BATTERY OR FUEL-CELL CARS? A CALIFORNIA CABAL WILL DECIDE

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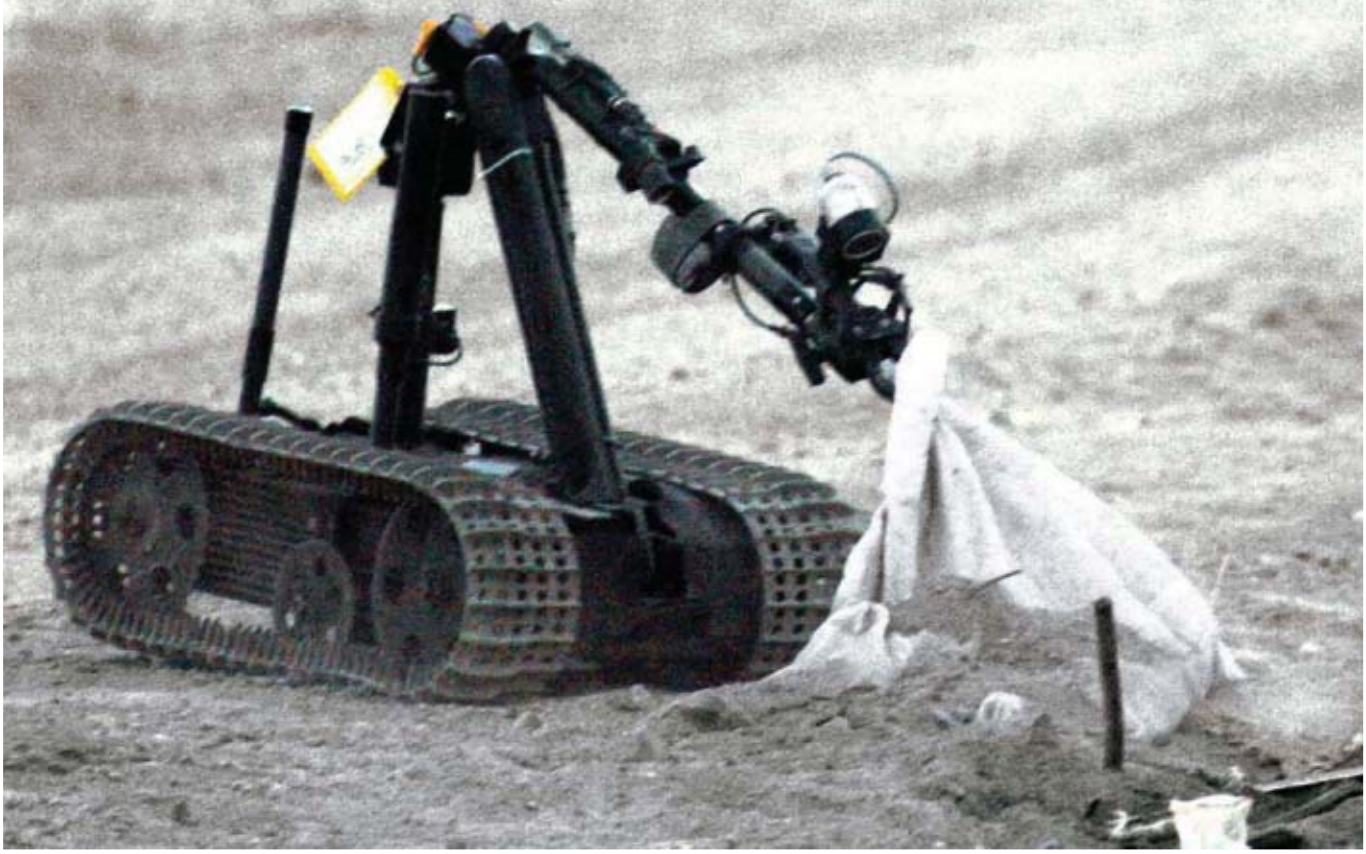

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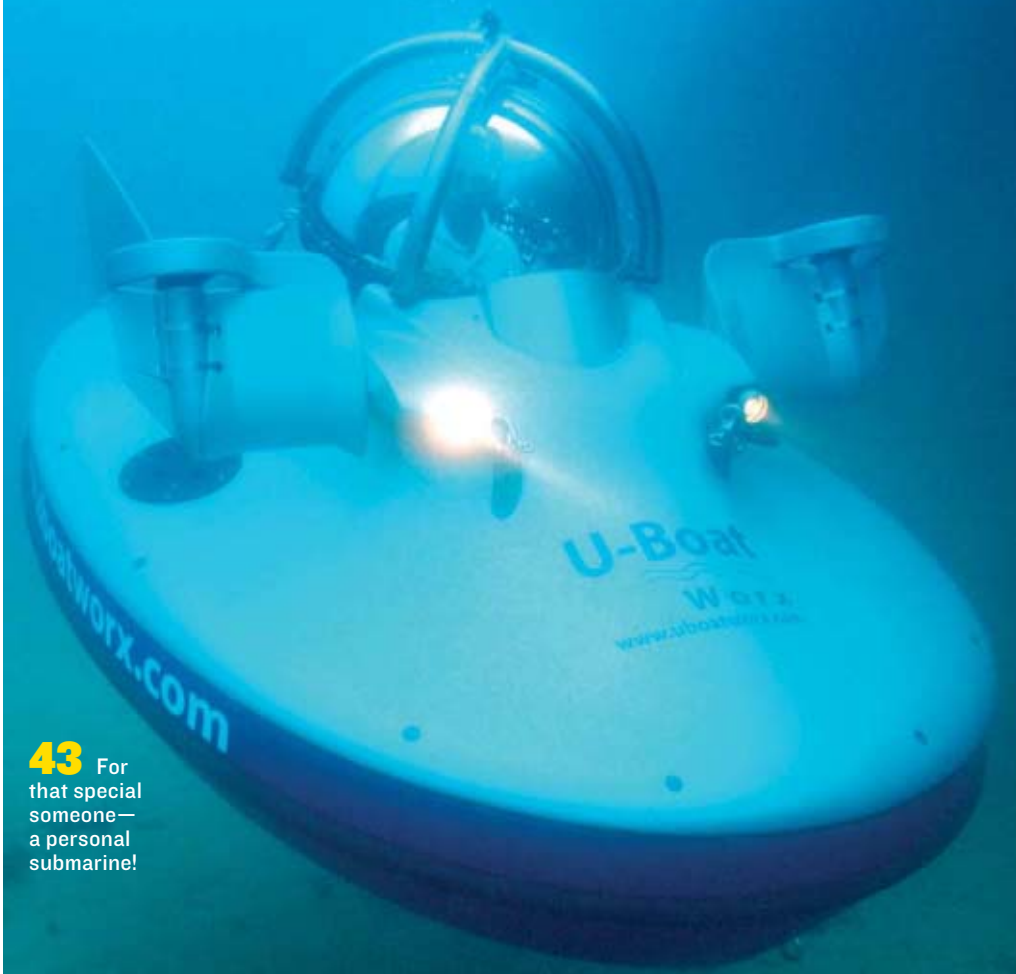

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NEWS

OPINION

RESOURCES

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THE BACK STORY

Unintended Consequences

When *IEEE Spectrum* contributing editor Peter Fairley heard of a new electric vehicle that could recharge its battery in less than 10 minutes, he was intrigued [see "California to Rule on Fate of EVs," in this issue].

Even the best-performing electric cars are notorious for their short range and long charging times. The potential of rapid charging seemed to address both problems by making long trips possible via quick pit stops.

Once he began talking to experts in the industry, however, Fairley encountered many skeptics who questioned the technology's usefulness—to charge that fast, the battery needed half a megawatt of electricity. An electric "charging station" with several cars plugged in would require more than "your typical power line," says Fairley.

He found that the new batteries were a perfect example of the unintended consequences of technology regulations. Practical or not, the rapid-charging batteries seem to qualify for incentives that the California Air Resources Board intended for fuel-cell vehicles.

"This story is about the challenge and complexity of trying to mandate technological development," says Fairley. Enterprising companies often find loopholes in regulations without providing the kinds of advances regulators expect.

Despite the inherent limitations of technology mandates, Fairley thinks they may be the best option available to deliver the advances required to confront climate change.

"There's a huge range of clean technology available and ready," says Fairley. "The problem is getting it into the market." ■

CITING ARTICLES IN IEEE SPECTRUM

IEEE Spectrum publishes two editions. In the international edition, the abbreviation INT appears at the foot of each page. The North American edition is identified with the letters NA. Both have the same editorial content, but because of differences in advertising, page numbers may differ. In citations, you should include the issue designation. For example, the first Resources page is in *IEEE Spectrum*, Vol. 44, no. 11 (INT), November 2007, p. 43, or in *IEEE Spectrum*, Vol. 44, no. 11 (NA), November 2007, p. 49.

RANDI SILBERMAN

FORUM

"Why not build small, two-wheel trailers equipped with batteries sufficient to double the range of an electric vehicle?"
—Paul Gottfried

BATTERIES ON THE MOVE

It seems unlikely to me that battery improvements in the next decade will lead to production of electric-only automobiles with range sufficient for more than relatively short trips ["Lithium Batteries Take to the Road," September]. It also seems to me that there is an obvious solution.

Why not build small, two-wheel trailers equipped with batteries sufficient to double the range—or more? Such trailers could be made available for rental, perhaps at existing service stations. A driver who ran low on reserve would simply attach a fully charged trailer. Another type of trailer—one equipped with fuel tank, internal combustion engine, generator, and perhaps additional batteries—could make it possible to use the basic electric-only automobile for travel across isolated areas such as deserts.

Paul Gottfried
IEEE Life Senior Member
Silver Spring, Md.

The executive editor responds: Between 1995 and 2001, Alan Cocconi, an electric-vehicle designer in San Dimas, Calif., built a series of electric sports cars he called tzero. Some of these could be attached to a trailer with a small gasoline engine that turned the car-trailer combination into a series hybrid. However, production plans for the vehicle were dropped in 2003. For more: http://www.acpropulsion.com/tzero.

RECHARGING R&D

In "Power Up" [News, September], the new U.S. energy research agency ARPA-E is criticized by congressional sources as follows: "How can ARPA-E's mission succeed when the means have not been provided, in the form of money or the ability to turn its findings into new regulations?" Those words tell me everything I need to know about those critics: they are not focused on developing a technology that will be taken up by the marketplace and grown countrywide through value delivery to the consumer. They are focused on "new regulations."

Hundreds upon hundreds of billions of dollars spent on energy research after the nuclear build-out era ended in the late 1970s are beginning to look like a lousy investment, because no technology has emerged from all that work that can compete economically with fossil fuels. I realize we must invest in basic research, and it will not bear economic fruit immediately. However, our entire national research process will be endangered if we don't soon get a major energy breakthrough that directly benefits the taxpayers funding it.

As technologists, we have a personal responsibility to be honest with ourselves about the economics of our work. It is dishonorable for a researcher to abdicate this responsibility. Marketplace demand for an innovative energy technology will fund its rollout worldwide. Some clever, honest researcher out there is going to be immortalized like Edison. Where are you?

Bruce Cavender
IEEE Senior Member
Murfreesboro, Tenn.

STUDYING ISS

I believe James Oberg's review of *ISScapades* [Resources, September] should be required reading for everyone who works at NASA and at its many contracting companies.

In the late 1990s, I worked as a senior software engineer for LM Space Mission Systems & Services on the Hubble Space Telescope's (HST) Vision 2000 project to modernize the HST ground systems. Eighty-hour weeks, mostly without paid overtime, got me a nice plaque—and even a US $1000 award. Most Saturday mornings, however, I was so exhausted from the previous week's work that I could hardly get up by noon from the grueling schedules imposed by management. All this work was in anticipation of the Second Servicing Mission, in February 1997, by the Space Shuttle astronauts.

During this time, I would speak from time to time by telephone with a former NASA chief scientist appointed by NASA Administrator Daniel S. Goldin, who told me that the policy established after the *Challenger* disaster—that of people checking people—was then being relaxed throughout NASA.

So, I guess, we now know what that led to in space—as well as back down here on Earth.

Joseph Roy D. North
Austin, Texas

READ AND REMEMBER

I enjoyed the article "Bet on It" [September], and was struck with an eerie sense of déjà vu! After a few minutes perusing my bookshelf of classic science fiction, I found my copy of *Shockwave Rider*, by John Brunner. It's interesting to note that over 30 years ago Brunner imagined Delphi pools—another name for prediction markets—as an integral part of his fiction. It would seem I wasn't the only person inspired by Brunner's work.

Kenneth R. Jongsma
IEEE Member
Albuquerque

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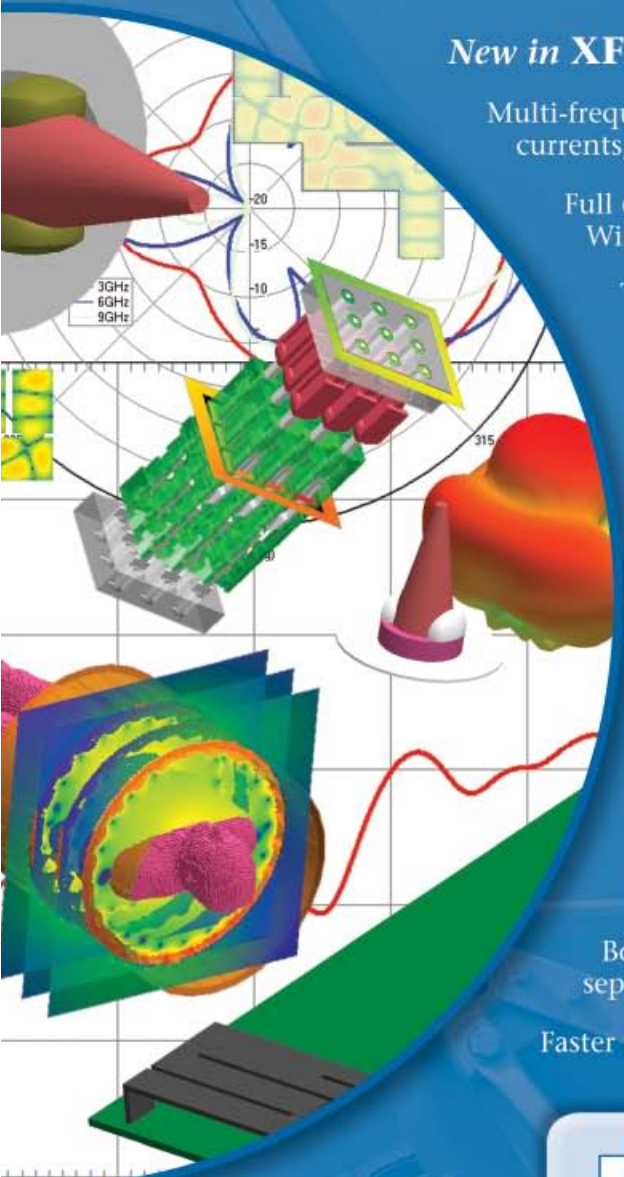

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SPECTRAL LINES

Trail Camera Controller Scores Big in Our DIY Competition

The winners of our second DIY competition, cosponsored with our friends and colleagues over at *Make* magazine, are IEEE members Don Kirk and Bill Green from Indiana. Don, an avid electronics hobbyist, has worked as an electrical engineer for the past 21 years at Magnequench International (formerly a business unit of the Delco Remy Division of General Motors), which produces high-energy permanent magnet materials. Bill, another long-time do-it-yourselfer, has worked for 17 years as a mechanical engineer, also at Magnequench.

SURPRISE! This infrared-light photo of raccoons was taken in Don Kirk's backyard. The bucket feeder lures critters into camera view.

Their winning submission: an all-in-one controller board for a trail camera that costs about US $20 to make. The board detects physical motion using a pyroelectric infrared sensor. When motion is detected, the board turns on the camera, signals the camera to take a picture, and also triggers a slave flash if it's nighttime. Don demonstrated their invention at the Maker Faire in Austin, Texas, on 20 and 21 October.

Animal lovers—and hunters—use trail cameras to keep an eye on animals that come prowling around, mostly at night. Bill, an outdoor enthusiast, had access to some wilderness property about 2 hours away from his home and used trail cameras there to monitor wildlife activity as well as unauthorized human activity (such as trespassers). He originally started building trail cameras using commercially available controller boards, but he couldn't find a single board that combined all of the features he wanted in one place.

So one day Bill and Don started talking about trail cameras, and Don, who was looking for a project that would allow him to use Microchip Technology's microcontrollers, decided to build a board for Bill. And that's how the Trail Camera Controller Board (All-in-One Design) was born.

Nighttime pictures are taken by using what Bill and Don call IR (infrared) setups. They've converted their cameras to be sensitive to infrared light by removing the infrared blocking filter located in the camera lens assembly and placing filters over the flash units to block visible white light but let through the infrared light that is also generated by the flash. When the camera takes a picture there's no white flash, and the only thing the animal sees is a little red light coming from the flash—but only if it is looking directly at it—so it really isn't aware that a picture is being taken.

Don and his wife, Chris, are now as hooked on trail cameras as Bill already was. They had no idea how much wildlife was running around in their backyard at night and can't wait until morning comes to see what creatures have been "captured." Congratulations, Bill and Don! ■

Got a Great Project? We Want to Hear From You!

IEEE Spectrum and *Make* magazines will be joining forces again in the future to call attention to the coolest and cleverest do-it-yourself projects. So if you've conceived and built something that you'd like to share with the combined readerships of *Spectrum* and *Make*—more than a million people—let us know about it. To enter, send a brief description of your project and include an estimate of how much it cost to build. Throw in a photo, a parts list, and a schematic. E-mail them to n.hantman@ieee.org, or snail mail them to: *Spectrum/Make* DIY Contest, 3 Park Ave., 17th Floor, New York, NY 10016-5997, U.S.A. Watch this space for our announcements of dates and deadlines.

If you win, you'll receive full coverage of your project in the print and/or online editions of both *Spectrum* and *Make*, as well as airfare and accommodations to attend the next Maker Faire. That's *Make* magazine's jamboree for do-it-yourselfers, where you will describe and demonstrate your project.

DON KIRK

EVS

California to Rule On Fate of EVs

Regulators rethink electric-drive options

Phoenix Motorcars' battery-powered pickup truck seems, at first glance, like any other electric vehicle. But it has a trick up its sleeve: the truck's hefty 35-kilowatt-hour battery can recharge in a record 10 minutes flat—a feat that would ruin or even ignite most EV batteries.

Phoenix, a start-up in Rancho Cucamonga, Calif., bets that rapid charging will eventually make battery EVs more popular with consumers by eliminating the threat of being stranded with a dead battery. But Phoenix is also counting on a more immediate payoff: the company may be eligible to cash in on California's ambitious and controversial zero-emissions vehicle mandate. The ZEV directive requires car manufacturers to market ultraclean and emissions-free vehicles or buy credits earned by others making such vehicles—credits that could translate into tens of thousands of dollars in extra income per vehicle for Phoenix.

"We're using the ZEV mandate as a tool to finance and progress our company," says Bryon Bliss, Phoenix's vice president of sales and marketing.

Phoenix's bid for extra credits is just one example of what has become a scramble to exploit California's ZEV incentives. Thanks to the heft of the state's huge automotive market—plus that of the many other U.S. states that have signed on to the ZEV program—the mandate has driven gasoline-electric hybrids onto car lots across the country. Now battery EV start-ups, major automakers, hydrogen fuel-cell developers, and coalitions promoting plug-ins (hybrid EVs that recharge on the power grid overnight) are lobbying the California Air Resources Board (CARB) to favor their respective automotive visions. This winter, the board plans to consider adjustments to the ratio of

JUSTIN SULLIVAN/GETTY IMAGES

EVs WILL BE BACK: California governor Arnold Schwarzenegger talks up his states's zero-emission vehicles program.

credits earned by various ZEV technologies, a ratio that currently favors fuel cells and offers relatively little help for hybrids.

"Changing that ratio has a lot of implications," says Daniel Sperling, director of the University of California, Davis, Institute of Transportation Studies—a longtime observer of the ZEV program and a member of CARB. Sperling says he is especially concerned about the impact on fuel-cell R&D if CARB reduces the generous credits for fuel-cell vehicles. "Automakers might abandon their fuel-cell programs," he warns.

CALIFORNIA LEGISLATORS created the ZEV mandate back in 1990 after General Motors vowed to mass-produce its sporty EV1, a battery-powered two-seater. The mandate consisted of just a few sentences, stating that major manufacturers' California sales must include at least 2 percent ZEVs in the model years 1998 through 2000, 5 percent ZEVs in 2001 and 2002, and 10 percent ZEVs in 2003 and subsequent years. Increasing volume was supposed to drive improvements in the performance of electric drivetrains and slash their cost.

In practice, however, battery development lagged. So CARB repeatedly trimmed the quotas for ZEVs, allowing manufacturers to build a larger number of ultraclean combustion vehicles, which the board oxymoronically termed *partial* zero-emissions vehicles. These include cars with advanced emissions controls, natural gas–powered vehicles, and gasoline-electric hybrids. Each category qualifies for a different number of credits toward the manufacturers' ZEV quotas.

More than half a million cars have been sold under the ZEV program. And the hybrid vehicles sweeping the market today, the Toyota Prius in particular, have their roots in carmakers' attempts to comply with the mandate. What is missing, however, are the thousands of emissions-free vehicles originally promised.

The regulation's downfall came in 2003 when the mandate, set to come into full force, was instead derailed by a GM-led lawsuit. The industry litigants argued that CARB's incentives for gasoline-sipping hybrids showed the ZEV mandate was regulating fuel efficiency, a power granted to the federal government. The board settled the suit by giving automakers a way out. Instead of making thousands of battery EVs each, automakers could embark on an industry-wide effort to commercialize fuel-cell vehicles, beginning with the demonstration of just 250 fuel-cell cars by 2008, with more to follow.

