untethered, autonomous, full-size walking humanoid robot built in the United States, according to Virginia Tech roboticist Dennis Hong. He and his team are now upgrading it with custom-made linear actuators that help mimic how human limbs move. In a soccer match against Asimo, Hong's team is confident that CHARLI would prevail.

PHOTO: VIRGINIA TECH

SURENA 2 University of Tehran's Advanced Vehicles Center, TEHRAN

This 1.45-meter-high humanoid was developed to help researchers explore aspects of bipedal locomotion, says Tehran University professor Aghil Yousefi-Koma. His team is working on a feedback control system that yields a much more humanlike motion. Surena 2 might be a slow walker, but it has its tricks: It can bow, stand on one leg, and according to some news reports, dance. Dance-off, Asimo?

PHOTO: ALIREZA SOTAKBAR/ISNA/AP PHOTO

HONDA

JUSTIN German Aerospace Center's Institute of Robotics and Mechatronics, OBERPFAFFENHOFEN-WESSLING, GERMANY

Justin is currently a four-wheeled robot with a head and two dexterous arms, but researchers have demonstrated a pair of legs [right] that may become its lower body. The legs use powerful yet lightweight motors to explore joint torque-based control concepts for biped balancing and walking, according to engineer Christian Ott. If Justin's legs turn out to be as nimble as its arms, Asimo might not stand a chance.

IMAGE: INSTITUTE OF ROBOTICS AND MECHATRONICS/DLR

Eyes in the Sky That See Too Much

Military analysts are buried in video from surveillance drones. Some software tricks could help

In 2009 alone, the U.S. Air Force shot 24 years' worth of video over Iraq and Afghanistan using spy drones. The trouble is, there aren't enough human eyes to watch it all.

The deluge of video data from these unmanned aerial vehicles, or UAVs, is likely to get worse. By next year, a single new Reaper drone will record 10 video feeds at once, and the Air Force plans to eventually upgrade that number to 65. John Rush, chief of the Intelligence, Surveillance and Reconnaissance Division of the U.S. National Geospatial-Intelligence Agency, projects that it would take an untenable 16 000 analysts to study the video footage from UAVs and other airborne surveillance systems.

The best—and perhaps only—way forward is to have a computer watch it all. But programming a system to automatically search video and pick out noteworthy information is not an easy problem. And so far, no one has developed software that can keep up with the military's high-tech hardware.

There were some glimmers of hope, however, at August's 7th IEEE International Conference on Advanced Video and Signal-Based Surveillance, in Boston. Mubarak Shah, director of the Computer Visions Lab at the University of Central Florida, in Orlando, identified three computer surveillance tasks that are notoriously difficult.

The first task involves tracking big swarms of objects, such as cars, traveling over a wide area, like an expressway. When shot from above, cars are exceedingly small (usually no more than 30 pixels), and there are often thousands of them. Plus, the plane that's shooting footage is moving faster than the vehicles it's capturing, so a tracking algorithm has only a few frames to work with for each car. And if a new technology developed under the direction of the Defense Advance Research Projects Agency, called ARGUS-IS, succeeds, a single drone-mounted video sensor and processor could easily "capture one and a half to 2 million vehicles [within a 40-kilometer radius] during one mission," says Rush.

WATCHING YOU: The MQ-9 Reaper drone is on the prowl.
PHOTO: LT. COL. LESLIE PRATT/U.S. AIR FORCE

Shah's solution depends on keeping track of all the possible paths a vehicle may have taken, then weeding out the poor choices. The computer does that by using some common sense: It knows two vehicles probably won't choose a collision course, for example. And it uses a bit of modern transportation theory as well: If one car is behind another, the two cars are probably accelerating at a similar rate.

Finding a person can be even harder than keeping track of cars. In aerial video, typical statistics-based algorithms mistake quite a lot of things—trees, mailboxes, traffic lights—for people. Instead, Shah proposes using some basic geometry tricks to find a person, based on the relationship between the height of an object and the length of its shadow. He admits, though, that this strategy wouldn't work so well on video shot on cloudy days or using infrared light.

The final challenge Shah addressed is how to map the movement patterns of many things at once. Say, for example, you have some aerial footage of a city and you want to figure out how it's laid out—where the roads are, the bridges, the intersections, where people regularly travel, the areas they avoid, where they gather. What a computer sees in a surveillance video is "very noisy optical flow," Shah says—lots of motion but not much order. But, using mathematical noise-reducing tools called Gaussian filters, Shah can find order in the noise and get his software to draw a picture of the city in motion. "We can basically discover the road networks without knowing anything about a city," he says.

But it may be a while before such technologies are accurate and usable enough to be adopted broadly. Military intelligence analysts "will use systems put in front of them now, then turn them off because it just makes their job harder," Rush told engineers in Boston. "Getting them to accept the results [of automatic video-search software] without going back and checking all the data—that's a long time coming."

—Ariel Bleicher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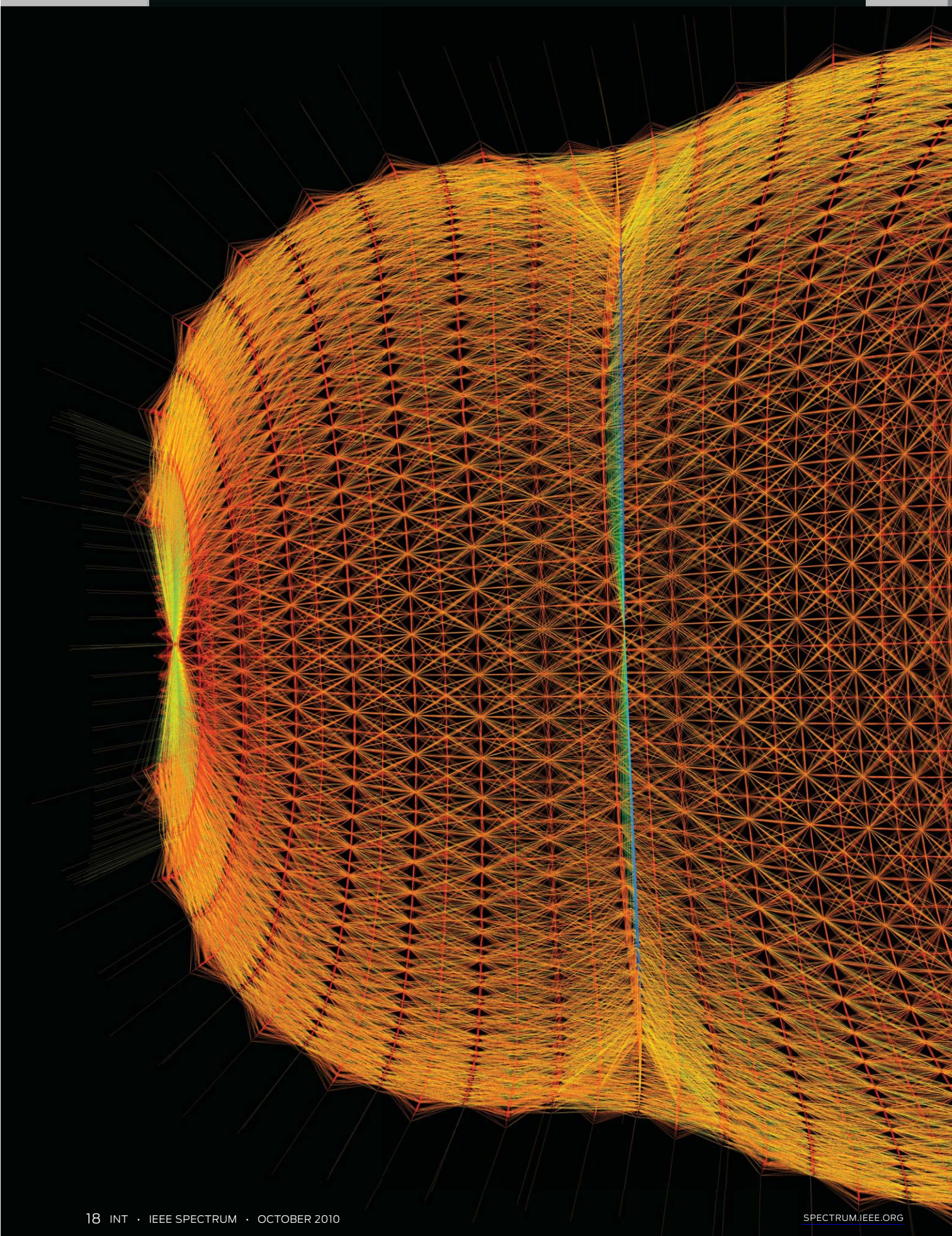

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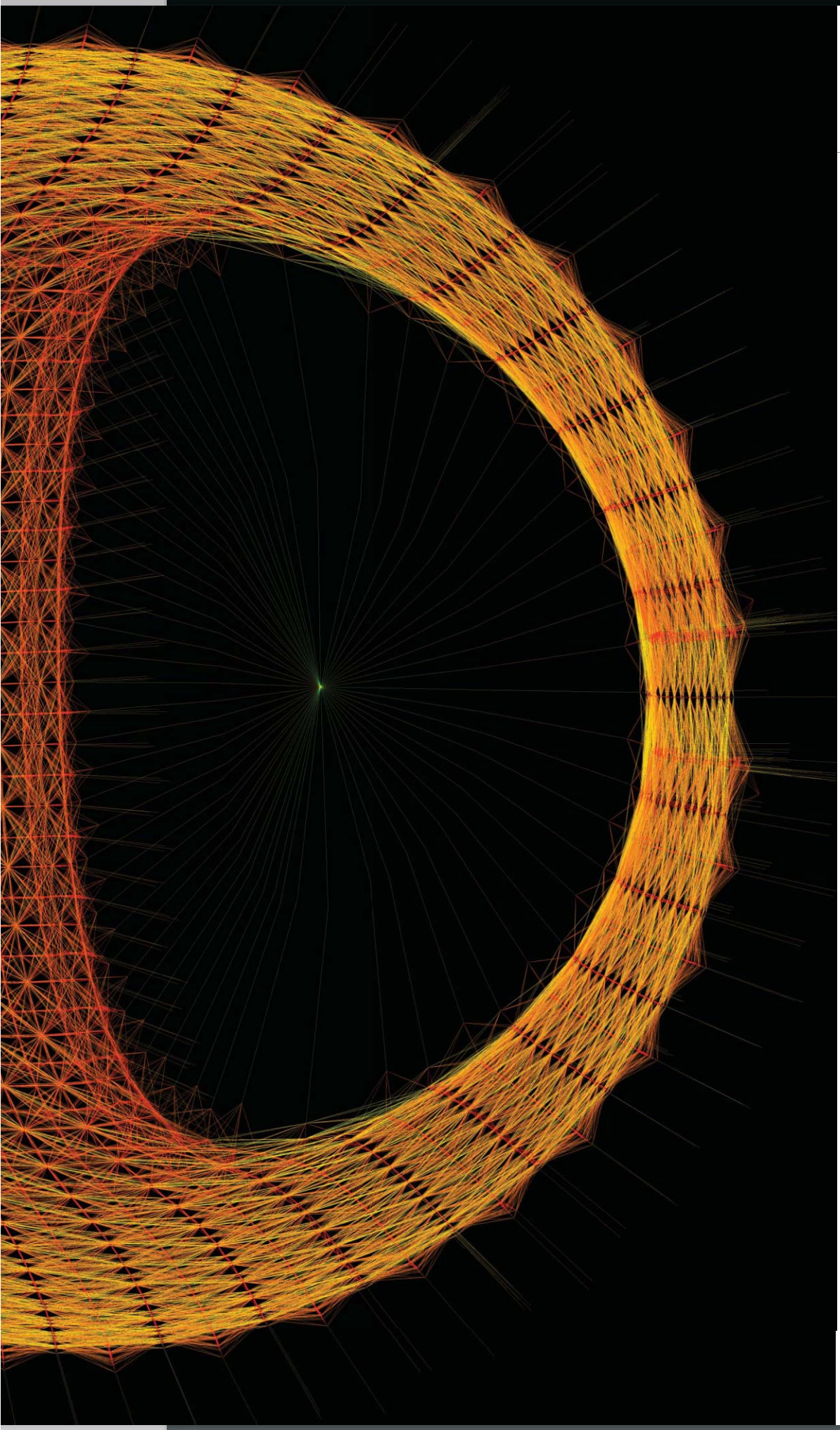


the big picture

PRETTY MATH PROBLEM

You're looking at the solution to a computational fluid dynamics problem. It is one of thousands of math-based artistic renderings stored in a database maintained by computer scientists from the University of Florida, in Gainesville, and AT&T Labs Research, in Florham Park, N.J. But what you don't see makes all the difference. The matrix, or table of values, is sparse, meaning that the number of zeros it contains far outweighs the number of nonzero values. This sparsity allows for a type of data compression that lets engineers working on a simulation store the data without taking up too big a chunk of memory.

IMAGE: YIFAN HU/ AT&T LABS VISUALIZATION GROUP

I, OFFICE WORKER

Build your own telepresence robot

In last month's issue, my fellow *IEEE Spectrum* editor Erico Guizzo investigated the up-and-coming universe of telepresence robots—electromechanical proxies that allow you to be there without actually being there. As a telecommuter, I was intrigued by the possibility of being able to "walk" over to a colleague's office, just as if I were working down the hall. The problem is that commercial telepresence robots are pricey. The one Erico tested, made by the company Anybot, will sell for close to US $15 000. I'm too sheepish to ask the boss to shell out for something like that.

But I'm not too sheepish to try to build one.

So with Erico's help I cobbled together a simple telepresence robot for about $1000 in parts. Initially, we thought about copying Sparky Jr., a telepresence robot built on an iRobot Create base. Construction is detailed at the Sparky Jr. Web site, which is "dedicated to DIY, open-source mobile telepresence." But this robot's cat-size stature wouldn't be adequate for office life; I'd need something taller to gossip with others around the water cooler and Xerox machine. And the iRobot Create is too small and light to support much of a superstructure. So instead I rolled a robotic base of my own design.

DROPPING BY: Casually strolling over to a colleague's office to chat is something most telecommuters miss. But robot technology now makes this possible—even on the cheap.

PHOTO: RANDI SILBERMAN KLETT

To propel it, I used the motor mount and wheel kit ($280) from Parallax, of Rocklin, Calif. The kit includes a pair of 12-volt DC motors with worm-screw reduction gearing that were surely designed for automobile electric windows. The gearing has more play than I would have liked, but Parallax integrated these motors with nice aluminum mounts, axles, and wheels. Each kit also includes an optical encoder and a position-controller board, providing closed-loop control of wheel movements. But the kit doesn't contain any motor-driver circuitry, so I purchased separate 25-amp units ($50 each), also from Parallax.

Many mobile robots, including the iRobot Create, have four wheels spaced around a circle at 90-degree intervals. Only the two wheels at either side are driven, the two at front and back merely being swiveling casters to keep things level. The nice thing about such an arrangement is that the robot can rotate in place.

I was set to arrange mine the same way, but a friend with considerable experience advised me otherwise. The problem with four wheels, he explained, was that an irregularity in the floor could cause one of the drive wheels to lift, sending the robot off in an unintended direction.

With three wheels, that can't happen. So I mounted the two driven wheels forward on each side and put just one swiveling caster in the rear. In truth, I incorporated five wheels in all, if you include the two small casters I added to the very front. These don't touch the floor: I added them only to prevent the robot from tipping over if it stopped suddenly or was bumped

MAJOR COMPONENTS

- MSI Wind L1300 netbook *CompUSA; $285*
- Motor mount and wheel kit *Parallax; $280*
- HB-25 motor drivers *Parallax; $50 (x 2)*
- Ping ultrasonic sensor *Parallax; $30*
- SLA-12V18 lead-acid battery *Battery Mart; $35*
- ACC-1206S charger for lead-acid battery *Battery Mart; $33*
- In-car adapter to power netbook *eBay; $18*
- Arduino Duemilanove microcontroller *Sparkfun Electronics; $30*
- Logitech C905 webcam *Staples; $80*
- SPT-50 pan-and-tilt mechanism *Servocity.com; $20*

Note: This list reflects prices at the time the project was built.

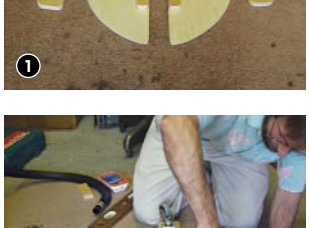
from behind. To be sure, with a heavy 18-ampere-hour lead-acid battery ($35) mounted on the base, there's really not much chance that this robot could topple anywhere.

An MSI Wind L1300 netbook ($285) provides most of the robot's smarts, along with a screen that shows my face when I operate it. Running it from the lead-acid battery required an "in-car" adapter ($18). The netbook sits atop a salvaged camera tripod, which is affixed to the base with hinges, making it easy to adjust the screen position to shoulder height.

At a lower level, literally and figuratively, sits an Arduino Duemilanove microcontroller ($30), a device that regular readers of this column will surely recognize. The netbook communicates over a USB cable with the Arduino, which in turn talks to the two motor-controller boards via 5-V serial lines. The Arduino is also hooked up to two small limit switches attached for right and left bumpers. And this little computer operates two radio-control servos I had on hand, which I rigged into a simple pan-and-tilt mechanism for the robot's webcam. (You could purchase a much better engineered unit for as little as $20.) In addition, the Arduino runs a Parallax Ping ultrasonic distance sensor ($30), which is mounted to the tripod at waist height.

As mobile telepresence robots go, I suspect that this collection of hardware is about as simple as you could get by with. The software that operates it all is, however, reasonably complicated. And for that, I must credit Hari Wiguna and the good people who gave us Skype. Let me explain.

Before purchasing any of the hardware, I wanted to be sure that I could turn this collection of components into a functioning robot without months of programming.



SKYPE ON WHEELS: A set of plywood parts [1] forms the basic robot platform. Drive hardware [2] is attached on the bottom, along with a swiveling caster in the back and two tip-prevention casters up front [3]. An Arduino single-board computer mounted on the base handles low-level tasks [4] while a netbook fixed to a camera tripod runs a Skype session. *PHOTOS: DAVID SCHNEIDER*

That's when I stumbled on Hari Wiguna's SkyDuino project, a DIY pan-and-tilt webcam that's remotely operated. Wiguna's code for SkyDuino, written in C#, makes use of Skype's application programming interface to send one-character messages to a remote Arduino. I'd just have to expand the repertoire of messages to include a set of robot-motion commands.

