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THE MAGAZINE OF TECHNOLOGY INSIDERS

SPECIAL REPORT

WINNERS & LOSERS 2009

THE YEAR'S BEST AND WORST TECHNOLOGY

Iraq Veteran Jonathan Kuniholm Is Helping Engineer The Prosthetic Arm Of The Future

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TWO WINNERS AND ONE LOSER: Steam from underground may slake Australia's thirst for energy [above]; DARPA's prosthetic arm promises to make the world a better place [top right]. And the car? Well, it's a good car—for a boat.

COVER: MIKE McGREGOR

THIS PAGE, CLOCKWISE FROM LEFT: GEODYNAMICS; MIKE McGREGOR; GIBBS TECHNOLOGIES

+− WINNERS & LOSERS VI

23 SPECIAL REPORT We judge projects so near to commercialization that we could be proved wrong in real time. But that's a risk you have to run if you want to grow a backbone. *By Philip E. Ross*

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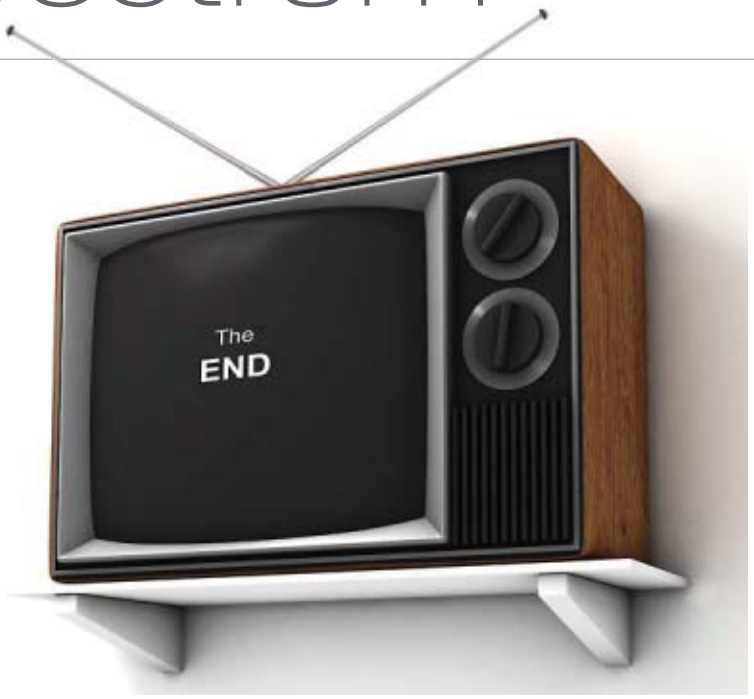

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SPECIAL REPORT: THE DAY ANALOG TV DIES

The National Television Systems Committee's (NTSC) analog television standard has ruled the U.S. airways since 1941, enabling viewers to tune in to free over-the-air television whether their TVs were built this year or inherited from a grandparent. But on 17 February 2009, NTSC broadcasts will end, replaced by the ATSC digital TV standard. For two decades *IEEE Spectrum* has been following the development of ATSC, the technology behind it, and its rollout. Now we're tracking this final transition to an all-digital broadcast world, a transition that might not go as smoothly as Congress, the FCC, the broadcasters, the consumer-electronics manufacturers, or the average viewer might hope.

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IEEE HUMANITARIAN WORKSHOP

Read highlights from the IEEE Humanitarian Workshop, which taught students and young professionals how to apply their skills to aid humanitarian work.

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back story

KARL SHREEVES

Breathe Deeply

REBREATHERS, an advanced kind of scuba-diving gear, let divers stay underwater for hours, silently, like the "fish men" that Jacques Cousteau envisioned at the dawn of the age of underwater exploration. So we jumped at the chance to review an innovative new rebreather. And then we had to wait almost a year before we could actually publish the review ("Winner: Poseidon Discovery," in this issue).

Our story starts in March of last year, when we contacted Karl Shreeves, the all-around tech guy at the Professional Association of Diving Instructors. Shreeves eagerly agreed to review the new rebreather, the Discovery Mark VI from Poseidon Diving Systems of Västra Frölunda, Sweden. It's one of the few rebreathers available to recreational divers.

There was just one problem. The gear, still being developed, wouldn't be available until June. Then July. Then August.

"Best guess now is Septemberish," Shreeves wrote us in June. Were we still interested? Of course we were.

Rebreathers are the state of the art in scuba gear. They use microelectronics and other technologies to scrub a diver's exhalations of carbon dioxide while capturing and reusing the oxygen, mixing it with precisely the right amount of nitrogen or other diluent gases.

Shreeves and Poseidon finally got together in October at a trade show in Las Vegas—barely. Poseidon had given Shreeves's number to Bill Stone, the American engineer and explorer who originally developed the Discovery and was coordinating the October test dive. But the day before the dive, Stone lost Shreeves's number before getting a chance to tell him where and when the dive would take place.

Fortunately, no one nowadays can stay missing for long. Stone logged into the social network site LinkedIn, found Shreeves's page, found Shreeves's wife's page, and contacted her. "I don't know what he would have done a few years ago," Shreeves says.

Just as Stone's anxiety was relieved, Shreeves's was to begin. The test dive was to be held in Henderson, Nev. Shreeves had two hours to get to Henderson—43 kilometers away—set up the equipment, do the test dive, and get back to Las Vegas for another commitment.

It all came off—the photo above shows Shreeves in the pool during his dive—because it took mere minutes to ready the Discovery for the dive. "I've used an awful lot of different rigs," he says. "It never takes less than an hour." That alone, he adds, makes the Discovery revolutionary. The key, as Shreeves explains in his review, is its built-in expert-system software—yet another application that didn't exist a few years ago. ❑

CITING ARTICLES IN IEEE SPECTRUM

IEEE Spectrum publishes two editions. In the international edition, the abbreviation INT appears at the foot of each page. The North American edition is identified with the letters NA. Both have the same editorial content, but because of differences in advertising, page numbers may differ. In citations, you should include the issue designation. For example, the first Update page is in *IEEE Spectrum,* Vol. 46, no. 1 (INT), January 2009, p. 7, or in *IEEE Spectrum*, Vol. 46, no. 1 (NA), January 2009, p. 11.

contributors

KENNETH R. FOSTER reviews SpaceTime, software for your mobile device that can do advanced mathematical functions, create three-dimensional graphs, and more [p. 19]. An IEEE Fellow, Foster is a professor of bio-engineering at the University of Pennsylvania and former president of the IEEE Society on Social Implications of Technology.

DOUGLAS HEINGARTNER wrote about Emotiv's new game controller in "Mental Block" [p. 34]. The gadget will supposedly let you play video games with just your thoughts—except that it doesn't. "The idea itself isn't dumb, and one day it could be a great thing. It's just premature," says Heingartner. A first-time contributor to *IEEE Spectrum*, Heingartner has written for *The New York Times*, *Wired*, and *The Economist*.

MIKE McGREGOR says his goal when photographing Jonathan Kuniholm and his prosthetic arm for "The Revolution Will Be Prosthetized" [p. 36] was to explore the device's life-changing impacts. One area Kuniholm excelled in, says McGregor, was video games. "It was totally humbling to get schooled in *Guitar Hero* by someone controlling his guitar with electrodes attached to his elbow," he says. McGregor's work frequently appears in *Wired*, *Discover*, and *Time*.

BRIAN SANTO, the editor of *CED* magazine and a former *Spectrum* staffer, coauthored "Multicore Made Simple" [p. 24]. "Whenever Intel chooses to enter a market, there's enormous potential for them to create fundamental changes in that market," Santo says, explaining why Intel's Larrabee chip was named this year's semiconductor winner.

PAUL WALLICH has built half a dozen computers in his lifetime. His most recent contraption is RepRap, a self-replicating machine, which he wrote about for Hands On [p. 18]. Despite his love of making machines, Wallich says he's "mostly a writer who builds stuff, not an engineer or builder." His work has also appeared in *Scientific American* and *Popular Science*.