The Big 6—DaimlerChrysler, Ford, GM, Honda, Nissan, and Toyota—lost no time getting to work on fuel cells, and they are on schedule to produce the fuel-cell cars promised for next year.

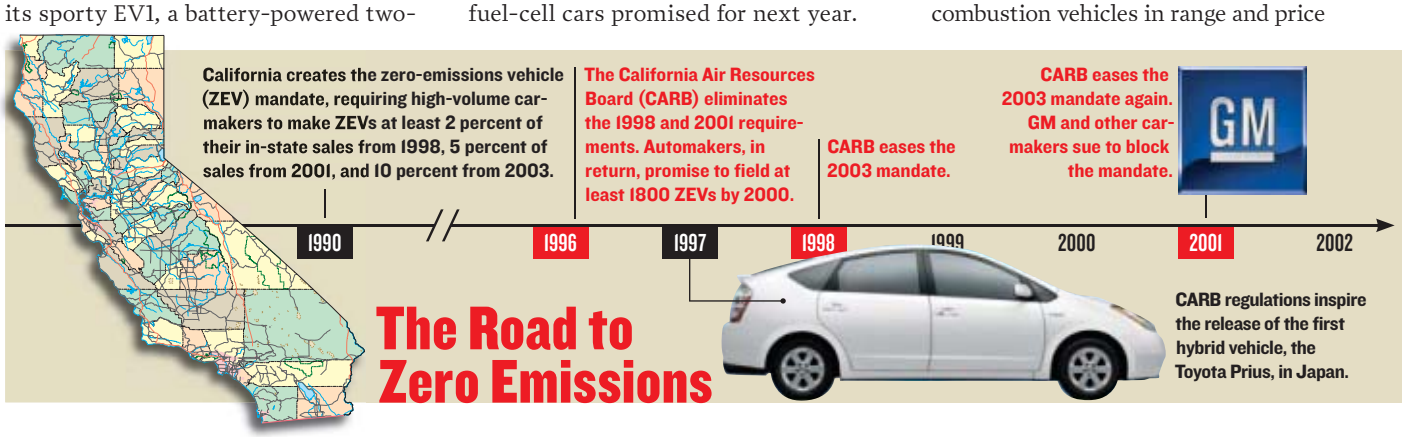
But with the emphasis on fuel cells, carmakers were free to give up on their battery EVs, and all but Toyota did so. By 2003 the Big 6 had built about 4400 battery EVs under the ZEV program. Most were recalled and crushed (in Honda's case, shredded) after the court settlement.

ACCELERATE FORWARD from 2003 to today and it's a brave new world. Hybrids are going mainstream, major automakers are once again engineering battery EVs, and start-ups such as Tesla Motors and Phoenix are actually bringing them to market. Even GM, vilified in the 2006 documentary *Who Killed the Electric Car?* for crushing its EV1s, says electric drive is the future. "We need to do everything we can to rid ourselves from complete dependence on oil as our single source for automotive transportation," says Dave Barthmuss, GM's environmental spokesman in California.

The question, yet again, is whether the ZEV mandate can help.

Automakers want more time, and more credits, for fuel-cell technology. The vehicles just aren't ready: according to an independent review released by CARB in April, fuel cells remain 20 times as expensive as combustion engines and last as little as three years, hydrogen storage tanks are inadequate, and hydrogen fuel stations are nonexistent. Carmakers propose delivering 2500 to 5000 fuel-cell vehicles through 2014, one-fifth to one-tenth of what they promised in the 2003 court settlement. And they want to continue receiving extra ZEV credits for every fuel-cell vehicle built. Right now each hydrogen vehicle earns four times as many credits as a battery EV, but that advantage is slated to narrow after 2009.

Proponents of battery EVs, on the other hand, want CARB to give them parity with fuel-cell cars. Technology is an issue for battery EV makers, too. CARB's April review concluded that battery EVs comparable to today's internal combustion vehicles in range and price



FROM LEFT: CARTESIA; TOYOTA; GENERAL MOTORS

GONE IN 600 SECONDS: Phoenix Motorcar's electric truck can charge in less than 10 minutes.

would not be ready for even small-scale commercialization before 2015. But battery EV proponents say that thanks to today's climate—economic, political, and atmospheric—some consumers are ready to trade range for a car that costs less to run and produces less pollution. CARB Chairwoman Mary Nichols agrees. "People are willing to take a chance on a car that doesn't necessarily do everything the old Taurus used to do," she says.

Nichols says she is especially bullish about plug-in hybrids—which could be good news for that technology's backers if it translates into new policy. At present, CARB offers to plug-ins less than one quarter of the credits it gives to battery EVs, mostly because there is no guarantee that drivers will plug them in.

THEN THERE'S PHOENIX, a battery EV developer that likes the ZEV mandate's favoritism for fuel cells. Why? Because the extra credits earned by fuel-cell manufacturers are the same credits Phoenix has requested for its rapid-charging truck. In 2003, when CARB shifted its emphasis to fuel cells, it did so by creating a new category of ZEVs, awarding the extra credits to any ZEV that travels 160 kilometers and refuels in 10 minutes or less.

When CARB wrote those rules, it assumed that only fuel cells would qualify, but Phoenix found a battery capable of the trick: a lithium titanate cell made by Altair Nanotechnologies of Reno, Nev. Charging a lithium battery generally means shifting lithium ions from a lithium metal oxide cathode into a graphite anode. Do that with too much force and lithium ions form a layer of highly energetic (and flammable) lithium metal on the graphite cathode. Altair Nano's battery replaces the graphite with a titanium oxide anode that is much less susceptible to such plating, so the battery can be charged rapidly at very high power. [See "Lithium Batteries Take to the Road," *IEEE Spectrum*, September.]

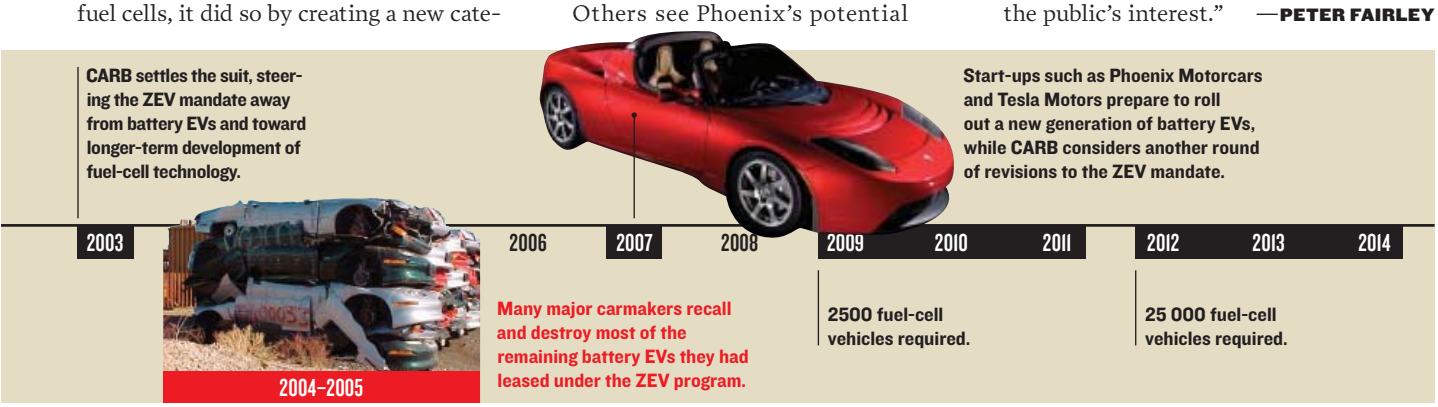
Alan Gotcher, Altair Nano's chief executive, says bonus credits, which were still pending at press time, would be a just reward. "That's what the program was designed for, to bring some innovation to solve a very tough problem," he says.

Others see Phoenix's potential windfall as a distortion of the mandate. J.B. Straubel, chief technical officer with Tesla, in San Carlos, Calif., is one of many critics. Straubel questions the practicality of rapid charging, because it requires megawatt power levels hard to find beyond electrical substations. And he says rapid charging is merely a loophole in the regulation. "That can change at the stroke of a pen, and I think it will," he says.

It would hardly be the first time a ZEV rule-change upended entrepreneurs. The board's rollbacks in the 1990s burned start-ups of that era. In Straubel's judgment, the ever-shifting targets diminish the program's impact. He and others expect the auto industry to wiggle out of CARB's quotas once again.

While Straubel stops short of dismissing the program entirely, other critics are less forgiving. "It's a political regulation driving impractical solutions. It's not really relevant to the real world," says EV battery expert Menahem Anderman, president of Total Battery Consulting, in Oregon House, Calif. Anderman argues that California should shelve the program in favor of broader measures now in the works, including tough fuel-economy standards legislated in 2002 and a cap-and-trade program for greenhouse gases. These measures would raise the cost of gasoline and gasoline-burning cars, leveling the field somewhat for electric-drive vehicles, he says.

Sperling and other energy policy experts say such broad measures would accelerate the adoption of existing alternatives such as plug-in hybrids, but they could prove insufficient to drive the immense investments needed for new technologies. "The challenge for policy is to somehow address the start-up barriers," Sperling says. He predicts that, without the ZEV mandate, short-term considerations determine what automakers offer the market. "Companies are going just to pick the easy way," he says, "and the easy way is not necessarily in the public's interest." —**PETER FAIRLEY**



TOP: PHOENIX MOTORCARS; BOTTOM: EV1 CLUB; TESLA MOTORS

Transistors Go Vertical

The semiconductor industry fights silicon sprawl by building up, not out

Through all the decades of microchip evolution one thing has remained constant: the silicon transistors of which they're made are basically flat. But that is very likely to change in the next five years. The semiconductor industry is facing a problem that can be solved only with a fundamental transistor redesign. Transistors are no longer the clean on-off switches they once were; instead, current leaks through them even when they are supposed to be off. As transistors shrink with each new generation of microchip, this errant current increases, draining batteries and heating chips up.

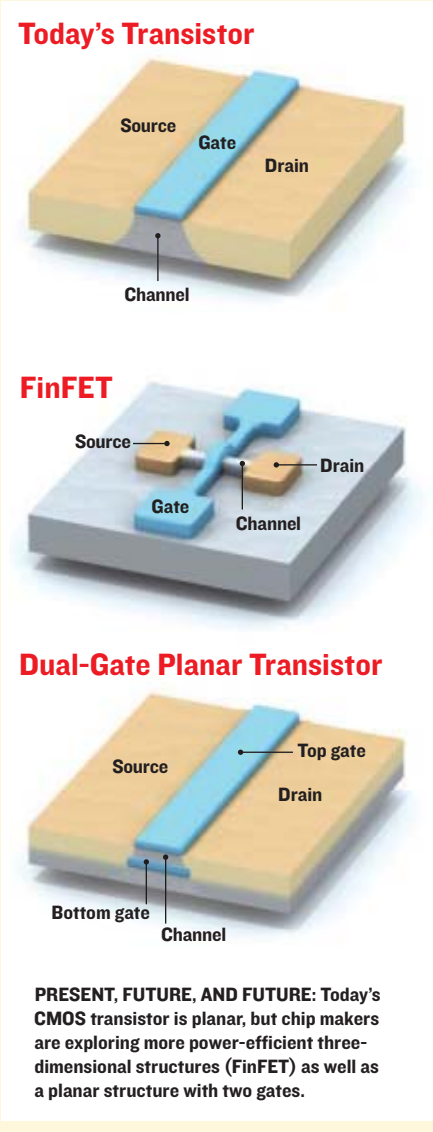
Major chip manufacturers will show off their latest proposed solutions from 10 to 12 December at IEEE's International Electron Devices Meeting, in Washington, D.C. What many of these experimental transistors have in common is that they are decidedly not flat.

Going from flat to three-dimensional in the conservative microchip industry is a radical shift, but as Leo Mathew, a research scientist at Freescale Semiconductor, says, "the payoff will be substantial."

The semiconductor industry has fed the consumer appetite for better electronics performance by shrinking the transistors' structure to cram more of them onto a chip. (However, some of the materials involved are changing for the first time in 40 years; see "The High-*k* Solution," *IEEE Spectrum*, October.) Normally, you can picture a transistor in four parts, the source and drain, connected by a channel and topped off by a gate. Most of the transistor is in one plane, built into the silicon substrate of the microchip. Only the gate and its extremely thin insulating layer, which lie directly above the channel, protrude slightly above the flat plane of silicon. Voltage on the gate causes a conductive path to form in the channel, allowing current to flow between the source and the drain.

However, shrinking this structure further means that removing the voltage on the gate no longer completely stops the flow of electrons. Even in today's transistors the source and drain are separated by mere tens of nanometers, a short enough distance for electrons to leak through the lower part of the channel, farthest from the gate. The result is wasted power and heat. It's one reason the battery power on an unplugged laptop seems to evaporate quickly and why companies have to spend huge sums to cool their server rooms.

Realizing that source-drain leakage will only get worse as chips shrink, researchers have sought to plug the leak by raising the channel, source, and drain out of the substrate. The gate is then draped over the channel on three sides like a lowercase "n." Now the current is constrained only to the raised channel, and electrons no longer have a path through which to leak. This general class of transistor is called multigate, because the wrapped gate is like having three gates instead of one. But "the shift to multigate transistors requires a fundamental change in transistor design," says John Pellerin, director of logic technology development at Advanced Micro Devices. That's because to make multiple gates, nearly everyone agrees you have to go vertical. According to Infineon Technologies' principal scientist for CMOS devices Klaus Schrüfer, multigate technology is a game changer: "Multigate is the only device architecture for scaling" into the foreseeable future, he says.



PRESENT, FUTURE, AND FUTURE: Today's CMOS transistor is planar, but chip makers are exploring more power-efficient three-dimensional structures (FinFET) as well as a planar structure with two gates.

BRYAN CHRISTIE DESIGN

The most common multigate transistor design is a structure called a FinFET. In a FinFET, the channel connecting the source and drain is a thin, finlike wall jutting out of the silicon substrate. The drawback to this design is the difficulty of etching it out of the silicon in the minuscule detail needed. Several researchers say that because the design changes are so substantial, the transition from planar to multigate will be more difficult than the transitions between any other past technology nodes.

The FinFET's co-inventor, University of California, Berkeley, professor Tsu-Jae King Liu, says that the early adopters of multigate technology will likely be DRAM manufacturers; logic device makers may follow eventually. There are two reasons for this: first, DRAM has much more stringent leakage current requirements than logic circuits do. In DRAM, a bit of information is stored as a puddle of electrons in a capacitor, with a transistor acting as the gatekeeper. If those electrons dribble out across the transistor, what's lost is not just heat or power—it's information. Another reason DRAM makers will likely move to multigate first is that they already have expertise etching the steep features needed, King Liu says. Because DRAM capacitors are already constructed in deep narrow trenches, the FinFET's form doesn't intimidate memory-chip makers.

In fact, the world's largest DRAM maker, Samsung Electronics Co., in Seoul, South Korea, has indicated that it may use a transistor structure like the FinFET for DRAM. But it will take longer for logic manufacturers to get on board, STMicroelectronics' Thomas Skotnicki explains. "Logic people are very much planar," he says. "For us, there are many barriers—including psychological ones."

Still, even the most conservative major chip makers, the foundries, are working on multigate transistors. Taiwan Semiconductor Manufacturing Co. (TSMC) hired FinFET co-inventor Chenming Calvin Hu to develop TSMC's proprietary FinFET. "A big foundry like TSMC generally tends to be more conservative," King Liu says. "They wouldn't go to a multigate transistor unless their major customers asked for it."

At the December conference, researchers from Freescale, IBM, Infineon, Intel, and others will feature their multigate devices. According to Intel director of

components research Michael C. Mayberry, Intel's transistor uses the archetypal FinFET structure. Freescale's new transistor bears some resemblance to the FinFET, says the company's Mathew, who invented it, but the finlike channel is shaped more like an inverted T.

If the shape of the transistor varies from company to company, the plans on when to introduce it do not seem to. "The earliest I see multigate transistors," says IBM Research Division's Wilfried Haensch, "is at 22 nanometers," which is planned for 2011. Infineon and Intel seem to be in agreement.

But does multigate have to be synonymous with 3-D? STMicroelectronics thinks not. The Franco-Italian chip maker has vowed to stay planar even beyond the 22-nm node, says Skotnicki, with a dual-gate device.

Imagine the ST transistor as a garden-variety FinFET but lying on its side. From the top you'd see a gate that looks like the one in today's transistor, but there is a second "shadow" gate buried beneath it, sandwiching the channel. The problem was that to make a double-gate transistor you needed to align the two gates with absolute precision. Perfectly aligning tiny gates is even harder than etching tiny fins. But Skotnicki says that ST has figured out how to do it, and the company showed a chip with the planar self-aligned double-gate structures in June: "It has the same electrical advantages as FinFET, but with probably the highest performance ever published," he says. "I don't know if FinFET can deliver that." He predicts that companies will abandon their multigate research and return to planar. And indeed, other firms such as IBM are working on planar dual-gate transistors alongside their 3-D multigate development. "We expect this to be a turning point," Skotnicki says.

Whether Skotnicki is right or not, multigate transistors are practically right around the corner. Usually companies have their technology figured out and in the pipeline a good two years before full production starts. By the time they take multigate transistors to market, they may have to dream up yet another design. At technology nodes beyond 22 nm, after 2013 or so, says Berkeley's King Liu, the FinFET might not deliver "any better performance" than a shrunk-down version of today's flat transistor. —SARAH ADEE

TRANSFER OF POWER: As this train in Oslo slows to a stop, its motors feed power back into the grid for other trains to use.

Oslo Metro Takes Greener Track

New trains share power captured by regenerative braking

Oslo has one of the world's smallest carbon footprints for a city of its size, but it wants to get even greener. To that end, it's replacing 63 of the T-bane Metro's trains with new three-car trains from Siemens that are 30 percent more energy efficient than the best cars currently in service there. The key is in the trains' ability to generate electricity while braking and transfer that power to other trains.

When a train's operator applies the brakes, the four 140-kilowatt, 750-volt dc electric motors are engaged as generators that use the kinetic energy of the turning wheels to send current back into the metro's power grid. This technique, called regenerative braking, allows the trains to recover up to 44 percent of the energy used to bring the trains up to speed.

Slowing vehicles down by transforming their inertia into electric current is by no means a new idea. Hybrid-electric cars use regenerative braking to charge onboard battery packs and help boost their fuel economy. The challenge with train systems is that the energy generation occurring in one train must be timed to coincide with a demand for power from a nearby train that is accelerating. The more these stops and starts can be paired, the less electricity the operating authority has to draw from the grid.

Regenerative braking is not to be confused with dynamic braking, employed in many diesel-electric trains to limit wear on the mechanical brakes. In dynamic braking, the current generated by a train's motors during deceleration goes to a set of large onboard resistors. They release the energy as waste heat or use it to warm the passenger compartments.

The environmental benefits from the new trains do not stop with the regenerative braking system. The 94-metric-ton, 54-meter-long MX3000 trains are made mainly of aluminum, so they are lightweight, and therefore require less energy than the average steel-bodied train to accelerate from a dead stop. What's more, 85 percent of the materials used to build each train are recyclable. Much of the rest can be burned at thermal energy plants.

Because of the MX3000's higher efficiency, plus the fact that most of Oslo's electricity is generated by hydroelectric plants, as little as 2.6 grams of carbon dioxide will be added to the atmosphere per kilometer traveled and per metric ton of vehicle weight, Siemens estimates. In other cities, the average electric train or tram contributes upward of 25 grams per kilometer traveled.

Two prototypes delivered to Oslo in 2005 for testing lived up to energy-efficiency expectations. The city has so far received a quarter of its 63-train order. By 2009 all of Oslo's metro system will rely on regenerative braking. —WILLIE D. JONES

SIEMENS

Superconductor Maker In Political Crosshairs

Congressional inquiry could jeopardize bold New York City grid project

NEWS Since the discovery 20 years ago of high-temperature superconductors (HTSs)—materials that could conduct without resistance at temperatures attainable with liquid nitrogen—the most exciting and far-reaching applications have been expected in electricity. And for many years, the most hard-charging, technically smart company developing HTSs for power has been American Superconductor Corp. (AMSC) of Westborough, Mass. So there's been a stir over the disclosure that AMSC is under investigation by the office of Representative John Dingell, a Democratic congressman from Michigan, one of the most influential U.S. legislators, and an aggressive inquisitor.

The incident that aroused Dingell's suspicions was the award in 2006 by the U.S. Department of Homeland Security of a multimillion-dollar no-bid contract to AMSC to develop and test what it's calling Secure Super Grids in New York City. Working with the local utility Consolidated Edison Co., AMSC plans to develop and install superconducting cables that would connect substations in a much tighter mesh, so that if stations or feeder cables fail, power can be instantly rerouted. Feeder cable failures were implicated in the 1999 and 2006 New York City neighborhood blackouts.

The AMSC–Con Ed plan squarely addresses that problem. But it makes use of technology that's on the verge of commercialization by other companies, not only in the United States but also in Europe and Japan. So it's easy to see why Dingell's investigators might have wondered not only why AMSC got this particular contract on a noncompetitive basis but also why it has received so many other government development contracts on similar terms.

A big part of the funding for the AMSC–Con Ed plan is not for the substation connections but for a second, research and development, component. These funds are to be doled out only as certain technical milestones are met. The second phase involves developing and testing an innovative HTS fault-current limiter system—a device designed to dampen huge current surges from grid-scale short circuits. These generally have been imagined as stand-alone devices, but AMSC proposes to incorporate the current-limiting function in the cables themselves, exploiting a special property of superconductors—they lose their superconducting property and become normally resistive if currents rise too high. So, if properly tuned, they have the innate ability to limit excessive currents.