I downloaded Microsoft's (free) Visual C# package and modified Wiguna's code so that in addition to controlling the remote webcam, I could also command the robot to rotate in place or move forward and back by given amounts, all while conducting a Skype video call. I also added some code so that the robot could communicate information back to its master. If the robot bumps into something, it halts and tells the operator whether the right or left bumper hit. Also, with each command sent to the robot, the ultrasonic sensor sends out an inaudible ping and listens for the echo. The Arduino then gauges the distance to the nearest obstacle and relays that information back to the person driving.

It took a while to get the hang of steering, mostly because of the delays inherent to Skype. It's a bit like maneuvering a Mars rover: Send a command, wait for the response, send the next command, and so forth. But with practice, even my 7-year-old son could manage it.

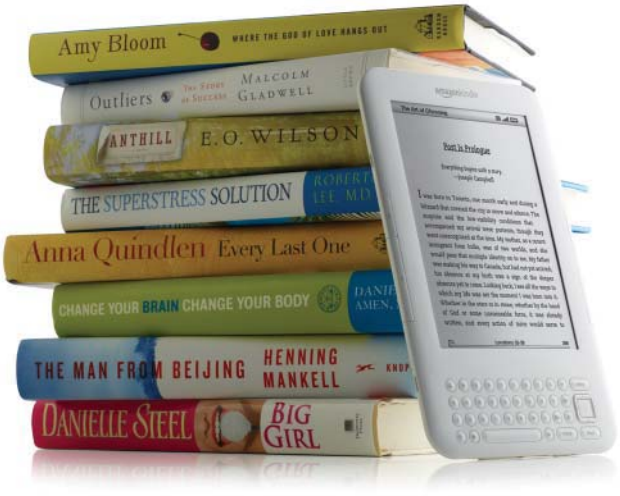
More problematic was a nasty software bug. I eventually traced the problem to the way that the SkyDuino code handled communication with the Arduino: For each command sent to that board, a virtual serial port is opened and closed. But my Arduino reset each time this serial port was opened, creating havoc. The remedy was simple—have the C# code open that port only once, at the beginning of the session.

This system is admittedly a bit fragile—it requires the interaction of three separate computer processes, one running on the Arduino, another on the netbook, plus the Skype application—and they must be started in sequence or else errors occur. And Skype suffers from dropped calls, which means that a person familiar with the robot needs to be available to nurse it back to life from time to time. But judging from Erico's experience test-driving Anybot's robot, such problems dog commercial models too.

My sense is that these machines are a bit like early personal computers—cool for hackers but not quite ready for prime time. Still, exploring the practicality of a telepresence robot is a lot of fun when you've laid out only a small fraction of what it costs to buy one.

—David Schneider

tools & toys



THE IPAD, THE KINDLE, AND THE IMMUTABLE LAWS OF THE MARKETPLACE

A culling of the herd of e-readers is already under way, as prices plummet

If you've considered buying an e-reader but haven't yet taken the plunge, there's no longer a need to wait. It's only been three years since Amazon jump-started the market with its Kindle [above], but the technology has improved greatly since then. And as this summer's price wars in the United States carry over to the holiday season and the rest of the world, e-readers are finally ready for a mainstream audience.

Back in January, at the annual Consumer Electronics Show, it seemed like every company wanted to ride in the wake of Amazon's success. Although the many e-readers introduced there all shared the same E Ink screen technology, each offered its own combination of trade-offs, and it seemed as if there might be a different ideal e-reader for each user. But after months of wild proliferation, the list of viable e-reader manufacturers is now shrinking, even as the market expands.

It's largely a matter of price. When the Apple's iPad hit the market in an explosion of hype and hysteria for just US $500, it suddenly seemed ludicrous that anyone would pay more for a dedicated reader with a monochrome display. To stay viable, manufacturers needed to slash their e-reader prices. At the end of June, the Barnes & Noble Nook went from $259 to $149 for a Wi-Fi version ($199 for the 3G model). Amazon countered by announcing that the next version of the Kindle would start at $139.

The price drops are partly due to more sophisticated chip sets that integrate the applications processor and the display controller, and partly due to scale: Reportedly, large manufacturers have reached quotas that qualify them for discounts. But both Barnes & Noble and Amazon have the added advantage of being in the book business. Just as Microsoft lost money on Xboxes and made it up in game sales, these two booksellers can survive, and thrive, even if they have to offer their hardware below cost.

In fact, the race to control the biggest slice of the e-book-buying public may bring even greater price cuts. It's not hard to imagine a future where you get an e-reader free with a pledge to buy a book every month.

But now is still the time to buy. The current Kindle and Nook greatly improve on their initial designs. Our recommendation is to stick with one of these major models, if only for their vast, easy-to-use bookstores. The convenience of shopping for books directly on your device only becomes clear when you're forced to try the frustrating alternative. The *IEEE Spectrum* staff generally prefers the Kindle, finding the Nook's separate navigation screen an inefficient use of space and a little too easy to activate unintentionally.

And what about Sony, the company that pioneered the e-reader? Although many *Spectrum* readers have vouched their love for the Sony e-readers in online comments, it's hard to recommend them now. Sony has announced a new line of readers but says it doesn't intend to compete on price. In this market, that's a lot like giving up.

To the extent that the price wars remain limited to the United States, there's still room for lesser-known companies. PocketBook's tiny, stripped-down e-reader made a positive impression on *Spectrum* testers, and the company currently has a commanding hold on the Russian market.

E-SURVIVORS: The $139 Nook [top] and the lightweight PocketBook [bottom] may be rare survivors in the harsh e-reader market.

The next big change for e-readers will be the addition of color displays that can be viewed in direct sunlight. But don't let that keep your wallet in your pocket: Mass production of color displays has only recently begun, so there's plenty of time to enjoy a black-and-white e-reader that doesn't break the bank.

—Joshua J. Romero

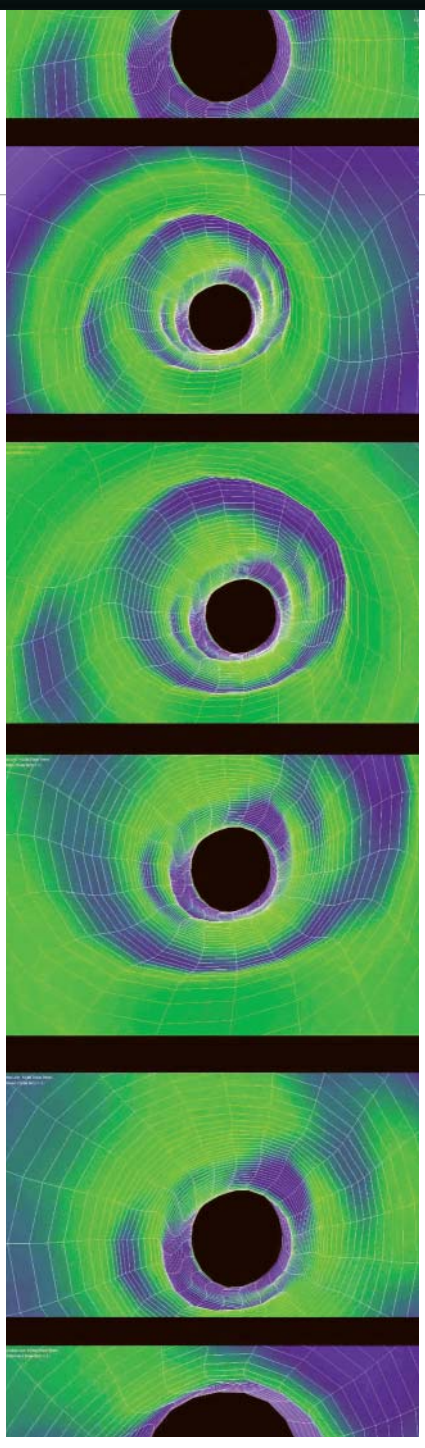
A version of this article appeared on IEEE Spectrum Online *in August.*

FROM TOP: AMAZON; BARNES & NOBLE; RANDI SILBERMAN KLETT

profile

CORONARY CALCULUS

Serbian engineer Nenad Filipovic's equations model blood flow and could predict heart attacks

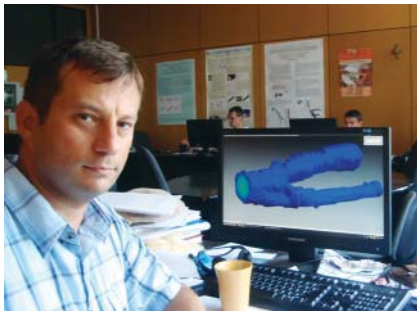


THE RED and blue glow of computer animations fills a lab in the Institute for Basic and Physical Chemistry in Belgrade. It's a warm summer day in Serbia. That we are only 5 minutes from a spot where U.S. cruise missiles once slammed into ministry buildings doesn't much register with Nenad Filipovic. To be sure, like most Serbians, he hopes to put the past behind him and forge a bright future for this rapidly changing heart of the Balkans. But at the moment, he's hunched over his computer, trying to create a new kind of imaging for cardiologists.

The NATO bombs that rained on Serbia during its 1999 conflict with the breakaway province of Kosovo led to the collapse of the Milošević government, sending Belgrade into chaos and Filipovic to Harvard. Five years ago, he came back as a bioengineering professor at the University of Kragujevac. At the Institute for Basic and Physical Chemistry, he helped start BioIRC, a spin-off that creates predictive software for visualizing the plaques that cause heart attacks and charting their future growth.

"We deal with small plaques," Filipovic says. "The point is, when does this plaque develop, and how much time does a patient need—one month, two months, six months, 10 years?" BioIRC is an interdisciplinary mashup of informatics and hemodynamics. CT and MRI imaging and catheter cameras build a precise geographic image of the individual patient's heart. Blood analysis shows lipids, hemoglobin, albumin, and cholesterol factors. Data-mining tools plumb genetic profiles, patient history, and lifestyle statistics. Vascular shear stress analysis adds precision. The data is crunched on the SEE-GRID (Southeastern European Grid), a computer network consortium of 13 countries. As yet, there is no one tool that measures all of these factors. It's a little bit like writing new software for each heart.

Predictive medicine is a growing but sometimes controversial field. The practice of modeling in itself can be controversial—after all, it didn't always work on Wall Street. But the results are already promising and may eventually affect more than just coronary plaque analysis.



BLOOD CENTER: Five years ago, Serbian-born and Harvard-trained bioengineer Nenad Filipovic [above] returned to his war-torn homeland [below] to develop software that visualizes the vascular system [left] and predicts heart attacks. PHOTOS: MICHAEL DUMIAK

BioIRC is doing clinical trials with 100 patients in Serbia. "We collect data, and we simulate," Filipovic says. "And we compare results over time." He says BioIRC can already predict plaque growth—not position, but growth—with 70 to 80 percent accuracy. Predictive medicine could also greatly improve the placement of medicated stents, drug-delivering mesh tubes that reinforce weak artery walls.

Other centers for predictive medicine include Stanford, the University of Texas, and Worcester Polytechnic. Filipovic is still a Harvard associate, but he has seen his department suffer tough cutbacks. "It's hard to be a scientist now. There's no money," he says. "It's hard here, too. But I see a chance for young people. The best students come to me, and they want to work. It's changed completely here. There's a vision. Not just here. I see changes in Europe." —MICHAEL DUMIAK

geek life

REAL MONEY: The film *Play Money* explores the thin line between virtual gold and real dollars. PHOTO: NAMELESS FILMS

THE END OF GOLD FARMING?

Real-world laborers make real-world money in virtual worlds. But maybe not for long

RIGHT NOW, thousands of gamers are doing menial jobs in their virtual worlds. And they're earning a living.

The process of contracting out a game's drudge work for real money is called "gold farming." This happens in the games that involve thousands of characters at a time, interacting in an online universe that players inhabit over the course of months or even years. Some tasks, such as gathering up virtual gold pieces, swords, and magic wands, can be done by any novice player who puts in the time. In other cases, you can hire a master player to surmount a game's challenges and raise your character to a higher skill level.

By any standard, gold farming is big business. Estimates range from a global workforce of 400 000 earning US $1 billion a year to a labor pool exceeding a million gold farmers generating more than $10 billion in annual, real-money revenue.

Yet the future of gold farming is uncertain. Some observers see it as a classic market inefficiency—a blip in the history of online games—that game designers can and should eliminate from their virtual worlds.

Edward Castronova, a virtual worlds economist at Indiana University, says it was Blizzard Entertainment's 2004 hit game *World of Warcraft* that turned the gaming industry on its head. Previous games had presumed their big attraction was their battles—seeking out monsters and killing them.

But in *World of Warcraft*, Castronova says, monster hunting was almost incidental to the larger quest, which made a player's status more important, pulling people deeper into the virtual world and thus increasing their demand for virtual goods. Eventually, players with more money than time sought ways to buy those virtual goods with their real-world credit cards.

Gold farming, in other words, was as natural a market response as putting up a lemonade stand on a hot day.

"Teens are cash poor and time rich," says novelist and celebrated blogger Cory Doctorow. Adult gamers are often the other way around. So long as youth in developing nations can make quick cash playing games they play for fun anyway, online "gray" markets will crop up that can compensate them—however meagerly, by developed-world standards.

Doctorow's latest thriller, *For the Win* (Tor, 2010), imagines gold farmers across the planet rising up to unionize and collectively improve the conditions of their labor. Researching the book—which is aimed at youngsters—Doctorow went to China, where an estimated 85 percent of the world's gold farms are based. Doctorow found "a gray-market activity [in which] everybody does it differently."

Yet though these gray markets are undoubtedly complex, they also still obey simple textbook laws of real-world economics. For example, when Blizzard increases the number of rewards, it adds more gold to the system, a sort of inflation that makes gold less scarce and therefore less valuable when exchanged for real dollars.

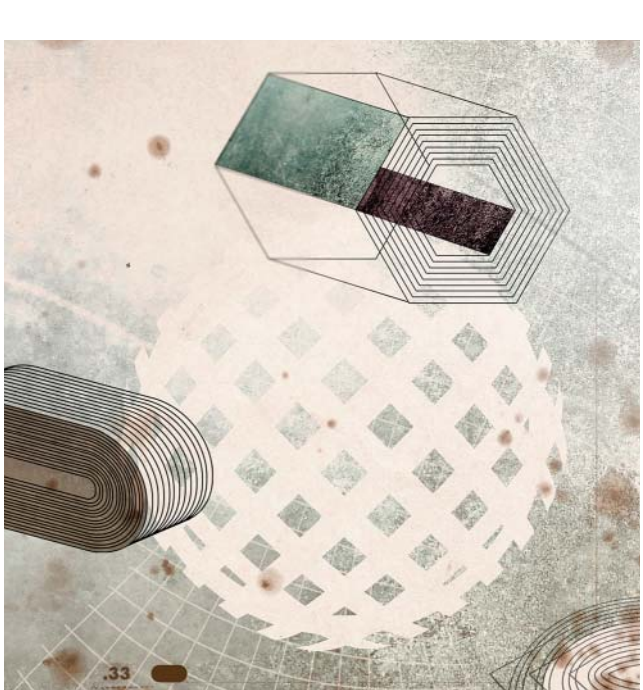
In some ways, gold farming has become more entrenched: Sony, for example, created its Station Exchange (now called Live Gamer Exchange), an auction site that the company says lets players trade avatars, items, and currency among each other for real money.

Yet in other ways, gold farming appears to be a temporary phenomenon, Castronova says. Virtual-world designers are now adding features that can cut gold farmers out of the picture. For example, rather than paying a third-party pro to ratchet up your character's level ("leveling"), a 2009 patch to *World of Warcraft* now enables players to teleport directly to battles that allow them to advance within the game faster. "Just press a button and boom, you're in a dungeon," Castronova says. "You can rapidly get everything you need to get a character up at a high level."

Virtual economies scholar Vili Lehdonvirta of the Helsinki Institute for Information Technology says that Castronova is undoubtedly right that new massively multiplayer online games will indeed avoid the inefficiencies that give rise to gold farming. But, he says, "the overall digital economy will grow. So even if individual opportunities are closed down by new game designs, there are always gaps that will be exploited." —MARK ANDERSON

technically speaking

BY PAUL McFEDRIES



CHAD HAGEN

The Age of Spimes

Spimes have identities; they are protagonists of a documented process. They are searchable, like Google. You can think of spimes as being auto-Googling objects.
—Bruce Sterling

A FEW YEARS ago, the writer Bruce Sterling envisioned a future generation of products that were, he said, "precisely located in space and time. They have histories. They are recorded, tracked, inventoried, and always associated with a story." He dubbed this new kind of thing a **spime**, a blend of *space* and *time*. In the *Los Angeles Times* a couple of years later, the writer and critic Susan Salter Reynolds wrote, "In an age of spimes—products with Web sites and bar codes—we can and will make the right decisions about what to purchase and produce."

This "age of spimes" isn't quite here yet, but we're getting closer, thanks to an increasingly sophisticated discipline called **life cycle assessment** (or **LCA**), which attempts to quantify the total environmental impact of all the inputs and processes used to take a product from raw materials to its final form. LCA (which can also stand for **life cycle analysis**) is an important idea, for sure, but for our purposes it's also a fount of new words and phrases.

Life cycle practitioners usually start by coming up with a **life cycle inventory,** which tots up the materials used, the energy consumed, and the emissions produced during a product's life, or with a **technoeconomic** analysis, which considers a product's technology in terms of its economic costs and benefits. They might then work on **impact assessment** and **life cycle improvement**, which look at the actual or potential environmental consequences of producing the product and at ways to reduce them. Some practitioners use **life cycle energy analysis** (**LCEA**) to examine not only the direct energy used in the production, distribution, and use of a product but also the indirect energy used to create and maintain the services, components, and systems that are used to manufacture and distribute the product.

The fundamental unit of LCA is the **whole-life cost**, which refers to the environmental cost accumulated during a product's entire life cycle. This is also called the **cradle-to-grave** cost. In this age of avid and expanding recycling programs, a more recent idea is **cradle-to-cradle**, which adds in as well the recycling of the product into something new.

LCA practitioners seem inordinately fond of breaking down a product's life cycle into smaller and smaller segments, usually in an effort to apportion life cycle costs appropriately. In the **cradle-to-gate** segment, the "gate" is the factory (or farm or mill or whatever) gate (or door or loading dock or whatever), so *cradle-to-gate* refers to everything that happens with a product until it's ready to ship.

If the product gets shipped to another link in the production chain, then that portion of the product's life cycle is called **gate-to-gate** or **gate-to-site** (for example, a construction site). If the product is edible, then the portion of its life cycle from the time it leaves the producer to the time the consumer is ready to eat it is called **gate-to-plate**. If the producer is a farmer, then that portion of the life cycle is known as **farm-to-fork**. If the producer is a fisherman or seafood processor, you can describe that stage as **boat-to-throat**.