PRACHI PATEL-PREDD, a frequent contributor to *Spectrum*, wrote two pieces for this month's issue. For Careers, she wrote about oDesk [p. 17], a company that manages contract employees by monitoring their computer activity, ensuring that the employer won't be billed for time spent on Facebook or YouTube. A freelancer herself, Patel-Predd thinks it's not a bad idea. "I would use it," she says. Her story in Update, "The Trouble With Touch Screens" [p. 7], explores the search for new transparent conductors, a problem that's literally at your fingertips.

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CLOCKWISE FROM TOP LEFT: KENNETH R. FOSTER; LISA SANTO; JULIE ROBICHAUX; JOEL PREDD; MIKE McGREGOR; WALLENBURG PERS

spectral lines

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IEEE Spectrum Gets Greener

WHAT DOES it really mean to go "green"? It's more complicated than you may realize. Environmental impact is hard for any business to measure in meaningful terms, but it's a particularly fiendish task for print publishers.

As you might have guessed, some very nice trees have to be sacrificed to bring you the print edition of *IEEE Spectrum*. But that's hardly the extent of our environmental impact. Logs must be trucked to paper mills, paper mills must be run, inks must be produced, printing presses must be operated. Magazines must be transported to the far corners of the globe. Come to think of it, reporters must be dispatched to the far corners of the globe, too, on fuel-guzzling jumbo jets, to ensure that there are stories worth printing and that they're not all about one country or one subject.

It's always good to start the New Year on a positive note, and so we're happy to announce that beginning with this issue, we're moving to a more environmentally friendly paper. On the table of contents page, you'll see our seal of approval from the Sustainable Forestry Initiative, one of the organizations that ensure that our paper is harvested from forests that are managed in a sustainable way. It also means that 100 percent of the paper fiber used to make the magazine comes from these sources. We will also continue to explore other ways to lessen our ecological impact in the coming year.

We love magazines and books, and you probably do, too. But the ugly truth is that publishing is a pretty toxic business. Some say that in the United States alone 39 million trees a year are used to make magazines. And then there are the petroleum-based inks and the hard-to-recycle waste by-products and atmospheric pollution that result from putting ink to paper on a press.

Nevertheless, since the 1990s, paper manufacturers and printers and publishers, working together, have been striving to make things better. They've moved to partly soy- and vegetable-based inks (you might have noticed more smudging on your fingers—get used to it!). They're now choosing from an expanding array of paper options, mixing "virgin fiber"—fresh-from-the-forest tree material—with recycled fiber and fiber from sustainable forests, which are maintained to meet standards set by the previously mentioned Sustainable Forestry Initiative (http://www.sfiprogram.org) and also the Forest Stewardship Council (http://www.fscus.org). Besides overseeing responsible forest-management practices, these groups also monitor the protection of water resources, biological diversity, and sacred or historical sites as part of their accreditation process.

Our own printer, Quad Graphics, has been a leader in this area since the 1970s. They recognized early that going green can make fiscal as well as environmental sense if managed properly. Reducing waste and making the most of the materials you have can increase output and profit—in theory, anyway. For now, the costs are still slightly higher. Like organic food, "green" paper is more expensive. We moved to vegetable-oil-based inks several years ago, but paper has been a different issue, and frankly, paper made the old-fashioned, environmentally unfriendly way was cheaper. But now, with traditional paper prices on the rise, paper fiber that comes from well-managed forests makes economic sense.

Some of you may ask, why not give up the paper edition altogether and just produce a digital edition? Sounds good at first, but to our knowledge no one has yet measured the environmental impact of publishing on the Internet or of creating electronic devices like the Kindle or the Sony Reader for digital reading—not to mention the fact that some of us still like to thumb through the pages rather than the pixels of a magazine, and do it in bed or on a train. Or maybe even on a fuel-guzzling jumbo jet.

In the meantime though, we're pleased to be able to move our print edition a step in a sustainable direction. There'll be more steps in this journey. Some of you will even help us on our way, designing better portable readers and more-efficient trucks and presses—and, of course, less-thirsty jumbo jets.

—SUSAN HASSLER

forum

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GETTING MORE BANG FOR THE BUCK

Robert N. Charette's article "What's Wrong with Weapons Acquisitions?" and Susan Hassler's Spectral Lines column "Driving the DOD Toward Change" [November] clearly point out that something is seriously broken in U.S. defense acquisitions. Given that the system is both broken and broke, we should aspire to a number of improvements your articles overlooked. Chief among these is a shorter, more evolutionary approach to system development and fielding. Modern system capabilities depend extensively on software and software-enabling components, which are driven by Moore's Law and worldwide development communities, so technology generations last only a year or two at most. This means that our development processes should operate on an approximately annual cycle. Five-year cycles might have seemed desirable 10 years ago, but now these cycles will fall two or three generations behind. As engineers, we understand that without a credible process and feedback loop, we might as well shut the whole activity down.

Rick Hayes-Roth
IEEE Senior Member
Monterey, Calif.

Your article made me wonder, for the umpteenth time, whether the Pentagon answers to the White House or the White House answers to the Pentagon. It also made me wonder whether the remarkable sums of money mentioned—such as US $137 000 000 for each F-22 fighter aircraft—should be dedicated to finding more efficient ways of dispatching an enemy.

Nazi Germany, having conquered much of Europe using superior weapons and tactics, sought to perpetuate its military edge by developing and using even more daunting weapons. Enormous outlays of materials and manpower resulted in, among other things, an armored fighting vehicle in the shape of a slow-moving mobile fortress weighing well over 100 tons. Germany also fielded an enormous railroad gun that had a crew of nearly 1000 and fired shells weighing several tons. Then there were the technologically advanced but slow and expensive Tiger tank and the first combat-ready jet (and also rocket-propelled) aircraft. The production of all these weapons usurped vital time and effort from the production of the cheaper conventional tanks and aircraft that Germany desperately needed. Some military analysts believe that this pursuit of overwhelming force may have cost Germany the war. In present-day warfare, as noted in recent issues of *IEEE Spectrum*, the most effective "weapons platform" can be a dead goat concealing a roadside bomb—not exactly a "Star Wars" project.

I think we can rest assured that no Afghan rebels are building an F-22 fighter plane. So why are we?

Lance Nizami
IEEE Member
Decatur, Ga.

GRIDLOCKED

Although the WaterMill ["Water Goes Off the Grid," Update, November] may be a better way to produce clean water than to ship truckloads of plastic bottles of filtered tap water around the country, it's not going to make a dent in the water grid. The water infrastructure in metropolitan areas exists to provide water for thousands of uses—from drinking, bathing, and flushing to fire fighting and industrial applications—and that framework is not going to go away, even given its deplorable condition.

The author mentions the WaterWall for developing areas and correctly identifies potential problems with a delicate power grid, but he doesn't take the logical step of combining a WaterMill with a solar-power system to produce a unit that could run off-grid to provide drinking water for a small family or combining a WaterWall with a larger solar-power system for a village.

Laurence G. Heine
IEEE Life Senior Member
Harrisonburg, Va.

ALL STEAMED UP

The Steampunk Contraptors" [November] mentioned such famous novels as Moorcock's *The Warlord of the Air* and Gibson's *The Difference Engine* but failed to mention two equally famous movies that were inspired by steampunk: the Hollywood blockbuster *Wild Wild West* (1999), directed by Barry Sonnenfeld, and the animated film *Steamboy* (2004), directed by *manga* artist Katsuhiro Otomo.