Both the substation connections and the fault limiters are of critical interest to New York City. Its power system is unusual among the world's megacities in that adjacent electrical zones are rather isolated from each other, observes James Baumstark, Con Ed's vice president for central engineering. As a result, if trouble develops in one of the zones, power can't be easily transferred from neighbors to make up for the shortfall. Con Ed would like to fix that by installing more feeder cables—the trunk cables that carry power into each zone—to connect substations to each other. Superconducting cables are an enticing choice, because they can carry up to 10 times as much current as a regular cable in an equivalent volume without dissipating heat that could damage nearby equipment. What's more, because the number of potential fault currents increases with the number of substation-to-substation connections added, superconducting cable's innate current-limiting ability is all the more appealing.

UNDER SCRUTINY: A congressman is investigating the maker of the superconducting tape used in these cables, scheduled for installation in New York City.

Despite that seemingly natural application, all efforts to design a commercially viable superconducting fault current limiter have come to grief so far, says Alexis P. Malozomoff, AMSC's chief technical officer. First-generation HTS wire embedded a bismuth-strontium-calcium-cuprate superconductor in a multifilamentary structure containing a lot of silver. As a result, even when the critical current threshold was exceeded and the HTS became resistive, the silver would still carry enough current to vitiate the desired fault-limiting effect.

In the past year, however, AMSC has introduced a second-generation conductor in which the HTS is deposited on a textured substrate, using techniques derived from the semiconductor industry and developed mainly at Oak Ridge National Laboratory, in Tennessee. Wire and cable made from the new yttrium-barium-cuprate tape, which contains much less silver, become much more resistive at critical thresholds.

With Siemens, AMSC has already tested a stand-alone fault-current limiter using the second-generation HTS wire. And Hyundai Heavy Industries Co., in Ulsan, South Korea, used the new wire in a limiter that set performance records. Building on such work, AMSC proposes to develop a cable system that is intrinsically current limiting. Specifications call for the superconducting cable to carry 4000 amperes continuously and no more than 40 000 A of fault current. With tweaks to the number of superconducting wires running in parallel, the cable can be set to become resistive at anticipated fault-current levels.

The important thing to understand—and this may have escaped Dingell's staff—is that the fault-current-limiter part of the project is an experiment. AMSC and Con Ed could get as much as US $25 million from Homeland Security over a period of years, but only if fault-current limitation is demonstrated in a series of lab and field exercises, starting this year. The program can be terminated at any time if the team fails to make progress.

IN THE 1980s, huge companies quaked when scrutinized by Dingell's investigators, including defense contractor General Dynamics Corp., in Falls Church, Va., which was revealed to be charging its lobbying expenses to the government under cost-plus contracts. A small company such as AMSC, which owes its viability and success almost entirely to government contracts, might be quaking, too. But to judge from the tone of conversations with its staff, it doesn't seem to be, and its collaborators in the New York City supergrid project are holding firm, too.

AMERICAN SUPERCONDUCTOR CORP. (2)

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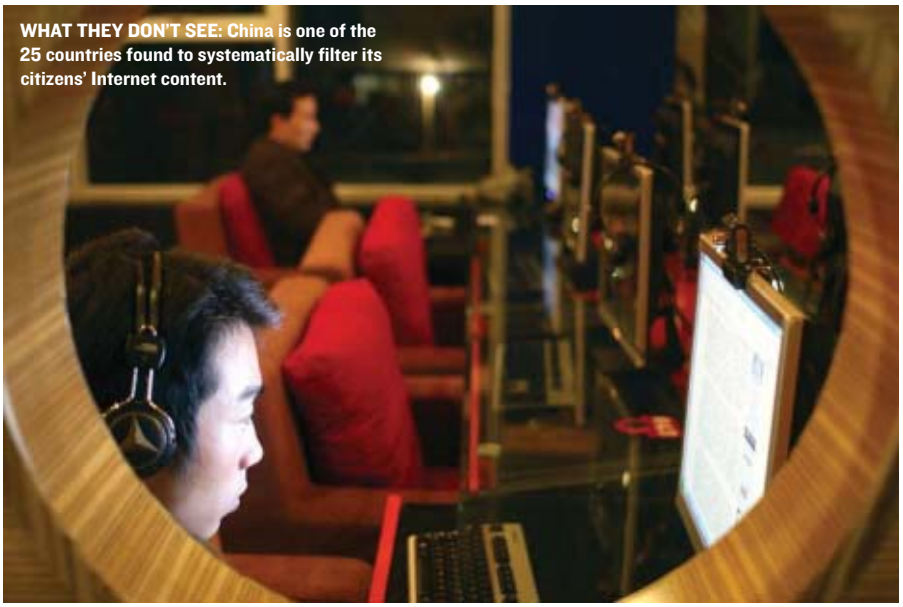
NEWS

Even if the contract had been awarded on a competitive basis, it's likely AMSC would have easily won it. The company owns the first commercial second-generation HTS factory, which is the technical and practical foundation for its current-limiting concept. And Southwire, its partner in Secure Super Grids, has set the record—2700 A—for an HTS cable in a working transmission grid using a cable it designed with AMSC's first-generation wire. Southwire, in Carrollton, Ga., conducted that test with American Electric Power in Ohio. As for fault-limiting cables, Malozomoff says "we're the only company out there that has come up with this"—a claim nobody disputes.

AMSC expects to survive the Dingell probe with its reputation essentially intact. But the investigation may be a shot across its bow. With superconductors on the eve of commercialization and set to become a big business, AMSC's claims will be subjected to ever closer scrutiny. Its days as a no-bid government contractor may be coming to an end, and increasingly it may have to cope with normal competitive pressures.

—WILLIAM SWEET



WHAT THEY DON'T SEE: China is one of the 25 countries found to systematically filter its citizens' Internet content.

Internet Censorship: As Bad As You Thought It Was

Maybe a bit worse, actually

"In the dot-com heyday of the '90s and early 2000s...there was a myth that the Internet can't be controlled," says Ronald Deibert, a researcher at the University of Toronto's Citizen Lab. "There was some mysterious, magical property associated with it that will route around censorship." The most exhaustive study yet of Internet censorship—*Access Denied: The Practice and Policy of Global Internet Filtering*, published this month by the MIT Press—pretty much disproves that notion.

The report's authors, the OpenNet Initiative—a multidisciplinary team at the University of Toronto, and Cambridge, Harvard, and Oxford universities—sent investigators to 41 countries that had been rumored to filter Internet content, whether to silence political dissent or to block access to pornography or religiously and culturally divisive material.

ONI set out to objectively confirm or invalidate the reports. It found that the situation was worse than the rumor mill suggested. "The big thing is that the scope, scale, and sophistication of Internet content filtering is on the rise worldwide, and it's really an alarming increase," says Deibert, one of the book's editors and contributors.

ONI discovered systematic Internet filtering in 25 countries, with nine of them—China, Ethiopia, Iran, Myanmar, Saudi Arabia, the United Arab Emirates, Uzbekistan, Vietnam, and Yemen—blocking content in every category it investigated.

"The vast majority of content [around the world] that is blocked is pornography," Deibert says. "But what we're seeing now is many countries broadening the scope of their filtering to political opposition movements, human rights information, Web sites of minority groups, secessionist movements, gay and lesbian information, translation services, and encyclopedias."

On the other hand, five countries—Azerbaijan, Jordan, Morocco, Singapore, and Tajikistan—that were rumored to broadly filter the Internet turned out to block just one or a few select Web sites.

ONI researchers travel to each country they test and, wherever possible, employ Internet-savvy locals who know the ISPs and cybercafés most likely to be targeted by the government. Using a Web browser in the Internet cafés, on the local ISPs, or both, they attempt to access approximately 1000 Web sites that might be targeted by any government. The sites include top human rights, activism, and pornography destinations, as well as ones that offer tools that let you surf the Web without being traced.

In-country researchers also run local lists of sites that might be targeted by the relevant authorities. In China, for example, they tried to access sites associated with Falun Gong and local democracy activists. In Arabian and Persian Gulf countries, ONI attempted to access women's rights and Islamic dissident sites.

Testing over a span of weeks, at various times of night and day, ONI researchers concluded that a site had been filtered if it was persistently unavailable in the country but accessible elsewhere in the world.

ONI has noted that censorious governments have become increasingly subtle about the way they filter Internet content.

One new frontier of Internet censorship, Deibert says, is "just-in-time filtering." For instance, ONI detected no noteworthy filtration in Kyrgyzstan in general. But in the weeks leading up to the country's February 2005 elections, Web sites of the country's opposition newspapers were regularly taken down by denial-of-service attacks. ONI traced those attacks back to Ukrainian hackers for hire but was never able to establish a direct link to the Kyrgyz government.

In a more recent instance, the Cambodian government blocked SMS messaging over the country's cellular network for the two weeks before elections last April. "One would have to surmise," Deibert says, "that they were doing this to prevent mobilization of opposition, especially street demonstrations."

—MARK ANDERSON

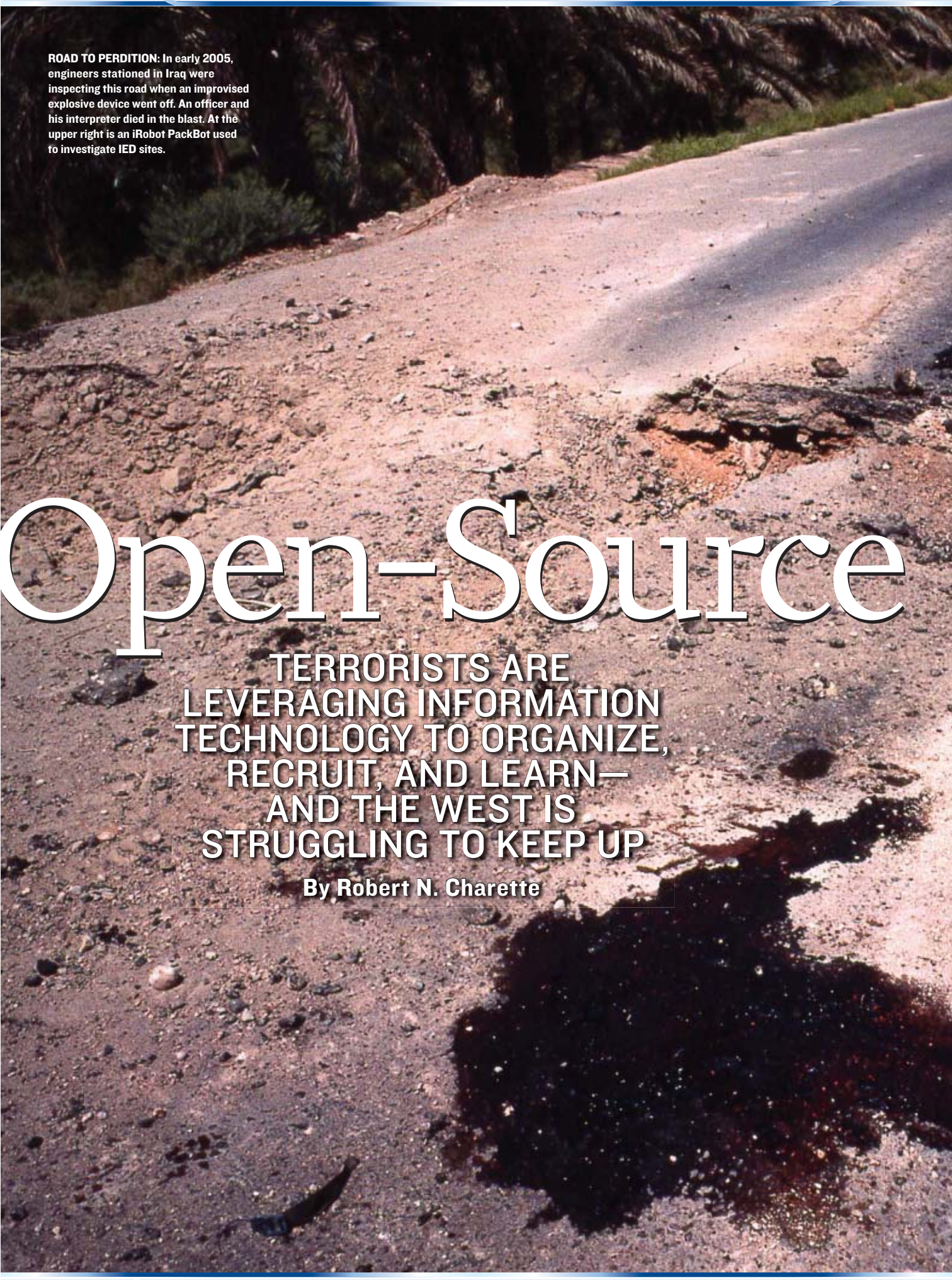
RYAN PYLE/CORBIS

THE BIG PICTURE

My Other Car Is A Flying Saucer

Late last month, at the 40th Tokyo Motor Show, Nissan Motor Co. showed off a concept car with a literally dizzying array of features. The passenger cab in the Pivo 2 electric car can swivel 360 degrees to face any direction. Why would you want to do that? Well, for starters, there's never any need to back the car up: simply swivel the cab 180 degrees and drive what is now forward. But wait, it gets weirder. The main improvement from the 2005 Pivo I, which had similar Tilt-a-Whirl action, is that the new car's wheels can all turn 90 degrees. So now you could drive sideways while facing diagonally... if you really wanted to.

Photo by Kazuhiro Nogi/ AFP/Getty Images

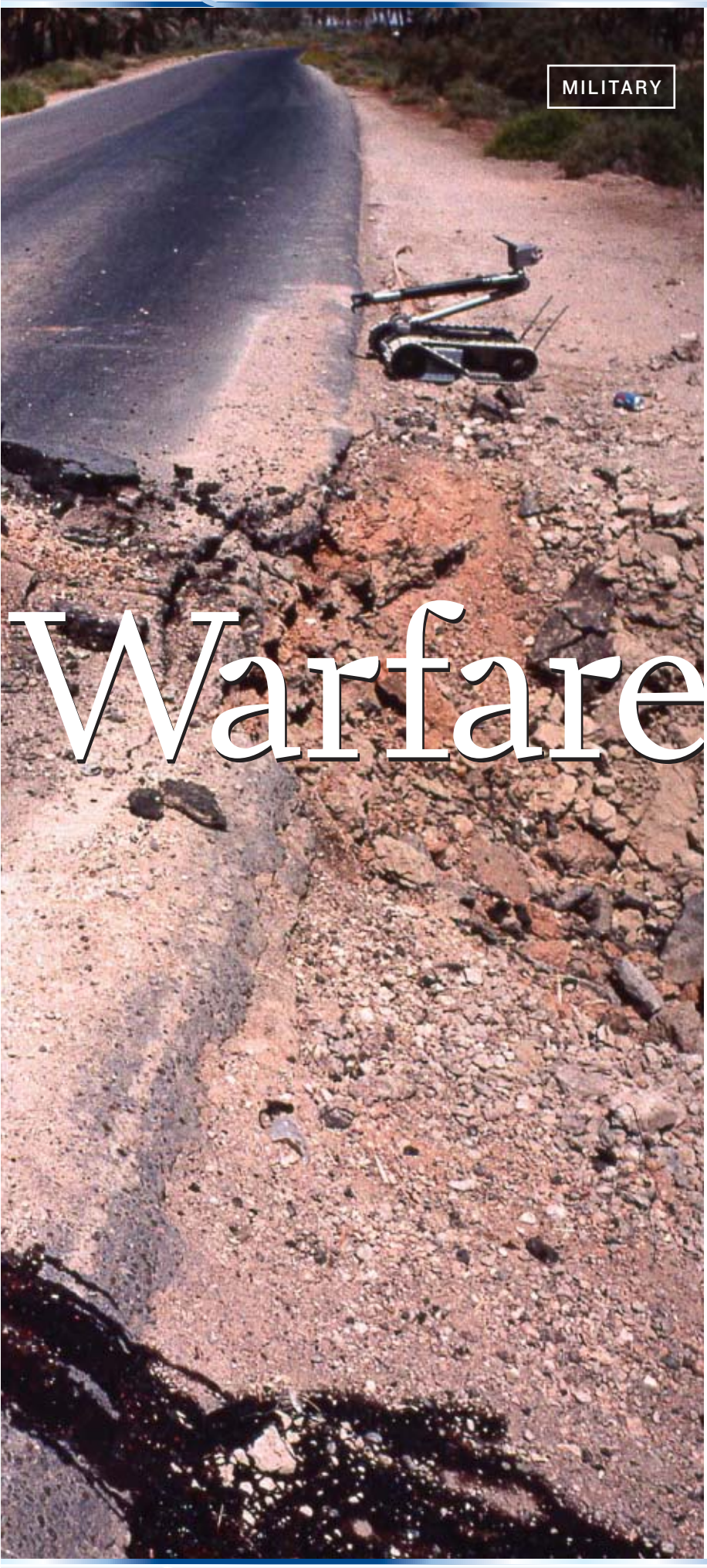


ROAD TO PERDITION: In early 2005, engineers stationed in Iraq were inspecting this road when an improvised explosive device went off. An officer and his interpreter died in the blast. At the upper right is an iRobot PackBot used to investigate IED sites.

Open-Source

TERRORISTS ARE LEVERAGING INFORMATION TECHNOLOGY TO ORGANIZE, RECRUIT, AND LEARN—AND THE WEST IS STRUGGLING TO KEEP UP

By Robert N. Charette



MILITARY

Warfare

ON THE AFTERNOON OF THURSDAY, 8 April 2004, U.S. troops stationed in Iraq deployed a small remote-controlled robot to search for improvised explosive devices. The robot, a PackBot unit made by iRobot Corp., of Burlington, Mass., found an IED, but the discovery proved its undoing. The IED exploded, reducing the robot to small, twisted pieces of metal, rubber, and wire.

The confrontation between robot and bomb reflects a grim paradox of the ongoing conflict in Iraq. The PackBot's destruction may have prevented the IED from claiming a soldier's life—as of 31 August, IEDs accounted for nearly half of the 3299 combat deaths reported by coalition forces. But the fact remains that a US $100 000 piece of machinery was done in by what was probably a few dollars' worth of explosives, most likely triggered using a modified cellphone, a garage-door opener, or even a toy's remote control. During the past four and a half years, the United States and its allies in Iraq have fielded the most advanced and complex weaponry ever developed. But they are still not winning the war.

Although there has been much debate and finger-pointing over the various failures and setbacks suffered during the prolonged conflict, some military analysts and counterterrorism experts say that, at its heart, this war is radically different from previous ones and must be thought of in an entirely new light.

"What we are seeing is the empowerment of the individual to conduct war," says John Robb, a counterterrorism expert and author of the book *Brave New War* (John Wiley & Sons), which came out in April. While the concept of asymmetric warfare dates back at least 2000 years, to the Chinese military strategist Sun-tzu, the con-

PREVIOUS PAGES: JONATHAN ROMANO; THIS PAGE: FAR LEFT: LUKE WOLAGIEWICZ/WPN; KAREEM RAHEEM/REUTERS

FAST, CHEAP & OUT OF CONTROL: Improvised explosive devices made from cellphones, radios, old mortars, and other low-tech mechanisms have exacted an enormous toll in Iraq.

flict in Iraq has redefined the nature of such struggles [see photo, "Road to Perdition"]. As events are making painfully clear, Robb says, warfare is being transformed from a closed, state-sponsored affair to one where the means and the know-how to do battle are readily found on the Internet and at your local RadioShack. This open global access to increasingly powerful technological tools, he says, is in effect allowing "small groups to...declare war on nations."

Need a missile-guidance system? Buy yourself a Sony PlayStation 2. Need more capability? Just upgrade to a PS3. Need satellite photos? Download them from Google Earth or Microsoft's Virtual Earth. Need to know the current thinking on IED attacks? Watch the latest videos created by insurgents and posted on any one of hundreds of Web sites or log on to chat rooms where you can exchange technical details with like-minded folks.

Robb calls this new type of conflict "open-source warfare," because the manner in which insurgent groups are organizing themselves, sharing information, and adapting their strategies bears a strong resemblance to the open-source movement in software development. Insurgent groups, like open-source software hackers, tend to form loose and nonhierarchical networks to pursue a common vision, Robb says. United by that vision, they exchange information and work collaboratively on tasks of mutual interest.

And just as in the software community, information technology and the Internet play a pivotal role in bringing insurgents together. The resurrection of al-Qaeda is a good example, says Brian Jackson, a terrorism expert and associate director of the Homeland Security Program at Rand Corp. "Given the structural changes that were required of al-Qaeda to adapt to its loss of Afghanistan as a safe haven," Jackson says, "the interconnections among disparate parts of the decentralized organization that the Internet made possible have been important for its survival."

The reliance on IT also enables open-source groups to identify and respond to problems much more rapidly than a more structured, top-down entity can—be it the Pentagon or a large software company such as Microsoft. According to some estimates, it now takes Iraqi insurgents less than a month to adapt their methods of attack, much faster than coalition troops can respond. "For every move we make, the enemy makes three," U.S. Brigadier General Joe E. Ramirez Jr. told attendees at a May conference on IEDs. "The enemy changes techniques, tactics, and procedures every two to three weeks. Our biggest task is staying current and relevant."

Unfortunately, the traditional weapons-acquisition process, which dictates how the United States and other Western militaries define and develop new weapons systems, is simply not designed to operate on such a fleeting timescale. It can take years and sometimes decades—not to mention many millions or billions of dollars—for a new military machine to move from concept

BOTTOM, FROM LEFT: SULTAN AL-FAHD/REUTERS; ANJA NIEDRINGHAUS/AP PHOTO; PETER MACDIARMID/GETTY IMAGES; MARCO DI LAURO/GETTY IMAGES; EDY PURNOMO/GETTY IMAGES

WORLD AT WAR: Bombings in [from left] Bali, Indonesia; Amman, Jordan; London; Madrid; and Riyadh, Saudi Arabia, highlight the ease with which extremists can now attack.

to design to testing and out into the field. Worse, the vast majority of the battlefield technologies now wending their way through the acquisition bureaucracy were intended to fight large force-on-force battles among sovereign nations, not the guerrilla warfare that typifies the conflicts in Iraq, Afghanistan, and elsewhere.