As you might imagine, fossil-fuels consumption is a huge part of LCA. The cradle-to-grave equivalent here is called **well-to-wheel**, where the "well" is the place where the unprocessed fossil fuel is extracted from the ground and the "wheel" is the vehicle burning the processed fuel. The segments in between are **well-to-station**, the costs of processing the raw fuel and its delivery to the gas station (or similar distributor); **station-to-tank**, the costs of storing and pumping the fuel; and **tank-to-wheel**, the costs and impacts of burning the fuel while driving.

LCA practitioners are the first to benefit from the coming age of spimes, but we're not far off from the day when we can all make smart and informed decisions on products. As Sterling said in the speech where he coined the word *spime*: "At the moment, you are end-using gizmos. My thesis here, my prophecy to you, is that, pretty soon, you will be wrangling spimes." ❑

The Great Spectrum Famine

MOBILE BROADBAND IS CONSUMING THE AVAILABLE RADIO SPECTRUM. SERVING UP MORE WON'T BE EASY

By Mitchell Lazarus

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Not even sci-fi writers foresaw what we'd be doing with our phones once technology put color screens and a lot of computing power in our pockets.

Now we know: We use them to stream YouTube and Facebook videos; we watch TV shows; we download and store songs and movies; we take pictures of everything going on around us; we read (and some of us even write) novels; we play video games; we surf the Web. Sometimes we even talk to each other. These days you can unleash a gusher of bits over the air that would have choked even a wired connection to the Internet not so long ago.

These transmissions consume radio bandwidth—lots of it. And they will take increasing amounts of this precious commodity as the iPad and its Androidgenous kin proliferate. People are already feeling the pinch.

Regulators have few options to head off the coming bandwidth crisis. They can't realistically expect to reduce demand. Nor can they expand the overall supply. That leaves the daunting chore of squeezing today's users into narrower slices of the radio spectrum, thereby eking out more space for other things. That's sometimes possible, but it's not easy. To reengineer existing radio systems—or their users—is a bit like trying to overhaul a car's engine while it's barreling down the highway.

Policymakers, at least in private, sometimes hold out hope for a fourth option: that some game-changing technical breakthrough will save the day at the 11th hour. But nothing now on the drawing board suggests that technology alone can get us out of this predicament.

In a sense, history is just repeating itself. Two decades ago, people who accessed the Internet typically did so with phone-line modems chugging along at 14.4 kilobits per second. That was fine for the largely static, text-based Internet of the day. But as the use of graphics and sound, and then video, expanded, so did the bandwidth needed, prompting more people to obtain broadband Internet connections. The spread of faster connections in turn spurred Web designers to load up their sites with multimedia. Technology and content each drove the other.

Now we are seeing an equally vicious cycle in the wireless realm. Smartphones, along with fully mobile laptops and tablets, are spreading fast, and people are using them ever more hours of the day. Estimates show the amounts of such wireless data doubling or tripling annually. We can expect a hundredfold expansion in just a few years.

Where will all the new capacity come from? Addressing this issue demands first an understanding of why all radio spectrum is not created equal.

Every application of radio works best within a certain range of frequencies, and mobile broadband is no exception. Its sweet spot is relatively narrow, roughly in the range of 300 to 3500 megahertz. That's because radio waves that are much above 3500 MHz (shorter than about 9 centimeters) do not penetrate well into buildings or through rugged terrain, leading to frustrating dead spots. Lower frequencies are better in this regard, but they require awkwardly large antennas for efficient transmission; 300 MHz is roughly the lowest frequency compatible with a reasonably efficient antenna that's small enough to fit in a handheld device.

Not surprisingly, this swath of the spectrum is already staked out in much of the world. Finding ways that use less radio bandwidth to carry out these communications is not impossible, but it requires the adoption of some new technologies.

Telecommunications regulators try to anticipate such developments, and sometimes they even help to bring them about. But much of their work consists simply of codifying and institutionalizing established ways of doing things, which can interfere with efforts to use the airwaves in better ways.

Two-way radio is a good example. It became popular in the 1960s with the appearance of compact transistor-based gear. Back then, a one-way FM voice channel required 25 or 30 kilohertz. That's a gluttonous use of spectral bandwidth by today's standards. Actually, it was inefficient even then: Amateur radio equipment in those days routinely squeezed a voice signal into 5 kHz. Nevertheless, when the Federal Communications Commission set aside portions of the spectrum for two-way radios, it subdivided the bands into 25-kHz channels. The FCC then made things worse by assigning blocks of channels to particular industries, including subdivisions as small as "Motion Picture" and "Forest Products." The result, a decade or two later, was a huge embedded base of inefficient radios, spread unevenly over dozens of channel blocks.

The FCC has since merged the channel blocks across all industries, keeping only public safety separate. But narrowing the channels proved more difficult. Not until 1992 did the FCC launch a "refarming" program to cut the standard 25-kHz bandwidth to 12.5 kHz, with plans for a further trimming to 6.25 kHz. Twenty years later a lot of 25-kHz equipment is still in use, and the FCC-required implementation of 6.25-kHz equipment is still years away. Users, happy with their inefficient radios, resist government efforts to take them away. In the meantime, the goals of the program have been overtaken by technology. Doubling and quadrupling capacity may have been worth the effort in 1992, but such a target seems almost pointless today. Cellphone systems can carry 10 to 100 times the amount of voice

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traffic in the same amount of spectrum by using a dense network of towers and taking advantage of digital encoding and data compression.

Sometimes the problematic consequences of outdated regulations are less obvious. For example, all radio communications services have power limits, typically chosen to provide for reliable communications under near-worst-case conditions. But even when conditions are good, transmitters can still blast away at the same high power, tying up their frequencies over a wide geographic area. The old rules ignore the fact that modern equipment can be designed to automatically adjust power levels to the minimum needed, varying its output from moment to moment. Cellphones do this routinely. Most of the time the transmitter in your phone runs at well under its full power rating, facilitating reuse of the same frequency nearby (and prolonging battery life to boot). But only a few kinds of radios, such as those used for wireless Internet access in the 5-gigahertz band, are required to have this spectrum-saving feature.

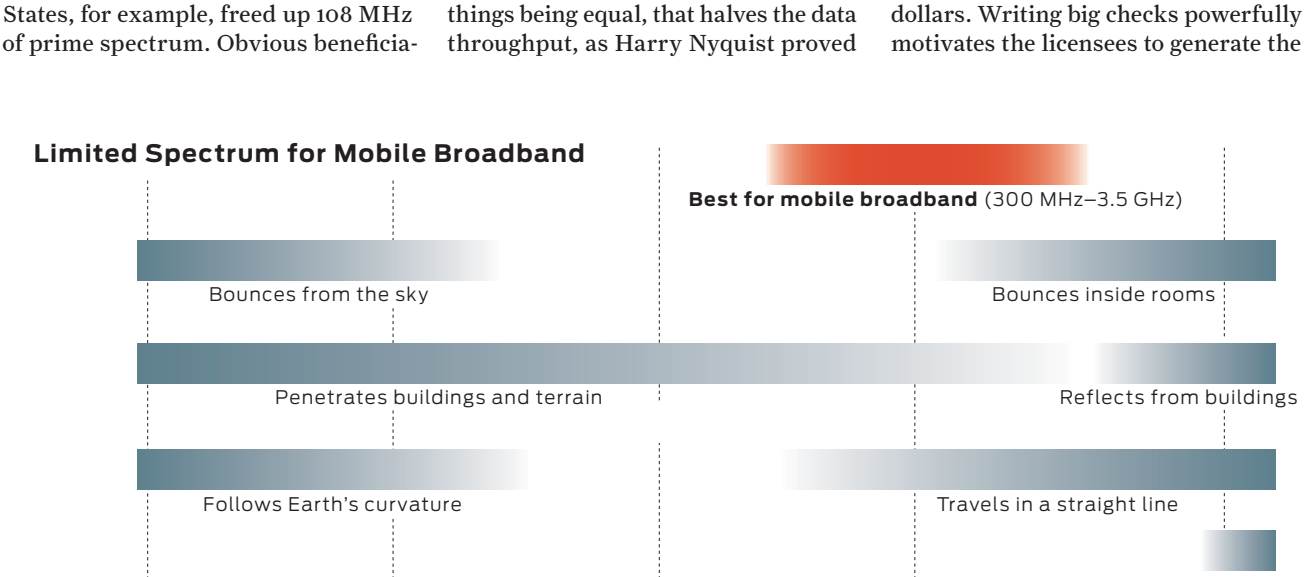
Why are such improvements not more readily adopted? One reason is that they cost money, and often those who must pay and those who will benefit are not the same. The recent shift to digital television in the United States, for example, freed up 108 MHz of prime spectrum. Obvious beneficiaries were the U.S. Treasury, which auctioned just under half that spectrum for US $19 billion, and public-safety personnel, who received some badly needed additional capacity without charge. But to make those gains possible, U.S. TV stations had to replace much of their equipment, and consumers had to shell out cash for new receivers. (The government subsidized digital-to-analog converter boxes, but for only 10 percent or so of the sets in use.) Similarly, the FCC's refarming program requires those now using two-way radios to replace their equipment at their own expense for the benefit of others.

The government sometimes does better and puts the costs where they belong. In the United States, for example, 1.9-GHz cellphones operate in spectrum formerly used for fixed point-to-point microwave communications. The FCC auctioned the spectrum for mobile use but warned bidders they would have to pay the costs of "relocating" the fixed users to other bands. Predictably, disputes broke out over the details. But the principle made sense: The party that benefits from a change should pay for it.

Money is not the only problem; practical considerations impose limits, too. Suppose, for example, a designer wants to modify a system to operate in half the radio bandwidth it currently uses. Other things being equal, that halves the data throughput, as Harry Nyquist proved for telegraph lines in 1928. Restoring the original throughput of that radio channel without changing anything else risks increasing the bit error rate. To keep the rate level, the designer can increase the power, which impairs battery life. Or he can limit the range—or perhaps compress the data to reduce the bit payload. But that delays the signal and may reduce how accurately it can be reconstructed at the receiver. The bottom line is, making more efficient use of spectrum usually means something else has to give.

Regulators sometimes try to boost spectrum efficiency by fiat. In the United States, fixed-location microwave equipment for some bands cannot legally be sold unless it can transmit at least 2.5 to 4.5 bits per second per hertz, the exact value depending on its bandwidth. Two-way radios in some bands also have a minimum, although it is much more lenient.

Often more effective, though, is a regulatory environment that gives licensees both the motive and the means to improve efficiency on their own. Wireless-phone carriers in the United States must bid at auction for exclusive use of a frequency band over a specified geographic area. Nationwide, the auction prices have totaled many billions of dollars. Writing big checks powerfully motivates the licensees to generate the



OPPORTUNITY WINDOW: The best frequencies for mobile broadband are high enough that the antenna can be made conveniently compact, yet not so high that signals will fail to penetrate buildings. This leaves a relatively narrow range of frequencies available for use [red band].

WORLD WIDE WORRIES

The growing popularity of mobile broadband is a global phenomenon, and the laws of physics that limit the frequencies available for it are the same everywhere. So it is no surprise that many other countries are facing the same spectrum famine as the United States.

All regions have large amounts of spectrum dedicated to TV, most of it in the frequency range suitable for wireless broadband. Most countries have targeted a conversion to digital broadcast TV as their best bet for obtaining more wireless spectrum—what the European Union calls a "digital dividend." Several have already completed the transition, including Belgium, Denmark, Finland, Germany, Luxembourg (the first anywhere), the Netherlands, Norway, Spain, Sweden, and Switzerland. Other countries have transitions in progress, most scheduled for completion between 2011 and 2013 (China in 2015). The amounts of spectrum harvested vary from about 100 up to 130 megahertz.

Many countries are also experimenting with spectrum auctions, some with a minimum of regulation of the technologies, as a way of fostering efficient use.

—M.L.

most possible revenue from the available spectrum, which in turn encourages the adoption of equipment that can serve the maximum number of subscribers. Licensees are free to choose whatever forms of radio technology they think will work best.

With that kind of financial incentive, coupled with minimal regulatory constraints, wireless-service providers have achieved dramatic improvements in spectrum efficiency. They've done that by being clever about the modulation schemes, data encoding, and tower configurations they adopt. Back in the 1970s the early mobile telephony providers used one transmitter to serve an entire city, typically with all users sharing just one or two dozen voice channels. The service was expensive, required a lot of heavy equipment stowed in the trunk of your car, and it often entailed long waits to make a call.

Cellular carriers in the 1980s vastly improved mobile services using 832 pairs of 30-kHz-spaced analog FM channels in the 800-MHz band. The cellular layout reused the same frequencies at different locations across a city to support many thousands of conversations. But charges for wireless minutes remained high, geared mostly to business customers.

The next iteration, in the 1990s, was 1.9-GHz "2G" voice service, among the first to make use of auctioned spectrum in the United States. Although the FCC's rules do not require it, all of the licensees opted for digital transmission, which yielded a big improvement. Digital modulation is not inherently more spectrum efficient than analog, but it allows much better compression and offers more ways to combine multiple communications onto one channel.

Those advantages were enough to persuade the companies operating older, analog cellphone systems to go digital. In the late 1980s, the carriers had begun shipping dual-mode analog/digital handsets and converting their base stations to digital. The handset automatically switched to whichever mode suited the equipment installed at the nearest tower. The conversion took about a decade, although carriers kept some analog service in place until 2008. The outcome was a tenfold increase in the capacity of these wireless networks.

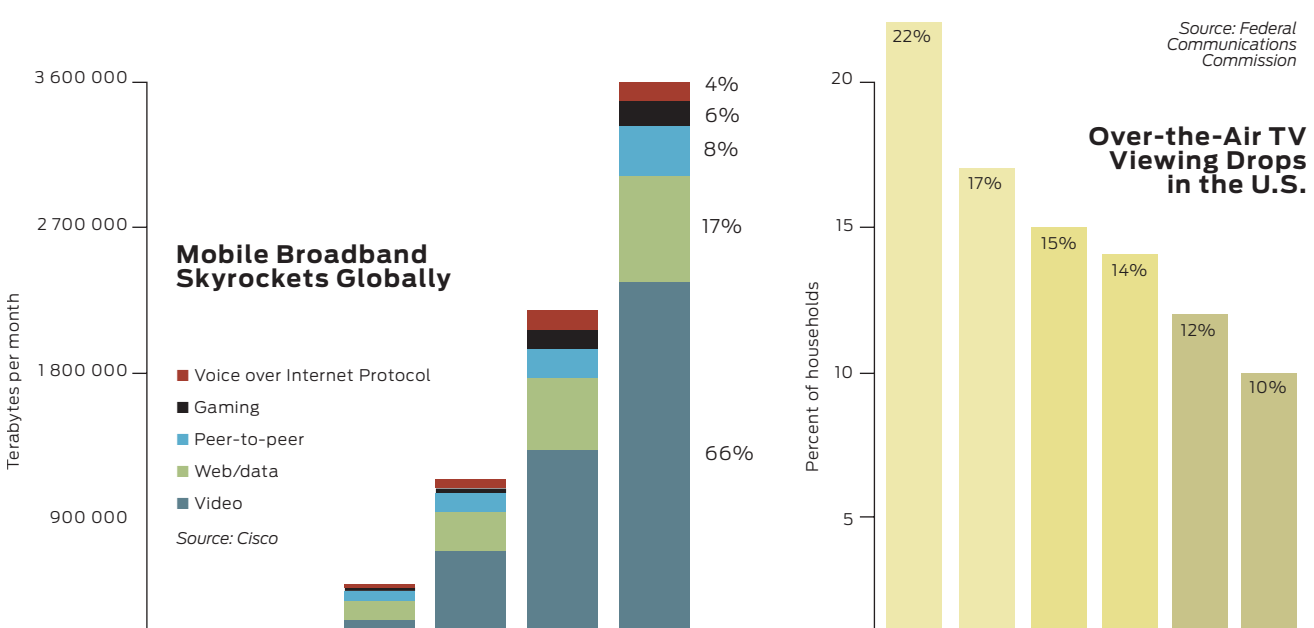
The regulators learned some valuable lessons from that transition. First, it can be done pretty painlessly. In this case, subscribers were mostly unaware of it—people just kept on talking, with no significant interruptions or inconvenience (although a few analog-only holdouts had to be urged to upgrade their handsets). Second, the changeover need not be forced from on high. The analog-to-digital switch required essentially no government involvement. Carriers made the change on their own, for their own benefit, and on their own timetables.

Contrast that with the transition from analog to digital television, which was mostly completed in the United States by June 2009. That job was only a little bigger—today the United States has just a few more TV receivers than cellphones—but it proved much harder.

The digital-TV conversion took 22 years and cost broadcasters, viewers, and the U.S. government billions of dollars. One key difference was that in the TV switchover none of the broadcasters stood to cash in, at least not immediately. Most of the money that changed hands went the other way, to buy new studio and transmission equipment. Consumers paid for new home TVs and converter boxes. With prodding from the government, the broadcasting and consumer-electronics industries mounted a massive publicity campaign to prepare viewers for the coming sea change. Cable and satellite-TV companies ran their own campaigns, promoting their services as a way to keep old sets working. The government offered free vouchers for converter boxes (then ran out of money to distribute them). Still, in the end, on the morning of 13 June 2009, many viewers were shocked to find that their beloved analog TV sets showed only snow.

Compared with the wireless-phone conversion, the shift to digital TV was slow and painful. Whereas the wireless-phone changeover was an inside job, one largely driven by the market's invisible hand, digital TV was directed by the government at every stage: adopting technical standards, setting required start-up dates for digital broadcasting, even imposing fines on electronics distributors who trafficked in analog-only TVs. Market forces and incentives played little part. And the TV transition required the participation of consumers in ways the wireless-phone conversion did not.

On the positive side, though, the switch to digital TV did work: It enabled the FCC to repack transmissions from



CHANGING TASTES: The amount of data being sent wirelessly over the Internet has shot up globally [left], while the small fraction of television-owning households that rely on over-the-air broadcasts has been steadily diminishing in the United States [right].

digital TV stations more tightly than their analog predecessors. That freed up 108 MHz of spectrum, over a quarter of the total bandwidth allotted to broadcast TV before the transition. And thanks to data compression, each digital channel accommodates about four analog-quality video signals, and digital TV also offers new options for high-definition programming and data services. The overall result is about a fivefold improvement in spectrum efficiency—a success by any measure.

Or maybe not. The United States still has 294 MHz of spectrum set aside primarily for TV. But the vast majority of U.S. TV-owning households subscribe to cable or satellite television. Just 10 percent watch only transmissions sent over the air. And the over-the-air fraction has declined steadily over the decades. So the 294 MHz of TV spectrum—much of it in a frequency range ideal for mobile broadband—serves a small and shrinking number of viewers.