Leroy Vargas
IEEE Graduate Student Member
Atlanta

CORRECTION

"Free the AAAA Six!" [Hands On, November] erroneously described the batteries' life span in terms of a 25-megawatt, not milliwatt, test. If and when such a miraculous power source is invented, *Spectrum* will eagerly bring you the news.

update

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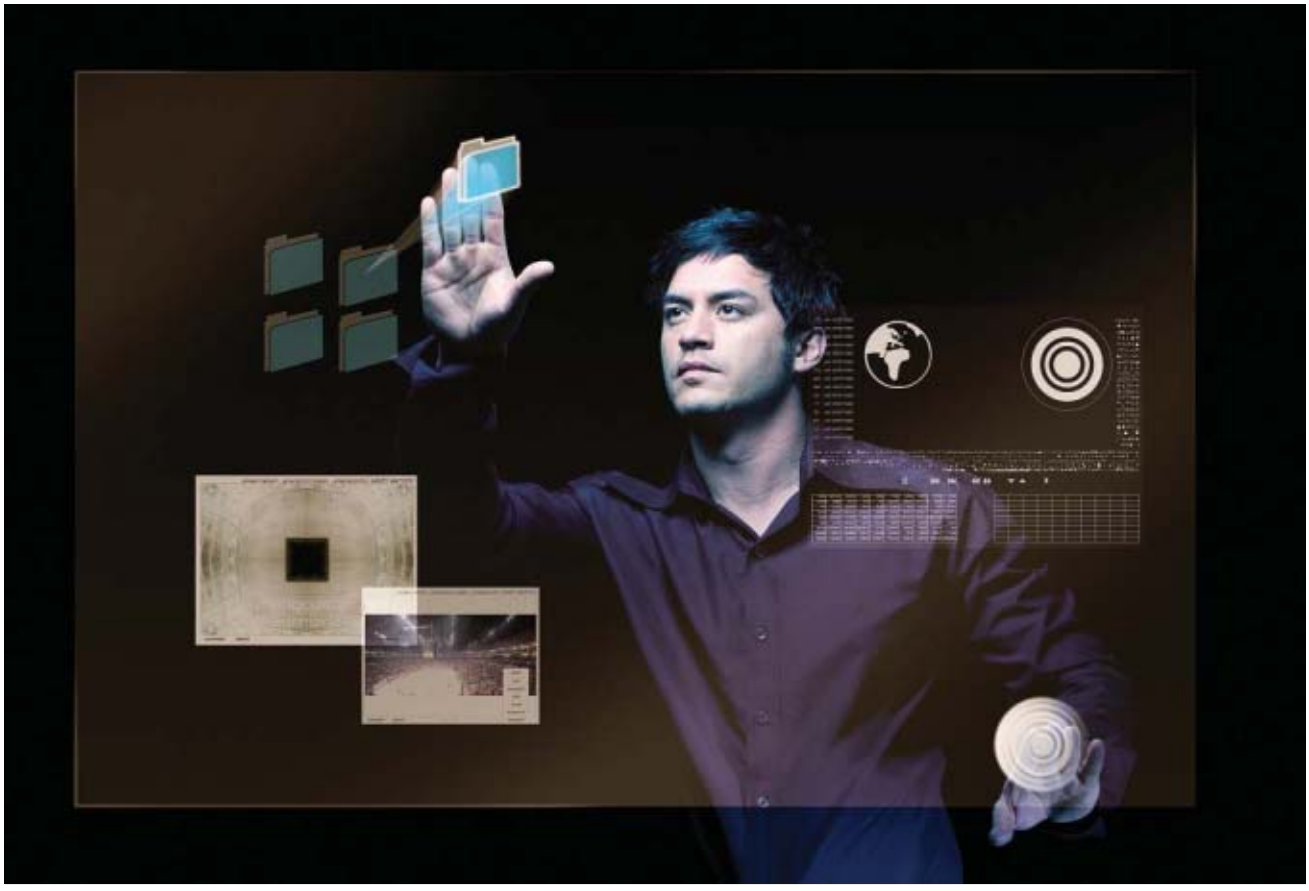

INVISIBLE FRIEND: The world's supply of indium, the key ingredient in the transparent conductor that makes touch screens and other displays possible, is running out.

PHOTO: THOMAS ROEPKE/ZEFA/CORBIS

The Trouble With Touch Screens

Scientists search for a replacement for indium-tin oxide, a transparent conductor that's vanishing fast

CHANCES ARE that if you purchased a new handheld gadget this holiday season, it had some kind of touch screen. That's good news for touch-screen makers, but they face a problem that is literally invisible. Indium-tin oxide (ITO), the transparent conductor used in touch displays, is in short supply. In fact, experts predict that we could run out of indium, a silvery metal produced as a by-product of zinc mining, in the next 10 years. The price of the metal has shot up from around US $100 per kilogram to nearly $1000 in the past six years.

Fortunately, many companies and research groups are coming up with alternatives to conventional ITO technology. These include alternative ITO formulations that save on indium, organic polymers, and exotic options like carbon. By 2015, these alternatives will make up more than half of the market for transparent conductors, predicts market research firm NanoMarkets, in Glen Allen, Va.

The bulk of ITO goes to make transparent electrodes in flat-panel displays such as computer monitors and ever-expanding LCD TVs. But touch screens like those used for PDAs, supermarket kiosks, and ATMs will be the easiest market to chase for makers of ITO substitutes. These devices contain ITO-coated plastic films separated by a thin space; touching the panel brings these two layers together, connecting a circuit and indicating where the touch

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update

occurred. Alternatives to ITO might gain easier entry to the market for touch screens, because these displays typically have lower conductivity requirements than high-resolution color TV screens. And because some alternatives are flexible, they might have an advantage over brittle ITO coatings, which can crack with repeated pressing and bending.

Any replacement technology will have to match ITO's transparency and come close to its conductivity while being more flexible and robust. Fujitsu has started selling touch screens made using the flexible polymer PEDOT. While this polymer is just as see-through as ITO, its conductivity (750 siemens per centimeter) is only one-tenth as much. Researchers at H.C. Starck, a German manufacturer of PEDOT, are getting higher and higher conductivities every year by doping it with different chemicals, says vice president Stephan Kirchmeyer, though environmental stability is an issue. Unlike ITO, PEDOT degrades over time when exposed to light or heat.

Carbon nanotubes look more promising. In addition to being strong and flexible, they are easier and cheaper than ITO to deposit on glass and plastic surfaces, because they can be formed into a solution. By comparison, ITO is "sputtered" onto a surface in a vacuum, "a clunky and expensive process," says Peter Harrop, chairman at research and consulting firm IDTechEx in Cambridge, England.

A tangled mat of carbon nanotubes a few nanometers thick (and hence transparent) can match ITO's conductivity, says Paul Drzaic, chief technology officer at Unidym, in Menlo Park, Calif. Unidym is working with Samsung on an electronic-paper device that uses such electrodes; Samsung demonstrated a prototype early in 2008. Unidym plans to start selling kilometers-long rolls of its nanotube-coated plastic films this spring. Drzaic claims that the cost of the films should compare favorably with that of ITO coatings.

Innovations are brewing in ITO laboratories too. Groups in Europe are working on ITO formulations that use less indium. These work well but are harder to coat on plastic, Harrop says. Others are making conductive inks by mixing ITO nanoparticles with carbon nanotubes and other nanomaterials. All of these approaches would save indium but are still in the lab. Meanwhile, researchers are cooking up indium-free transparent conducting metal oxides such as antimony tin oxide. Those are cheaper than ITO but just as brittle.

Indium-tin oxide won't be completely dethroned anytime soon—too many devices rely on the material. But for anyone who can develop a viable alternative, says Harrop, there are lots of opportunities.

—Prachi Patel-Predd

Bye-Bye, Blur

You're watching an American football game on your LCD television. Everything looks crystal clear until someone throws the ball downfield, at which point the ball becomes a smear. Once the motion stops, the picture is crystal clear again. The problem is with the LCD, which creates a psycho-visual phenomenon called LCD motion blur. Broadcom Corp. hopes to make LCD motion blur a thing of the past with a new processor. Other chip-based blur fighters use hardwired algorithms, but Broadcom's can be programmed to let your TV tailor the antiblur algorithm to suit what you're watching.

MAN: LOUNGEPARK/GETTY IMAGES; SCREEN: TOM DAHLIN/GETTY IMAGES

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update

Cryptographers Take On Quantum Computers

Researchers prepare for the day when quantum computers can easily crack today's codes

Software updates, e-mail, online banking, and the entire realm of public-key cryptography and digital signatures rely on just two cryptography schemes to keep them secure—RSA and elliptic-curve cryptography (ECC). They are exceedingly impractical for today's computers to crack, but if a quantum computer is ever built—which some predict could happen as soon as 10 years from now—it would be powerful enough to break both codes. Cryptographers are starting to take the threat seriously, and last fall many of them gathered at the PQCrypto conference, in Cincinnati, to examine the alternatives.