Meanwhile, time is on the insurgents' side. Since the start of the war, the consumer-grade products on which they rely have undergone several generations of improvement. Microprocessor speeds, for instance, have leaped by a factor of at least four in that time, while the cost per MIPS—or million instructions per second, a standard benchmark for processors—has dropped by roughly 70 percent.

This past spring and summer I interviewed dozens of current and former military officers, analysts, weapons developers, and others to try to understand why the coalition forces' technological might has proved so ineffectual. Nearly everyone I spoke with agreed there is a serious mismatch between the West's industrial-age approach to warfare and the insurgents' more fluid and adaptive style. All agreed, too, that the West will likely face more such confrontations in the years and decades ahead. The big concern, many people told me, is that once the war in Iraq has ended, the innovation that has occurred there and the lessons learned will be lost as the Pentagon returns to "business as usual"—that is, building enormously complex and costly weapons systems and training troops to fight large-scale wars.

TO UNDERSTAND open-source warfare, it's instructive to revisit Eric S. Raymond's 1997 manifesto, *The Cathedral and the Bazaar*, in which he describes how a large community of open-source software hackers created the operating system Linux.

"Linux is subversive," Raymond wrote. "Who would have thought even five years ago [1991] that a world-class operating system could coalesce as if by magic out of part-time hacking by several thousand developers scattered all over the planet, connected only by the tenuous strands of the Internet?" He likened the rise of Linux to the public marketplace of the bazaar. The programmers agreed to observe a few simple principles but were otherwise free to innovate and create. Raymond contrasted that style with the "cathedral" approach to software, in which a single organization, using highly planned, sequentially structured steps, maintained tight managerial control over every aspect of the process.

Eventually, the open-source culture would triumph over the proprietary world, Raymond argued, not because it was morally right "but simply because the closed-source world cannot win an evolutionary arms race with open-source communities that can put orders of magnitude more skilled time into a problem."

In studying the behaviors of insurgencies in Iraq and elsewhere, as well as organized-crime syndicates and other groups, Robb noticed the many parallels to the open-source model in software. In addition to working in counterterrorism, he has also had a successful career as a software entrepreneur.

Groups like al-Qaeda resemble in some ways the classic insurgents of the past, such as the Palestine Liberation Organization, but several factors distinguish them from their predecessors, Robb says. For one, they aren't state-sponsored, which makes them harder to track down and eradicate. Being self-financed, they generate significant income from donations as well as from black-market commerce. Also, members of the group don't report to a central authority; they operate relatively autonomously, and they tend to be well educated, media-savvy, and comfortable operating in a globalized, high-tech world. And the use of information technology has given modern terrorists an operational edge their predecessors lacked.

Mimicking open-source developers, insurgent groups "hack at the source code of warfare," Robb says. By that, he means they aren't bound by the traditional rules of military engagement; they use whatever works, with their tactics, techniques, and procedures all open to scrutiny and improvement by the community. Although such groups are weak by conventional military benchmarks—they'd clearly be outgunned and outmanned on an open battlefield—they can still threaten strong national militaries. That's because they don't aim to invade, hold, or govern territory, but rather to exert political influence by exhausting an adversary's capacity to fight back. Their preferred method of attack is to disrupt infrastructure, whether physical, financial, or political [see photos, "World at War"]. "System disruption is going to be the main thrust of warfare for quite a long time," Robb predicts.

RAND CORP.'S JACKSON has also studied terrorist organizations with an eye toward how they learn and share information—which he discussed in a recent report titled "Aptitude for Destruction." Access to the Internet, Jackson says, has given such groups "a quantum leap in capability to get their message out."

Many of the insurgent groups in Iraq, he notes, "are very Internet-savvy in terms of using it as an information-dissemination medium." The number of Web sites run by terrorists climbed from fewer than a dozen in 1997 to nearly 5000 in mid-2006, according to Gabriel Weimann, a professor of communications at the University of Haifa, in Israel, who has studied terrorism and the mass media. Not all of those sites pose a significant threat. Last year, a team of Pentagon analysts told Congress that of the thousands of jihadist sites they monitor, they closely watch fewer than 100—the ones they deem the most hostile.

Whereas the mass media used to control access to the public, Jackson says, insurgents now post videos and descriptions of their attacks online within hours of their occurrence, many of which are then picked up and replayed in the global media. Al-Qaeda has a media affiliate that produces slick, branded video and audio files for online distribution. The videos are often encoded in multiple formats, so you can watch them on your cellphone or play them on a big-screen television. Some insurgents are even shooting in HDTV.

Terrorist Web sites serve not only to spread propaganda but also to share knowledge among insurgent groups, Jackson says. That helps explain why the learning cycles among Iraqi insurgents are some 20 times as fast as the Irish Republican Army's were in Northern Ireland in the 1980s, according to military estimates. The SITE Institute, a group in Washington, D.C., that monitors terrorist Web activities, has documented numerous cases of technical know-how being exchanged online. These include a slide presentation posted on a password-protected Arabic-language forum purporting to teach "beginner jihad fighters" how to rig a car bomb, as well as a training manual—linked to from various jihadist forums—that claims to cover explosives, poisons, and forgery, among other topics [see photos, "Bomb Building 101"].

To be sure, the technical information that goes up on such sites is not always to be trusted, notes Michael Kenney, an assistant professor of public policy at Pennsylvania State University in Harrisburg. "Some of the terrorist instructional manuals and online chat rooms that have received so much attention in the press are, in fact, littered with basic mistakes," Kenney says. He had one of the world's leading explosives experts review some online training manuals. The expert found that "for every four or five recipes, one may work, [but] only a trained eye can catch" the errors, Kenney says.

Kenney also wonders how much a budding guerrilla can learn by simply reading. "Building bombs with your bare hands is still the best way to learn how to build bombs," he says. "Shooting a firearm over and over is the best way to become a sharpshooter. These are skills that cannot really be learned from recipes that you download through the Internet.... The reason Iraq has proven to be such a rich learning environment for insurgents has more to do with practical, on-the-ground opportunities for learning that the fighting provides."

Nevertheless, he agrees with Jackson that terrorist groups are proving to be fast learners. They're able to change their activities in response to practical experience and technical information, store this knowledge in practices and procedures, and select and retain routines that produce satisfactory results. As they gain experience, their learning cycles will only continue to shorten.

All the bomb-building advice in the world would be meaningless, of course, if the materials to build those bombs weren't also easy to come by. But they are, and terrorist groups are proving adept at using commercial, off-the-shelf technology to create effective and low-cost weapons systems.

A good example is last year's plot to smuggle common chemicals on board commercial flights using drink containers. The chemicals would then be mixed together to form explosives, which if detonated by a small charge from, say, a few modified AA batteries, could be powerful enough to bring down the aircraft.

Here again, information technology plays a crucial role. Fast and efficient worldwide distribution channels set up by the likes of Wal-Mart and Federal Express greatly simplify the acquisition of requisite components. Free from the administrative burdens of maintaining their own infrastructure, terrorist groups can spend the majority of their time on how best to achieve their collective vision.

THE CONFLICT IN IRAQ has become a test bed for open-source war, and the insurgents' weapon of choice is the IED. Since the beginning of the war, insurgents have rapidly improved their ability to create, deploy, and detonate IEDs [see photos, "Fast, Cheap & Out of Control"]. They've moved from simple makeshift explosives—old artillery shells or fertilizer—to shaped charges that can penetrate heavy armor plate and to buried explosives that can destroy a 61-metric-ton Abrams tank. In one favored mode of attack, insurgents detonate an IED beneath a military convoy vehicle, then follow up with a barrage of rocket-propelled grenades and rifle fire.

Even as coalition troops have become proficient at identifying roadside bombs, insurgents have shifted to using IEDs to booby-trap houses. "Nothing they're doing is going to win any prizes from the Department of Defense for high tech, but the stuff is deadly," says Lawrence Husick, a senior fellow at the Foreign Policy Research Institute, in Philadelphia. "They're using a huge variety of cheaply available stuff." One recent innovation is IED detonators made from battery-powered doorbells. The doorbells consist of crude 400-kilohertz transmitters and receivers. "They're sloppy as hell, but they are really hard to jam," Husick says.

That unconventional style of mine warfare is something coali-

BOMB BUILDING 101: These Arabic-language Web sites offer how-to tips on constructing homemade explosives. The factual information is often sketchy, though.

SITE INTELLIGENCE GROUP (2)

tion forces clearly didn't anticipate, and response has been slow. Earlier this year, for instance, the Pentagon decided to spend $25 billion on mine-resistant ambush-protected (MRAP) armored vehicles, whose V-shaped hulls and raised chassis make them better than armored Humvees at fending off bomb blasts [see photo, "Help Is on the Way"]. The price tag includes $750 million to airlift the 12-metric-ton vehicles to Iraq, instead of sending them by ship. In August, though, the Pentagon scaled back its schedule, saying only 1500 of the planned 3900 vehicles would be delivered by year's end.

"As the war winds down, the forces of standardization will reassert themselves. That's likely to kill many of the innovations now in use on the battlefield"

It's a race against time. As happened first to unarmored Humvees and then to armored Humvees, insurgents have made destroying MRAP vehicles a high priority—a "trophy kill," as some observers call it. MRAP designs are already reportedly being rethought to deal with emerging insurgent tactics.

You might think that the lag time was due to bureaucratic screwups, but in fact, that's just how long the bureaucracy takes to respond. Marine commanders in Iraq first requested MRAP vehicles in May 2006. Acquisition officials reviewed the request and ultimately approved it late in the year. By April, five suppliers had demonstrated they could meet survivability requirements, production numbers, and delivery timelines, and they were then awarded contracts. But ramping up production doesn't happen overnight. Before MRAP vehicles became a high priority, the sole manufacturer, Force Protection, in Ladson, S.C., was making only about five per month.

Acquisition is even more cumbersome when the United States wants to send equipment to Iraqi security forces. Any request for equipment is first given a congressional review, which takes up to a month. Then the U.S. government has to draw up a letter of acceptance, which must be signed by the Iraqi government, after which a payment schedule is negotiated. Only then can the Defense Department begin to procure the requested equipment—which itself takes time. Clearly, the longer it takes Iraqi security forces to get their equipment, the longer coalition forces will have to remain there.

Meanwhile, U.S. military strategy has only slowly started to move away from the objective it has had since the start of the Cold War: acquiring a technologically superior military capable of fighting (and winning) two major wars simultaneously. During the past decade, efforts have been under way to transform the military into a more agile force, one that can fight not only traditional wars but also irregular or asymmetric conflicts.

But while the overall strategy may be shifting, the dependence on high-technology weaponry has not. Creating and maintaining a high-tech force has proven both costly and time-consuming. Today, it takes 12 to 15 years to field a major weapons system, according to the U.S. Government Accountability Office (GAO). The newest U.S. Air Force jet fighter, the F-22A Raptor, was finally declared operational in December 2005—*25 years* after the requirement for the aircraft was approved. Although the Air Force originally planned for a force of 750 Raptors, at the current price of $138 million per plane, fewer than 200 will likely ever be built.

The weapons acquisition process is still geared toward building traditional battlefield systems like the F-22. Even after the Cold War ended—and with it, the pressure to build large numbers of complex weapon systems—decisions made decades earlier continued to prevail.

There has been no shortage of attempts to streamline weapons acquisition. Since 1975, at least 129 studies have been conducted on how to reform the process and make it more rational and responsive. Few of the recommendations have had any lasting impact, though. A March 2006 GAO report found that for the largest acquisition programs, the average estimated development time has risen from 11 years to 14 years. Even if you could design an F-22 in a single day, it would still take years to prepare the paperwork to win funding and more years of operational tests before the plane could go into full-scale production.

The financial stakes work against reform. In a report to Congress earlier this year, David Walker, comptroller general of the United States, said that annual U.S. investments in major weapons systems had doubled between 2001 and 2006, from $750 billion to more than $1.5 trillion.

Many of the defense experts I spoke with advocate a separate acquisition process to deal with the type of irregular warfare now being fought in Iraq. Robb, for one, isn't convinced that this would make much of a difference. "The big-war crowd doesn't want to understand open-source warfare," he says.

As Upton Sinclair once said, "It is hard to get a man to understand something if his living depends on him not understanding it."

STAFF SGT. JASON ROBERTSON/DOD PHOTO

HELP IS ON THE WAY: The Pentagon plans to send thousands of mine-resistant ambush-protected vehicles to Iraq in the coming year. But MRAP supply is lagging far behind demand.

FACED WITH THE CRISIS IN IRAQ, the Pentagon has made a number of attempts to speed up the acquisitions process. The U.S. Army, for example, has established a Rapid Fielding Initiative to try to shorten the time it takes to get requested equipment to soldiers. That has enabled the deployment of the Advanced Combat Helmet, which offers better protection, comfort, and hearing, and an improved first-aid kit for treating bleeding and removing airway obstructions. The Army's Rapid Equipping Force identifies unconventional commercial products that may be of use on the battlefield. Industrial leaf blowers, for instance, are now being strapped on to vehicles to blow away dirt and debris from hidden bombs.

The Pentagon is also now granting certain high-priority projects "rapid-acquisition authority." That process allowed warheads for the thermobaric Hellfire missile, used to attack caves and tunnels, to be developed in just 60 days, rather than the year it might have taken.

Then there are the robots, like the PackBot and the unmanned combat air vehicles (UCAVs), which have proved invaluable in Iraq and elsewhere. Many of these systems are not being developed as "programs of record"—although they're in wide use, they are still considered prototypes in the R&D phase. As such, they are continually being improved and refitted based on real-world experience. The companies that design the robots tend to be small, entrepreneurial enterprises, and therefore quick to respond and change. Already, some 3000 smaller ground robots have been deployed in Iraq and Afghanistan. About 1000 unmanned aerial vehicles of various stripes have also been deployed—from hand-launched, low-altitude surveillance planes to high-altitude, remotely piloted Reaper UCAVs equipped with infrared, laser, and radar targeting as well as four air-to-ground Hellfire missiles and two 500-pound bombs. These machines are probably the closest thing to an "insurgent-resilient" weapons system that the West has.

> "What do you do when women and children come out with spray cans and hammers and start attacking your robots?"

The West's reliance on robotic war machines is certain to continue. Back in 2001, Congress mandated, as part of the National Defense Authorization Act, that "by 2010, one-third of the operating deep-strike aircraft of the Armed Forces are unmanned, and by 2015, one-third of the operational ground combat vehicles are unmanned." The danger is that as the cost and complexity of the robots grow, they will cease to be considered "expendable" assets. Already, a four-aircraft package of Reapers carries a price tag of nearly $70 million. It's not hard to imagine the day when UCAVs will end up costing as much and taking as much time to develop as the manned systems they're intended to replace.

Growing reliance on robots also raises operational—if not ethical—questions. "What do you do when women and children come out with spray cans and hammers and start attacking your robots?" asks William Lind, a military expert with the Free Congress Foundation, a conservative think tank in Washington, D.C. "Are you going to shoot them to defend your robots?"

And so, for the most part, such shortcuts in acquisition are mere Band-Aids. The current approach effectively decouples the needs of soldiers on the ground from the process of acquiring the equipment they'll ultimately get. No sustained attempt has been made to create an insurgent-resilient model of acquisition.

WHAT ALL THIS LIKELY MEANS is that when the wars in Iraq and Afghanistan finally end, the Pentagon's current "cathedral" approach will envelop robots, UCAVs, and any other interesting technology developed in the heat of battle. "As the war winds down, the forces of standardization will reassert themselves," says Rand Corp. vice president Thomas McNaugher, an expert on defense acquisition. "That's likely to kill many of the innovations now in use on the battlefield."

Robb says the solution is for defense acquisition to move away from what he calls "point innovations"—that is, stand-alone systems—to platform-based systems. A platform, he explains, is a collection of services and capabilities that everyone gets access to. Think of the Internet and how eBay and Google exploit it.

How would such platforms work in the military sphere? Consider a project under way at the Space Vehicle Directorate at Kirtland Air Force Base, in New Mexico. Researchers are attempting to design inexpensive "plug and play" satellites that could be fielded in six days or less. Each satellite would be built from a set of standard components that could then be quickly programmed to fit the specific mission.

To avoid getting trapped in a one-size-fits-all mentality, says Jim Lyke, technical advisor to the project and its principal electronics engineer, "We intentionally made it easy to swap out a small battery for a big battery, [an] X-band radio for a Ku-band radio, and so on." The concept is sort of like adding components and loading software onto your PC, depending on whether you want to create spreadsheets, play games, or listen to music.

"We are waging a battle against complexity," Lyke says. The six-day target "became a rallying theme to force us way out of our comfort zone."

Lind of the Free Congress Foundation says it's also important to capture the innovations going on in the trenches. "There is a tremendous amount of creativity at the junior level, but there is no outlet for it. We need to richly resource sergeants and let them tinker," he says. "The kinds of technology that are useful in these wars are what I call garage and junkyard technologies." The original armor for Humvees, for instance, was cobbled together by soldiers in the field, who dubbed it "hillbilly armor." Once a useful technology has been discovered, Lind adds, that information can be rapidly conveyed using the military's secure intranets. The idea is to make use of information and IT just as the insurgents do.

Meanwhile, what is happening in Iraq and Afghanistan is only a foreshadowing of the types of conflicts that Western countries will likely face in the coming decades. Insurgent learning will continue long after coalition forces have withdrawn from those countries. To face this future, it seems clear that the West urgently needs an insurgent-resilient process for developing and fielding effective military systems and tactics, along with a radical change in strategic thinking.

"We have to look outside the normal bureaucratic way of doing things," U.S. Secretary of Defense Robert M. Gates noted at a press conference in June. "For every month we delay, scores of young Americans are going to die." If the United States and its allies fail to embrace the need for change, they will inevitably pay the cost in both treasure and blood. ■

ABOUT THE AUTHOR

Contributing Editor ROBERT N. CHARETTE is an IEEE member and risk-analysis expert in Spotsylvania, Va. His blog Risk Factor is at http://blogs.spectrum.ieee.org/riskfactor.

TO PROBE FURTHER

Michael Kenney's *From Pablo to Osama: Trafficking and Terrorist Networks, Government Bureaucracies, and Competitive Adaptation* (Penn State University Press, 2007) looks at the learning styles of terrorists and drug traffickers.

John Robb's *Brave New War: The Next Stage of Terrorism and the End of Globalization* (John Wiley & Sons, 2007) describes the emergence of open-source warfare.

Transcripts from three of the author's interviews are available at http://www.spectrum.ieee.org/nov07/moreosw.

The author plans to explore the topic of weapons development and acquisition in a future issue of *IEEE Spectrum*.

PROFILE

THE SLASHDOT SUPREMACY

BY DAVID KUSHNER

How a Michigan geek tamed the online masses

DEXTER, MICH., POPULATION 2338,

is not the sort of place you'd expect to be one of the hotbeds of Planet Geek. The downtown, located 10 miles west of Ann Arbor, is a one-block strip of mom-and-pop shops. Tiny kids in white outfits file out of the Dexter Karate Academy. The yeasty smell of hops and barley wafts from Jolly Pumpkin Artisan Ales, the local microbrewery.

But behind the front door of an unmarked beige warehouse on Broad Street, you'll find an übernerd hunched over a desk precariously stacked with books on network security and ASP.net development, choosing the technology news stories that half a million fellow geeks will read that day.

On the opposite wall, there's a satirical "demotivational" poster. "DEFEAT," it trumpets, over a sweeping photo of marathon runners, "For Every Winner, There Are Dozens of Losers. Odds Are You're One of Them."

"The company that makes that poster was going out of business," Rob Malda, a 31-year-old with a pointy beard and glasses, tells me as we pass by. "But then we linked to them, and they survived."

That's the power of Slashdot, the Web site Malda runs from here. Launched long before blogs and news aggregators ruled the Internet, Slashdot has spent the past decade cherry-picking and linking to what the site bills as "news for nerds"—the cool and crucial science and technology stories that Malda and his crew of nine think you must know: a massive cave found on Mars; artificial intelligence used to train firefighters; a "chairbot" that walks you around while you sit. The site has run more than 78 000 articles since it launched in 1997, and it is still growing rapidly.

As a result of its erudite linking, Slashdot has built one of the most feverishly loyal and influential communities of geeks online. Each day the site gets about 500 000 visitors, who view some 2 million pages. And as it is the early adopter's tastemaker, its power is mighty. Getting a link from the site—getting "Slashdotted"—has a viral impact. Just ask the makers of the demotivational posters or anyone else who has experienced the so-called Slashdot effect, which can sometimes be too much of a good thing. Slashdot is the 800-pound gorilla of discussion sites, and a single mention there can generate enough traffic to overwhelm a smaller site's servers with traffic, temporarily killing it with attention. *Fortune* magazine once called Slashdot "the future of media." In 2001, *Time* named Malda one of the top innovators of the 21st century.

The online landscape has changed, though. The selection and linking that Slashdot pioneered has since become the stuff of the blogosphere, and now news aggregators, like Digg, have been stealing its thunder. Taking into account a combination of page views and users, research firm Alexa Internet, in San Francisco, ranks Digg's site close to 100th, whereas Slashdot falls near 600th. *Business 2.0* recently listed Malda as one of 10 "People Who Don't Matter." "The buzz has moved elsewhere," the story said. "Slashdot's editor-driven story selection model is being supplanted by user-generated systems such as Digg."

Not everyone agrees. "Obviously, Digg is much bigger than Slashdot," says Barry Parr, media analyst at JupiterResearch, a technology research firm in New York City. "But the truth is that every day the home page of Slashdot is a must-read for a certain part of the online community in a way that Digg is not."

The value of Slashdot in the age of online social networks is precisely in its editorial capacity, the fact that techies—whether astrophysicists or toy designers—can count on Malda and his discerning squad of geeks to sift through the Web's vast detritus for the worthy nuggets. And if you want to know what Malda counts on, it's the unabashed certitude of his position in, and contribution to, the online ecosystem. "I want to tell my friends about the 15 things that matter most," says Malda. "If we pull that off, then we're doing our job." He says Digg's recommendations are haphazard and that the two services are "apples and oranges."