Noting this fact, some policymakers have proposed to divert still more of the TV broadcast spectrum to mobile broadband. One such plan in the United States would reallocate and auction 120 MHz, or about 41 percent of the postanalog TV capacity. Broadcasters who lose their channels could receive part of the auction revenues. Or they might be allowed a share of the newly expanded channel capacity taken from a fellow broadcaster whose station stays on the air

Not surprisingly, broadcasters as a group vehemently oppose any such reorganization of the airwaves, although some individual station owners would likely be happy to take the money and close shop. Others favor keeping their channels but renting out bandwidth for wireless use. Maybe that would be less disruptive to these businesses. And it does seem a little soon to require American TV watchers to relearn how to orient their antennas and tune their sets.

That we're even talking about revamping the U.S. TV bands barely a year after the last reorganization suggests how thorny spectrum issues have become.

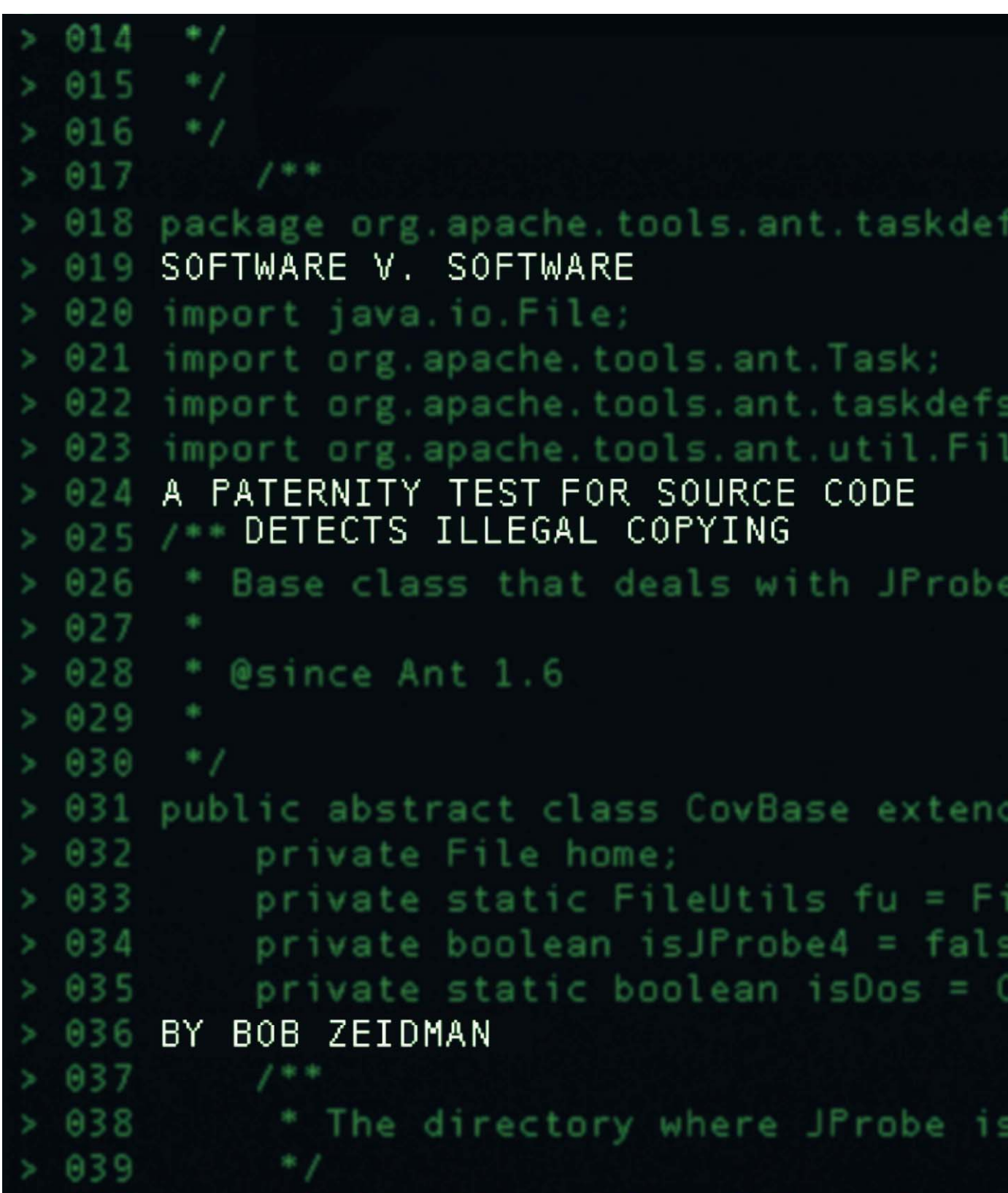
Any solution ultimately has to identify the least efficient or least critical services and redesign them to use less spectrum. Consider, for example, the current situation with two-way radios: 12.5 kHz for a one-way voice channel, with many channels vacant at any given moment. Such radios are indispensable to police, firefighters, and other emergency responders, as well as utility workers, taxi drivers, plumbers, construction crews, and many others. But their collective traffic could be handled in far less spectrum than is being used today. Unfortunately, there's no practical way to improve these devices on their present frequencies, beyond the long-awaited halving of their bandwidth.

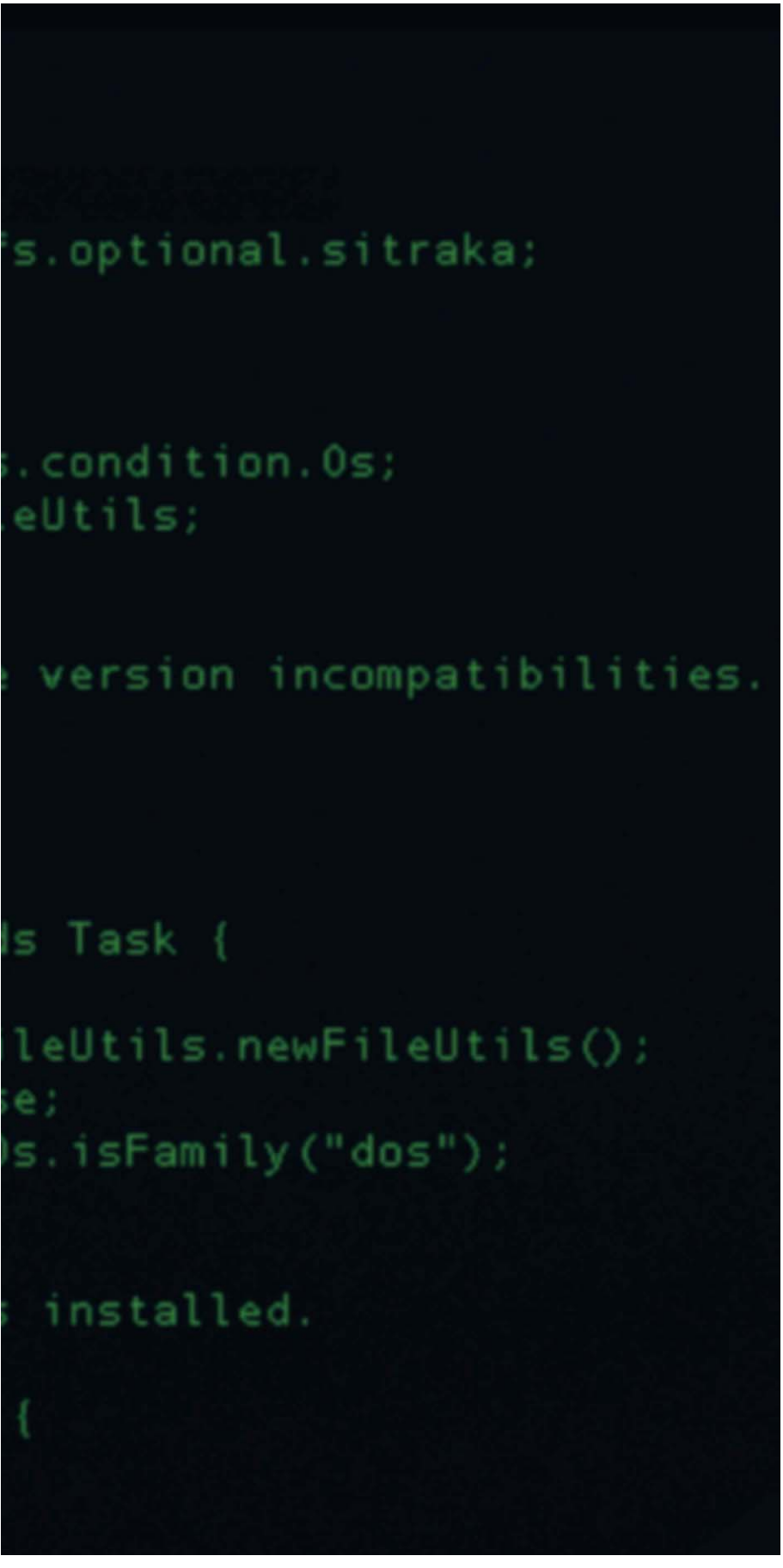
We need to offer these people a more efficient alternative while making it more costly for them to use their old equipment. Suppose the FCC gave a nonprofit industry group a few megahertz in which to provide efficient, digital, two-way radio service on an at-cost basis. To be sure, many users would prefer to keep their existing radio gear. But the FCC could make their licenses more expensive and equipment requirements more demanding, while pointing users to the new collective service as a better option.

Eventually, enough will have migrated out of the original band to allow the FCC to take it back and reallocate it for other purposes. The result would be two-way radio use that is 10 to 100 times as spectrum efficient as today's with little disruption along the way.

Other bands may require different approaches. For example, the FCC is considering ways to convert underused mobile satellite bands to a primarily terrestrial cellphone-type service. And the U.S. government occupies large swaths of valuable spectrum that Congress could help to make available for private use.

True, any such reorganization of the airwaves would take years. But what solution wouldn't? Given the growing hunger for mobile broadband, we ought to get cracking. ❑


014 */
015 */
016 */
017 /**
018 package org.apache.tools.ant.taskdef
019 SOFTWARE V. SOFTWARE
020 import java.io.File;
021 import org.apache.tools.ant.Task;
022 import org.apache.tools.ant.taskdefs
023 import org.apache.tools.ant.util.Fil
024 A PATERNITY TEST FOR SOURCE CODE
025 /** DETECTS ILLEGAL COPYING
026 * Base class that deals with JProbe
027 *
028 * @since Ant 1.6
029 *
030 */
031 public abstract class CovBase exten
032 private File home;
033 private static FileUtils fu = Fi
034 private boolean isJProbe4 = fals
035 private static boolean isDos = (
036 BY BOB ZEIDMAN
037 /**
038 * The directory where JProbe is
039 */
040 public void setHome(File value)
041 this.home = value;
042 }



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TWO INTERNATIONAL COMPANIES. AN ACCUSATION OF PLAGIARIZED SOFTWARE. A COURT TRIAL. TWO EXPERT WITNESSES WHO OFFER DIRECTLY CONFLICTING OPINIONS. A JUDGE WHO HAS NEVER OWNED A COMPUTER MUST DECIDE WHO'S RIGHT.

Just a few years ago, the experts' testimony would have been the only technical evidence the judge would have considered. But now a third point of view is available: that of a sophisticated software forensics program. By interpreting the program's results, an expert computer scientist can give a definitive, quantitative answer.

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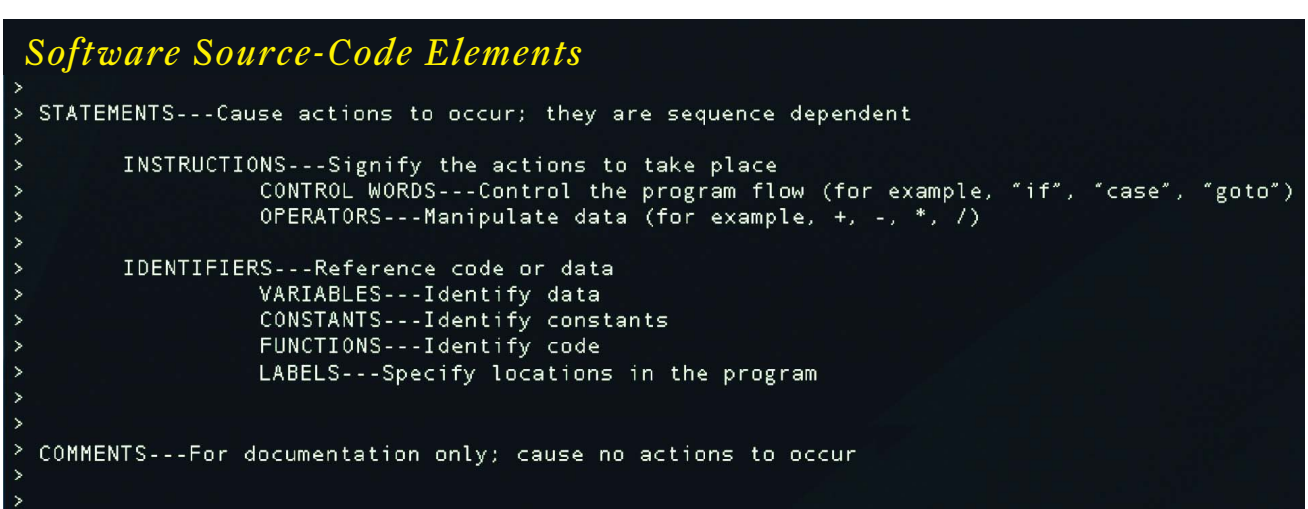


In recent years, litigation over software in the United States and elsewhere has skyrocketed. Partly that's due to the 1998 case *State Street Bank & Trust v. Signature Financial Group*, which established that most kinds of software are patentable. Partly it's due to the fact that you can easily and surreptitiously make a copy of copyrighted source code and put it on a flash drive or send it by e-mail. And partly it's due to our increasing reliance on computers and the increasing value of the software that runs our businesses and our equipment.

Clearly, it's in society's best interest to resolve these lawsuits as efficiently and equitably as possible. But settling such disputes can get exceedingly technical, and few people have the expertise to parse source code—the human-readable form of a program—to determine what, if anything, has been illegally reproduced. A program that runs something as simple as a clock radio can have thousands of lines of code; a more complicated device, such as an airplane, can have millions. That's why automatic software forensics tools are so useful. Just as software for analyzing DNA has become crucial in resolving criminal cases and paternity suits, tools that can quickly and accurately uncover illicit software copying are becoming key to copyright infringement litigation.

Detecting illegal copying without the aid of forensics software can be like finding the proverbial needle in a haystack. In one high-profile case that some colleagues of mine worked on, Cadence Design Systems, one of the largest developers of software for electronic design automation, sued Avanti Corp., a much smaller competitor. As is common in the tech business, Avanti had been founded by high-level engineers and executives who'd previously worked for Cadence.

In the mid-1980s Cadence introduced a product called Symbad for laying out the physical structure of integrated circuits. In a surprisingly short time Avanti came out with its own circuit-layout program, called ArcCell. Not only did the product development time seem too short, but a Cadence engineer noticed that ArcCell exhibited a very strange bug that was identical to a bug in Symbad. Given these suspicious circumstances, Cadence filed a motion with the court and convinced a judge that there was reason to believe its software copyright had been infringed.

Avanti had a lot of financial backing, though, and so it was able to delay the trial for some years. By the time the case reached the discovery phase, during which attorneys turned over relevant documents, including source code, to the opposing side, Avanti's software had gone through many revisions.

At that time, no sophisticated forensics software yet existed that could spot illegal copying. Teams of experts spent months manually poring over the code, but they found few signs of copying. Eventually, though, they turned up one curious comment in both programs. The comment was a description in which a single word was spelled incorrectly. It was known that some of the same programmers had worked on both programs, which is completely legal as long as the programmers don't literally copy the code. Perhaps one of them wasn't a very good speller.

But this comment stood out. What were the chances that the same misspelling would show up in the same comment in nearly identical positions in both programs? Practically zero. Based largely on that seemingly tiny concurrence, Avanti lost both the civil and criminal lawsuits, and several of its executives went to jail. After paying fines that effectively put it out of business, what was left of Avanti was bought by a Cadence rival, Synopsys.

In that case, justice prevailed, but much of the time and expense involved in trying the case could have been avoided with forensics software.

Computer scientists have studied software copying since at least the late 1970s. In 1987, J.A.W. Faidhi and S.K. Robinson of Brunel University, in England, published a paper in the journal *Computers & Education* on detecting plagiarism in students' programming projects. The paper characterized six types of source-code modifications that students tended to make, but it didn't really define what constituted plagiarism or provide useful measurements for determining whether or not it had occurred.

Later research sought to fill that gap. Many of these efforts were based on the earlier work of computer scientist Maurice H. Halstead. Halstead wasn't interested in plagia-

rism but in ways of measuring the complexity of code and the "mental effort" required to create it. He devised quantitative measurements, later called Halstead metrics, that counted the number of unique operators and operands as well as the number of operator and operand occurrences in source code.

Starting in the late 1970s, various researchers used the Halstead metrics to create more sophisticated metrics that were intended to detect plagiarism. If two computer programs produced similar values for these metrics, the conclusion was that plagiarism was likely to have taken place. In 1989, Alan Parker and James Hamblen of Georgia Tech documented at least seven plagiarism-detection algorithms that relied on Halstead metrics.

Although these algorithms vary somewhat, they are similar in that they all yield a single score. If the score exceeds a certain threshold value, it indicates that plagiarism has probably occurred. But having one score for an entire program means that small sections of plagiarized code could be missed entirely. Algorithms of this kind reflect their creator's aim: They are written by university professors trying to spot plagiarism in student projects, and so they are mainly concerned with flagrant incidents of cheating.

Investigating illegal copying in commercial software is quite different. Copied code is not necessarily there illegally; it may have been purchased from a third-party vendor, or it may be open-source code. So an algorithm that assumes that any instance of copying is illegal—that is, plagiarized—ignores the fact that sometimes the copying was authorized. There can be many other reasons that one source-code file is similar to another, most of which are not due to copying. More about that later.

> Few people have the expertise to parse source code--the human-readable form of a program--to determine what, if anything, has been illegally reproduced

The other key difference between plagiarism-detection software and forensics software is that the former is designed to execute quickly, and that by design, it favors false negatives over false positives. In other words, a professor would rather miss a few cheaters than falsely accuse a student of cheating. One professor explained to me that just the threat of a plagiarism-detection program, whether it worked or not, was enough to discourage cheating.