Any replacement will have some big shoes to fill. RSA is used for most of our public-key cryptography systems, where a message is encoded with a publicly available key and must be decrypted with a mathematically related secret key. ECC is used primarily for digital signatures, which are meant to prove that a message was actually sent by the claimed sender. "These two problems are like the two little legs on which the whole big body of digital signature and public-key cryptography stands," says Johannes Buchmann, cochair of the conference and professor of computer science and mathematics at Technische Universität Darmstadt, in Germany.

The reason that quantum computers are such a threat to RSA and ECC is that such machines compute using quantum physics. Unlike a classical computer, in which a bit can represent either 1 or 0, in a quantum computer a bit can represent 1 or 0 or a mixture of the two at the same time, letting the computer perform many computations simultaneously. That would shorten the time needed to break a strong 1024-bit RSA code from billions of years to a matter of minutes, says Martin Novotný, assistant professor of electrical engineering at the Czech Technical University, in Prague.

But quantum computers don't have an advantage over every type of cryptography scheme. Experts say there are four major candidates to replace RSA and ECC that would be immune to a quantum computer attack. One prominent possibility is an ECC digital-signature replacement known as a hash-based signature scheme. A hash function is an algorithm that transforms text into a relatively short string of bits, called the signature. Its security is based on being able to produce a unique signature for any given input. Even inputs that are only slightly different from one another should produce different hashes, says Buchmann.

Error-correcting codes are a potential replacement for public-key encryption, Buchmann says. Such a scheme would introduce errors into a message to make it unreadable. Only the intended receiver of the message would have the right code to correct the error and make the document readable.

Another potential type of public-key cryptography replacement is known as multivariate public-key cryptosystems (MPKC). To crack it, a machine must solve multivariable nonlinear equations. This type of cryptography is extremely efficient and much faster to produce than other schemes, such as RSA, which must use numbers hundreds of digits long to be secure, says Jintai Ding, mathematics professor at the University of Cincinnati and cochair of the cryptography conference. So MPKC could be particularly useful in certain applications like RFID chips. "RFID chips and sensors have very limited computing power and memory capacity," says Ding, whose specialty is MPKC. "But they are also very important in practical applications, so they need to be secure," he adds.

Cryptographers are also discussing a lattice-based system, where the lattice is a set of points in a many-dimensioned space. Possibly useful for both digital signatures and public-key cryptography, a lattice system would be cracked by finding the shortest distance between a given point in space and the lattice. Buchmann says lattice systems are promising but still need much more research.

For the time being, our cryptosystems are safe, yet both Ding and Buchmann caution that the need to develop alternatives is growing more urgent. As we build more-powerful classical computers, RSA and ECC must become more complex to compensate. In 10 or 20 years, we might need to base RSA on prime numbers thousands of digits long to keep our secrets. That's long enough to bog down some computers and prompt a replacement, even if quantum computers turn out to be a dead end.

—Monica Heger

BRANDON PALACIO

US $585 MILLION Criminal fines to be paid to the United States by LG Display of South Korea, Sharp of Japan, and Chunghwa Picture Tubes of Taiwan for fixing the price of LCD panels between 2001 and 2006. Prices for panels have been plummeting, but apparently not as fast as they should.

Europe Replaces Old Wind Farms

More power from fewer, bigger turbines

THE CONSTRUCTION crane hauling wind turbines at the 20-year-old Nørrekær Enge wind farm in northern Jutland, Denmark, is performing a highly energetic sleight of hand. By next summer it will have transformed a 77-turbine facility into one with just 13. Amazingly, this reduction will help double the farm's energy production. The trick is in the scale of the replacement turbines. At 2.3 megawatts, they should each generate as much peak power from Nørrekær Enge's winds as 8 to 15 of the vintage turbines installed on the site in 1988 and 1990.

The wind farm, owned by Stockholm-based utility giant Vattenfall, is the largest project to date under a Danish incentive program to promote the "repowering" of wind sites. It's an early example of what will soon become one of the largest sources of additional wind energy in Denmark, Germany, and California, whose governments pioneered wind energy in the 1970s and 1980s. Bundesverband WindEnergie (BWE), Germany's wind-energy industry association, set a goal of adding at least 15 000 MW of new wind-power capacity through repowering by 2020. That's 50 percent more than BWE expects to be added over the same period at new wind sites on land or at offshore wind farms.

The big challenge, wind developers acknowledge, is modifying site permits that restrict the spacing and height of turbines. Neighbors are often put off by the visual impact of the turbines themselves, which have morphed from blade spans of just a dozen meters or so in the early 1980s to as large as 126 meters today. And the new rotors ride higher than ever, perched on towers exceeding 100 meters, whereas hub heights generally maxed out at 60 to 70 meters in the 1990s.

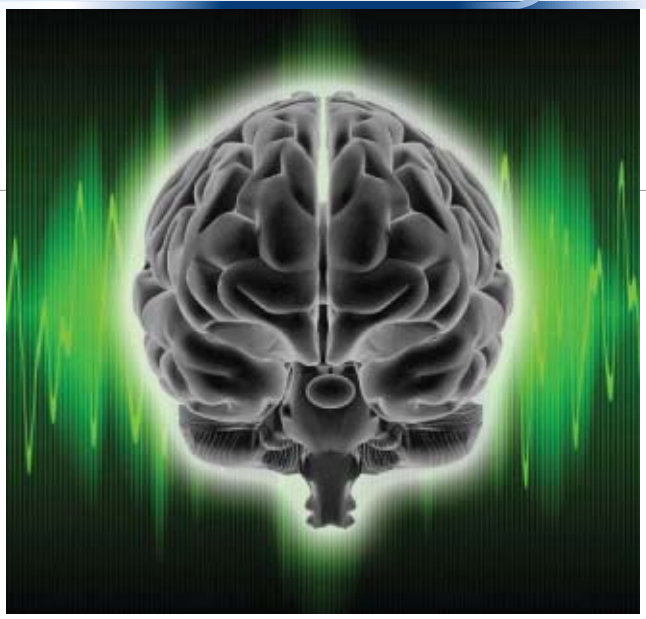
Higher hubs are key to repowering's profitability, because they place the turbines in stronger, more consistent winds, thereby increasing the number of hours per year that a given turbine will run. As a result, a repowered wind farm with double the power capacity of the original wind farm can deliver as much as four times as much energy. Held to the height restrictions commonly included in the wind-farm permits of previous decades, however, a repowered site is likely to generate just 50 percent more energy, according to Claudia Grotz, a BWE senior policy advisor. Grotz says that's a nonstarter for wind developers. "If people can't harvest the full potential on a site, then they won't repower it," says Grotz. "They'll let their old turbines run and make more money."

Grotz looks forward to a conference of regional planning authorities that the German government is organizing for early 2009, which she hopes will accelerate the process of approving wind-farm repowering.

Wind developers face an additional hurdle to repower in Denmark, where legislation going into effect next year will require wind-park operators to compensate residents if wind turbines reduce their property values. That's not an issue at Nørrekær Enge, according to Vattenfall spokesperson Arne Rahbek, because the site's repowering plan predates the new requirement.

So what happens to the old turbines littering the ground at Nørrekær Enge? Rahbek says they will be dismantled for shipping and sold, to resume making electricity in emerging markets like Eastern Europe and Cuba. —PETER FAIRLEY

BEFORE AND AFTER: A wind farm at Simonsberg, in northern Germany, produces more electricity now with just a few large turbines than it did with many small ones. *PHOTOS: BUNDESVERBAND WINDENERGIE*



update

Sound Waves For Brain Waves

Researchers use ultrasonic pulses to control the brain

When most people hear the word *ultrasound*, they think of the diagnostic tool used to look inside the womb and steal glimpses at a fetus. But researchers at Arizona State University at Tempe have developed a new use for it: to control brain activity from outside the skull.

William J. Tyler, one of the technique's developers and an assistant professor at ASU, says ultrasound will someday allow physicians to substitute neural implants with external devices. "We're trying to develop the technology to the point where we can do away with the electrodes that are used in vagus nerve stimulation and deep brain stimulation," says Tyler.