Although Malda's site has been criticized for lagging on redesigns—it's had only one major overhaul since its inception—it has succeeded by harnessing and, in a sense, gaming the tyranny of the masses. Behind the scenes, Malda and his team have designed and coded a unique system for keeping information and opinions flowing but under control.

Malda has plenty of work still ahead. In the wings is another big change, a system called Firehose, which will try to meld the assessments of knowledgeable moderators with a popularity rating. Just don't call it the "D" word. "This idea was pre-Digg," says Malda. "The wisdom of crowds is a good thing, but mob rule is a problem," he adds. "The successful way of dealing with that is to be a little of both."

SLASHDOT SERVES ITS GEEKY AUDIENCE so well because Malda himself is among them. "I've always characterized it as 'me,'" he says. "It's people who like to write code and love technology."

Like his readers, Malda was a self-educated brainiac from the start. Growing up in the bit-size town of Holland, Mich., he started coding on his Radio Shack TRS-80 in fourth grade and never looked back. He spent so much time writing computer games and surfing primitive bulletin-board networks on his 1200-baud modem that his mother once grounded him by locking his keyboard in the trunk of her car. But Malda fought back with ingenuity, as he once described on his blog: "Since this was the days of DOS, I just added a keyboard error-code check to my autoexec.bat file, which launched a BBS so I could simply get at my data from a friend's house. Sorry, Mom."

While studying computer science at nearby Hope College, Malda stumbled on a like-minded group: the community that had formed around Linux, the open-source operating system. The appeal of Linux was intense. "You could pop off the lid and study it," Malda says. In July 1997, years before anyone knew a blog from a podcast, Malda started posting his technology takes on a site he cheekily called Chips and Dips. Two months later, he renamed it Slashdot because the original URL "was difficult to pronounce." He chose his handle, CmdrTaco, from a joke about bad restaurant names in a book by humor columnist Dave Barry.

It didn't take long for Slashdot to unfurl its geek flag. In December 1997, Malda anticipated the marketplace victory of Microsoft's Internet Explorer 3.0 browser and suggested that Netscape's only way to compete would be to cough up its source code. Six days later, Netscape obliged. Although Malda doesn't think he was the singular catalyst, his prescient call earned techie respect—and influential readers.

"That was an era when the plumbers of the Internet had the power," Malda recalls. "If you knew a lot about Linux, you could

SLASHDOTTER-IN-CHIEF: In June 1999, at the very height of the dot-com boom, Slashdot, brainchild of Rob Malda, was acquired by Andover.Net.

be a major corporation's entire Internet department. I wasn't conscious [of anything] except that I was a plumber, too. So I was making the site I wanted to read, and it turned out I was one of tens of thousands of others."

By the fall of 1998, Slashdot had about 300 000 daily readers and enough ads for Malda to quit his day job as a PC technician, pay himself a US $40 000 annual salary and run the site full-time, with the help of buddy Jeff Bates. They set up shop in what Malda calls a "crappy college house." But the water-rotted ceiling was the least of their troubles. The plumbers piping into Slashdot proved to be just as unkempt.

Although communities had been coming together on the Internet in the form of bulletin-board services and newsgroups for years, the Web's rapid growth was, by this time, testing the limits of online crowd control. New breeds of disrupters began taking to the Slashdot forums: trolls who were looking for a fight, plagiarizers, spammers, copyright-violating cut-and-pasters, and grammar fanatics who savaged every entry with overzealous critiques. After Malda proposed marriage to his girlfriend in a Slashdot forum on Valentine's Day in 2002, one of the comments made was, "Good luck to you, but bah humbug on valentines day."

"The ultimate goal is sharing ideas and information," Malda says, "and if you're nitpicking about grammar, you're wasting everyone's time." To survive, Slashdot had to achieve the unimaginable: tame the geeks without turning them away. "If you put up a billboard in front of all of New York, someone will climb the pole and spray-paint it," Malda says. "You can't stop them. You have to gain leverage against them. It's a never-ending arms race."

In June 1999, at the very height of the dot-com boom, Slashdot was acquired by Andover.Net, the Linux hub, which was itself bought the next year by VA Linux, the computer systems service. Andover.Net went for more than $1 billion, but Malda, who prefers not to divulge his specific earnings, insists his take in stocks was not retirement money and, essentially, "nowhere near anything impressive." He remained onboard as Slashdot's chief; he still had plenty he wanted to accomplish.

IT'S MIDMORNING AT SLASHDOT as Malda bounds into his office. There's a doll of Tim the Enchanter from *Monty Python and the Holy Grail* on his desk and a lamp filled with marbles. Anime posters cover the wall. When his cellphone rings with the presumably ironic ringtone of Britney Spears's "Baby One More Time," Malda taps the mute button. He has work to do.

Every day, Slashdot receives anywhere from 200 to 500 story submissions from readers, but it runs only 20 to 30 of them. To submit a piece, visitors are urged to use the Submissions Bin, an online form, instead of e-mail. Malda instructs users to include concise subject headers and not to submit duplicate stories, but the growing pool of candidates gets harder and harder to wade through. Malda and his team judiciously fish out only the best.

"Machine-learning algorithm fights cancer," Malda says, reading from his screen. "We've already run that story." He taps Delete, then scrolls down and opens up another message. "Edible RFID? I'm not sure if I'm interested in that; it's sort of overhashed." Delete again.

To hold back the flood of information, the team has engineered a method to the madness. It all starts with "Daddypants," the term given to the person in charge of weeding through the submissions at any given moment and making the executive call as to what gets on the site. Malda isn't the only one who wears the pants.

Each Slashdot worker has a specific shift and expertise, and although the staff has an office, team members generally work from their homes. Bates handles the science and biology beat; Malda oversees the techie stories; an editor nicknamed "Zonk" covers gaming and Linux. "We all trust each other's judgment," Malda says. If the story meets their criteria to be "stuff that matters," it gets categorized and placed into an appropriate section of the Slashdot site, such as Linux, Supercomputing or Geeks in Space.

But selecting and classifying submissions is only the first step. Every day, the two dozen or so stories Slashdot publishes elicit thousands of comments from readers. The problem, of course, is that a lot of the comments come from people making off-topic remarks or stirring up arguments just for the sake of arguing. A few such submissions can be tolerated, but enough of them, like spam, can overwhelm readers and make the worthwhile comments too hard to find.

After some experimenting, Slashdot enlisted voluntary moderators to grade the comments and help make sense of the chaos. "The way the system is designed," Malda says, "it's hard for one person to be a tyrant and wreck it."

Today, Slashdot moderators are chosen from readers who put themselves up for consideration and have been, as Malda puts it, "actively contributing to the system." Qualifying activities include spending time on the site, submitting stories that get accepted, and having other readers move you up the scale by rating your comments highly.

Malda's code crunches the numbers and creates a curve representing the statistical distribution of reader activity. Malda then eliminates the outliers. At the highest point of the curve are the people whom he considers to be typical Slashdotters. These are the ones he wants moderating the threads. Malda likens the selec-

ALL PHOTOS: ROY RITCHIE

tion process to jury duty. On any given day, 30 000 readers may be eligible to be moderators, but only a few thousand are chosen. Although some moderators have been around since the early years of the site, newbies can join the ranks in as little as a few weeks.

Each moderator reads a comment and assigns it a numeric value on a scale of 1 (worst) to 5 (best). Readers elect to view only those comments that receive a minimum numeric value of their choosing; the average threshold selected is close to the default value, 2. Moderators also assign descriptive tags from a drop-down menu. If a comment is made simply to start a fight, it gets marked "Flamebait." Comments that don't move the conversation forward are branded "Redundant." Other labels include "Funny," "Informative," and "Off-topic."

The moderators' assessments carry weight. Each grade affects a member's so-called Karma level—a scale that ranges from Terrible to Excellent, reflecting the person's standing within the community. The better your Karma, the greater your chances of being chosen as a moderator. But to ensure that everyone gets as fair a shake as possible, Slashdot also uses something called "metamoderation," a means by which visitors can rate the skill of the moderators. "It's a way of watching the watchers," Malda says.

THE COLUMBINE TRAGEDY TOUCHED ON POPULAR SLASHDOT THEMES OF GAMING AND MEDIA

SLASHDOT'S BIGGEST CHALLENGES have tended to follow major news events, such as the 1999 Columbine shootings or the levee failures during Hurricane Katrina in 2005. Because the Columbine tragedy touched on popular Slashdot themes of gaming and media, the site's coverage generated huge discussion threads. Although a typical story ordinarily garners about 300 comments, Slashdot's Columbine pieces engendered more than 1000 each—numbers that may sound tame by today's standards but that felt overwhelming in 1999. "Our system was not made to deal with that amount of comments," Malda says. "We had to rewrite it so it would handle thousands."

By 2001, Slashdot's 10 servers, located in San Francisco, were able to sail through the biggest story they'd ever faced: 9/11. Other online news sources were getting crushed under the weight of traffic that day. Even CNN was crashing now and then. But Slashdot, with its new system in place, stepped up to the plate. "We knew how to sort through information and run the site effectively," Bates says. And as word spread, nontechnical readers began visiting the site that day—and the following days—in droves. To handle the tripling of traffic, Malda switched off nonessential features such as the logging of server activity.

But keeping everything in line is a work in progress. In 2004, Malda and his colleagues took Slashdot through its first major redesign. The site, which was originally written in HTML, had to be rebuilt, which proved to be a formidable challenge. They opened up the process to users, calling for their suggestions as to what they thought the site should be. More than 100 readers sent in opinions, and Malda incorporated the best ideas.

Currently, the system employs asynchronous JavaScript and XML, a more structured superset of HTML that is increasingly the lingua franca of interactive online applications, in addition to Perl. And Slashdot is currently beta-testing two tools to help improve the flow. One is Discussion 2, a system that allows a reader to expand and contract a comment thread without having to reload the page. This feature doesn't work well with Internet Explorer, a situation about which Malda is not exactly apologetic. The vast majority of Slashdot readers use Firefox. "We only have 20 percent of our population on Internet Explorer," he says. "It's exactly flipped from the Internet as a whole."

While Slashdot gets refined, however, it has become harder for Malda to ignore the impact of competitors, particularly Digg, which positions itself as a populist answer to the top-down model. "Digg is like your newspaper, but rather than a handful of editors determining what's on the front page, the masses do," Digg founder Kevin Rose recently said. "Our algorithms make sure a diverse pool of unique Diggers likes a story before promoting it to the front page." The algorithms also weight the recommendations of some Diggers more than others.

Malda, however, questions the integrity of that system. People on Digg "have the feeling that they are the ones determining what goes on the main page, and administrators on the site are all too happy to let that delusion persist," he says. "[But] stories randomly disappear. Obviously there are higher powers at work."

Although Malda says the comparison between the two sites is apples and oranges, Slashdot is experimenting with its Digg-like project, Firehose, to open up the editorial process. The idea came from a mounting problem: how to deal with the increasing flood of submissions, as many as 500 a day. Firehose lets readers see and rate submitted stories just as the Slashdot crew does, before the stories hit the main site. Readers can expand or contract the list of stories and filter those that have already been ranked according to popularity.

"The interface for maintaining the site behind the scenes was old and dated," Malda says. "It was designed for me when I was the only one doing it in '98. Right now, three or four people are looking at stories on any given day. Why not make it work for thousands?"

So far, the response to the Firehose test has been "surprisingly positive," Malda says. "I don't know exactly how this will change us," he adds. "I want to use the Firehose but still maintain the quality and consistency that makes Slashdot great. Currently I use the Hose as a trusted bit of advice on each selection. Sometimes I disagree, but in general it's a very useful tool."

Malda makes no bones, however, about the value of the top-down model that has made Slashdot a must-click. "The stories on Slashdot are ones I chose," he says. "They're not chosen by democracy or random voting. I'm not pretending to say it's your opinion."

Slashdot's latest features are staying in beta for the time being. No matter how progressive the site's readers may be, they're averse to change, Malda says. "Slashdot people are ornery. When you change things, they get cranky." ■

ABOUT THE AUTHOR

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TO PROBE FURTHER

The ongoing Digg versus Slashdot brush war has been widely explored. Back in 2005 *Wired* speculated in a headline that "Digg Just Might Bury Slashdot" (http://www.wired.com/science/discoveries/news/2005/11/69568), which of course inspired a long Slashdot thread ("The Rise of Digg.com," http://slashdot.org/articles/05/11/17/1439224.shtml?tid=95&tid=124).

INTELLECTUAL PROPERTY

Keeping Score in the IP Game

QUANTITY AND CONCENTRATION OF PATENTS STRENGTHEN THE CASE FOR LEGISLATIVE REFORM

BY WILLIAM SWEET

A U.S. federal jury in February ordered Microsoft to pay Alcatel-Lucent US $1.52 billion in damages for infringing its intellectual property in MP3, the ubiquitous music-encoding software. Although in August an appeals judge reversed the decision in part and canceled the damages, the new ruling did not address Microsoft's main complaint, namely that U.S. patent law encouraged the jury to put excessive value on the IP in question. Microsoft may ultimately obtain a settlement it considers completely fair, but that could take so many years of costly litigation that even if the company wins, it will have lost.

The Microsoft-Alcatel MP3 case is just one of many that suggest to some that the patent system itself has lurched out of control, giving too much power to those laying claim to intellectual property and allowing too much leeway to patents of dubious quality or worth. Surely the case that has most captured the

Rank	Company/Organization, Country	2006 U.S. Patents	Pipeline Impact	Adjusted Pipeline Impact	Pipeline Generality	Pipeline Originality	Pipeline Power	Adjusted Pipeline Power
Aerospace and Defense								
1	**Boeing Co., U.S.**	**478**	**0.84**	**0.78**	**1.12**	**1.13**	**599**	**556**
2	Lockheed Martin Corp., U.S.	288	1.04	1.04	1.15	1.05	407	407
3	Raytheon Co., U.S.	221	0.81	0.81	1.00	1.03	229	229
4	Smiths Group PLC, United Kingdom	86	1.37	1.37	1.35	0.99	212	212
5	Northrop Grumman Corp., U.S.	221	0.74	0.74	0.85	1.03	154	154
6	Pratt & Whitney (subsidiary of United Technologies), U.S.	56	1.14	0.90	0.91	1.05	109	87
7	Goodrich Corp., U.S.	61	0.89	0.89	1.28	1.12	83	83
8	Airbus SAS (subsidiary of EADS NV), France	93	0.71	0.71	0.77	1.01	80	80
9	Rolls-Royce Group PLC, United Kingdom	107	0.71	0.71	0.74	0.81	75	75
10	Snecma (subsidiary of Safran SA), France	112	0.69	0.69	0.62	0.86	73	73
Computer Peripherals and Storage								
1	**Ricoh Co., Japan**	**727**	**1.77**	**1.22**	**1.92**	**1.04**	**3719**	**2575**
2	Seiko Epson Corp., Japan	1212	1.00	1.00	1.14	0.96	1796	1796
3	EMC Corp., U.S.	174	1.94	1.94	1.77	1.07	798	798
4	Hitachi Global Storage Technologies (subsidiary of Hitachi Ltd.), Japan	381	1.11	1.11	1.13	0.93	732	732
5	Immersion Corp., U.S.	34	2.12	2.12	2.55	1.62	562	562
6	Konica Minolta Holdings Inc., Japan	491	0.81	0.81	0.89	0.99	545	545
7	Symbol Technologies Inc. (subsidiary of Motorola Inc.), U.S.	119	1.68	1.68	1.48	0.93	536	536
8	InFocus Corp., U.S.	42	2.17	2.16	2.13	1.18	480	478
9	Seagate Technology LLC, U.S.	347	1.13	1.13	1.12	1.05	471	471
10	Network Appliance Inc., U.S.	63	1.99	1.99	1.91	1.08	464	464
Computer Systems and Software								
1	**Microsoft Corp., U.S.**	**1469**	**1.39**	**1.39**	**1.35**	**1.00**	**5300**	**5300**
2	International Business Machines Corp., U.S.	3651	0.96	0.96	1.04	1.00	4459	4459
3	Hewlett-Packard Co., U.S.	2115	1.05	1.05	1.16	1.06	3157	3157
4	Toshiba Corp., Japan	1987	0.97	0.97	1.01	0.93	2421	2421
5	Digimarc Corp., U.S.	77	3.32	2.46	2.42	1.28	1695	1254
6	Sun Microsystems Inc., U.S.	849	1.05	1.05	1.14	1.03	1248	1248
7	Fujitsu Ltd., Japan	1674	0.76	0.76	0.82	0.90	1168	1168
8	E Ink Corp., U.S.	24	5.00	2.73	5.00	1.46	1617	884
9	NEC Corp., Japan	1083	0.63	0.63	0.63	0.96	435	435
10	Oracle Corp., U.S.	211	1.01	1.01	1.03	0.90	396	396
Electronics								
1	**Hitachi Ltd., Japan**	**3198**	**0.91**	**0.91**	**0.96**	**0.93**	**3280**	**3280**
2	Matsushita Electric Industrial Co., Japan	2507	0.81	0.81	0.89	0.94	2185	2185
3	Sony Corp., Japan	1970	0.77	0.77	0.88	1.02	2164	2164
4	Xerox Corp., U.S.	552	1.04	1.04	1.22	1.04	907	907
5	TDK Corp., Japan	428	1.05	1.05	1.25	0.94	904	904
6	Sharp Corp., Japan	856	0.87	0.87	0.80	0.96	812	812
7	Koninklijke Philips Electronics NV, Netherlands	957	0.83	0.83	0.73	0.98	674	674
8	Hon Hai Precision Industry Co., Taiwan	474	1.08	1.08	0.86	0.77	548	548
9	LG Electronics Inc., Korea	712	0.78	0.78	0.74	0.92	534	534
10	Nichia Corp., Japan	38	2.63	2.63	3.16	1.01	392	392
Medical Equipment/Instruments								
1	**Medtronic Inc., U.S.**	**376**	**1.54**	**1.54**	**1.60**	**1.03**	**1229**	**1229**
2	Boston Scientific Corp., U.S.	551	1.44	1.11	1.45	1.11	1481	1146
3	Guidant Corp. (subsidiary of Boston Scientific), U.S.	230	1.78	1.21	1.48	1.08	676	457
4	Align Technology Inc., U.S.	17	2.19	2.19	3.35	1.01	357	357
5	Ethicon Inc. (subsidiary of Johnson & Johnson), U.S.	113	1.00	1.00	1.12	1.11	262	262
6	LifeScan Inc. (subsidiary of Johnson & Johnson), U.S.	31	2.13	2.04	4.13	1.10	265	254
7	Cardiac Pacemakers Inc. (subsidiary of Boston Scientific), U.S.	136	1.70	1.01	1.56	0.92	410	243
8	Sherwood Medical Co. (subsidiary of Tyco International Ltd.), U.S.	35	3.25	1.96	1.54	0.89	391	236
9	Baxter International Inc., U.S.	71	1.15	1.15	1.88	1.26	220	220
10	General Hospital Corp., U.S.	61	1.49	1.49	1.36	1.10	173	173

Semiconductor Equipment Manufacturing

Rank	Company/Organization, Country	2006 U.S. Patents	Pipeline Impact	Adjusted Pipeline Impact	Pipeline Generality	Pipeline Originality	Pipeline Power	Adjusted Pipeline Power
1	**ASML Holding NV, Netherlands**	**297**	**1.48**	**1.16**	**1.92**	**1.09**	**1897**	**1491**
2	KLA-Tencor Corp., U.S.	**127**	2.81	2.45	2.88	0.98	1632	1427
3	Applied Materials Inc., U.S.	**369**	1.74	1.62	1.91	1.15	1397	1298
4	ASM International NV, Netherlands	**95**	3.97	3.97	3.03	1.06	1060	1060
5	FormFactor Inc., U.S.	**36**	5.00	5.00	2.87	1.25	726	726
6	Micronic Laser Systems AB, Sweden	**14**	5.00	5.00	3.68	1.27	457	457
7	Amberwave Systems Corp., U.S.	**15**	5.00	4.24	4.96	0.99	426	362
8	Tokyo Electron Ltd., Japan	**237**	0.90	0.90	1.22	1.11	309	309
9	Advanced Semiconductor Engineering Inc., Taiwan	**83**	1.44	1.44	1.58	0.88	306	306
10	Aixtron AG, Germany	**13**	5.00	5.00	3.72	1.06	257	257

Semiconductor Manufacturing

1	**Intel Corp., U.S.**	**1961**	**1.18**	**1.18**	**1.23**	**1.04**	**3752**	**3752**
2	Broadcom Corp., U.S.	**661**	1.51	1.51	1.47	1.04	2410	2410
3	Micron Technology Inc., U.S.	**1617**	1.43	0.93	1.38	1.13	3696	2394
4	Samsung Electronics Co., Korea	**2474**	0.84	0.84	0.84	0.92	2346	2346
5	Semiconductor Energy Laboratory Co., Japan	**403**	1.90	1.16	2.32	1.17	2831	1728
6	Texas Instruments Inc., U.S.	**890**	1.06	1.06	1.11	0.94	1183	1183
7	Xilinx Inc., U.S.	**261**	1.49	1.47	1.87	1.03	1106	1088
8	SanDisk Corp., U.S.	**116**	2.51	2.24	2.47	1.04	845	755
9	Altera Corp., U.S.	**202**	1.42	1.25	1.70	0.98	822	726
10	Rambus Inc., U.S.	**101**	1.73	1.61	1.89	1.29	731	679

Telecom Equipment

1	**Cisco Systems Inc., U.S.**	**676**	**1.41**	**1.41**	**1.28**	**1.00**	**1796**	**1796**
2	Motorola Inc., U.S.	**798**	1.18	1.18	1.18	0.98	1484	1484
3	Nokia Corp., Finland	**744**	1.04	1.04	1.09	1.03	1340	1340
4	Qualcomm Inc., U.S.	**415**	1.23	1.23	1.30	1.01	1285	1285
5	Alcatel-Lucent, France	**885**	0.92	0.92	0.96	0.96	1002	1002
6	Finisar Corp., U.S.	**126**	1.60	1.59	2.01	1.14	515	513
7	Tekelec, U.S.	**44**	1.71	1.71	2.19	1.12	475	475
8	Juniper Networks Inc., U.S.	**85**	2.18	2.18	1.51	0.84	430	430
9	Telefonaktiebolaget LM Ericsson, Sweden	**390**	0.99	0.99	1.04	0.97	388	388
10	Nortel Networks Corp., Canada	**322**	1.17	1.17	1.20	0.99	374	374

Telecom Services

1	**AT&T Inc., U.S.**	**763**	**1.12**	**1.12**	**1.16**	**0.96**	**1445**	**1445**
2	Research in Motion Ltd., Canada	**88**	3.57	2.56	1.21	1.08	1233	882
3	Siemens AG, Germany	**1514**	0.67	0.67	0.69	0.99	822	822
4	Sprint Nextel Corp., U.S.	**191**	0.99	0.99	0.92	0.95	323	323
5	Nippon Telegraph & Telephone Corp. (NTT), Japan	**237**	0.86	0.86	0.96	0.96	298	298
6	Verizon Communications Inc., U.S.	**103**	1.46	1.46	1.40	1.04	203	203
7	InterDigital Communications Corp., U.S.	**213**	0.84	0.75	0.79	1.01	225	201
8	NTT DoCoMo Inc. (subsidiary of NTT), Japan	**140**	0.69	0.69	0.60	0.95	102	102
9	BenQ Corp., Taiwan	**138**	0.53	0.53	0.87	0.96	85	85
10	Qwest Communications International Inc., U.S.	**39**	0.94	0.94	1.23	1.05	68	68

Source: 1790 Analytics

The number for **2006 U.S. Patents** is a proxy for relative patent prowess worldwide. The **Pipeline Power** score is derived by multiplying the company's patent count by the product of four other variables. **Pipeline Growth** (not shown here) represents the firm's 2006 patent activity, relative to its average performance in the five previous years. For the other three variables, a score above 1.00 indicates that the company performed better than average in its technology class; below 1.00 indicates worse than average performance. **Pipeline Impact** indicates how frequently all 2006 patents cited a company's patents from the previous five years. **Pipeline Generality** is a measure of the variety of technologies drawing on a company's patents. **Pipeline Originality** measures the variety of the technologies upon which an organization's patents build. **Adjusted Pipeline Impact** eliminates self-citation. The final score, **Adjusted Pipeline Power**, is an estimate of a company's overall patent power. For the complete data, which include all of the top 20 companies in each category, as well as the Pipeline Growth and percentage of self-citation numbers, see http://spectrum.ieee.org/nov07/scorecard.

public imagination was the dispute over the technology of the BlackBerry personal communicator—which went on for years between Research in Motion, of Waterloo, Ont., Canada and NTP, a patent holding company in McLean, Va. Finally, last year RIM paid NTP upward of $600 million, complying with a court judgment.