The goals of a software forensics tool used in intellectual-property litigation have to be very different. In these cases, there may be hundreds of millions of dollars at stake. The tool must favor false positives over false negatives so that it does not miss any cases of copying; an expert can then examine the results and eliminate those false positives. And it must be fast, but not at the expense of accuracy; in these high-stakes cases, it's fine to dedicate a computer or set of computers to analyze the code for a day, a week, or even a month if necessary.

So how do you go about creating such a software forensics tool? I spent about a year developing CodeMatch, for use in copyright infringement cases. My company released the first version in 2003, and the program has been evolving ever since. Here are the basic principles I followed in developing CodeMatch. First, the tool can analyze source code in a way that's independent of the programming language. That's extremely important, given the wide variety of software cases in which the program is used. To be able to do that, CodeMatch focuses on characteristics in the code that are generic to all types of source code. If the program were comparing automobile designs instead, it might look at characteristics such as gas mileage, rather than unique features, such as the number of tail fins. And rather than rendering a definitive verdict that illegal copying has or hasn't occurred, CodeMatch relies on measurable quantities that can be used to judge the likelihood of copying.

CodeMatch works by gauging the statistical correlation of two variables. A correlation of 0 indicates that the two variables are unrelated. A correlation of 1 indicates that a change in one variable always causes a similar change in the other. And –1 indicates a completely opposite correspondence between their variations. For source-code files that have no similarities, the correlation is 0; for identical files, it's 1.

CodeMatch looks for such correlations by examining and comparing two collections of source-code files. Source code consists of statements, which include the instructions and identifiers that guide the program, as well as comments and strings that serve to document the code but cause no action to occur. A single line of source code may include one or more statements and one or more comments.

CodeMatch spots correlations in four places: statements, comments/strings, identifiers, and instruction sequences. Each type of correlation offers a clue to plagiarism that the others may miss. Statement correlation finds the percentage of matching statements. Comment/string correlation finds the percentage of matching comments and strings. Identifier correlation finds the percentage of matching or partially matching identifiers. Identifier names in copied code are often changed to disguise the copying, but because they contain useful information for debugging and maintaining the code, the new names are usually similar to the original names. For example, the identifier "count" may be renamed "count5" or "cnt." CodeMatch flags such similarities.

Instruction-sequence correlation compares long sequences of instructions. Even if the identifiers, comments, strings, labels, and operators are completely different, the sequence of instructions will likely be preserved to maintain the functionality of the original code. For instance, an unscrupulous programmer may decide to use another party's copyrighted code as a reference, perhaps even rewriting the code in a different programming language to evade detection. If the programmer duplicates only the program concepts, that's not copyright infringement. But if he takes anything literal, like a sequence of instructions, and converts it directly into the new language, that could be infringement, because the programmer is making an unauthorized derivative of the work, which is protected by the copyright. CodeMatch can spot such similarities in code, even when they're written in different languages. Copyright infringement can also involve copying nonliteral elements like software architecture or organization, but CodeMatch is not as useful in detecting these forms of copyright infringement.

PARTIALLY MATCHING IDENTIFIERS (highlighted in red) may be signs of copying

BLANK LINES (highlighted in yellow) may also be signs of copying

SNIPPET FROM FILE 1

```
001 /* Check __INT_MAX__ */
002 #if __INT_MAX__ < 2147483647
003  int main (void)
004  {
005   exit (0);
006 }
007 #else
008 /* Failed on powerpc */
009  struct ieee
010  {
011   unsigned int negative:1;
012   unsigned int exponent:11;
013   unsigned int mantissa0:20;
014   unsigned int mantissa1:32;
015 } x;
016 unsigned int foobar (void)
017 {
018   unsigned int exponent;
019   /* Calculate the exponent */
020   exponent = x.exponent;
021   if (exponent == 0)
022     return 1;
023   else if (exponent > 1)
024     return 2;
025   return 0;
026 }
```

SNIPPET FROM FILE 2

```
001
002 #if __INT_MAX__ < 2147483647
003  int main (void)
004  {
005   exit(0);
006 }
007 #else
008
009  struct ieee
010  {
011   unsigned int neg:1;
012   unsigned int exp:11;
013   unsigned int mant0:20;
014   unsigned int mant1:32;
015 } x;
016 unsigned int bar(void)
017 {
018   unsigned int exp;
019
020   exp = x.exp;
021   if (exp==0)
022     return(1);
023   else if (exp > 1)
024     return(2);
025   return(0);
026 }
```

A SIDE-BY-SIDE comparison of two snippets of source code reveals some of the telltale signs of copied code. A forensics program that measures source-code correlation would note that many of the statements are identical and that the sequence of instructions is also identical. But the fact that many of the identifiers match or partially match (__INT_MAX__, main, ieee, negative and neg, exponent and exp, mantissa and mant) isn't necessarily due to illegal copying, because they are commonly used identifiers. Finally, note that the comments in file 1 at lines 1, 8, and 19 correspond to blank lines in file 2. There's no reason to have blank lines in those locations. Comments are typically removed for only two reasons: because they are wrong—which is not the case here—or to hide signs of copying.

Once these four correlations have been determined, CodeMatch combines them into a single overall correlation value. Even then, the work is not done. A software expert must still go through the results and rule out any reasons for the correlation other than copyright infringement.

As mentioned earlier, a correlation may occur when two programs use the same widely available open-source code or code purchased from a third-party vendor. Correlations can also spring from automatic code-generation tools like Microsoft's Visual Studio and Adobe Dreamweaver, which use standard identifiers for many variables, classes, methods, and properties. The structure of the code generated by these tools also tends to fit into a certain template with an identifiable pattern. So it's common for two programs developed using the same code-generation tool to have a correlation.

A correlation may happen simply because the programmers who created the software studied at the same school or work in the same industry and therefore rely on the same identifier names. For example, many programmers like to use the identifier "result" to designate the result of an operation, so that identifier appears in lots of unrelated programs. A search on the Internet can determine whether an identifier is widely used or relatively rare.

Similarly, the same algorithm may show up in unrelated programs. An algorithm is a set of instructions for accomplishing a given task—say, calculating the square root of a number. In one programming language there may be an easy or well-understood way of writing that algorithm. If it's taught in programming classes at universities or appears in a popular programming textbook, then it's likely to show up in many programs, too.

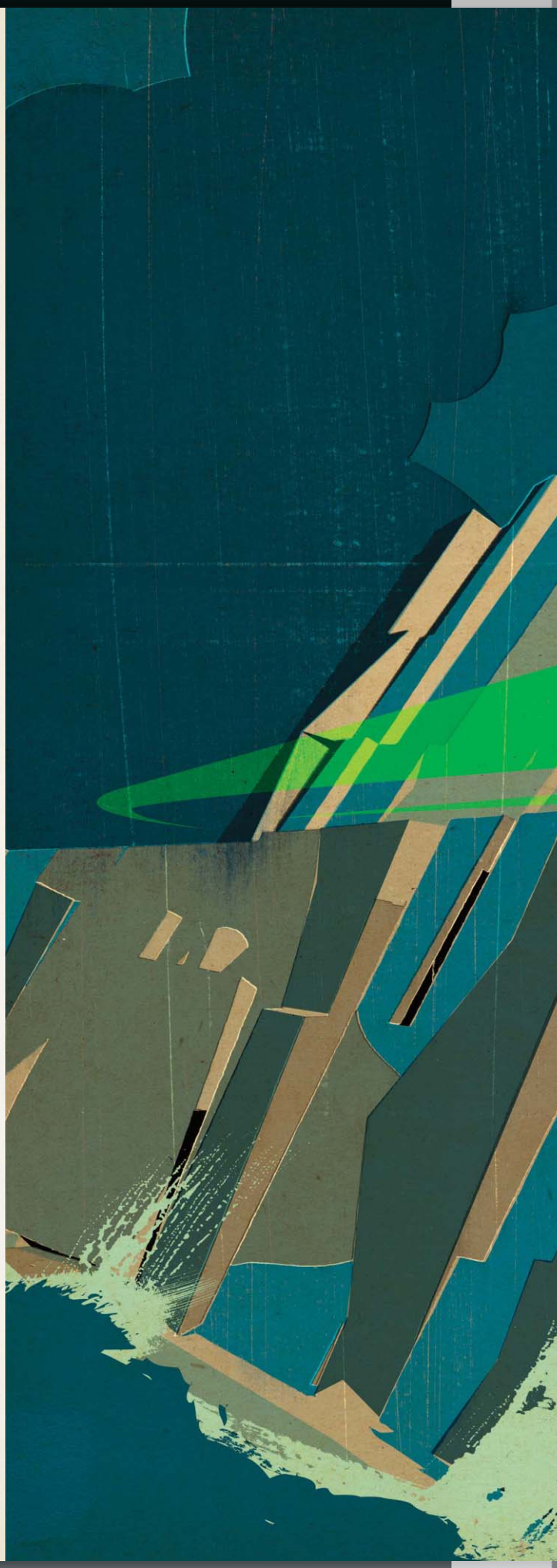
What about two blocks of code written by the same person? Just as books by the same author may have a similar style, even when the subject matter is completely different, software written by the same programmer may also have a telltale style. He might repeatedly use a unique identifier name, for instance.

For these reasons, a software forensics expert must examine each instance where CodeMatch *Continued on page 50*

The GREENING of the SUPERCAR

Ferraris, just like Fords, must now conform to environmental regulations

By Lawrence Ulrich



TAVIS COBURN

SOMEDAY SOON THERE WILL BE AN AFFORDABLE and clever electric vehicle that will conquer the world, as the Model T and Volkswagen Beetle did in their day. In the meantime, there's the Tesla Roadster, a US $109 000, 300-horsepower, two-seat toy for rich, environmentally conscious gadget hounds. Yes, for every Nissan Leaf or Chevy Volt with mainstream pretensions, there's a battery-powered land rocket that's way more Bugatti than Beetle.

Makers of automobiles more associated with tearing up the earth than with saving it are suddenly rushing to outdo each other in the automotive industry's next big battleground: electric and plug-in hybrid cars. Their pitch is the familiar best of all worlds: cars that look hot, go fast, run clean, and consume either no gasoline or very little.

But really now, does a man who buys a six-figure missile on wheels really fret over fuel bills or global warming? Probably not, but carmakers say that affluent buyers increasingly want to make a green statement anyway. In a world where a fuel-sucking V-12 engine seems not just passé but nearly pathological, an electric

AUDI e-TRON

In the movie *Iron Man*, billionaire adventurer Tony Stark drives an Audi R8 supercar. But even Iron Man has yet to get his metal mitts on the e-Tron, which Audi will bring to market around 2012 at an estimated US $150 000. Looking like a scaled-down R8 but sharing its aluminum Audi Space Frame construction, the e-Tron takes advantage of four electric motors—two each at the front and rear axles—to offer a torque-vectoring take on its trusty Quattro all-wheel-drive system. Those motors send a total of 230 kilowatts (313 horsepower) and 681 newton meters (502 foot-pounds) of torque to all four wheels, urging the Audi from 0 to 100 kilometers per hour (62 miles per hour) in 4.8 seconds—not quite as quick as the V-10 powered R8 but impressively swift for an electron-enabled sports car. And while the standard R8 is guzzling from a premium nozzle, the e-Tron can draw from its 53-kilowatt-hour battery to cover 248 km (154 miles) on a charge.

Like other EV sports cars, the Audi is limited to a modest top speed—in this case, 200 km/h (120 mph)—because of how quickly precious electrons are used up at autobahn speeds. "You could take out the high-speed limiter, but you'd only travel a few miles," Audi head of electromobility strategy Frank Van Meel says; at high speed, "the electric motor has a tendency to suck the battery dry." Weight is another enemy of EV range and performance: At 2000 kilograms (4400 pounds), the e-Tron prototype weighs as much as a full-size luxury sedan. Audi insists it will chop up to 408 kg (900 pounds) from the finished product. But it won't be easy: the lithium-ion battery,

Continued on next page

sports car marks its owner as not just loaded but also progressive, ahead of the curve in both auto technology and fashion. Auto execs, of course, are only too happy to propagate this perception. "In the long run, we're either going to run out of oil or the price will go up dramatically," says Frank Van Meel, head of electromobility strategy for Audi. "There's a need to act right now."

And yet, it's not really the warming planet that's spurring the supercar makers. It's the heated rhetoric, and the forging of new government regulations. This is quite a change for a niche market that has obsessed over miles per hour while largely ignoring miles per gallon.

Under a controversial European Commission plan, new cars in Europe may be required by 2015 to meet a strict fleetwide average of 130 grams of carbon dioxide per kilometer driven. The United States is expected to adopt similar CO_2 standards and has already mandated a 22 percent improvement in fleet average fuel economy, to about 35 miles per gallon (6.7 liters per 100 kilometers) by 2016. Because CO_2 emissions are a remorseless function of how much fuel you burn, the EU target means that a gasoline car would need to consume just 5.1 L/100 km, or achieve 46 mpg.

There's just one problem: No conventional sports car in the world today achieves that kind of fuel economy or squeaky-clean emissions, let alone supercars like the 21.4 L/100 km (11 mpg) Lamborghini Murciélago, among the industry's worst offenders, belching 480 grams of CO_2 per kilometer. Even Lotus's tiny Elise, soon to be equipped with a shrimpy new 1.6-L four-banger, will emit 155 g/km. That's less than any current gas-driven sports car but still above the proposed target.

Small-scale sports-car builders such as Ferrari and Porsche have long been excused from meeting the United States' Corporate Average Fuel Economy rules. Other purveyors of power and luxury have paid fines for missing fuel-consumption standards, with Mercedes shelling out nearly $300 million since 1983—a practice the company has vowed to end by boosting efficiency.

Yet a fast-car fan might ask: In a world steaming with emissions from coal-fired power plants and hundreds of millions of cars, who cares if a Lamborghini guzzles gasoline more greedily than a Citroën? For years, sports-car makers have offered precisely that defense of their guzzling: These exclusive cars sell in such tiny quantities—and are driven so lightly, as weekend toys—that their environmental impact is negligible. Ferrari sells fewer than 10 000 new cars a year around the world, compared to the millions of a GM or Toyota. Ferrari officials say their exotic baubles tend to be driven less than 10 000 km a year on average, about half as much as a typical passenger car. Even so, regulations may limit the free passes and no longer allow major companies to buy indulgences for green sins.

Colin Peachey, Lotus's chief engineer, frankly allows that political and social forces are driving the industry. "In an ideal world, where burning fuel didn't damage the planet, there wouldn't be a case for electric cars. We'd carry on with our V-8s and V-12s and have all the performance and convenience that gas gives you."

It's hard to imagine a world in which wealthy car buyers can't have the cars they want—or one in which carmakers can't even make the cars they want. Peachey insists that sports-car builders could be effectively legislated out of existence if they don't hybridize or otherwise green their lineups. "The emissions may be a relative drop in the ocean, yet legislators are saying we're going to tax you until it hurts, and above a certain emissions level, you just won't be able to sell the car," he says.

The writing on the wall is even being translated into Italian: Ferrari has unveiled the 599 HY-KERS hybrid supercar concept, which combines a V-12 engine with an 80-kilowatt (107-horsepower) electric motor—and a 3-kilowatt-hour lithium battery said to be just 2.5 centimeters (1 inch) thick—boosting fuel efficiency to as much as 9.4 L/100 km (25 mpg) and reducing CO_2 emissions to 270 g/km.

The car adopts energy-capturing regenerative-braking technology from Ferrari's KERS (Kinetic Energy Recovery System, used in Formula One race cars), delivering an estimated 1.5 percent gain in fuel efficiency. And as if that weren't surprising enough to traditionalists, Ferrari chairman Luca di Montezemolo said recently that every car in Ferrari's lineup will adopt hybrid technology within three to five years. (Note to collectors: Now's the time to buy up the soon-to-be "classic" gas-burning models.)

Colin Chapman, the engineer, Formula One genius, and founder of Lotus, created the most enduring mantra of sports- and racing-car design: Add lightness. And for today's performance geniuses, electrified cars pose a tremendous challenge: how to reduce emissions and keep cars fast and razor sharp in handling—as customers demand—even as batteries and electric motors add weight and greatly complicate the pursuit of perfectly balanced (roughly 50-50) weight distribution between front and rear axles.

In a briefing on Ferrari's environmental issues, technical director Roberto Fedeli expressed confidence that the company would dramatically reduce CO_2 emissions while "keeping its soul" and honoring all its performance and fun-to-drive traditions. Yet further gains in engine efficiency won't be enough,

Continued from previous page

power inverter, and control electronics saddle the Audi with more than 470 kg (1040 pounds).

To boost efficiency, Audi adds an automotive first: A heat pump, typically used in buildings, that can scavenge heat or cold from one part of the car and send it to another, without the energy-sapping electric climate control found in other hybrids and EVs. Audi cites a 2.5-hour waiting time for a high-voltage charger, or up to 8 hours on household current. Audi is also developing a wireless inductive charger, akin to an electric toothbrush setup, that can begin charging as soon as the car is parked, no plug required. Owners can use a smartphone to manage and monitor charging remotely, including preheating or precooling the cabin and drive system using juice from the grid instead of drawing from the car's battery.

he said. Ferraris and other models will begin to adopt the start-stop functions of hybrids, shutting engines down automatically at stoplights to save fuel.

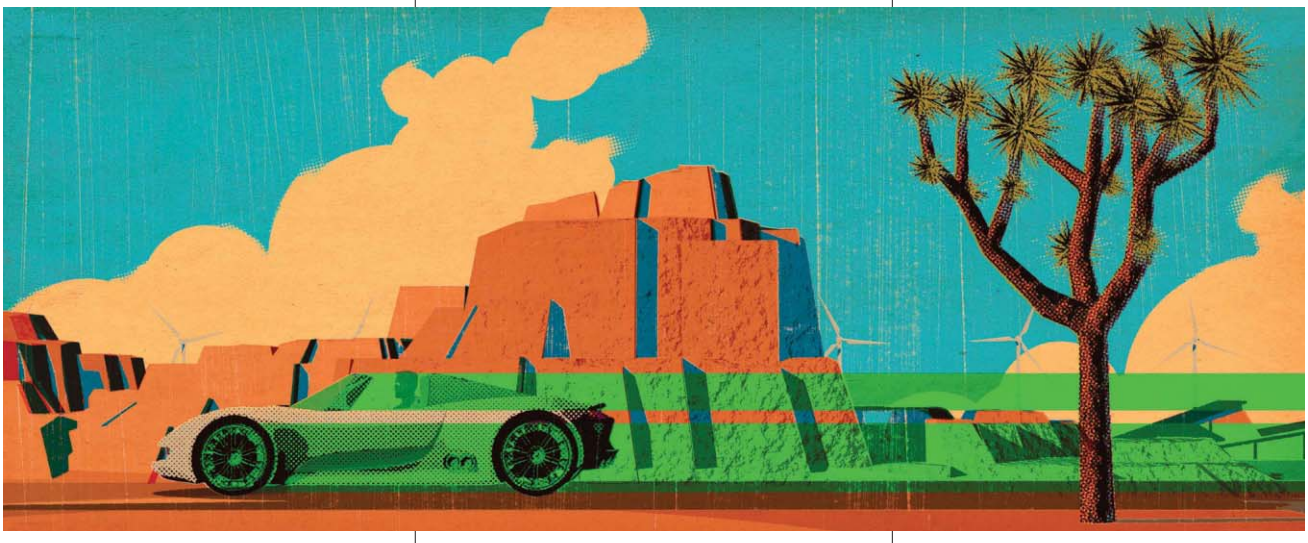
Ferrari's performance strategy is to add 1 additional horsepower for every kilogram of mass added to its hybrid cars. In fact, its recently unveiled hybrid concept car actually accelerates more quickly than the standard 599 GTB Fiorano model. Critically, that extra weight must be distributed in a way that doesn't spoil a car's handling balance or intrude unduly on passenger and cargo space. Virtually every sports-car maker is designing batteries and hybrid components to fit into a thin "skateboard" entirely under the car's floor, lowering the vehicle's center of gravity.