Vagus nerve stimulation is used to treat epilepsy and severe depression; deep brain stimulation treats Parkinson's disease and, experimentally, other neural and psychiatric ailments. Both rely on pacemaker-like systems surgically implanted in a patient's chest, with electrodes running either to nerves or the brain. Eliminating the risks of surgery could make neurostimulation more widely available.

In October, Tyler and his colleagues reported that they had used low-power, low-frequency ultrasound to stimulate activity in thin slices of brain tissue preserved on slides; by early November, the team had performed an experiment on a live mouse in which they induced involuntary movement by stimulating certain regions of the mouse's brain from outside its head. In both cases, they used bursts of ultrasound at frequencies between 0.44 and 0.67 megahertz—much lower than the frequencies used in imaging. The device delivers 23 milliwatts per square centimeter of brain—a fraction of the roughly 180 mW/cm^2 upper limit established by the U.S. Food and Drug Administration (FDA) for womb-scanning sonograms.

This combination of low frequencies and low power represents a sweet spot where the sound readily penetrates the skull and affects brain cells. The sound waves temporarily knock open the cells' voltage-gated sodium channels, special proteins that allow sodium ions to pass through the cells' membranes. The result is a localized change in a cell's polarity from negative to positive. The polarity change can be strong enough to cause the cell to release chemical neurotransmitters and thereby induce similar voltage changes in other neurons to which they are linked, resulting in movement or other behaviors.

Expectant mothers needn't worry that ultrasound imaging would harm fetal brains, says Tyler. His group has shown that at the higher frequencies and power ratings used for imaging, ultrasound's bone-penetrating and brain-modulating potential is greatly diminished.

Tyler reports that he and his colleagues are also investigating low-power, low-frequency ultrasound's use in another device: instead of triggering precisely controlled brain activity in a focused area, it would lower the metabolic rate across the entire brain. One application for this is the prevention of secondary damage that occurs in the minutes or hours after a head injury—when a trauma-induced slowdown of blood flow and a cascade of biochemical reactions result in cell death.

"Imagine an infantryman rocked by an explosion or a football player knocked to the ground by a helmet-to-helmet hit," says Tyler. "Some sensor would detect that there was enough force generated for it to be a concussive event. Then an array of ultrasound transducers mounted in the helmet would automatically turn on, modulating neuroprotective pathways in the brain that would slow the brain's metabolic rate, [limit the destructive chemical cascade], and prevent cell death."

The low frequencies used can travel some distance through the air. So could you be zapped with a mood-altering blast from across a room? Probably not, Tyler says. In theory, the ultrasound technique could work from up to about a meter away, he says. "The farthest we've tried so far has been roughly 50 millimeters."

It will take at least five years for any version of remote ultrasound brain control to make it through development, clinical trials, and FDA approval, Tyler estimates. He says he is establishing a spin-off company that will do the further research required to get a device to market. "I feel like I have the social responsibility to try to develop this as much as possible," he says.

—Willie D. Jones

PHOTO-ILLUSTRATION: BRANDON PALLACIO; ORIGINAL PHOTOS: MAX DELSON/ISTOCKPHOTO (BRAIN), CLEARVIEWSTOCK (SOUND WAVES)

Tsunami Alert System Starts Up in Indonesia

Four years after the mother of all monster waves struck, Indian Ocean countries will know of a possible tsunami just 3 minutes after an earthquake

INDONESIA HAS switched on a tsunami detection system designed to prevent a recurrence of the disaster following the monstrous wave of 2004, which killed at least 130 000 of its people and nearly half that many in other countries.

Waves that big strike the shores of the Indian Ocean only about once every two centuries, on average. But even between such big events, the German-Indonesian Tsunami Early Warning System (GITEWS) should pay for itself by helping to mitigate the effects of relatively small earthquakes and the lesser waves that they produce. The first test came on 17 November 2008, just days after the system went live, when a fairly strong earthquake hit central Indonesia and the government issued a tsunami alert, though no killer wave appeared.

The detection system uses ocean-floor devices that measure changes in water pressure and surface buoys that both relay the information to a satellite network and add their own measurements of changes in sea level. Software then analyzes the data with algorithms calibrated to account for the depth of the water, the shape of the ocean floor, and other factors identified previously during simulations. By thus precalculating aspects of any conceivable tsunami, the system cuts the time it takes to recognize a killer wave. That time is critical, because most quakes in the Indian Ocean occur uncomfortably close to the Indonesian archipelago.

"You have to be very quick, because wherever the earthquake happens, [the tsunami] will hit the coastline in no more than 30 to 40 minutes," says Jörn Lauterjung, of the German Research Centre for Geosciences, in Potsdam, which designed much of the system. "We had to develop new seismic analysis programs to reduce warning time from the 10 to 15 minutes that are usual worldwide to just 3 minutes."

EARLY WARNING: Indonesian engineers install a system of tsunami-detecting sensors. *PHOTO: DADANG TRI/REUTERS*

Germany has donated €51 million (US $68 million) to the project, which is between one-third and one-half of its estimated final cost. Indonesia furnished most of the remaining money, about half of which went to establish communications systems and public-education programs. Without such "soft" technology, extra warning time would be of little value. A case in point was Somalia, where an estimated 289 lives were lost in 2004 because the country was not able to exploit the 8 hours of warning it had of a tsunami's approach.

Spotting a tsunami is harder than it may seem. The wave starts off in water so deep and at an amplitude so low that it could pass under a small boat without waking its occupants. Only in the shallows near the shore does it stand up as a wall of water on the beach. For that reason, scientists must track several different sorts of information in time and in space.

"You have to find the right waves," Lauterjung says. "There's the primary wave; the secondary waves, which are slower; and then the surface waves, which are slower still. If your instruments are far enough from the earthquake, you can pull the various signals apart, but if you're nearby, they'll overlap, making it hard to estimate the magnitude."

Such fine-tuning isn't needed in most of the Pacific region, where quake epicenters are so distant that saving 9 or 10 minutes is of no particular advantage. The exception is Japan, which like Indonesia is in an earthquake zone; it came up with its own analysis system years ago.

Why not take the Japanese results and apply them directly? Lauterjung says the conditions are so different that the work had to be done from scratch. Why turn for such advice to Germany, which has nearly no experience with tsunamis?

"Seismology was developed in Germany," he responds, the pride audible in his voice. "We also have a long tradition with ocean modeling, tide models, and other such things. So though we're not dealing with tsunamis, all the different components needed to detect them are already there for us."