The BlackBerry case drew attention to another much-criticized effect of the U.S. patent system: the presence of "trolls," who allegedly acquire patents, sit on them hoping that one or more will turn out to have crucial business applications, and then go to court to obtain what critics call extortionist payouts.

The data on U.S. patent awards for 2006 show that the patents in any given field still go to a few top companies, that there is little change from year to year among the dominant firms, and that big gaps yawn between the leaders and the runners-up. In almost all branches of electronics, computing, and telecommunications, awards made to the leading company jumped mightily from 2005 to 2006—by as much as 48 percent in semiconductor manufacturing, 60 percent in telecommunications equipment, and 65 percent in electronics [see table, "Patent Push"].

Steven J. Frank, a patent lawyer in Boston and author of the 2006 book *Intellectual Property for Managers and Investors* (Cambridge University Press), cautions that such studies of patent concentration and impact should be treated warily. "Just looking at the leaders, you have to ask what their game is," Frank muses. "Are they just trying to look like IP dynamos? Are they engaged in a kind of land grab?"

Of course that goes, too, for smaller companies making big jumps in the ranks [for some examples, see table, "Patent Performers on the Move"], some of which might be emerging stars, while others might be merely padding their patent portfolios as a public relations exercise. To take the numbers at face value, however, and to judge from the fields in which the companies are shifting position most radically and frequently, computing, semiconductors, and telecommunications appear to be among the most dynamic areas in what the patent world broadly calls information technology (IT). Presumably, some chip and telecom companies are being truly innovative, while others may be acquiring patents mainly to defend themselves against possible litigation and position themselves to bargain effectively in cross-licensing arrangements.

IEEE Spectrum's compilation of patent awards and patent impact was prepared by 1790 Analytics, a Haddonfield, N.J., company that specializes in evaluating intellectual property. This is the second year that the firm, which takes its name from the year the first U.S. patent was awarded, has provided its data to us.

The methodology this year is essentially the same as last year's [see "Patent Power," *Spectrum*, November 2006 at http://spectrum.ieee.org/nov06/4699]. This year, however, 1790 added a measure to account for self-citation, which produces lower Pipeline Impact ratings for companies whose patents are referenced mainly internally.

Take Boeing as an example, suggests 1790's director of research, Anthony Breitzman: its raw Pipeline Impact value of 0.84 drops to 0.78 when adjusted for self-citation. Largely because of the self-citation penalty, Micron Technology, a semiconductor maker in Boise, Idaho, falls sharply from being last year's overall patent winner and is replaced at the top of the heap by Microsoft.

Looking at the compilation as a whole, the impression is more one of stability than of change. In almost every major

subfield of IT, the same two or three companies appear among the top three or four. In fact, the top scorer changed in only one of the nine subfields: the newly merged Alcatel-Lucent overtook Motorola in Telecom Equipment.

The more things change, the more they stay the same, the French say...until, they might add, things really do change. This year, as this issue goes to press, Americans may at last see some real change in a patent system that almost every analyst considers seriously flawed. In fact, Congress is debating a reform bill that appears to have been developed in an intellectual and rational process, an event as happy as it is rare.

THE REFORM PROPOSAL began to take shape about three years ago, when a unit of the National Academy of Sciences headed by Stephen A. Merrill produced a report called "A Patent System for the 21st Century." The report recommended creating a procedure for challenging patents after they are issued, bolstering the traditional standard that patents should be confined to "nonobvious" ideas, and strengthening the overwhelmed U.S. Patent and Trademark Office. It also questioned U.S. rules that grant triple damages for "willful" infringement and give priority to those who are the first to invent something over those inventors who are the first to file for a patent.

The result was the proposed Patent Reform Act of 2007, sponsored in the Senate by Patrick Leahy (D-Vt.) and Orrin Hatch (R-Utah) and in the House by Howard Berman (D-Calif.) and Lamar Smith (R-Texas). It would establish a procedure for challenging patents after their issuance, limit the ability of litigants to shop around for courts deemed sympathetic, redefine what constitutes willful infringement, and set damages based on the patent's contribution to a product's value, rather than on the product's total value (a policy known as balanced apportionment). This last point addresses the issue in the Microsoft MP3 case. Microsoft's penalties were evidently set according to the total value of MP3 use involving its Windows Media Player.

Who will gain and who will lose if the bill becomes law? Basically, lobbying on the legislation has pitted the IT industries—including electronics, computing, and semiconductors—against the biomedical and pharmaceutical industries, which together account for most U.S. patents, says Frank.

Biomedical and pharmaceutical companies want ironclad patent protection, because they depend on a tiny handful of blockbusters to defray the billions of dollars they spend investigating hundreds of drug candidates that never pan out. Those blockbusters typically stand or fall on one or two patents. In IT, on the other hand, a winning product often results from a great many patents—MP3, Wi-Fi (IEEE 802.11), and 3G cellular telephony are excellent examples. Here, "things are less clear-cut" than with pharmaceuticals, Frank says, as it's less obvious that any particular patent is essential to accomplishing any particular thing. The big IT companies typically worry about being held liable by too many different parties for exorbitant damages.

Lobbyists include, on one side, the Business Software Alliance (composed of Microsoft, Apple, Hewlett-Packard, and a host of others) and on the other side, the Biotechnology Industry Organization and the Coalition for 21st-Century Patent Reform (representing, among others, drug maker Eli Lilly & Co. and consumer goods maker Proctor & Gamble). But even within the broad IT and pharmaceutical groupings, there are significant differences of opinion.

A survey last year of U.S. members of the IEEE found that they were not unanimous on the merits of the proposed bill. The IEEE's volunteer-driven lobbying arm, IEEE-USA, has submitted critical opinions about the draft legislation, saying it wants a bill but a better bill.

Under the circumstances, it's more than a little remarkable that a bipartisan consensus has formed around a patent reform bill that largely captures the spirit of what the NAS and what other critics such as Adam B. Jaffe and Josh Lerner have had in mind [see "Patent Prescription," by Jaffe and Lerner, *IEEE Spectrum*, December 2004]. Taken together with two significant Supreme Court decisions this year, which reinforced the "nonobvious" standard and limited the right to obtain an immediate injunction following a patent victory, enactment of the patent reform bill "would be a major step in the direction" of what Jaffe and Lerner proposed, says Jaffe, of Brandeis University, in Waltham, Mass.

At press time, it's considered a toss-up as to whether patent reform passes this year before the presidential election cycle begins. In any event, Lerner, of Harvard, expresses satisfaction that at least "something's finally happening after a long time of nothing happening." ■

Patent Push

Leading Company	Subfield	Number of Patents Awarded 2006	Number of Patents Awarded 2005	Percent Change (2006/2005)
Boeing	Aerospace	478	405	**18%**
Seiko Epson	Computer Peripherals	1212	887	**37%**
IBM	Computer Systems	3651	2972	**23%**
Hitachi	Electronics	3198	1941	**65%**
Boston Scientific	Medical Equipment	551	293	**88%**
Applied Materials	Semiconductor Equipment	369	371	**Flat**
Samsung	Semiconductor Manufacturing	2474	1676	**48%**
Alcatel-Lucent, Motorola*	Telecom Equipment	885 (Alcatel-Lucent)	552 (Motorola)	**60%**
Siemens	Telecom Services	1514	1294	**17%**

*Alcatel acquired Lucent in 2006; had they been one company in 2005, they would have led the field in that year as well, instead of Motorola.

Patent Performers On the Move

Company	Subfield	Subfield Rank 2006	Subfield Rank 2005	Number of Patents 2006	Number of Patents 2005	Pipeline Power 2006	Pipeline Power 2005
Symbol Technologies	Computer Peripherals	7	11	119	61	536	92
MediaTek	Computer Peripherals	11	20	105	32	460	20
Microsoft	Computer Systems	1	3	1469	780	5300	1699
Digimarc	Computer Systems	5	9	77	36	1695	283
Oracle	Computer Systems	10	16	211	104	396	79
Hon Hai Precision Industry	Electronics	8	17	474	295	548	133
Guidant	Medical Equipment	3	17	230	41	676	33
Ethicon (subsidiary of Johnson & Johnson)	Medical Equipment	5	16	113	59	26	48
ASML	Semiconductor Equipment	1	3	297	144	1897	968
Altera	Semiconductor Manufacturing	9	20	202	118	822	252
Qualcomm	Telecom Equipment	4	8	415	211	1285	319
AT&T	Telecom Services	1	3	763	305	1445	346
Sprint Nextel	Telecom Services	4	9	191	98	323	97

THE CHARGE OF THE ULTRACAPACITORS

Nanotechnology takes energy storage beyond batteries

BY JOEL SCHINDALL

IN 1995, A SMALL FLEET of innovative electric buses began running along 15-minute routes through a park at the northern end of Moscow. A decade later, a few dozen seaport cranes in Asia, a couple of light-rail trains in Europe, and a battalion of garbage trucks in the United States have joined their high-tech ranks.

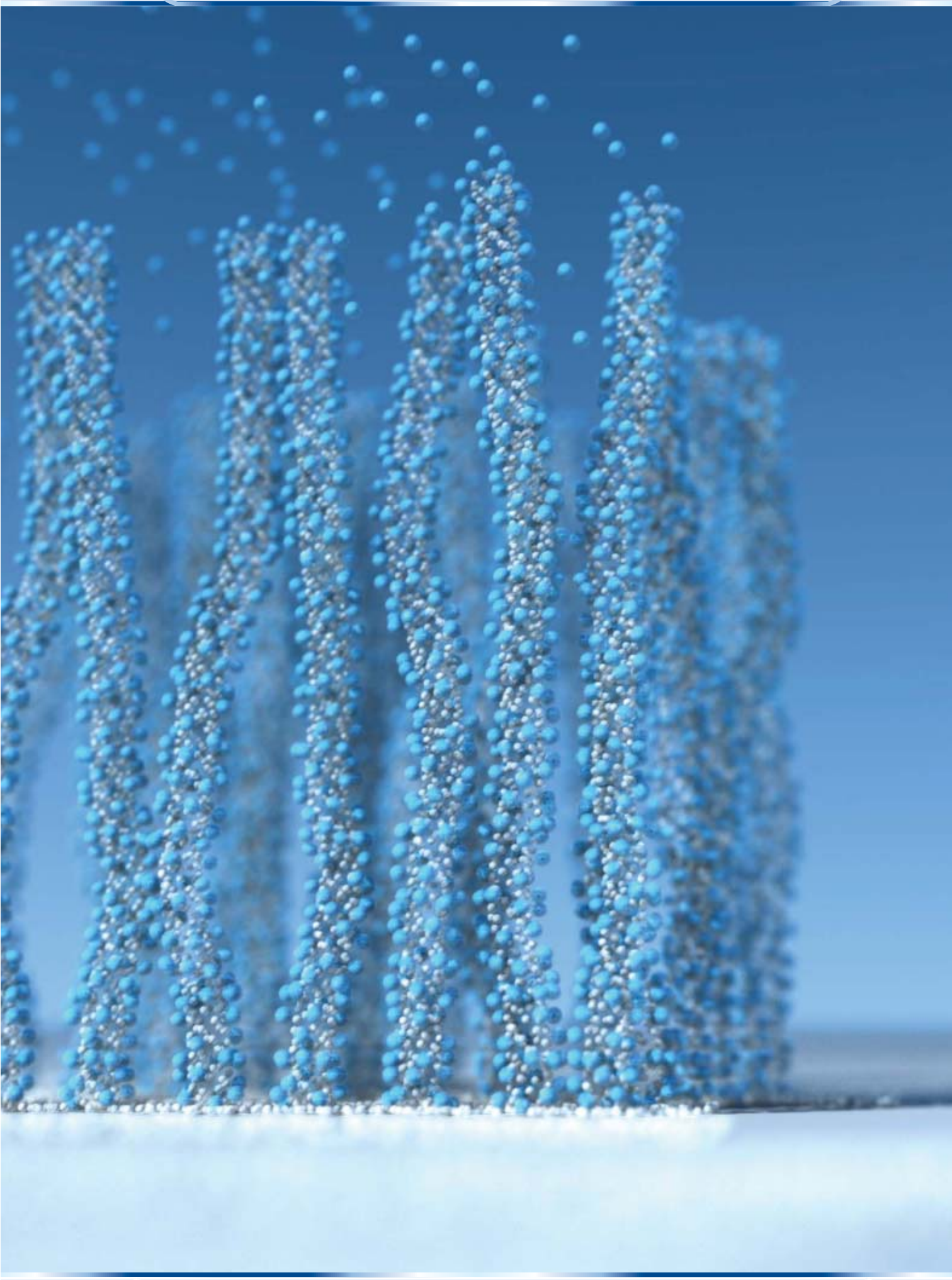
A smattering of mass-transit vehicles and industrial machines may seem like one wimpy revolution, but revolutionary they are. Unlike most of their electric relatives, these vehicles all share one key attribute: they don't run on batteries. Instead, they are powered by ultracapacitors, which are souped-up versions of that tried-and-true workhorse of electrical engineering, the capacitor.

A bank of ultracapacitors releases a burst of energy to help a crane heave its load aloft; they then capture energy released during the descent to recharge. Buses, trams, and garbage trucks powered by the devices all run for short stretches before stopping, and it's during braking that the ultracapacitors can partially recharge themselves from the energy that's normally wasted, giving the vehicles much of the juice they need to get to their next destinations.

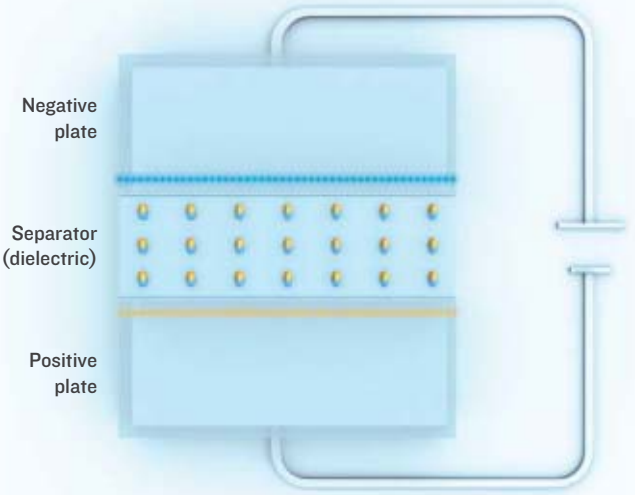
Because no chemical reaction is involved, ultracapacitors—also known as supercapacitors and double-layer capacitors—are much more effective at rapid, regenerative energy storage than chemical batteries are. What's more, rechargeable batteries usually degrade within a few thousand charge-discharge cycles. In a given year, a light-rail vehicle might go through as many as 300 000 charging cycles, which is far more than a battery can handle. (Although flywheel energy-storage systems can be used to get around that difficulty, a heavy and complicated transmission system is needed to transfer the energy.)

The synergy between batteries and capacitors—two of the sturdiest and oldest components of electrical engineering—has been growing, to the point where ultracapacitors may soon be almost as indispensable to portable electricity as batteries are now.

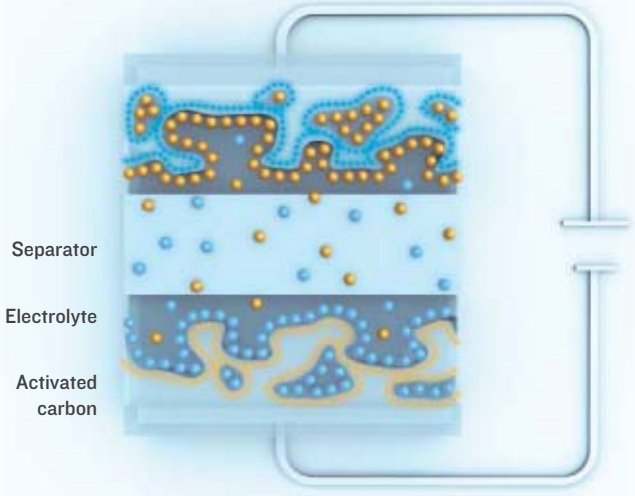
ALL ILLUSTRATIONS: BRYAN CHRISTIE DESIGN



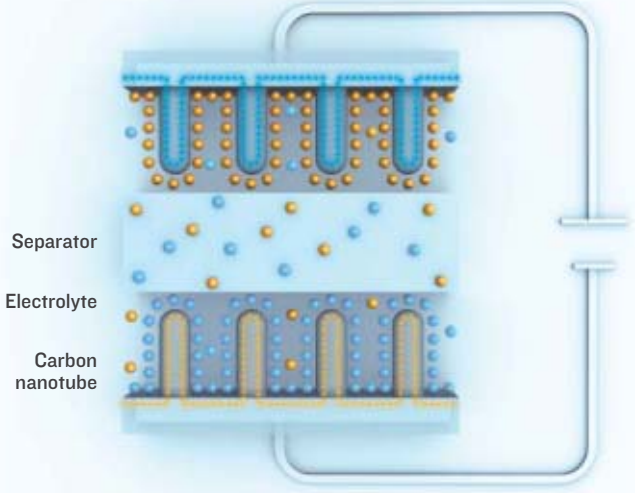
PILING ON THE FARADS



In a typical capacitor, electrons are removed from one plate and deposited on the other. Polarized molecules in the dielectric concentrate the electric field. One major factor determining capacitance is the surface area of the plates.



An ultracapacitor can store more charge than a capacitor can, because the activated carbon has a pocked interior, much like a sponge. This means that ions in the electrolyte can cling to more surface area.



With finer dimensions and more uniform distribution, carbon nanotubes enable greater energy storage in ultracapacitors than activated carbon does.

Ultracapacitors are already all over the place. Millions of them provide backup power for the memory used in microcomputers and cellphones. They also supply brief bursts of energy to numerous consumer products containing batteries. In a camera, for example, an ultracapacitor can extend battery life by providing the oomph for power-intensive functions, like zooming in for a close-up.

Perhaps most exciting is what ultracapacitors could do for electric cars. They're being explored as replacements for the batteries in hybrid cars. In ordinary cars, they could help level the load on the battery by powering acceleration and recovering energy during braking. Most deadly to the life of a battery are the moments when it is subjected to high-current pulses and charged or discharged too quickly. Conveniently, delivering or accepting power during short-duration events is the ultracapacitor's strongest suit. And because capacitors function well in temperatures as low as −40 °C, they can give electric cars a boost in cold weather, when batteries are at their worst.

Commercially available ultracapacitors already address those needs to some extent and can provide many times the power of batteries of the same weight or size. But in terms of the amount of energy they can hold, ultracapacitors lag far behind. The major difference is that batteries store energy in the bulk of their material, whereas all forms of capacitors store energy only on the surface of a material. Like a battery, an ultracapacitor is filled with an ionic solution—an electrolyte—and its current collectors attach to the electrodes and conduct current to and from them. The collectors are coated with a thin film of activated carbon that has orders of magnitude more surface area than ordinary capacitors. The amount of surface area in ultracapacitor designs has so far been constrained by the limitations in the porosity of the activated carbon.