The Tesla Roadster, which is based on the gasoline-powered Lotus Elise, proved that EVs can be fast and fun. But they still don't outperform comparable gasoline models, especially in handling. That goes for hybrids, too. Much has been made of an electric motor's ability to deliver its full monty of torque the instant you mash the gas—er, throttle. But for pure EVs, those motors must counteract hundreds of kilograms in batteries, cooling systems, and electronic controls. Take the Elise, a featherweight at less than 910 kilograms (2000 pounds). It gains more than 300 kg (660 pounds) of electric fat in its transformation to the electric Tesla Roadster. And because batteries run out of energy so quickly, especially at higher speeds—a single gallon of gasoline contains 33 kWh of energy, about two-thirds of the energy stored in the entire battery pack of a typical EV—electric

TAVIS COBURN

MERCEDES SLS AMG eDRIVE

From its shape to its fanciful gull-wing doors, the US $186 000 Mercedes SLS AMG harks back to the classic SL gull-wing of the '50s. But the zero-emissions version of the SLS casts an eye toward a distant gas-free future, even as Mercedes readies its lithium-ion supercar for sale around 2013. Using the same lightweight aluminum body as the standard model, the Mercedes ditches its massive V-8 in favor of four electric motors with a total of 392 kilowatts and 880 newton meters of torque. It thus loses 7 percent of the power (420 to 392 kW) but more than makes up for it by adding 35 percent more torque (649 to 880 Nm). Mercedes is targeting the same 3.8-second squirt from 0 to 100 kilometers (62 miles per hour) achieved by the fossil-fueled version—albeit with the far lower top speed of roughly 200 km/h (125 mph), versus 317 km/h (197 mph) for the gas burner. A 48-kW modular battery is divided into three 16-kW units, one mounted below the elegantly stretched hood, another along the center tunnel, and the third behind the passenger compartment. An intelligent all-wheel-drive system features the torque-vectoring capability of other sports-car EVs. Mercedes figures the electric SLS will cover from 150 to 180 km (93 to 112 miles) on a charge, with 8 hours required to juice the batteries on household current, or 5 hours on a high-density charger—plenty of time for its owner to chat up admirers.



cars are generally limited to 200 km/h (125 mph) or less; your mom's Toyota Camry can go faster.

Fortunately, electric motors themselves are much more efficient than internal combustion engines, losing much less power between the motor and pavement. That's why an electric vehicle can travel 25 or more kilometers on the energy equivalent—from its batteries—of barely a liter of gas. Of course, those batteries are heavy and can't store nearly as much energy per cubic centimeter as gasoline does. "If you're carrying enough battery for a 200-mile range, a lot of the time you're dragging that battery as deadweight and actually hurting your handling and fuel economy," says Peachey, the Lotus engineer. So in real life, your choice comes down to limited range or a hybrid drivetrain. Lotus, Porsche, and Ferrari are all going the hybrid route. They can travel, say, 55 km (about 34 miles), on electricity alone. A supplementary engine eliminates the "range anxiety" of a pure EV, allowing smaller, lighter batteries and a less-powerful electric motor.

But electrics hold intriguing advantages as well. Multiple electric motors allow "torque vectoring"—independent control of the drive speed of each individual wheel to improve cornering, stability, and safety—with no need of complex mechanical or hydraulic differentials to divvy the power among the wheels (BMW and other manufacturers are already applying torque vectoring to their gasoline-powered all-wheel-drive cars).

Next up will be electric wheel-hub motors, which will push the performance envelope even farther. Michelin, for example, has been developing its Active Wheel system for over a decade. It puts a motor, a brake, and suspension control in each of a car's four wheels, eliminating the need for an engine, traditional suspension, gearbox, and transmission. This offers formidable performance: A typical sports car takes roughly 6 seconds to stop from 100 km/h; Michelin's concept system can do it in 2.8 seconds.

Gearheads may worry that today's speed merchants will be shackled by environmental demands, just as the original '60s muscle cars were driven to extinction by the first-ever emissions rules. Yet a modern sports car like the Corvette Z06 somehow manages to combine an impressive 26 mpg with 505 hp and a 198-mph top speed, figures that shame any car of the '60s. (For those of you in the metric realm, that translates as 9 L/100 km, 377 kW, and 319 km/h.)

An optimist might gather that there's nothing to fear: Ferraris and Corvettes will still be duking it out, going faster and handling better than ever. This time, though, the drivers will have a new metric to brag about: fuel efficiency. ❑

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TAVIS COBURN (2)

PORSCHE 918 SPYDER

When Porsche designs a concept car, it's not fooling around—the company reliably follows through with a production model. And that's what makes the 918 Spyder such catnip for speed demons and green demons alike. This heart-stopping, roughly US $630 000 successor to the Carrera GT ditches that supercar's V-10 guzzler for the one-two punch of a plug-in hybrid.

The all-wheel-drive Spyder starts with the small-but-mighty 3.4-liter V-8 from the RS Spyder racer, with 367 kilowatts (500 horsepower) and a symphonic 9200-rpm redline. That midmounted engine is mated to a fluid-cooled lithium-ion battery pack and a pair of electric motors—one for the front wheels, one for the rears—that spool up another 160 kW (218 hp). It's an extravaganza of thrust, good for a 3.2-second trip from 0 to 100 km/h (that's 62 mph), a 319-km/h top speed, and a Porsche-tested lap time that breaks 7 minutes, 30 seconds around the famed Nürburgring Nordschleife circuit in Germany's Black Forest—faster than the Carrera GT.

But—and here's the change from yesteryear—if you drive the 918 Spyder more economically, it can sip as little as 3 liters of petrol per 100 kilometers on the latest European Driving Cycle—or 78 miles per gallon. That puts the Porsche's CO_2 emissions at just 70 grams per kilometer. By way of comparison, the Toyota Prius, among the greenest cars sold around the world, emits 89 g/km. (As for gas-powered supercars, the Lamborghini Murciélago, among the worst CO_2 offenders, blows out 480 g/km).

One reason for the economy is a diet of carbon fiber, magnesium, and aluminum that keeps the Porsche light on its toes, at just 1490 kilograms (3300 pounds). Another is the Spyder's good-cop, bad-cop personality, enabled by four driver-selectable modes: Toggle up to E-Drive and the Porsche can travel up to 25 km (16 miles) on electricity alone, drawing juice from its battery, supplied in part by the regenerative brakes. The Hybrid mode mixes and matches power as needed from the electric motors and gas engine. Sport Hybrid employs both drive systems but sends more power to the rear wheels, with a torque-vectoring unit to boost handling by speeding or slowing individual wheels. Finally, the Race Hybrid setting kicks performance to warp-speed limits, including the push-to-pass E Boost, which feeds a jolt of current to shoot past competitors. It's the equivalent of a nitrous oxide tank from the 2001 film *The Fast and the Furious*, but without the environmental baggage.

LOTUS 414E HYBRID CONCEPT

Lotus's tiny, two-seat Elise provided the backbone for the groundbreaking Tesla Roadster EV. Yet with the concept 414E, Lotus has adopted the plug-in hybrid approach of the Chevy Volt and Fisker Karma: pairing a smaller, lighter, and less-powerful battery pack with a tiny, range-extending gasoline engine—which Lotus insists will deliver a smaller carbon footprint over the vehicle's life than a full Tesla-type EV. Lotus reaches that conclusion by taking into account not simply energy consumption and emissions but also the energy used to manufacture the vehicle and, above all, the battery.

Based on the slinky new two-plus-two Evora, the 414E gets 306 kilowatts (408 horsepower) and 800 newton meters (590 foot-pounds) of torque from lithium-polymer batteries, dual electric motors, and a 1.2-liter midmounted engine that burns either gasoline or alcohol. Lotus figures the 414E will travel 56 kilometers (35 miles) on electricity alone and more than 480 km (300 miles) once its gas engine kicks in, while hitting 96 kilometers per hour (60 miles per hour) in less than four seconds.

Coming from Lotus—the British company dedicated to sports cars in their purest form—the 414E plug-in hybrid is also a rolling rejection of the idea that electric cars can't be fun. For one thing, it lets the driver shift gears, as all true sports cars should. Most EVs deprive you of that connection because they don't need a multigeared transmission to maximize power; that's because an electric motor delivers explosive, instant-on torque no matter how fast it's turning. (That's why EVs like the Tesla Roadster can get away with a mere single-speed transmission.) In the Lotus, though, the gearbox can mimic the driver-selected gears of a conventional transmission, heightening the fun.

Lotus also designed its regenerative braking—which captures kinetic energy and converts it into electricity to charge the battery—to mimic the "engine braking" effect of a conventional six-speed gearbox. Drivers can downshift through paddle-selected gears to slow the vehicle without using the brakes—a key technique when heading into corners on road or track—with the electric motors varying their electrical resistance to do so. And the more regenerative braking you engage in, the more electricity there'll be to pour back into rpm's.

The Lotus also gains a big edge in traction and handling from its motors' ability to power individual wheels. By speeding up the outside rear wheel in a turn, the Lotus is able to pivot through the corner at a higher speed. Such torque vectoring also allows sophisticated control of the car to boost stability in emergency situations. And it's all done without the weighty clutches and differentials used by torque-vectoring gasoline cars, such as the Porsche Panamera.

"The car becomes even more like a go-kart," Lotus chief engineer Colin Peachey says.

Specialized designs breathe new life into the world's oldest aircraft technology

By RON HOCHSTETLER

RESIDENTS OF CARIBOU, MAINE, WHO HAPPENED to glance up at the skies over the former Loring Air Force Base recently got a glimpse of the future—although they might have thought they were looking at something out of the past. Engineers from my company, Science Applications International Corp. (SAIC), in McLean, Va., have been conducting test flights of a new type of lighter-than-air vehicle.

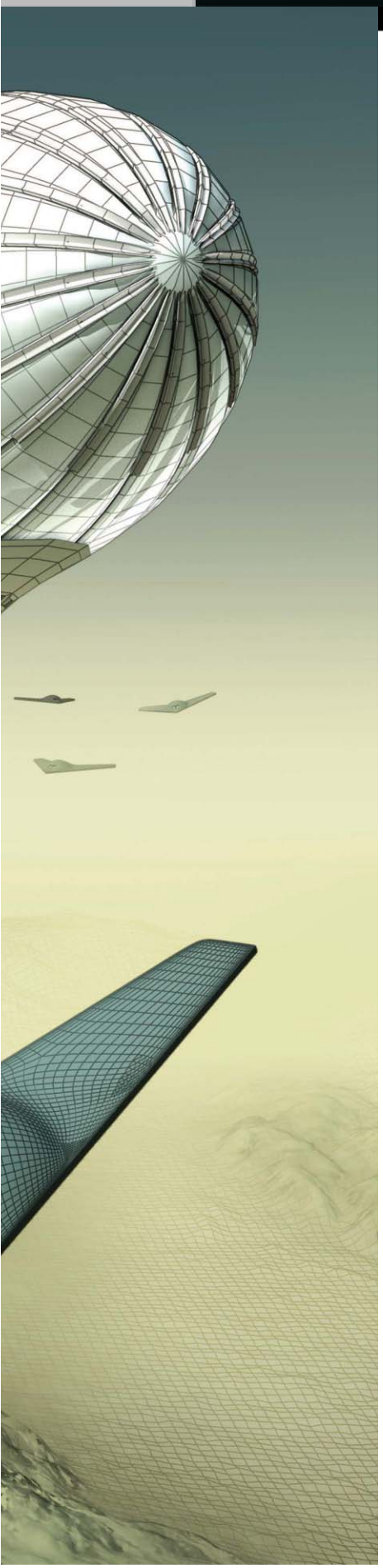
In appearance, the Skybus 80K bears the same oblong shape as the Goodyear Blimp, and it's based on the same flight principles that have governed airships since the 1800s. But this airship, one of a number of commercial and military vehicles now under development, represents a distinct break from tradition. Unlike their dirigible cousins of past centuries, these new vehicles are being designed to lift heavy payloads, remain aloft for weeks or even months at a time, and fly without pilots—all while expending far less energy than a conventional airplane or unmanned aerial vehicle. The Predator UAV, for instance, can carry a payload of 340 kilograms on a typical mission of up to 40 hours. SAIC's Skybus 1500E pilot-optional airship is being designed to carry a payload three times that size and stay aloft for up to 21 days.

THE RENEWED INVESTMENT IN AIRSHIPS comes at a time when the energy footprint of all modes of transportation is being scrutinized. Some aviation visionaries now argue that we can't continue using exclusively petroleum-based fuels to power our aircraft. Such concerns have prompted new research into jet biofuels and energy-efficient jet engines. We've also begun to understand that not every flight has to be made at eight-tenths the speed of sound. For certain tasks, airplanes just can't compete with airships.

Modern airship designers are targeting two pressing needs: intelligence, surveillance, and reconnaissance missions and the transporting of multiton payloads to locations unreachable by conventional transport. For example, airships are ideal for continuously monitoring sites where improvised explosive devices or rocket launchers may be deployed. They also excel at scanning for distant airborne threats. That's why, in June, the U.S. Army awarded a US $517 million contract to Northrop Grumman and British firm Hybrid Air Vehicles to build three airships, each as long as a football field, to monitor trouble spots in Afghanistan. Cargo airships, meanwhile, are especially attractive for places that have poor roads and for remote regions that have no roads at all. At a transportation conference I recently attended in Canada's Northwest Territories, mining company executives and community leaders expressed strong support for using airships to shuttle equipment and supplies to distant mining outposts and villages. Such needs are driving the reinvention of the airship.

AN AIRSHIP FLIES PRIMARILY BY ARCHIMEDES'S principle, which describes the buoyancy of a body submerged in a denser fluid. That is, an airship operates more like a submarine than an airplane or a helicopter. Those aircraft have to generate 100 percent of their lift from the flow of air over their wings or rotor blades. An airship, however, employs a lighter-than-air nonflammable gas such as helium to give it buoyancy. When the lifting gas displaces a volume of air that weighs more than the entire airship (including fuel and payload), the airship floats. That resultant lift is what's known as the airship's static buoyancy. For instance, to lift 1 kilogram at sea level, the airship needs approximately 1 cubic meter of helium gas. Airships weigh considerably more than that, of course; the Skybus that recently flew in Maine tipped the scales at 1600 kg unfilled.

The lifting gas is contained within the airship's outer skin, a large fabric bag or envelope that is aerodynamic, lightweight, and rugged. Inside the envelope are one or more smaller bags, called ballonets, which hold ordinary air. On the ground, electric fans pump air into the ballonets until the pressure of the helium surrounding the ballonets exceeds atmo-



EMILY COOPER (2); PREVIOUS PAGES: SCIENCE APPLICATIONS INTERNATIONAL CORP.

THE FLYING AIRCRAFT CARRIER

Back in the 1930s, the USS *Akron* and USS *Macon*, two U.S. Navy airships, supported a small squadron of scout biplanes from internal aircraft hangars in their huge bellies. A modern version of this concept would be an airship designed to carry dozens of small, low-cost, unmanned aerial vehicles (UAVs), each equipped with miniaturized sensors, antisubmarine warfare systems, or even lightweight precision weapons. This pilot-optional airship could serve as a sky base from which the UAVs would launch, refuel, and relaunch. The airship itself could also be designed to be refueled in flight, meaning that the entire system could serve as an almost permanent airborne platform. To minimize its vulnerability to attack, the airship would be positioned away from any areas of conflict into which the UAVs would be deployed. Equipped with its own lightweight self-defense systems, this flying aircraft carrier could be a game-changing military system.

spheric pressure by a very slight margin of about 480 pascals. The ballonets occupy between 25 and 50 percent of the airship's total gas volume. Bleeding off a measured amount of air through valves in the ballonets provides room inside the envelope for the helium to expand as the ship rises.

As the airship ascends, the decreasing atmospheric pressure causes the helium inside the airship to expand steadily. Once all the air in the ballonets is gone, the airship cannot ascend higher without either bursting or venting its helium. This point is known as the airship's pressure altitude. To descend, the airship uses its electric fans to blow air back into the ballonets. This gas-management system must constantly keep the helium at a pressure that's slightly higher than the surrounding atmosphere, to preserve the aerodynamic shape of the envelope.

If ascending and descending were all an airship did, this combination of gases and ballonets would be sufficient. But an airship also needs a certain amount of power and propulsion, to run the onboard navigation and communications systems and any electronics in the payload, and to maneuver to different locations. Most current airships use traditional gasoline engines, but increasingly designers are looking at alternative power and propulsion systems. One idea is a regenerative system incorporating photovoltaics and fuel cells, in which hydrogen fuel cells produce water vapor. The solar power could be used to separate the water back into its component gases; the hydrogen would then be fed back into the fuel cells.

Almost all airships flying today are of a nonrigid design, which means the ship's shape comes only from the pressure of the gases inside. By contrast, the giant airships of the 1930s, the *Hindenburg* being the most iconic example, had rigid internal skeletons made of aluminum or wood. Inside this cage were a dozen or more gas-filled lifting bags. Those days also saw the development of semirigid designs, which typically had a stout aluminum keel running lengthwise from the nose to the tail, providing a convenient mounting point for the individual gas cells and distributing the lift of each cell evenly. The only semirigid airships flying today are the Zeppelin NT series, which began operations in the late 1990s and are used primarily for sightseeing and advertising.