—PHILIP E. ROSS

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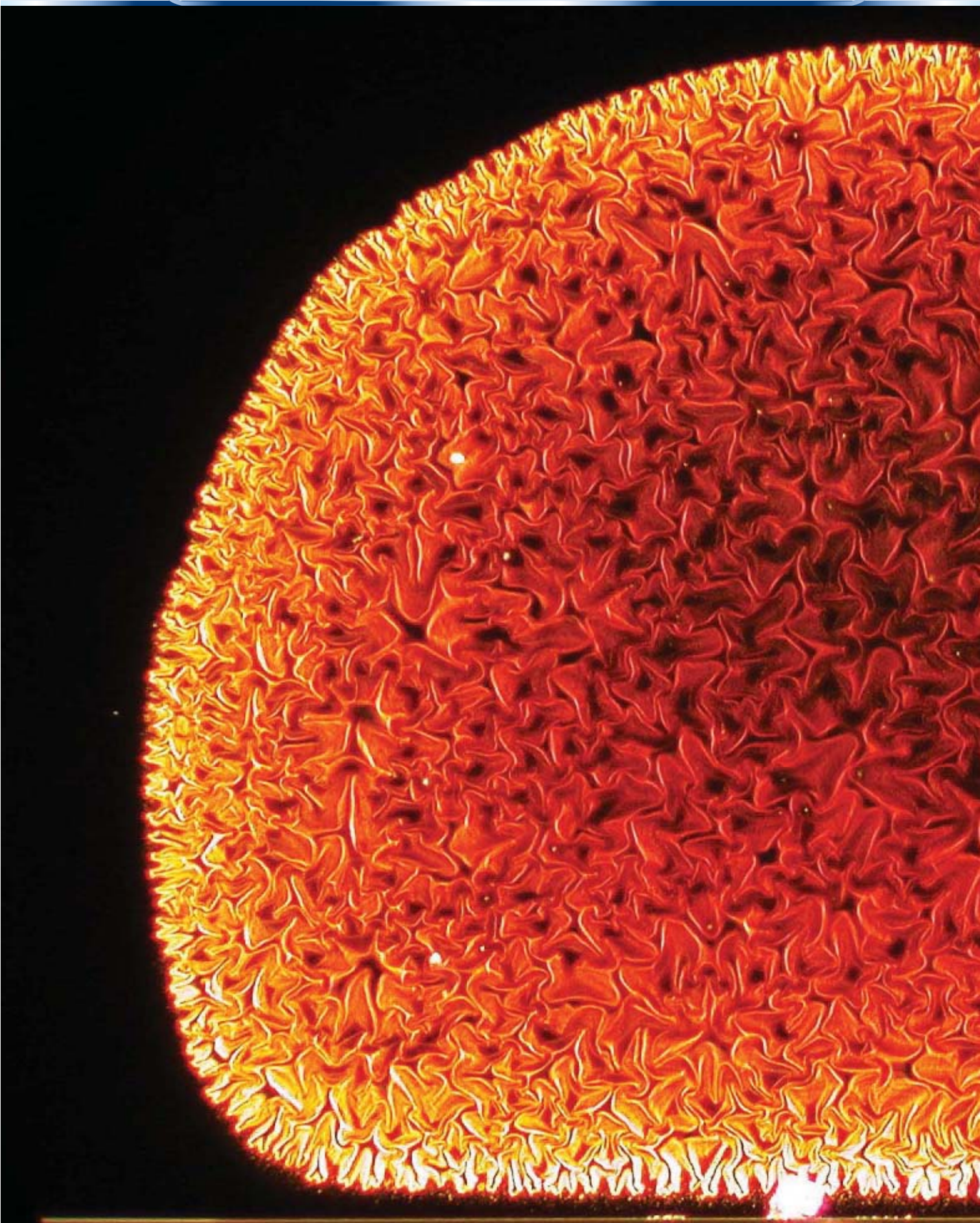

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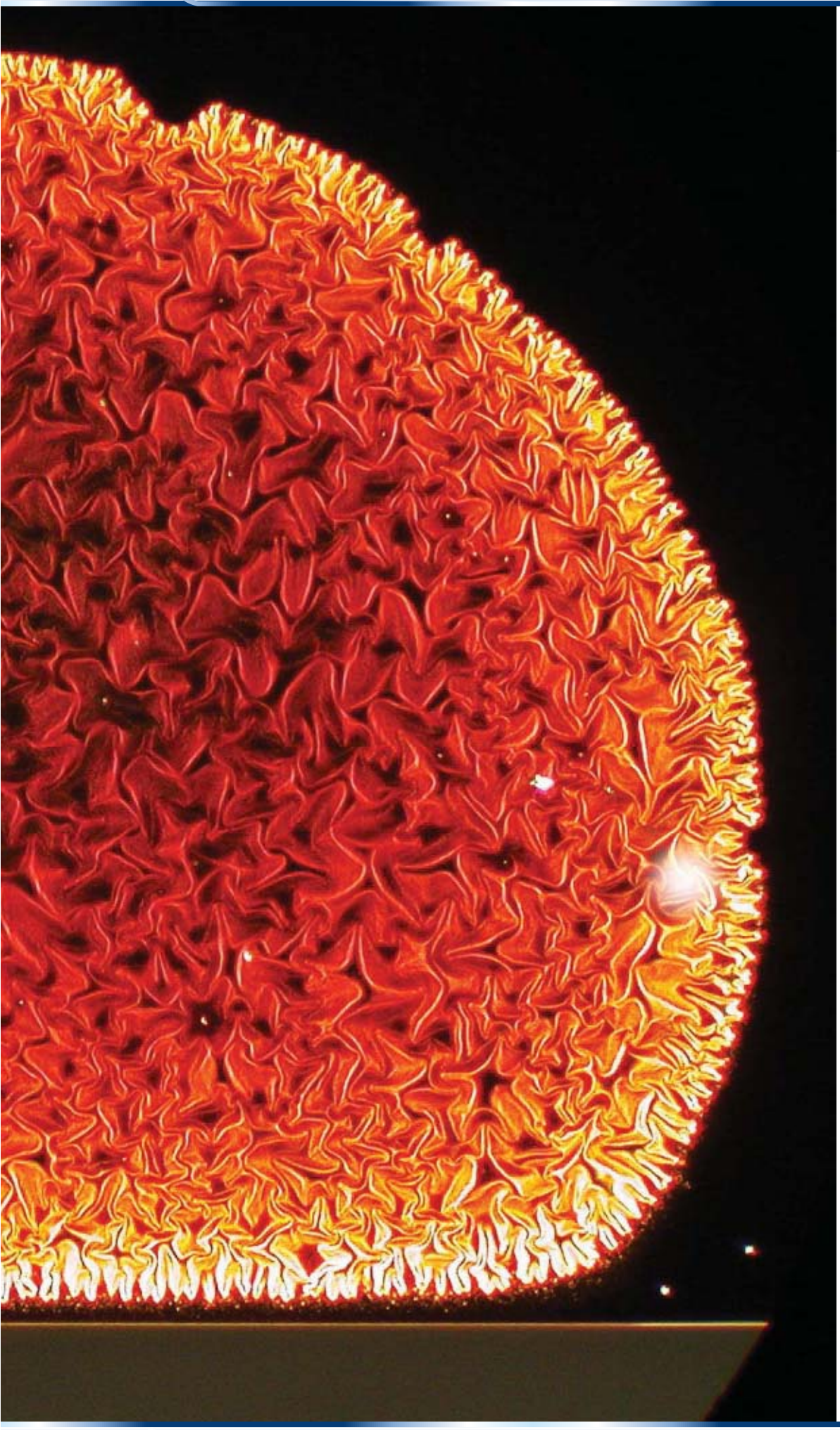


the big picture

CARBON IN BLOOM

It looks like a single flower bud, but it's actually an entire quick-growth forest with tens of millions of "trees" in the cluster. You can't see them, but each tree is a single-wall carbon nanotube, roughly 3 angstroms across and 2 millimeters tall, according to Paul Marshall, the researcher at the National Research Council of Canada, in Ottawa, who took second prize at Nikon's Small World Photomicrography Competition with this image. Although a single nanotube is too tiny for a 30X stereo microscope to resolve, particles that make up the forest's canopy are visible in the photo. They are in a slightly liquid state, giving off energy as they solidify. That energy—and a special microscope attachment—is responsible for the wavy patterns, the balloonlike shape, and the bright, glowing colors.

IMAGE: PAUL MARSHALL

reflections BY ROBERT W. LUCKY

To Twitter Or Not to Twitter?

TWITTER, THE social-networking Web site that allows users to broadcast short text messages to a group of friends, has burst into popularity with millions of subscribers. I'm a confirmed e-mail user, but that's *so* 20th century. I feel a certain pressure to get with it. So, to Twitter or not to Twitter? I view it as a question for the ages—the ages of the users, that is.

It was my generation of engineers that created the Internet, but it is largely today's youth who are molding the social connectedness that is coming to characterize cyberspace. These are the so-called digital natives, who grew up with the Internet already a part of everyday life. They're always online, inhabiting multiple identities, living a culture of sharing and peer collaboration. For them, multitasking is just the way it is. We older engineers built cyberspace, but our kids live in it, and for many of them the technology is transparent and almost irrelevant.

So as a digital immigrant, already an adult as the new culture was forming, I am amazed at what I see. At a recent meeting a young speaker casually mentioned that every morning he Twitters that he has just woken up. Alarm bells went off in my head. I thought about the fact that several scores of people are going to read a message that this guy has awakened. Isn't this is an incredible waste of time for everyone involved? But a more unpleasant thought also formed in the back of my head—the worry that no one would care that I myself had just arisen. There must be some social consequence that I'm missing. An older acquaintance told me that he had been using Twitter and that after a week he had begun to feel a sense of connectedness.