The innovation that my colleagues John Kassakian and Riccardo Signorelli and I have pursued at MIT is to replace the activated carbon with a dense, microscopic forest of carbon nanotubes that is grown directly on the surface of the current collector. We think—and our work so far supports our theory—that by doing so, we can create a device that can hold up to 50 percent as much electrical energy as a comparably sized battery. This feat would allow ultracapacitors to supplant batteries in a number of mainstream applications.

IT'S ALMOST ENGINEERING HERESY to suggest that a capacitor could power a car. Indeed, the common capacitor stores a puny amount of energy. At equivalent voltage, a chemical battery can store at least a million times as much energy as a conventional capacitor of the same size. Put two ordinary capacitors the size of a D-cell battery in your flashlight, each charged to 1.5 volts, and the bulb will go out in less than a second, if it lights at all. An ultracapacitor of the same size, however, has a capacitance of about 350 farads and could light the bulb for about 2 minutes.

Before delving into our methods, I should explain the basics of capacitors and ultracapacitors. Capacitors have been around since 1745, beating batteries to the scene by half a century. Ultracapacitors are much more recent, but they're not exactly new, either. Engineers at Standard Oil patented ultracapacitor technology in 1966, an unanticipated product of their fuel-cell research. Standard Oil licensed the technology to NEC Corp., of Tokyo, which commercialized the results as "supercapacitors" in 1978, to provide backup power for maintaining computer memory.

A capacitor consists of two electrodes, or plates, separated by a thin insulator. When a voltage is applied to the electrodes, an electric field builds up between the plates. A capacitor's energy is stored in such an electric field, without requiring any sort of

chemical reaction. Thus a capacitor has an almost unlimited lifetime. It's also fast. Depending on its physical structure, typical charge and discharge times are on the order of a microsecond; sometimes they are as quick as a picosecond.

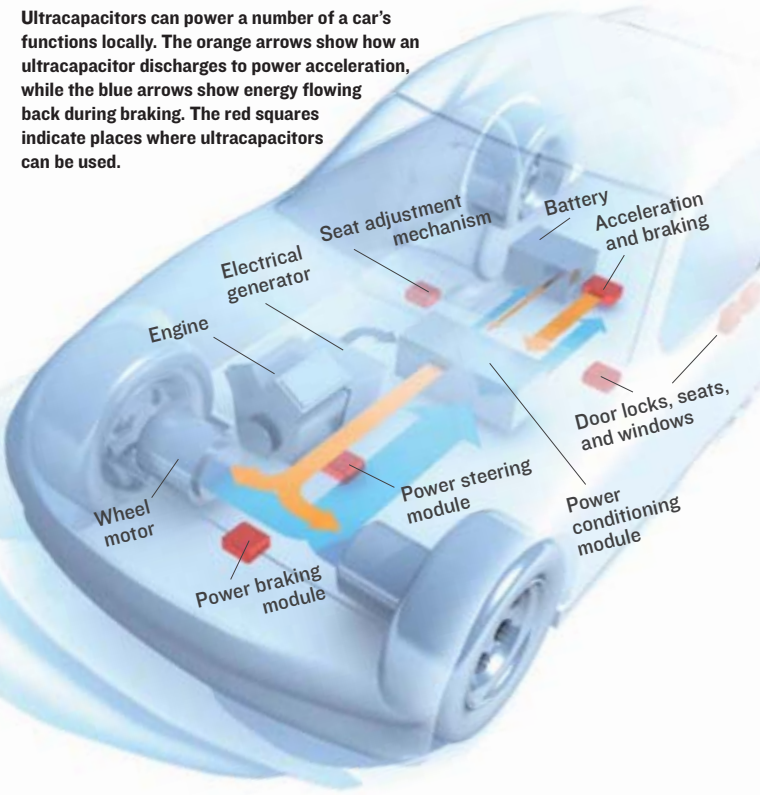
Three main factors determine how much electrical energy a capacitor can store: the surface area of the electrodes, their distance from each other, and the dielectric constant of the material separating them. However, you can push conventional capacitor designs only so far. What the Standard Oil engineers did was to develop a capacitor that functions differently. They coated two aluminum electrodes with a 100-micrometer-thick layer of carbon. The carbon was first chemically etched to produce many holes that extended through the material, as in a sponge, so that the interior surface area was about 100 000 times as large as the outside. (This process is said to "activate" the carbon.)

They filled the interior with an electrolyte and used a porous insulator, one similar to paper, to keep the electrodes from shorting out. When a voltage is applied, the ions are attracted to the electrode with the opposite charge, where they cling electrostatically to the pores in the carbon. At the low voltages used in ultracapacitors, carbon is inert and does not react chemically with the ions attached to it. Nor do the ions become oxidized or reduced, as they do at the higher voltages used in an electrolytic cell.

This approach allowed the engineers at Standard Oil to build a multifarad device. At the time, even large capacitors had nowhere near a farad of capacitance. Today, ultracapacitors can store 5 percent as much energy as a modern lithium-ion battery. Ultracapacitors with a capacitance of up to 5000 farads measure about 5 centimeters by 5 cm by 15 cm, which is an amazingly high capacitance relative to its volume. The D-cell battery is also significantly heavier than the equivalently sized capacitor, which weighs about 60 grams.

HOW TO ULTRACAP A CAR

Ultracapacitors can power a number of a car's functions locally. The orange arrows show how an ultracapacitor discharges to power acceleration, while the blue arrows show energy flowing back during braking. The red squares indicate places where ultracapacitors can be used.



HUNDREDS OF THOUSANDS of ultracapacitors are manufactured each year, for applications that require rapid recharging, high power output, and repetitive cycling. In 2005, the ultracapacitor market was between US $272 million and $400 million, depending on the source, and it's growing, especially in the automotive sector. Though ultracapacitors have generally remained a niche player, the situation may soon change.

My laboratory at MIT—the Laboratory for Electromagnetic and Electronic Systems—works with several automobile manufacturers to investigate ways to improve vehicle performance. About four years ago, I assisted on a project to evaluate commercial ultracapacitors for use in cars. While on a flight from Boston to Detroit, I read an article describing a way to grow vertically aligned carbon nanotubes on a flat surface. This is a truly amazing process. A sheet of silica is covered with a nanometer-thick layer of an iron catalyst. The sheet is placed in a vacuum, heated to 650 °C, and exposed to a thin hydrocarbon gas, perhaps ethanol or acetylene. The heat causes the iron to form tiny droplets, which steal carbon molecules from the gas. The carbon molecules then begin to self-assemble into tubes, which grow upward from each of the droplets.

By virtue of their dimensions, it struck me that those nanotubes held the promise of even higher porosity than the activated carbon used in commercial ultracapacitors. Together the nanotubes have an enormous surface area, and their dimensions are more uniform than those of the activated-carbon pores, making them more like a paintbrush than a sponge.

There are two major limitations to the conductivity of activated carbon—the high porosity means there isn't much carbon material to carry current, and the material must be "glued" to the aluminum current collector using a binder, which exhibits a somewhat high resistance. If my colleagues and I replaced the activated carbon with billions of nanotubes, we predicted we could make an ultracapacitor that could store at least 25 percent—and perhaps as much as 50 percent—of the energy in a chemical battery of equivalent weight. (To get that much improvement, we'd have to make a number of other changes, as well, such as increasing the number of ions in the electrolyte to reflect that new-found storage space.)

Another advantage of nanotubes over activated carbon is that their structure makes them less chemically reactive, so they can operate at a higher voltage. And certain types of nanotubes, depending on their geometry, can be excellent conductors—which means they can supply more power than ultracapacitors outfitted with activated carbon.

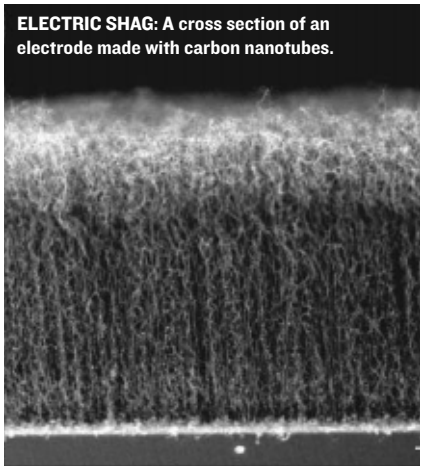
Even better, this nanotube-enhanced ultracapacitor would retain all the advantages ordinary ultracapacitors have over batteries: they would deliver energy in quick bursts, they would perform well in cold weather, and they would have much longer life spans. If this ultracapacitor could be developed, it would be revolutionary.

It was clear from the outset that a lot of know-how would be needed to make an ultracapacitor according to our design—knowledge of chemical-vapor deposition, electron microscopy, material science, quantum chemistry. And it's a challenge to get people with all those skills together. One of the strengths of a research university is its incredible diversity of expertise and equipment, plus there's the willingness of faculty to collaborate. Nobody in my lab had experience fabricating carbon nanotubes, but much of the early research in that area at MIT was done in the building next door, at a laboratory under the direction of Mildred Dresselhaus. Using those facilities and aided by Dresselhaus and her lab colleagues, we succeeded in synthesizing a nanotube forest on a small piece of silica in only a few months.

Nanotubes can vary in size, and the ones we're growing are about 5 nm across, or about 1/10 oooth the diameter of a human hair. Each tube is about 100 μm long, and they can be spaced as little as 5 nm apart.

But the sliver of silica was only the start. Silica is an insulator, and we needed a conducting material. After more than a year of false starts, we finally designed and built a custom reactor for chemical-vapor deposition and have used it to grow nanotubes on a conducting substrate. We are now packaging this collection of nanotubes in a prototype ultracapacitor.

We believe that within a few months we'll be able to demonstrate results that outperform today's designs by a wide margin. There will still be a big challenge ahead of us at that point: to see whether our devices can be manufactured at prices that make them attractive for mainstream applications. We are optimistic, though, because chemical-vapor deposition is already used on a huge scale in semiconductor manufacturing, and the raw materials that we need are cheap.



ELECTRIC SHAG: A cross section of an electrode made with carbon nanotubes.

It's not a straight path from high-density ultracapacitors to practical electric cars, but what my colleagues and I have done may constitute one big step along a tortuous route to making such vehicles more convenient and attractive to consumers. Even if it takes many years before ultracapacitors on their own can power either full battery-electric or hybrid cars, we're already at the point where such devices could easily assist lithium-ion batteries. When the car's electric motor needs high current for a short time, the ultracapacitor supplies it. After the demand eases, the ultracapacitor recharges from the battery. When the motor, working now as a generator, delivers high current for a brief interval—which is typically what happens with regenerative braking—the same thing happens in reverse. A computer would monitor voltages, the state of charge, load, and demand, and then adjust the current flow accordingly using some additional dc-dc power electronics. The added weight and expense involved might not matter if it improves vehicle performance and makes the battery last longer.

Small-cell ultracapacitors can be used in cars for purposes other than in the drivetrain. They can be integrated into air-conditioning, electric power steering, power locks, and window systems—components that demand high peak currents, which typically require large-diameter wiring. The need is intermittent, and the average power is low, so having ultracapacitors provide the high current at strategic points would permit thinner wiring to be installed. With the high price of copper these days, such changes can shave an appreciable amount from the cost of a vehicle.

Safety is another motivation. Suppose a car has electrically actuated brakes or door locks and the wiring harness fails because of a defect or an accident. A local ultracapacitor can still provide power for a few precious seconds or minutes.

Such devices are by no means limited to vehicles. Society is in the midst of an energy crisis, and many sources of green energy would benefit from regenerative energy storage. Electric power grids could be 10 percent more efficient if there could be simple, inexpensive ways to store energy locally at the point of use. And if renewable energy is ever to displace fossil fuels, engineers will need to devise better ways to store wind power when the wind is not blowing and solar power when the sun is not shining.

My colleagues and I are not the only ones researching ultracapacitor technology, of course. All the existing ultracapacitor manufacturers—including Maxwell Technologies, NessCap, Panasonic, Nippon Chemi-Con, and Power Systems Co.—are working on improved activated carbons or devices where one electrode functions as a battery and the other as an ultracapacitor. The Japanese government has provided $25 million for nanotube research, money that has supported a promising joint effort between Nippon Chemi-Con and AIST National Lab to explore nanotube-based techniques. Investigators at Rensselaer Polytechnic Institute, in Troy, N.Y., recently announced, in the *Proceedings of the National Academy of Sciences of the United States of America,* an exciting combined battery-nanotube ultracapacitor fabric to store electrical energy.

And nanotube forests are not the only way to provide increased porosity. Power Systems, in Japan, for example, has been getting good results with a type of graphene structure that it calls a "nanogate."

There's a slightly different approach to modified capacitors that has been generating a lot of buzz lately, developed by a start-up called EEStor, in Cedar Park, Texas. EEStor has focused on improving the dielectric, rather than the capacitor's plates. Its design uses barium titanate, which has a high dielectric constant. High-dielectric-constant substances allow for high-value capacitors that are still small in size. The downside is that such materials generally are unable to withstand electrostatic fields of the same intensity as low-dielectric-constant substances such as air. EEStor claims that the capacitors can operate at extremely high voltages, on the order of several thousand volts, leading to very high storage capacities. One concern is that high voltages can cause a dielectric to break down irreversibly in the presence of even slight imperfections in the material. Only time will tell how its design fares.

Improving substantially on the means to store electrical energy would be a welcome development, and high-density capacitive storage is one promising avenue of research. Although batteries and capacitors are old inventions, our particular technique could not have been pursued until recently. Just as semiconductor designers have created smaller and smaller transistors, so have engineers in other areas learned to manipulate objects with ever-more-minuscule dimensions. The ability to sculpt materials at the atomic level is new and evolving. Engineers can use these new techniques to achieve novel properties and, in the case of my lab's research, to move toward a nanoengineered carbon that might usher in the next generation of energy storage. ■

ABOUT THE AUTHOR

JOEL SCHINDALL spent 35 years working in the telecommunications and satellite industries before joining the faculty of MIT, where he is now associate director of the Laboratory for Electromagnetic and Electronic Systems.

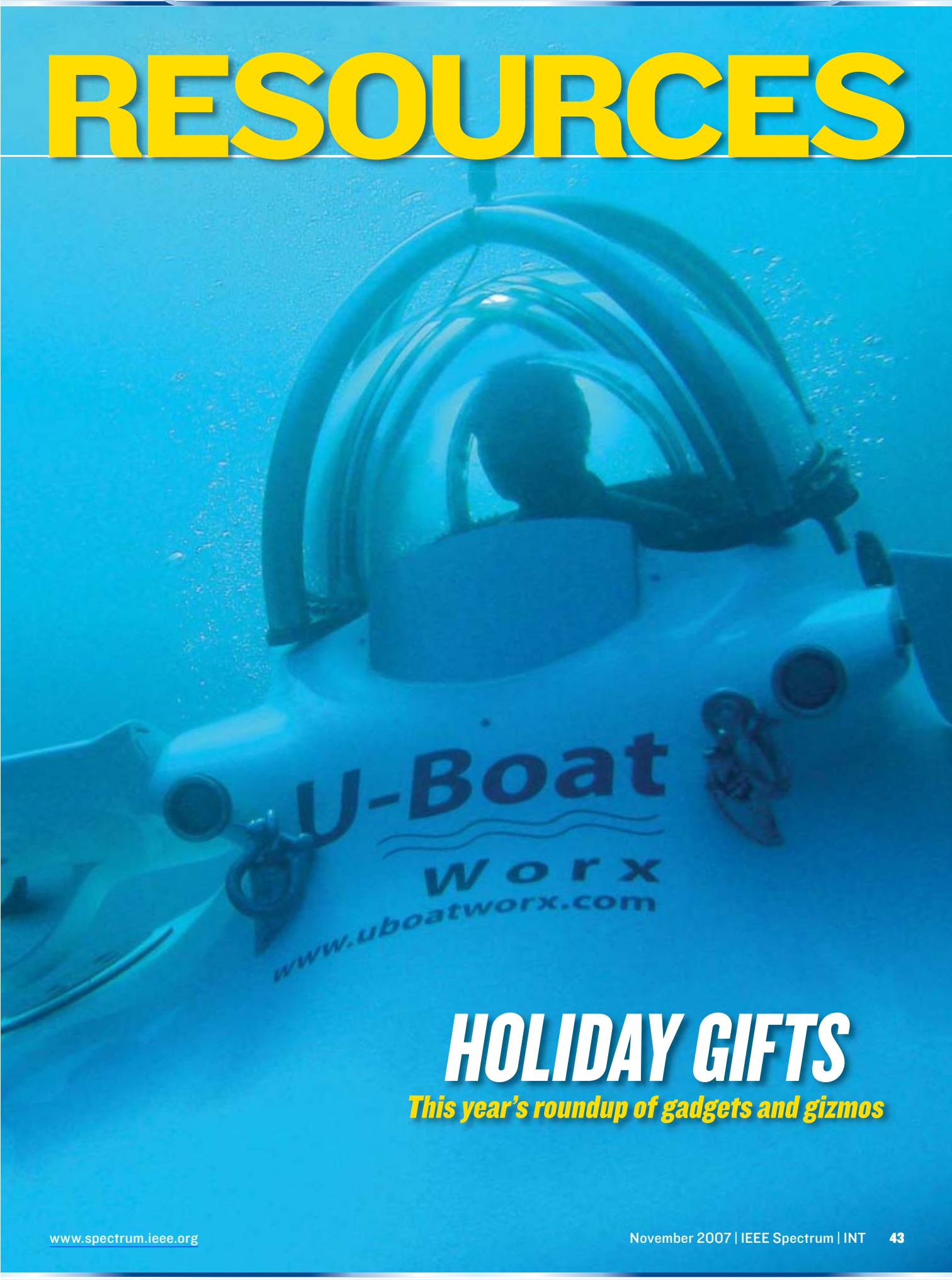
TO PROBE FURTHER

For an overview of ultracapacitors and their applications, as well as a number of free technical papers (after registration), visit http://www.maxwell.com/ultracapacitors/technical-support/white_papers.asp.

The National Renewable Energy Laboratory, in Golden, Colo., surveys its energy storage research at http://www.nrel.gov/vehiclesandfuels/energystorage/ultracapacitors.html.

RICCARDO SIGNORELLI/MIT

RESOURCES

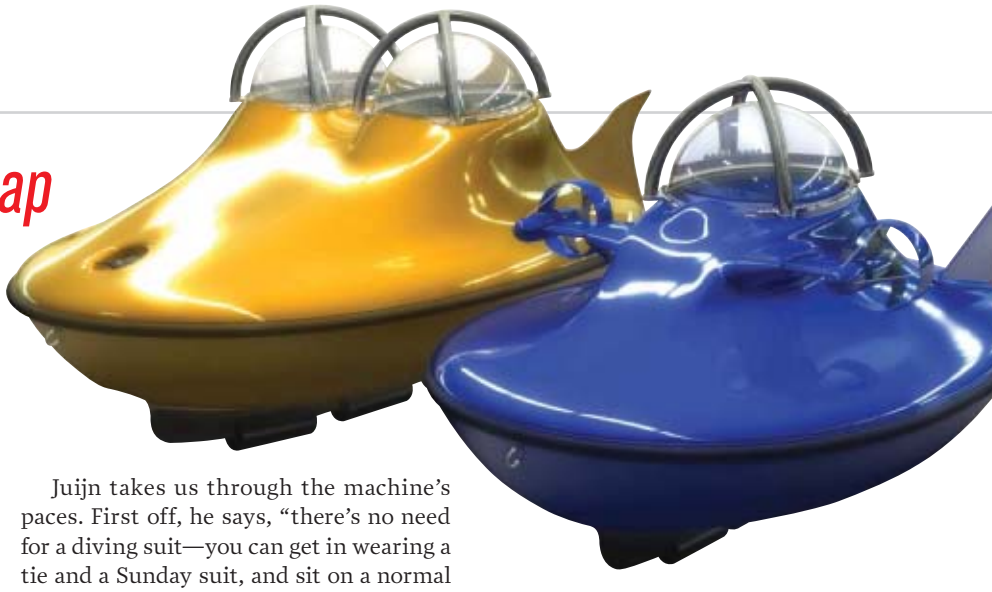


HOLIDAY GIFTS

This year's roundup of gadgets and gizmos

RESOURCES

Run Silent, Run Cheap



What do you get for the friend who has everything? How about a personal submarine from U-Boat Worx of Breda, Netherlands?

Now, you might want to quibble with our headline, because the **C-Quester I** submersible costs about US $130 000, which many would say is anything but cheap. Then again, it's a submarine, and that means it takes you where no other commercial product can go.

"This is a fantastic toy, and it's very easy—anybody who can drive a car can drive this little thing," says Tom Juijn, who early this year became the first person to purchase one. Juijn, a professional diver who operates a marine salvage company in Cartagena, on Spain's Mediterranean coast, likes the sub so much that he has become U-Boat Worx's designated retailer in Spain and the Middle East.

Juijn takes us through the machine's paces. First off, he says, "there's no need for a diving suit—you can get in wearing a tie and a Sunday suit, and sit on a normal chair," which puts your head in an acrylic dome that affords 360 degrees of visibility. Next you turn on the computer and check the safety data, including carbon dioxide concentration, air pressure (which always stays at 1 atmosphere), and temperature (which remains at whatever level you've set the air conditioner to). "Then you push the joystick forward, and you go forward; push it left or right, and you go left or right." The stick controls a rudder in the back as well as side thrusters, which can rotate through 45 degrees. You can power your way up and down, also, but for serious vertical motion you can always blow out the air tanks in order to dive or release ballast in order to rise.

The sub is 2.8 meters long, weighs

Backseat Driver

You've just piled the family into the car for the much-awaited summer vacation, and you're barely out of the driveway when your older son declares he forgot to charge his PlayStation Portable. Next your daughter complains that her cellphone is on its last bar. Then your younger son throws a tantrum over the electrical state of his iPod. With your blood pressure rapidly escalating, you pull onto the expressway, only to realize that you are also part of the problem, because you neglected to charge the laptop you had planned to use to finish a last-minute report once you'd turned the driving over to your spouse.