Although nonrigid airships aren't

THE SAILING AIRSHIP

In 1940 the noted American airship engineer Charles P. Burgess speculated that it might be possible to sail an airship at sea. He proposed lowering from an airship by cables a hydrodynamic body that would serve as an underwater wing, translating the force of the wind blowing on the airship into controllable motion through the water. The airship's great surface area, he suggested, would capture enough wind to allow it to be used for dedicated transoceanic airships. To date, nobody has realized Burgess's vision, but it would surely represent the greenest of air-transportation systems.

weighed down by an internal framework, they still have to support the gases, fabric, and other components, as well as any payload. Obviously, the greater the airship's weight, the larger the volume of lifting gas needed and the bigger the envelope size. As the size increases, so does the vehicle's surface area and consequently the amount of aerodynamic drag during flight. These and other factors dictate the amount of power required to propel the airship through the sky.

ALTHOUGH PEOPLE PILOT MOST OF TODAY'S airships, the newer designs are increasingly pilot optional, meaning that a crew can fly them during tests or initial deployments and then quickly switch them to remote operation. Several fully remotely operated airships are also in development. One of their chief uses right now is for battlefield surveillance. These airships carry various imagers and detectors to altitudes of 1500 to 5500 meters on missions lasting 24 hours or more. Guardian Flight Systems, based in North Carolina, developed the pilot-optional Polar 400 for the U.S. Department of Defense. In the fully pilotless category is SAIC's Skybus 80K airship, which so far has conducted more than 62 hours of flight tests in Maine. To date, the Skybus 80K is the only unmanned airship to hold an experimental designation from the U.S. Federal Aviation Administration. It has a gas volume of 2300 m^3 (80 000 cubic feet) and is designed to carry a 230-kg surveillance payload as high as 3000 meters for up to 24 hours.

More ambitious is the U.S. Army's Long Endurance Multi-Intelligence Vehicle. The LEMV will carry a 1100-kg payload up to 6000 meters for as long as 21 days without refueling. Its first deployment is to be in Afghanistan in late 2011 or early 2012. A number of defense companies considered vying for the LEMV contract. But two months ago, the five-year contract—one of the largest airship contracts to be awarded since World War II—went to Northrop Grumman and Hybrid Air Vehicles.

To operate in the thin atmosphere at such high altitudes for extended periods of time, an airship needs to be light (at least compared with lower-flying counterparts) and have an efficient propulsion system that can function with little or no oxygen. Also essential is a design that minimizes aerodynamic drag, which is why high-altitude airships almost always have the familiar ellipsoidal shape. Among the power sources being considered for high-altitude airships are electric motors coupled with lithium-ion batteries, hydrogen fuel cells, and flexible-film photovoltaics, which would blanket the upper parts of the airship's huge surface. Any of these options would need to weigh less and be more efficient than standard engines.

UP THERE: The SkyHook [above] will haul oil-drilling equipment in northern Canada. The U.S. Army's pilot-optional Long Endurance Multi-Intelligence Vehicle [left] will conduct surveillance in Afghanistan.
TOP: BOEING; BOTTOM: NORTHROP GRUMMAN

To fly even higher and longer with heavier sensor payloads is the ultimate goal of military leaders who see the modern airship as an unblinking, ever-present eye in the sky. Under the Defense Department's $149 million High Altitude Airship program, Lockheed's Maritime Systems & Sensors Division in Akron, Ohio, is now exploring ways to build an airship capable of carrying a 230-kg sensor package into the stratosphere, as much as 18 kilometers up, where it would remain for a month at a time. At that altitude, one airship would be able to monitor a patch of ground 1200 km across. Just 11 of them could provide radar coverage of the coastal and southern borders of the continental United States, according to the North American Aerospace Defense Command.

If that sounds ambitious, consider the proposed high-altitude airship known as the Integrated Sensor Is Structure, or ISIS. Under this $400 million program jointly funded by the Defense Advanced Research Projects Agency and the U.S. Air Force, Lockheed's Skunk Works is building an unmanned stratospheric airship powered by solar cells and fuel cells that would be capable of operating at 21 kilometers' altitude for up to 10 years at a time. A one-third-scale prototype, itself longer than a football field, is scheduled to fly in 2013.

What makes ISIS unique is the integration of its mission sensors—a UHF radar for monitoring vehicles and soldiers on the ground and an X-band radar for tracking cruise missiles up to 600 km away—into the body of the airship. According to Raytheon, which is building the radars, the radar antennas form a cylinder in the center of the airship. By integrating the sensor system into the structural supports, the design reduces the airship's overall weight and adds structural stiffness. Even so, the demands of a 10-year high-altitude mission mean that the full-scale ISIS will

need to be made of extremely durable, yet lightweight materials—materials that may not yet exist. In addition, its power system will need advanced photovoltaics and fuel cells capable of generating enough power to operate the radars, navigation system, communications gear, and the electric motors that will turn the airship's giant propellers. A lot of extreme engineering is going into today's airship designs.

WHILE THE UPCOMING STRATOSPHERIC surveillance airships will carry relatively small payloads, some airships now in development will lift a great deal more—payloads of hundreds of tons, albeit at lower altitudes. That presents an entirely different set of challenges.

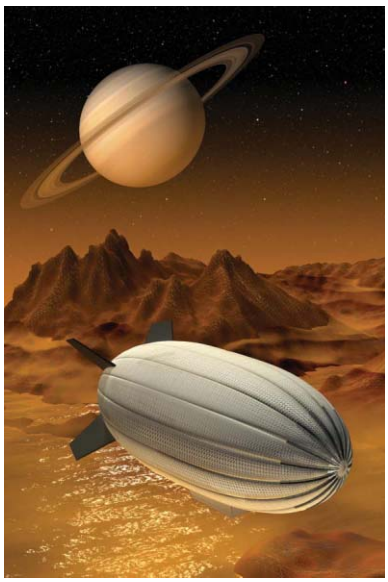
An airship designed to carry 50 metric tons of cargo would be hundreds of meters long and weigh tens of tons lying empty of helium on the factory floor. The sheer size would make its assembly a daunting task. These new vehicles would likely be built in smaller subsections that would later be joined together in immense hangars.

A more critical issue is how to compensate for the sudden increase in the airship's static lift that occurs when a heavy payload is unloaded. The most straightforward remedy is to add onto the airship an amount of weight equal to the payload as the payload is removed.

Some heavy-lift designers are also developing hybrid vehicles. These incorporate the static lift of helium along with some form of dynamic lift, such as helicopter-style rotors or airplane-like wings. In most of these designs, the helium is sufficient to lift the vehicle's weight, while the dynamic lift is devoted to the payload's weight. This produces an aircraft that is slightly heavier than air and so is much less buoyant during cargo unloading.

Lockheed's Skunk Works first test-flew its P-791 proof-of-concept hybrid airship in 2006. The aircraft has two propulsion motors on the exterior of its envelope and two attached to its tail. This generates about 20 percent of the dynamic lift when the vehicle is flying forward. Other hybrid airships under development include Hybrid Air Vehicles' SkyCat, which will be the basis for the U.S. Army's LEMV; the Worldwide Aeros Corp.'s Aeroscraft, which was recently submitted to the FAA for design certification; and the proof-of-concept Dynalifter, being readied for test flight by Ohio Airships.

EMILY COOPER



AIRSHIPS IN SPACE

Earth isn't the only place where airships could find a home. A number of off-world destinations have enough of an atmosphere to support airships, including Mars, Venus, and Saturn's largest moon, Titan. Compared with robotic rovers, airships would be able to survey far more ground. And they don't require much power, which is always at a premium on planetary missions. So far, the only successful extraterrestrial deployment was the Soviet Union's 1984 Vega mission to Venus, which sent two balloons to float 54 kilometers above the planet's surface for nearly two days.

More recently, NASA has funded a number of balloon and airship projects for solar system exploration. Researchers at the Jet Propulsion Laboratory in Pasadena, Calif., have developed several lighter-than-air designs for use on a possible follow-up mission to Titan and Venus. They've also conducted extensive flight tests over the Mojave Desert with an 11-meter-long autonomous airship. There's even talk of sending entire fleets of rovers and airships to scout out new planetary frontiers.

While these hybrids hold promise, they also have some inherent technical challenges. For one, the additional dynamic lift increases aerodynamic drag. To help with generating dynamic lift, they also typically have a flatter profile than conventional airships, but this shape gives them a higher ratio of envelope fabric to gas volume, increasing the airship's empty weight. Higher weight and drag, of course, mean more propulsive power and more fuel, both of which make the ship even heavier. And some hybrids employ multiple lobes in their design, which can create problems as the gases inside heat up from the sun's rays. Helium conducts heat six times as efficiently as air, so a multi-lobed hybrid may tend to list toward the side that's not exposed to the sun.

Perhaps the biggest issue, though, is the hybrid's potential to pitch nose up or down and to roll from side to side. A conventional, single-hulled airship avoids this problem because the majority of its gas volume is positioned well above its center of gravity, imparting what's known as pendulum stability. The higher up the center of lift is, the more stable the airship is; conversely, the closer the center of lift is to the center of gravity, the greater the tendency of pitching from wind gusts.

To get around these problems, Boeing and the Canadian company SkyHook International are collaborating on a different approach: a rotary-airship hybrid. It combines a conventional ellipsoidal envelope with four powerful helicopter rotor units, which are installed below the helium envelope. The helium is sufficient to support the weight of the vehicle itself, leaving the full power of the rotors to lift a 36-metric-ton payload. One of the first applications of the SkyHook is moving equipment and supplies for oil-drilling operations in northern Canada.

To spur further progress in heavy-lift designs, I and several other airship enthusiasts are setting up an international contest to promote the development of airships as a green, low-carbon form of cargo transport for commercial operations. The Zero Emissions Transport Airship Prize, or Z-Prize, similar to the more familiar X-Prize, will offer a large cash award for the successful development and flight test of a heavy-lift airship that meets the competition's criteria. We hope to entice airship developers to focus their efforts on designing cost-effective cargo airships that will have their greatest applications in developing regions—places where moving freight by conventional transport is difficult and hugely expensive or subject to disruption by criminals or terrorists. And by emphasizing airship designs with low carbon emissions, we hope also to encourage the creation of the first environmentally sustainable air-transport system.

It's an exciting time to be an airship engineer. These vehicles represent both the oldest and now the latest forms of aircraft. They're also an aviation technology that has yet to be fully exploited. While some naysayers may think the time of these leviathans is long past, in fact their day is just dawning. ❑

Software v. Software

Continued from page 36

finds a strong correlation. If all of the benign reasons can be ruled out, the correlation must be due to unauthorized copying. In that case, the owner of the copyrighted software has a strong legal case.

Here's how CodeMatch worked in one real-world case. A small start-up had developed software for viewing e-mail attachments on handheld devices; the software was good, but the company went out of business. The founders then started a new software company, which was quickly bought by a large competitor for a hefty sum of money. The large company, unsurprisingly, incorporated the acquired company's code into its own program. I was hired in late 2003 by the bankrupt start-up's investors, because they believed their start-up's code had been illegally copied and that they were entitled to some money. The large company, again unsurprisingly, insisted that the software it had acquired did not infringe on the bankrupt start-up's work.

To begin, I used CodeMatch to examine and compare the source code of the bankrupt company's program and the large company's program. I found a strong correlation between the two. I then checked whether each instance of correlation might have a legitimate explanation. Ultimately, I found matching statements, comments, and identifier names that seemed to be unique to the two programs; searching online, I could find no use of them anywhere else. I concluded that the code had been copied.

> Just as software for analyzing DNA has become crucial in resolving criminal cases and paternity suits, tools that can quickly and accurately uncover illicit software copying are becoming key to copyright infringement litigation

The next step was the deposition, the pretrial process during which the opposing side's lawyers question witnesses and experts in an attempt to uncover new information. I presented a report comparing sample snippets of copied code, and I included CD-ROMs containing the results of the complete CodeMatch analysis of the code.

The defendant's lawyer showed me a slide with three snippets of code. Two of the snippets were ones I'd included in my report as evidence of copying. But it was the third snippet that nearly tripped me up. It was identical to the other two snippets. "Did you know that this third snippet of code is open-source code that is freely available on the Web, accessible to anyone?" the lawyer asked.

I didn't in fact know that, and I began to feel really nervous. Had I overlooked something? *Continued on page 52*

> Just as books by the same author may have a similar style, even when the subject matter is completely different, software written by the same programmer may also have a telltale style

Continued from page 50 Had I not done a complete search? If both programs contained code from a third party that allows its code to be copied, then there was no copyright infringement. I told the lawyer that I would need to know more about the third-party code. He assured me that the expert hired by his client would provide the necessary information in his own report.

A few days later I received the opposing expert's report. Sure enough, it contained snippets of open-source code that were identical to snippets from both parties' code. But I noticed something else. Whereas in my report I had included dozens of lines of code in each snippet, the other expert gave only a few lines.

I then searched the Internet and found the open-source code that both programs had obviously relied on. Comparing the snippets again, I discovered that while maybe 10 to 20 percent of the lines matched exactly in all three sets of code, the vast majority of the lines were different. I concluded that the original company's programmers had taken open-source code and made significant functional changes to it. The defendant had tried to make it appear that the open-source code had simply been copied without alteration, but in actuality proprietary changes had been made by my clients' company and then copied by the defendant's company. After my discovery, the two sides reached a settlement, and there was no courtroom trial. My clients didn't divulge the terms, but they told me they were pleased with the result.

Since CodeMatch came out seven years ago, it's become an accepted tool for sorting out cases of software copyright infringement. CodeMatch has evolved into CodeSuite, a set of tools for comparing, measuring, and filtering the results of a source-code comparison, not only for copyright infringement but also trade-secret theft and even tax cases. CodeSuite can run on a standalone computer, a multiprocessor machine, or a network of computers; my company trains lawyers and other consultants to run and interpret the results so that they can effectively use the software.

As the importance of software in our daily lives grows, intellectual property disputes over that software are also likely to escalate. You may consider all that litigation a good thing, righting a wrong, or a bad thing, draining valuable resources. But software forensics tools that automate, quantify, and standardize such disputes can only be beneficial, in that they leave less room for misunderstanding and get to the important results and help resolve disputes much faster than ever before. ❑

BAYLOR UNIVERSITY

The Electrical and Computer Engineering Department of

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seeks faculty applicants in all areas of electrical and computer engineering, with preference in the areas of cyber-physical systems (i.e., embedded systems, computer/network security, and sensor networks) as well as power and energy. The department anticipates filling three positions in August 2011 and approximately seven more over the next five years, and invites applicants at any rank. All applicants must have an earned doctorate and a record of achievement in research and teaching; applicants at the ranks of associate or full professor must also demonstrate a record of sustained research funding. The ECE department offers B.S., M.S., M.E. and Ph.D. degrees and is poised for aggressive expansion of its faculty and facilities, including access to the Baylor Research and Innovation Collaborative (BRIC), a newly-established research park minutes from the main campus.

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Application reviews are ongoing and will continue until available positions are filled. Applications must include:

1) a letter of interest that identifies the applicant's anticipated rank,
2) a complete CV,
3) a statement of teaching and research interests,
4) the names and contact information for at least three professional references.

Additional information is available at

www.ecs.baylor.edu.

Send materials to
Dr. Robert Marks
Baylor University
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Waco, TX 76798-7356

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

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

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

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

Linnæus University
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2-3 Senior Lecturers in Media technology

The Department of Media Technology at the School of Computer Science, Physics and Mathematics at Linnaeus University in Sweden invites applications and nominations for tenured faculty positions at a senior lecturer level, to begin August 2011. We are interested in strong candidates in a number of teaching and research areas of media technology – including digital media and interactive systems, collaborative technologies and Web 2.0 applications, mobile media and services, advanced interface and interaction design, 3D modelling/animation – as well as interdisciplinary areas such as interactive media and learning and Internet technologies and their social implications.

The department is committed to increasing the diversity of its faculty, and we strongly encourage applications from women.

A successful candidate must have a solid disciplinary foundation and demonstrate promise of outstanding scholarship in every respect, including teaching and research. Please refer to **http://www.celekt.info** for information about the department's current research focus.

A PhD in media technology, computer science, interaction design or related area is required. To guarantee full consideration, applications, scientific publications and letters of reference should be received by November 22, 2010. Detailed information about the application process can be found at:

http://lnu.se/about-lnu/jobs-and-vacancies?l=en

Linnaeus University is an affirmative action, equal opportunity employer.

Requirements:
A successful candidate must have a solid disciplinary foundation and demonstrate promise of outstanding scholarship in every respect, including research and teaching.

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The requirements: You need a PhD in Electrical Engineering or an advanced degree with industrial experience. It is required that you have experience from performing laboratory experimental works and multi-physics numerical simulations, as well as real time co-simulations. You are familiar with software tools – such as Maxwell, FLUX, Simplorer, Fluent, COMSOL and Matlab – and have experience from project management. You are proficient in English, both spoken and written. Knowledge of Swedish is an advantage. Any relevant industry or advanced R&D experience is qualifying. Your experience enables your analytical mind to think strategically regarding technological R&D. You are structured and creative with strong drive. Further, you can work both independently and in a team environment to reach set goals.

The department of Power Technologies at ABB Corporate Research in Västerås is responsible for ABB's strategic research and development worldwide in the areas of Power Systems, Power Products and Electrical Machines. The department is a highly international environment with 130 researchers and engineers from all over the world working at the forefront of research and development in the field of power technology. The group of Electrical Machines and Motion Control provides the core technology development activities within ABB in areas of electrical machines and generators. The group works in close partnership with all business unit partners from the Discrete Automation and Motion division.

More information: Robert Chin, Group Manager of Electrical Machines and Motion Control, robert.chin@se.abb.com, +46-21-32 31 63, will answer your questions on the position. Union representatives – Sveriges Ingenjörer: Anne-Marie Imrell, +46-21-32 32 09, Unionen: Laila Wadstedt, +46-21-32 30 65. Any other questions can be directed to recruitment consultant Eva Björklund, +46-21-32 53 47. Please apply by submitting a cover letter, resume and other supporting material to Robert Chin.

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The Edward S. Rogers Sr. Department of Electrical & Computer Engineering UNIVERSITY OF TORONTO

The Edward S. Rogers Sr. Department of Electrical and Computer Engineering at the University of Toronto invites applications for faculty positions, starting July 1, 2011, in the following three areas:

1. SYSTEMS CONTROL Applications are welcomed from outstanding candidates in all areas of systems control, including candidates whose research is interdisciplinary in nature. Applications for this position should be addressed to Professor Manfredi Maggiore, Chair of the Systems Control Search Committee, and sent to: **ControlSearch@ece.utoronto.ca**.