At this same meeting, another young speaker berated the whole audience of industry leaders. "I was told this was a conference of executives, so I'm going to talk slow and use big slides," he began. "You are living in a bubble. You come here to find out what kids do. You guys are pencil pushers. You're forced to make money." I shrank in my seat, blanking out the rest of this tirade while testing unspoken counterarguments. And I wonder: years from now will this young person adopt the ways of us older workers, or are we seeing the rise of an entirely new social fabric?

Later, I discussed a forthcoming meeting with other organizers. Should we encourage the audience to Twitter during the next meeting? On the one hand, we felt this would distract from our speakers. Moreover, we had reviewed the unsolicited Twitters during a previous meeting and concluded that they were largely vacuous. On the other hand, perhaps the Twitters encouraged engagement. And anyway, how could we deny a growing use of that technology in a technology meeting? Alas, we could draw no rational conclusion other than to designate a "tag" for that particular meeting for Twitters to congregate around. We're in the middle of something happening around us, and we don't really understand the consequences.

I am constantly fascinated with the development of the sociology of the Web. Perhaps two insightful cartoons from *The New Yorker* illustrate the evolution. In 1993, the magazine published Peter Steiner's famous cartoon of two dogs at a computer, one saying to the other, "On the Internet, nobody knows you're a dog." At that time the Internet was relatively young, and we all rejoiced in the unbridled freedom the cartoon embraced.

By 2005, in the same magazine, Alex Gregory had a cartoon with two dogs (I'm thinking the same dogs!) at a computer. One says to the other, "I had my own blog for a while, but I decided to go back to just pointless, incessant barking."

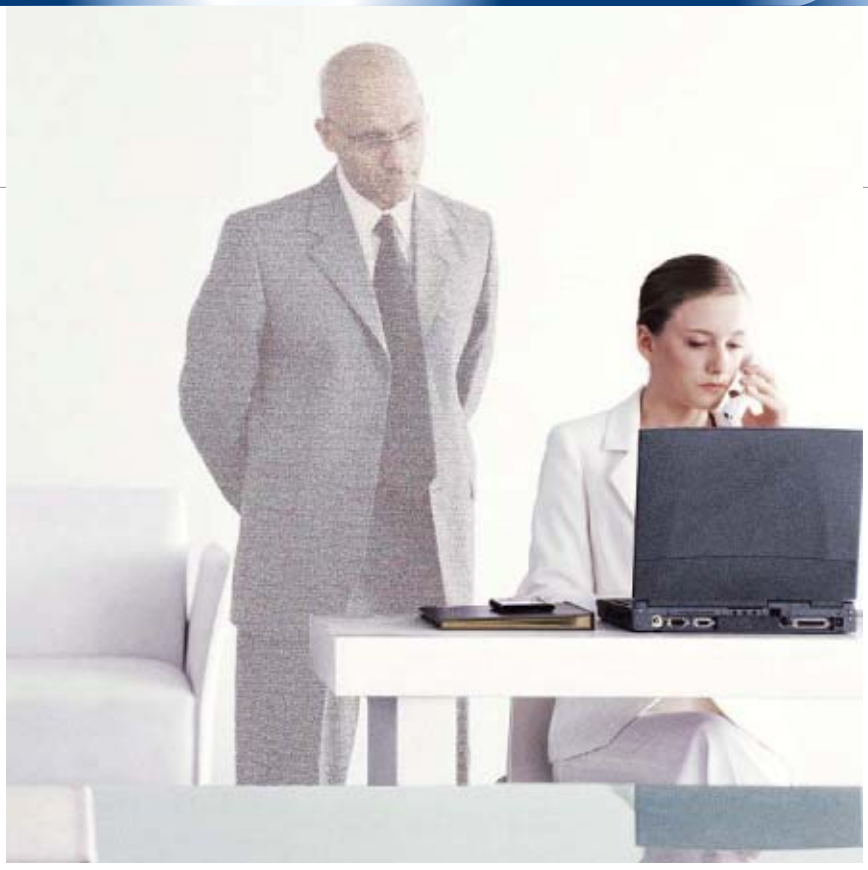
So is the networking phenomenon a great revolution in social consciousness, or is this just a lot of pointless, incessant barking? If you get a message that I've just awakened, you'll know what I've decided. ❑

GREG MABLY

careers

THE ALL-SEEING EMPLOYER

An overseer of remote employees stops by their virtual cubicles every few minutes



FREDERIC CIROU/GETTY IMAGES

AT FIRST glance, oDesk, a site that helps employers hire, manage, and pay online contractors, looked like just another marketplace to Web developer Jason Cartwright. So when a former colleague booked him to work on a few projects already managed through oDesk, Cartwright agreed.

There turned out to be one catch: oDesk's electronic monitoring feature, which takes computer screen shots randomly six times an hour. If you're reading personal e-mails or watching YouTube on billed time, your employer will find out. "As I'm an independent developer, it was very invasive at first," Cartwright says. But he quickly got used to the screen shots and saw the flip side. "I like the accountability. Knowing that I was being monitored forced me to reduce distractions and stay focused."

He's not alone in not seeming to mind. Some 100 000 Web developers, programmers, graphic designers, writers, and other contractors, most of them working outside the United States, have put their profiles on oDesk since the company was launched in Menlo Park, Calif., in 2004. But not everyone thinks the electronic monitoring is ethical. Critics have called the feature "Big Brotherism" and even a form of slavery.

But all work requires accountability. When output is hard to measure, you pay by input, which is why lawyers, French tutors, and physical therapists charge by the hour. When output is measurable, you pay by the job, so writers bill by the published word and house painters by the square foot. The point of oDesk is to make both options available.

Gary Swart, the CEO of oDesk, argues that when small businesses hire independent contractors for quick-turnaround projects, his service can benefit both parties. Employers know that their work is getting done and that they are not being overcharged, and contractors rest assured that they'll be paid for their time and effort.

Swart says that oDesk tries to make remote work and outsourcing more effective by emulating the real world. Contractors log into a "team room," which punches them in on an Internet "time clock." oDesk then tracks the time and bills for it, taking care of currency conversions and international payments.

Contractors do have some control over what gets sent to their bosses. They can edit their work logs, add time spent working while not logged in, and delete any screen shots they choose, forfeiting payment for that time.

Swart says that having a member of a work team virtually walk by your cubicle is a small inconvenience for what you get in return: guaranteed payment. "You don't want to send an invoice a month from now and have the employer question that you really worked 60 hours last week," he says. "And you don't want to chase after your money."

But there are better ways to build trust, says Peter Weddle, an HR consultant and former CEO of Job Bank USA. He likens having your screen monitored to "sitting in your office and every single moment of every single day there is an eye up in the corner watching you." When a buyer and seller first start working together, there is value to electronic monitoring to build trust between the two parties. "But after some period of time," says Weddle, "there is no need for those kinds of technological handcuffs."

Employers who have used oDesk disagree. Start-up developer Jan Zands hired two software firms in India through oDesk to develop an online software tool for managing phone messages. He says that employers have a right to know how billed time is being spent. "If you're hiring somebody from all the way across the world and they're billing you by the hour, it's really nice to be able to confirm that they're working during that time," he says.

In fact, Zands argues that monitoring via screen shots can be less intrusive than a nosy boss who calls and checks in periodically. "Developers are creative people, and sometimes their creative flow can be interrupted by constantly asking for updates."