Avert that painful scene by equipping your car with the **Coleman Powerworks** 225-watt inverter. It is simplicity itself: you plug it into the cigarette lighter, and it transforms the car's 12-volt dc current to standard ac, which goes to a power strip with two wall-type outlets. It can also feed power into a device's USB port. That way you can charge any device without needing a unique adapter to fit the lighter jack.

The inverter comes with straps and Velcro strips so that it can be conveniently hung from a headrest or attached to the dashboard. All that, plus reduced stress and enhanced family happiness, from a company best known for handy and reliable camping equipment.

—William Sweet

The 225-watt Coleman Powerworks sells for US $41 at http://www.compsource.com.

Clocks That Multitask

One of the most popular programs on MTV is a show called "Pimp My Ride," in which mechanics transform beat-up, marginally functional automotive eyesores into rolling works of art, laden with loads of new features—practical or not. Alarm clock makers, no longer content with waking you up, are performing similar magic with their products.

The Ferrari Monza **Weather Station,** from Oregon Scientific

PREVIOUS PAGE AND THIS PAGE, TOP: U-BOAT WORX; BOTTOM LEFT: TEAM PRODUCTS; BOTTOM RIGHT: AMBIENT DEVICES

1030 kilograms, and works off three electric motors that draw on good old-fashioned lead-acid batteries. The oxygen supply and the CO_2 filters could, in an emergency, keep a person alive for 36 hours.

Juijn and his company's employees have taken their sub to speeds of 2.5 to 3 nautical miles per hour for as long as 2.5 to 3 hours, two figures that together define its range of about 6 nautical miles. It can descend as far as 50 meters, "which is fine, because most of the interesting stuff is under 20 meters," he says. That diving floor is not a suggestion but a requirement: try to go lower and the submarine's depth-control system will stop you.

You might think an undersea voyager could just sneer at the weather, but that is not the case, Juijn says. You need to be able to get into and out of the sub without getting swamped—which means sailing only when the short waves (as opposed to long swells) measure less than half a meter.

The natural customers are marine biologists, environmentalists, and tour guides. Guides will be particularly interested in a $190 000 two-seat model, the CQ2, which is in development.

Of course, the truly wealthy may enjoy such a bauble if they can use it to entertain a guest: "Perhaps you would like to see my little underwater operation before I kill you, Mr. Bond."

One thing affluent owners will be able to afford is a crew to maintain the sub between dives and to watch over it while it's running. Nobody should ever dive without a surface vessel and crew standing at the ready with a crane and other rescue equipment, Juijn says. A pilot who loses wireless contact with the surface crew must surface immediately—a person who gets stuck has no way to get out. *—Philip E. Ross*

The C-Quester I costs about US $130 000, plus taxes, import duties, and registration fees. Contact the manufacturer at http://www.uboatworx.com.

[right], is just such a multitasker. It provides weather forecasts 12 to 24 hours into the future and indicates whether nearby road conditions are dry, slick, or very wet. The 9.65- by 18.8-centimeter unit also displays the temperature and humidity of the room it's in and the same information for up to three other locations as far as 30 meters away. You can set the base unit's alarm to go off if a remote unit detects that it is too cold in the baby's room or so damp in your greenhouse that mold will grow on your plants. One battery-powered wireless sensor comes with the clock; you can purchase others separately.

The unit automatically synchronizes itself with the standard U.S. atomic clock in Boulder, Colo., and it adjusts itself for daylight saving time.

Ambient Devices of Cambridge, Mass., which began as a data aggregator, has brought the all-things-to-all-people ambitions of cellular handset makers to bedside tables and desktops with a line of satellite-connected, battery-operated gadgets that also go far beyond telling the time. Its **Weather Wizard** [far left] station displays conditions reported by meteorologists at AccuWeather.com, along with local predictions—including high and low temperatures—for the next four days. It can also give weather readings for any U.S. ZIP code and any major world city. And oh, yes, it tells time, too.

The Ambient **MarketMaven** allows you to track the performance of the Dow, Nasdaq, and S&P 500 stock indexes all at once. You can also customize it to track single stocks. The main drawback is that data displayed on the device lags the market by 20 minutes. Of course, it also works as a clock. *—Willie D. Jones*

The Weather Station costs US $200 at http://www.partshelf.com/osfaw101ak.html. The Weather Wizard sells for $85; see http://www.ambientdevices.com. The MarketMaven costs $130 at http://www.hammacher.com.

LEFT: OREGON SCIENTIFIC; RIGHT: HOGWILD TOYS (2)

Hot or Cold

Because LEDs don't slurp much power and can fit in where no Edisonian bulb can go, designers are trying them in a lot of out-of-the-way places—sides of cars, ends of key chains, soles of shoes. Now they're lighting up tap water as well.

The Faucet Light—a rather tame coinage from a toy maker called Hogwild, based in what it calls "Porkland," Ore.—incorporates two LEDs, one red, the other blue. When the water runs cool, the aerated stream glows blue; when the temperature rises above 32 °C, it switches to red. The effect is most striking when you pour yourself a drink in the middle of the night.

Of course, the gadget's mainly meant to make washing more fun for the kids, but it does have a serious side. Pediatric studies have shown that thousands of children, particularly preschoolers and toddlers, are scalded by hot tap water each year, most often in baths but also at the bathroom sink.

The light comes with two adapters that fit most fixtures and with two extra batteries. *—P.E.R.*

Go to http://www.hogwild.com to buy the Faucet Light for US $18.

Why, a Child Could Fly This

Last year's holiday review featured an electric miniature helicopter that could lift off from the palm of your hand. But because the chopper couldn't stall and didn't need a sensitive hand on the remote control, it was almost too easy to fly—more an executive desk ornament than a toy an actual child would be bound to respect.

The **Palm-Z Indoor Flyer,** made by Silverlit Electronics of Hong Kong, costs half as much as the copter, which is good, and it is considerably more challenging to fly, which is also good—in a way. The *IEEE Spectrum* staff took some time just to get the plane to sail in a straight line without going nose up and then dropping; it took even longer to get it to turn smartly enough to make it around office cubicles and other traps.

The pilot controls the speed of the motor with a small console, using a vertically sliding throttle and horizontally sliding yaw control, which broadcast in three infrared frequencies. That means one person ought to be able to fly three models, but with only one plane on hand, we couldn't test this. The manufacturer warns that the infrared signal may get swamped in sunlight, but then again, this product isn't meant for the great outdoors, where any puff of wind would knock it for a loop. With that possibility in mind, the manufacturer has thoughtfully included an extra rudder, probably the single most vulnerable part.

The superlight, plastic-foam plane has a wingspan as long as your hand, a tiny electric motor, and a rechargeable lithium polymer battery, which charges from the same small console used to steer the plane in flight. A full charge keeps the thing buzzing for about 5 minutes. The control works to a radius of about 5 meters. The manual notes that the console will accept an optional infrared signal booster to extend the range to 30 meters, but neither the manual nor the Web sites we checked quoted a price for the booster. *—P.E.R.*

You can buy the Palm-Z Indoor Flyer at http://www.playasia.com for US $28, plus about $16 for shipping. The charging console requires four AA batteries.

Etch A Sketch Grows Up

Computers, even the laptop variety, aren't yet as comfortable as tablets of paper. Now comes a happy medium—a digital medium, that is—that lets you doodle to your heart's content on a solid, satisfyingly roomy pad. The Pensketch 9x12 USB tablet from Genius purports to serve the professional graphics designer, and indeed its bundled software, including Adobe Photoshop and other standards, allows you to create, edit, and annotate all kinds of art, but it all comes at a price the amateur can justify paying.

The light, cordless stylus reacts to pressure sensitively, acting as a ballpoint, a fountain pen, or a paintbrush. You can begin by writing your signature and plopping it into a letter. The computer seems optimized for Windows, and although it worked on a Mac—a computer often favored by graphics artists—it was a bit of a pain to install. *—Param Bhattacharyya*

The company's site, http://www.geniuseshop.com, lists the Pensketch 9x12 at US $199, but a number of Internet retailers offer it for less than $145.

Hi-Fi, Low Price

Class-D amplifiers are known for their superhigh efficiencies and precise, detailed sound, and much of their growing success can be credited to a single remarkable product: the Universal Class D (UcD) amplifier module designed by Bruno Putzeys of Hypex Electronics, in Groningen, the Netherlands.

It's used in high-end amps from Channel Islands Audio, Meridian, Kharma, MM Audio, and Exodus, and it's gotten raves from the audiophile press. But at prices in excess of US $1000 for a stereo setup, the sound has been enjoyed by a relatively small community of cognoscenti.

Now you can build yourself the **Hawk Audio D-402** amplifier kit for less than half as much. Hawk, of Ledegem, Belgium, sells two kits featuring the Hypex UcD: the basic D-402, which retails for $445, and a new high-grade version that goes for $575. Both come with a power supply that delivers 40 watts per channel into 8-ohm speakers. The $575 model has improved input circuitry and more vigorous decoupling of the power supply from the signal paths.

I built the basic version and connected it to my Grande 8 speakers from Omega Speaker Systems of Norwalk, Conn. I fed it with output from my Sony NS999ES universal disk player, which I use as a transport that sends bits to a separate digital-to-analog converter unit based on the Analog Devices AD1853EB board. After a few minutes of listening I became a true believer in Class D, preferring it to the two amplifiers I'd used in the same setup—both tube amps that had cost me several thousand dollars to build.

The plastic case of the D-402 is a bit tacky, and the simple, ganged carbon potentiometer volume control will make some audiophiles cringe. Get over your distaste. Hide the amp in a closet if you must. My only regret is that I discovered Class-D audio so late. *—Glenn Zorpette*

You can buy the Hawk Audio D-402 kit for US $445 and the high-grade version for $575; see http://www.hawkaudio.com.

FROM TOP: SILVERLIT ELECTRONICS; HAWK AUDIO; GENIUS

50th ANNUAL IEEE GLOBECOM
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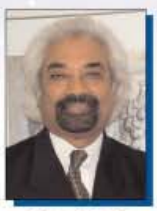

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RESOURCES

Must...Mow...Lawn...<click>

A few months ago, I moved to an apartment with a backyard, and I was excited about barbecuing. But one thing stood between me and my kebabs: an unruly thicket of grass all over the yard.

I had never mowed a lawn, and I must say I wasn't thrilled about pushing a machine with rapidly spinning blades under a scalding sun. Then I found something that would do it for me.

No, it's not a goat—it's **Robomow.** Made by the Israeli firm Friendly Robotics, it promises a "beautifully manicured lawn effortlessly." I liked the "effortlessly" part, so on a sunny afternoon, I unleashed the robot on my yard.

I had already pegged a wire, included in the package, around the edges of my lawn, so that the robot could know the edges of its domain. After setting the mowing height, I pressed the Go button.

The 35.2-kilogram, tortoiselike machine began to zigzag, to the amusement of my neighbor's cats. At first, I thought it was missing some swaths, but later it returned to finish the job.

The robot's blades, spinning at 5800 revolutions per minute, chop the clipped grass so fine that you don't need to rake the lawn afterward. Password protection keeps kids from unleashing the machine themselves, and sensors in the bumpers stop it if someone gets in the way.

The mower did a great job overall, but it missed some grass at the edges along the fence. I took care of that by guiding the robot with its manual controller. My neighbors peppered me with questions, but they were disappointed by the price tag. The RL1000 model (for lawns of up to 2000 square meters) costs US $2000, and the RL850 (for 1500 m^2) costs $1500. The RL1000 can be programmed to run at a preset time, returning to its docking station to recharge.

Friendly Robotics says the RL1000's power is equivalent to that of a 5.5-horsepower gas mower. Its lead-acid batteries last 2.5 to 4 hours per charge, enough to cover 400 to 600 m^2. A large lot could require several recharges. And because of its random zigzagging, it takes longer than if a brain were guiding a mower. But why should I care? I'm busy at the grill, flipping burgers. *—Erico Guizzo*

You can buy a Robomow for US $1500 at http://www.friendlyrobotics.com.

Turn On, Tune In—To Any Station Anywhere

A computer-scientist friend of mine once noted that his computer's sound system was the best he had ever owned, and why shouldn't it have been? He spent more time at the computer than in bed. Still, some audio functions cry out for a stand-alone device.

Internet radio is a great example. Radio, whether coming from your hometown or from the other side of the world, is something you listen to while doing something else—like shaving, eating, or riding an Exercycle.

Get yourself a **SoundBridge Radio** Wi-Fi music system from Roku, a company founded five years ago by Anthony Wood, known as the inventor of the digital video recorder. The radio's elegant and compact black form packs excellent speakers, including a subwoofer, and it tunes into local stations in the AM and FM bands as well as to Internet stations, whose signals are conveyed wirelessly over your local area network.

You quickly get used to switching from the BBC to Radio Helsinki to Minnesota Public Radio—a one-handed operation, thanks to the remote control. A number of Internet stations are preset in the radio, and it's simple enough to add more. You aren't limited to the Internet's offerings, because any audio available on your network will register. Your computer's music library will therefore be at your disposal, so long as its files are in MP3 or WMA formats.

There are some limitations. You can't take the radio to the beach, because it hasn't got battery power, and few beaches offer Wi-Fi coverage. The system buffers streaming audio—which means that excessive lag in the Internet will sometimes cause it to interrupt a show while it rebuffers. Also, the controls take a little time to master because Roku packed so many functions into a small number of button combinations. A more intuitive interface would let the user twirl dials and punch buttons instead.

None of the drawbacks matter in the long run, though, because once you've set up the system it's a breeze to get it to do whatever you want. *—P.E.R.*

You can buy the SoundBridge Radio system at http://www.rokulabs.com for US $300.

TOP: ERICO GUIZZO; BOTTOM: ROKU

In-Your-Face Goggles

Back in the 1950s, stereoscopic movies came and went, first thrilling audiences with gut-wrenching effects, then faintly nauseating them with subtly disorienting cues. Today 3-D is back again, this time appearing in controlled, virtual-reality environments where the cues fit more seamlessly. Even so, stomachs continue to churn, in part because most systems still take shortcuts, notably by rapidly alternating views shown to the left and right eyes.

The **TDVisor** headset from TDVision avoids that drawback by offering continuous views in both the left and right channels. It should, therefore, give gamers and other heavy users less of a headache. It sure made an auto-racing game a lot of fun [see photo] when a few of us tried it here in the office.

What seemed on the flat screen to be a rotating, murky mass appeared in the visor as a revolving medical model, the veins and nerves popping out clearly. A virtual walk-through made a room come to life.

But the visor worked best of all when juggling fast-motion video, as in a clip a TDVision employee made riding a roller coaster. That footage had been taken with an associated product, a weirdly alert-looking, two-lens camera that easily fits into one hand.

The film-it-yourself feature is important, because until Hollywood embraces 3-D, users will have to generate a lot of the content themselves. Games, of course, will be the biggest draw for customers, because their programs calculate motion in space by design, just to render scenes on a regular display.

The company, in Naperville, Ill., is still in the start-up phase, so it can't begin mass production until it gets enough preorders. Therefore, to prime the pump, it is now courting early adopters. If you tell the company you're an IEEE member, it will sell you a preproduction model that offers 800- by 600-pixel resolution, with the option to trade up later to a planned 1280-by-768 model. In other words, TDVision's elves will make the visor for you by hand.

TDVision has already sold about 40 such handmade units, most of them to people doing research in virtual reality, says Ethan Schur, the company's director of product marketing.

The company says its standard is compatible with most video equipment. What's more, it lets you watch something coded in 3-D while the same video runs in 2-D on a conventional display; that way, you can still watch with the goggles off. It won't work, however, with systems such as Nintendo's Wii, that use an analog rather than a digital signal.

The eyepieces are optically adjustable, and there's enough room inside the goggles to accommodate spectacles. The 142-gram visor rested lightly enough on the brow, but the heavy user probably will want to push it up on the forehead once in a while to rest the nose. *—P.E.R.*

The 800-by-600 TDVisor is priced at US $1000; the upcoming 1280-by-768 TDVisor HD can be preordered for $1500 at http://www.tdvision.com/preorder.html.

It's Not a Key, It's a Window

Just as you might stuff important computer functions into handy toolbars, the **Optimus Mini 3** packs a toolbar into a stand-alone keyboard. The imaginative design, from Moscow's Art. Lebedev Studio, gives you the option to use its three keys to convey information in both directions: as commands to the computer and as visual output to the user.

That's because the keys use organic light-emitting diodes (OLEDs) to show images, static or animated. You configure the keys to do whatever you want. It runs on Windows 2000, XP, and Vista and on Mac OS X.

When not actively using the device, you might have the buttons display general information such as system status with free memory and CPU usage graphs, or the time in any city. Then, when you press the Control, Shift, or Alt keys, or combinations thereof, on your computer keyboard, the buttons might serve as an extension of the toolbars in a browser or as a remote control for a PowerPoint slide show (complete with a preview of the previous, current, and next images). One enterprising programmer used the provided development tools to knock together code that previews video on the OLED screens. I can see how the OM3 could provide a novel way of interacting with users where a full screen and keyboard are not desirable, say an interactive session at a museum exhibit or in a schoolroom.

The keys can present a dynamic image that refreshes three times per second. The rather low refresh rate means that it's not the best of video screens, but that's not what the OM3 is about. *—Christopher J. James*

You can buy the Optimus Mini 3 at http://store.artlebedev.com for US $149.

TOP: RANDI SILBERMAN; BOTTOM: ART. LEBEDEV STUDIO

The Edward S. Rogers Sr. Department of Electrical and Computer Engineering at the University of Toronto invites applications for tenure-stream Assistant or Associate Professor positions, beginning July 1, 2008, in three areas:

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Fax: +61 3 9620 2811

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For further information, obtain the position description and selection criteria at ***www.jobs.unimelb.edu.au*** *and search under the job title or job no. 0017840.*

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Please send a cover letter stating research aims and a CV to: Dekan der Fakultät für Elektrotechnik und Informationstechnik der RWTH Aachen, Prof. Dr. Kay Hameyer, Templergraben 55, 52062 Aachen, Germany.
The deadline for applications is November 16, 2007.

RWTH Aachen University aims to increase the number of women in areas in which they are under-represented.

Persons with disabilities are encouraged to apply.

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REFLECTIONS

By Robert W. Lucky

A Billion Amateurs

I log on to the Internet from my little attic office, and I'm connected to the world, feeling both alone and part of the largest crowd ever assembled. There are a billion people out there on the Net with me.

The news is always full of the spammers, the predators, the evil hackers, and the other miscreants who would be found in any such crowd, because that's the way news works—it mainly tells you about the bad stuff.

Today, though, I want to talk about the wonders and the enormous potential of this congregation of amateurs. I never cease to be amazed at the creativity and, yes, the generosity that has been unleashed by the social embrace of the infrastructure that we technologists created originally to connect our computers.

I love to hear from people who have found something on the Web that I've provided. It gives me the feeling of having reached across oceans to bestow a small gift on a stranger, thereby dispelling our common facelessness within the crowd. On the Internet there is an irresistible urge to contribute.

There are many examples today of "business" models that are enabled by our urge to be generous. I put *business* in quotation marks because many of the models are themselves acts of charity. Others make money only as an afterthought. I recently asked the founder of a Web site that enables people to subtitle videos what his business model was. He replied in one word: "ubiquity."

In the current list of the 20 most popular Web sites, half have essentially all their content provided free by amateurs: MySpace, YouTube, Facebook, eBay, Craigslist, Wikipedia, Blogger, the Internet Movie Database, Photobucket, and Flickr. They're all examples of what open-source guru Tim O'Reilly has termed an "architecture of participation." Build it, and they will come.

I am entranced by the vision that Jimmy Wales, for example, showed in creating Wikipedia. I can't imagine announcing that I was establishing an encyclopedia not by writing anything myself but just by letting anyone come and create entries. People would have told me I was crazy. Yet it worked so well that Wikipedia has become one of the most popular sites on earth. You don't need to pay people to write articles—the thrill and satisfaction of contributing provides the motivation.

I imagine the legion of paid professionals in the traditional encyclopedia world looking skeptically at the Wikipedia endeavor. "Amateurs! What do they know?" Well, when there are a billion of them, they know pretty much everything. Of course, there are a lot of unpaid professionals out there, too.

Meanwhile, those billion amateurs are taking pictures of everything on the planet and placing the images on Flickr and other sites. There are thousands upon thousands of pictures of every known place, taken from all angles and under all lighting conditions. Researchers are now using those pictures to create three-dimensional images and panoramic vistas.

And those amateurs are writing blogs—an estimated 80 million of them. Who reads them all, I wonder? But never mind—what a treasure trove of living news, feelings, observations, and information! Again, researchers are pawing through the rubbish, looking for nuggets with such tools as sentiment analysis, asking questions like "Is the world relatively happy today?" The billion amateurs know the answer, and they have found their voice.

There is no lack of free labor if the smallest incentive is offered. I've heard it said that last year people spent 9 billion hours playing computer solitaire. (I have no idea where such a number comes from, but we'd all agree that it's bound to be large.) In contrast, it is said that it required only 20 million hours of human labor to build the Panama Canal. So if you could offer people a game that incidentally collected information, you'd be in business, so to speak. One such game, ESP, in which contestants suggest captions for pictures that they believe will agree with captions submitted by an unknown partner, is being used to caption pictures on the Web—a job that computers are not yet capable of doing.

The Iowa Electronic Markets provide proof of "the wisdom of crowds"—the idea that everybody put together in a market is smarter than any one individual [see "Bet on It!" *IEEE Spectrum*, September]. There you can invest in political futures, and the vibrant market of amateurs has proven a better election predictor than the polls run ever so scientifically by professionals.

Just think: a billion people out there willing to work for nothing more than a little credit! Let the business models flow! ■

ROBERT W. LUCKY (IEEE Fellow), now retired, was vice president for applied research at Telcordia Technologies in Red Bank, N.J. (rlucky@telcordia.com).

DAN PAGE