2. ELECTROMAGNETICS Research areas of particular interest include: biomedical applications of electromagnetic waves, microwave devices with emphasis on nanoscale effects, novel electromagnetic materials, microwave circuit integration/packaging, RF MEMS, remote sensing and radars. Applications for this position should be addressed to Professor George Eleftheriades, Chair of the Electromagnetics Search Committee, and sent to: ***EMSearch@ece.utoronto.ca***.

3. ELECTRICAL ENERGY SYSTEMS Research areas of particular interest include: power system dynamics, power system automation, protection, integration of renewable energy sources/storage, and other emerging technologies within the scope of power systems. Applications for this position should be addressed to Professor Peter Lehn, Chair of the Energy Systems Search Committee, and sent to: ***EnergySearch@ece.utoronto.ca***.

Successful candidates are expected to pursue excellence in research and teaching at both the graduate and undergraduate levels, and must have (or be about to receive) a Ph.D. in the relevant area.

The ECE department ranks among the top 10 in North America. It attracts outstanding students, has excellent facilities, and is ideally located in the middle of a vibrant, artistic, and diverse cosmopolitan city. The department offers competitive salaries and start-up funding, and faculty members have access to significant Canadian operational and infrastructure research grants. Additional information on the department can be found at: ***www.ece.utoronto.ca***.

Applicants must submit their applications by email to one of the three email addresses given above. Please submit only Adobe Acrobat PDF documents and include a curriculum vitae, a summary of previous research and proposed new directions, and a statement of teaching philosophy and interests.

Applications should be received by January 15, 2011.

The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas.

All qualified candidates are encouraged to apply; however, Canadian citizens and permanent residents will be given priority. Salary will be commensurate with qualifications and experience.

UNIVERSITY OF TORONTO
The Edward S. Rogers Sr. Department of
Electrical & Computer Engineering
10 King's College Road
Toronto, ON, Canada M5S 3G4

THE UNIVERSITY OF UTAH

The Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, seeks applications to fill one or more tenure-track positions at all levels. We are particularly interested in candidates with expertise in analog and mixed-signal electronic circuits; electric power system dynamics with focus on distribution system and micro-grid; and RF/microwave electromagnetics. Outstanding applicants in other areas will also be considered. Information on department research activities and curricula may be found on the web at

www.ece.utah.edu.

Faculty responsibilities include developing and maintaining an internationally recognized research program, effective classroom teaching at the undergraduate and graduate levels, and professional service. Résumés with names and contact information for at least three references should be sent to Ms. Debbie Sparks, Faculty Search Committee, University of Utah, Electrical and Computer Engineering Department, at **dsparks@ece.utah.edu**. Applications will be reviewed starting November 1, 2010, and will be accepted until the positions are filled. Applicants must hold a Ph.D. by the time of appointment. The University of Utah values candidates who have experience working in settings with students from diverse backgrounds and possess a strong commitment to improving access to higher education for historically underrepresented students.

The University is fully committed to affirmative action and to its policies of nondiscrimination and equal opportunity in all programs, activities, and employment. Employment decisions are made without regard to race, color, national origin, sex, age, status as a person with a disability, religion, sexual orientation, gender identity or expression, and status as a protected veteran. The University seeks to provide equal access for people with disabilities. Reasonable prior notice is needed to arrange accommodations. Evidence of practices not consistent with these policies should be reported to: Director, Office of Equal Opportunity and Affirmative Action, 801-581-8365 (V/TDD).

NANYANG TECHNOLOGICAL UNIVERSITY

NUS National University of Singapore

TEMASEK RESEARCH FELLOWSHIP (TRF)

The Nanyang Technological University (NTU) and the National University of Singapore (NUS) invite outstanding young researchers with a PhD Degree in science or technology to apply for the prestigious TRF awards.

The TRF scheme provides selected young researchers an opportunity to conduct and lead research that is a relevant to defence. It offers:

- 3-year research grant, with an option to extend up to a further 3 years,
- possible tenure-track academic appointment with the university at the end of the TRF,
- attractive and competitive remuneration.

Fellows may lead and conduct research, and publish in these areas:

1. Biomimicry
2. Cognitive Sciences
3. Cyber Security
4. Computational Photography
5. Microsystem Technologies

Other fundamental areas of science or technology, where a breakthrough would be of interest to defence and security, will also be considered.

Singapore is a globally connected cosmopolitan city-state with a supportive environment and vibrant research culture. For more information and application procedure, please visit

NTU – **http://www3.ntu.edu.sg/trf/**
NUS – **http://www.nus.edu.sg/dpr/funding/trf.htm**

Closing date: **11 January 2011**

Shortlisted candidates will be invited to Singapore to present their research plans, meet local researchers and identify potential collaborators in April/May 2011.

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY POSITIONS IN Electronic and Computer Engineering

The Department of Electronic and Computer Engineering invites applications for a faculty position at the rank of Assistant Professor. Applicants should have a PhD with demonstrated strength in research and commitment to teaching. We are particularly interested in qualified applicants with relevant research experience in areas related to RFIC design. However applications are also encouraged from candidates whose research programs are non-traditional and inter-disciplinary and whose instructional programs will bring innovation to the curriculum. Outstanding candidates at the Professor and Associate Professor ranks may also be considered for these positions on an exceptional basis.

The Hong Kong University of Science and Technology is a truly international university in Asia's world city, Hong Kong, and its Engineering School has been consistently ranked among the world's top 25 since 2004. The high quality of our faculty, students and facilities provides outstanding opportunities for faculty to develop highly visible research programs. All formal instruction is given in English and all faculty members are expected to conduct research and teach both undergraduate and graduate courses. The Department has excellent computing resources, state-of-the-art teaching and research laboratories and currently has about 40 faculty members, 813 undergraduate students and 388 postgraduate students. The Department is also an equal opportunity employer and is open to applicants from all backgrounds.

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

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

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

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

UNIVERSITY OF MINNESOTA

The University of Minnesota – Twin Cities invites applications for faculty positions in **Electrical and Computer Engineering** at all ranks in the areas of computer engineering; power and energy systems; and communications and signal processing, including networking. Women and other underrepresented groups, and those with interdisciplinary interests in medical devices, the biosciences, and the nanosciences, are especially encouraged to apply. An earned doctorate in an appropriate discipline is required. Rank and salary will be commensurate with qualifications and experience. Positions are open until filled, but for full consideration, apply by November 30, 2010. Apply at **http://www.ece.umn.edu/**. The University of Minnesota is an equal opportunity employer and educator.

Job Opening for Tenure-Track Associate Professors
TOKYO INSTITUTE OF TECHNOLOGY

Tokyo Institute of Technology (Tokyo Tech) in Japan invites applicants for two Tenure-Track Associate Professor positions in the following research fields.

- **Energy-conversion Materials** (Nanotecnology, Meta-material, Photoelectric conversion, Thermoelectric conversion, Piezoelectric conversion, Electromagnetic conversion, Organic semiconductor)
- **Advanced Interdisciplinary Fields being rooted in Mechanical and Control Engineering** (including but not limited to: Environmental Issues; Energy Engineering; Security; Biomechanics; Robots; and Advanced Materials and Processing)

Tokyo Tech is the largest university in Japan specializing in science and technology. Since its foundation in 1881, Tokyo Tech has always been at the forefront of the researches and played a pivotal role as a reliable leader in science and technology.

We are interested in candidates who are committed to high standards and professionalism in their areas of expertise. The successful candidates will belong to the department offering the positions and carry out research and educational activities as an independent faculty member. In the longer term, they are expected to progress to the key positions within Tokyo Tech.

The candidate should have a PhD degree in natural science or engineering and have English-language proficiency. In cases where the applicant's degree is from Tokyo Tech, two or more years experience of research and/or education at other institutions (academic or industry) is additionally required.

To apply to the positions, please visit our website and read the application guideline.
http://www.global-edge.titech.ac.jp/tenure-track/
Deadline Date for Online Entry: **October 22, Friday, 2010**

Office of Tenure-Track System, Tokyo Institute of Technology
2-12-1 S6-20 Ookayama, Meguro, Tokyo 152-8550, JAPAN
Phone: +81-3-5734-7627
E-mail: **tt.apply@jim.titech.ac.jp**

TOKYO TECH Pursuing Excellence

LCN LONDON CENTRE FOR NANOTECHNOLOGY — UCL

London Centre for Nanotechnology and the
UCL Department of Electronic and Electrical Engineering

Academic Position in Nanoelectronics/ Nanophotonics

The appointment will be at Lecturer, Senior Lecturer, Reader or Professor level and will be a joint appointment between the London Centre for Nanotechnology (LCN) and the Department of Electronic and Electrical Engineering (EEE).

The salary range (inclusive of London Allowance) will be Lecturer Grade 7: £35,415 - £38,441 per annum or Grade 8: £39,510-£46,635 per annum; Senior Lecturer / Reader Grade 9: £50,700 - £55,142 per annum; Professor: negotiable on the professorial scale but not less than £61,713 per annum.

The post-holder will conduct research at the London Centre for Nanotechnology (www.london-nano.com), teach in the Department of Electronic and Electrical Engineering (www.ee.ucl.ac.uk) and perform the normal administrative duties expected of a member of academic staff, as required by the LCN Director and the Head of the Department of Electronic and Electrical Engineering.

For further details about the vacancy and how to apply on line please go to http://www.ucl.ac.uk/hr/jobs/ and search on Reference Number 1151781.

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

Closing Date: 30th October 2010.

University College London Taking Action for Equality.

FACULTY POSITION OPENING at ICE/ NSYSU, TAIWAN

The Institute of Communications Engineering at National Sun Yat-Sen University, Taiwan, invites outstanding candidates to apply for faculty positions at all ranks (Full, Associate and Assistant Professors) with emphasis on wireless communications, communication systems, and EM wave-related areas.

Applicants should have a PhD degree in EE with a strong commitment to research and teaching graduate courses. Applicants need to prepare a letter explicitly expressing the intended rank to apply, CV with publication list, statement of interest and plans in both research and teaching, reprints of selected published papers, three recommendation letters, and other supporting materials. The application materials should be sent to

Professor Chih-Wen Kuo, Director
Institute of Communications Engineering
National Sun Yat-Sen University
Kaohsiung, Taiwan 80424

and be received by ICE/NSYSU before Feb. 28, 2011. For further information, please e-mail the institute director **cwkuo@mail.nsysu.edu.tw**, or contact us directly
Tel: 886-7-5252000#4475(or #4162)
Fax: 886-7-5254475 **http://www.ice.nsysu.edu.tw**

NSYSU has been named by the Ministry of Education (MOE), Taiwan as one of the top seven research-intensive universities in Taiwan since 2002. Our campus is located right at the scenic beach of Kaohsiung city, southern Taiwan.

Positions Open
Toyota Technological Institute

Toyota Technological Institute has openings for full professor or tenure-track professor positions at Department of Advanced Science and Technology, Faculty of Engineering.

For more information, please refer to the website **http://www.toyota-ti.ac.jp/Jinji/home_E.htm**.

Research field

1. Intelligent information processing including learning theory and its application, information theory and its application, intelligent systems, computer vision, etc.

2. Solar energy conversion science and technology including solar cell research on physics, basic materials, devices, systems, etc.

Starting date
September 2011, or at the earliest convenience

Documents
(1) Curriculum vitae
(2) List of publications
(3) Copies of 5 representative publications
(4) Description of major accomplishments and future plans for research activities and education (3 pages)
(5) Names of two references with e-mail addresses and phone numbers
(6) Application form available from our website

Deadline
December 20th, 2010

Inquiry
1. Intelligent information processing: Professor Tatsuo Narikiyo
Phone +81-52-809-1816
E-mail n-tatsuo@toyota-ti.ac.jp

2. Solar energy conversion science and technology: Professor Yasutake Ohishi
Phone +81-52-809-1860
E-mail y-ohishi1@toyota-ti.ac.jp

Documents should be sent to Mr. Takashi Hirato Toyota Technological Institute; 2-12-1, Hisakata, Tempaku-ku; Nagoya, 468-8511 Japan

Please write "Application for (fill in the research field you would like to apply)" in red on the envelope.

Ministry of Higher Education
King Fahd University of Petroleum & Minerals
Dhahran, Saudi Arabia

College of Engineering Sciences
ELECTRICAL ENGINEERING DEPARTMENT

The **Electrical Engineering Department** at King Fahd University of Petroleum & Minerals (KFUPM) in Dhahran, Saudi Arabia, invites applications for faculty positions at the rank of Associate Professor or Full Professor starting from September, 2010 in the following area :

POWER SYSTEMS WITH HIGH VOLTAGE and PROTECTION

Required Qualifications:

An earned Ph.D. degree in the area of specialization from a reputable University is required. The applicant's GPA in the first university degree should be 3 points out of 4 or the equivalent. Research experience and a strong publication record in refereed international journals are also required. Also required is a full command of teaching English with demonstrated evidence of quality teaching as well as university teaching experience in the specified field. The successful candidates are expected to teach undergraduate and graduate courses, conduct scholarly research, supervise graduate students and carry out some administrative duties.

Salary and Benefits:

Two-year renewable contract. Competitive salaries based on qualifications and experience. Free furnished air-conditioned on-campus housing unit with free essential utilities and maintenance. The appointment includes the following benefits according to the University's policy: air ticket/s to Dammam on appointment; annual repatriation air ticket/s for up to four persons; assistance with local tuition fees for school-age dependent children; local transportation allowance; two months' paid summer leave; end-of-service gratuity. The KFUPM campus has a range of facilities including a medical and dental clinic, an extensive library, computing, research and teaching laboratory facilities and a recreation center.

To apply :

Candidates should send their CV/Resume, copies of their degree, diplomas, transcripts, and the application forms (can be obtained from the site: **http://www.kfupm.edu.sa/fpa/**) to the following address :

Dean of Faculty & Personnel Affairs
DEPT. REF.No. EE-101
KFUPM Box 5005, Dhahran 31261, Saudi Arabia
E-mail: **faculty@kfupm.edu.sa**
Fax: **+966-3-860-2429** or **860-2442**

Please always refer to the above DEPT. REF. No. in all correspondence

For more information, please visit the following website/links:
http://www.kfupm.edu.sa/fpa

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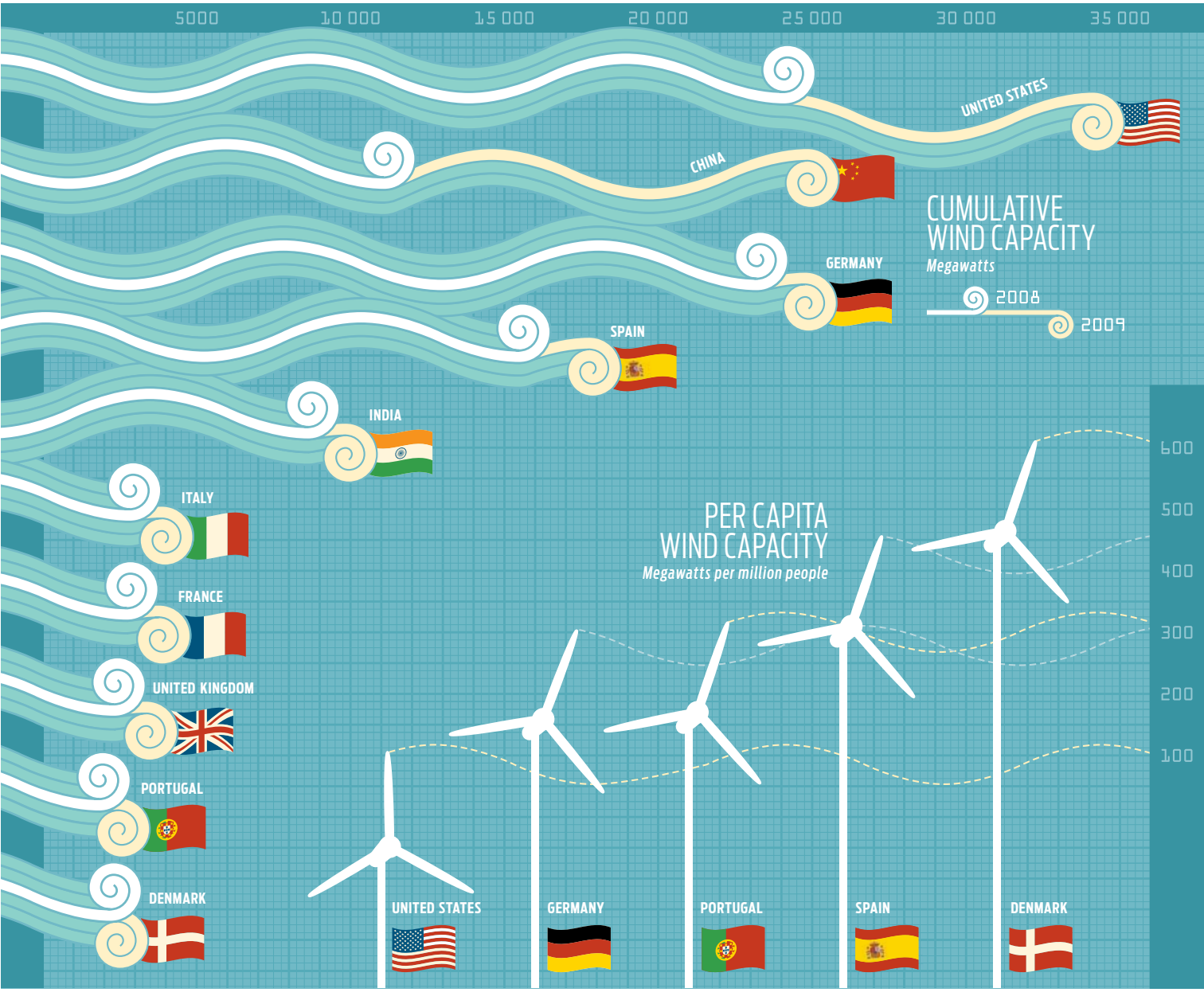

The Long and Windy Road

According to a new U.S. Department of Energy report, 2009 was a banner year for wind power. China led the way, adding almost 14 gigawatts of new capacity for a total of 26 GW in cumulative capacity. The United States kept its overall lead in cumulative capacity by adding 10 GW, representing a 40 percent increase.

By a coincidence, 40 percent was also the share of new U.S. electric generating capacity from wind installations—"the largest single form of [newly on-line] power production," the report said.

The United States and China are at the top of the lists in large part because they're so large. According to the study, written by researchers from Lawrence Berkeley National Laboratory, if Texas were a separate nation, its 9.4 GW of total capacity would rank sixth, after India. But other countries are doing even better on a per capita basis. Last year, Portugal added 60 megawatts per million people, while Denmark still comfortably leads in cumulative capacity per capita at 618 MW.

—Steven Cherry

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