—PRACHI PATEL-PREDD

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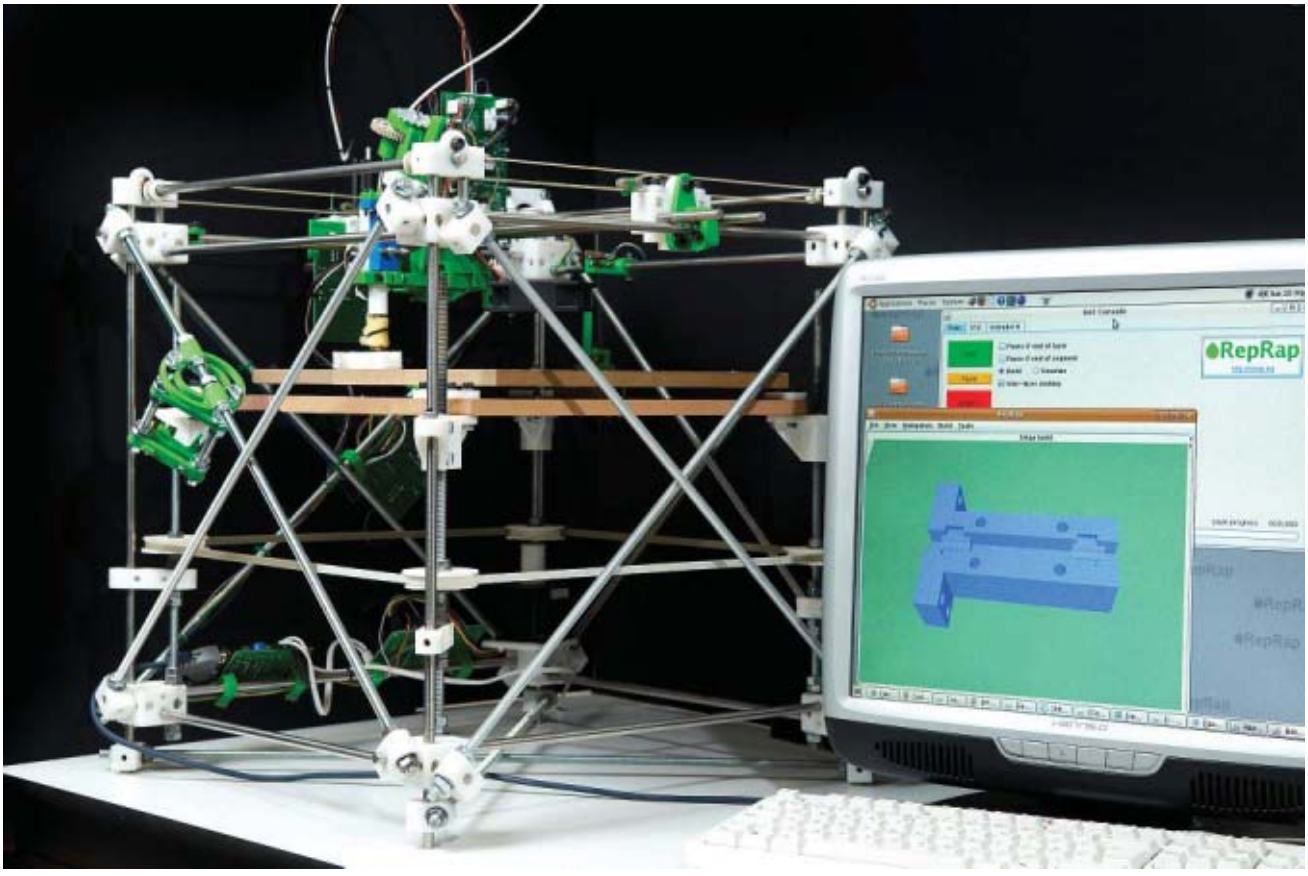
hands on



WRITE ONCE: RepRap turns computer-based designs into real-world objects. PHOTO: REPRAP

A SELF-MADE MACHINE

RepRap, a new open-source hardware project, goes a long way toward fulfilling the dream of self-replicating machines

More than 50 years ago, computer pioneer John von Neumann conceived of a self-reproducing machine. It would mine its own ore, smelt it into metal ingots, machine the ingots into parts, and assemble the parts into a copy of itself. During the 1980s, nanotechnology evangelists worked out the same idea on a much smaller scale, prompting critics to envision a horror scenario in which molecule-size bots reduce the entire world to a featureless mass dubbed "gray goo."

Today there's RepRap. Unlike gray goo or von Neumann's idealized machines, RepRap (short for "replicating rapid-prototyper") doesn't harvest its own materials. But also unlike them, it's entirely real. For about US $725 in parts, this self-reproducing machine, spawned by a global band of engineers and hobbyists, will squirt out complex three-dimensional patterns of molten plastic filaments that will solidify into most, if not all, of the mechanical parts for another RepRap (see sidebar, "Self-Reproduction Is Hard; Self-Assembly Is Harder").

RepRap consists of a roughly cubical half-meter frame enclosing its fabrication volume, along with motors, drive electronics, and one or more "write heads" that extrude plastic (or some other material) into the desired shapes.

RepRap gets its instructions from your PC, via a USB connection. Software on the PC, written in Java, takes design files produced by 3-D drawing programs and turns them into instructions for the RepRap. The software converts solid-object models into a series of movements with the extruder on or off, and with

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either sparse or solid interior filling, depending on a part's structural requirements.

Because all of RepRap's software and hardware designs are open source, no one knows exactly how many people are using it on projects. Adrian Bowyer, a senior lecturer in mechanical engineering at the University of Bath, in England, and the originator of the project, recalls the day last winter when a RepRap machine appeared on exhibit at the Science Museum in London. He had never even heard from the team building it, much less known of their plans to put one on display.

Zach Smith, who manages the RepRap Research Foundation (http://www.rrrf.org), in New York City, counts a dozen or so core developers, but about 500 more have bought parts from the foundation's online store. Some of the circuit boards and other components can't be purchased elsewhere, he notes, although a determined builder could fabricate them from scratch.

I'm fascinated not only by the idea of RepRap but also by the possibility of building one. I already have some ideas that would extend RepRap's ability to create different forms—for example, how to implement some of the rough designs others have floated for additional assembly heads that pick up and place components or wield cutters that in turn would cut parts from materials that can't be extruded.

But for me, RepRap's biggest appeal is its appetite for prefabricated circuit boards that I don't have to etch or solder and for structural components that call for a minimum of epoxying or lathe work. In other words, even if *I* build it, this thing might actually work.

You'll be reading more about my attempts to build a self-reproducing machine. And if you're working on a RepRap, I would very much like to hear from you.

—Paul Wallich

SELF-REPRODUCTION IS HARD; SELF-ASSEMBLY IS HARDER

REPRAP ISN'T a von Neumann–style omnivore but rather a parasite. To reproduce, it needs a ready supply of metal rods, machine screws, stepper motors, microcontroller boards, and meltable plastic filament. And geeks. Separating self-reproduction from self-assembly makes sense for any number of reasons, starting with Earth's supply of billions of highly functional assemblers—humans.

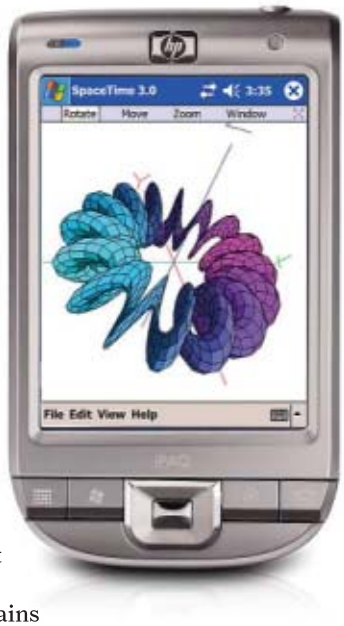
Biological viruses similarly self-reproduce but don't self-assemble; they hijack the assembly mechanisms of individual cells. The University of Bath's Adrian Bowyer prefers to characterize his machine more as a symbiote than a virus.

Although RepRap relies on people to assemble its parts into a working whole, its programmable extrusion head also produces whatever other objects (within its capabilities) those people program it to build. If something—a cup, a coat hook, a door handle—can be made out of cheap plastic, RepRap can make it. As developers work out ways to deposit wires as well as structural elements, RepRap's bailiwick will grow. Conceptual designs for simple motors and actuators are already being sketched out, Bowyer notes. Researchers contributing to the similar but separate Fab@Home project (http://fabathome.org), which is oriented toward making other objects but not copies of itself, have even managed to print working semiconductors. —*P.W.*

THE MOBILE POLYNOMIAL

New software puts the power of Mathematica into your phone

YOU NEVER know when you'll be dining out with your friends and have to work out a partial derivative or two. This neat little program puts hundreds of mathematics and graphics functions into such a small package that it fits into Palm, Windows Mobile, and other smart phones, including—most recently—the iPhone. Of course, it also runs on regular Windows, Macintosh, and Linux computers.



SPACETIME
US $10 to $30
http://www.spacetime.us

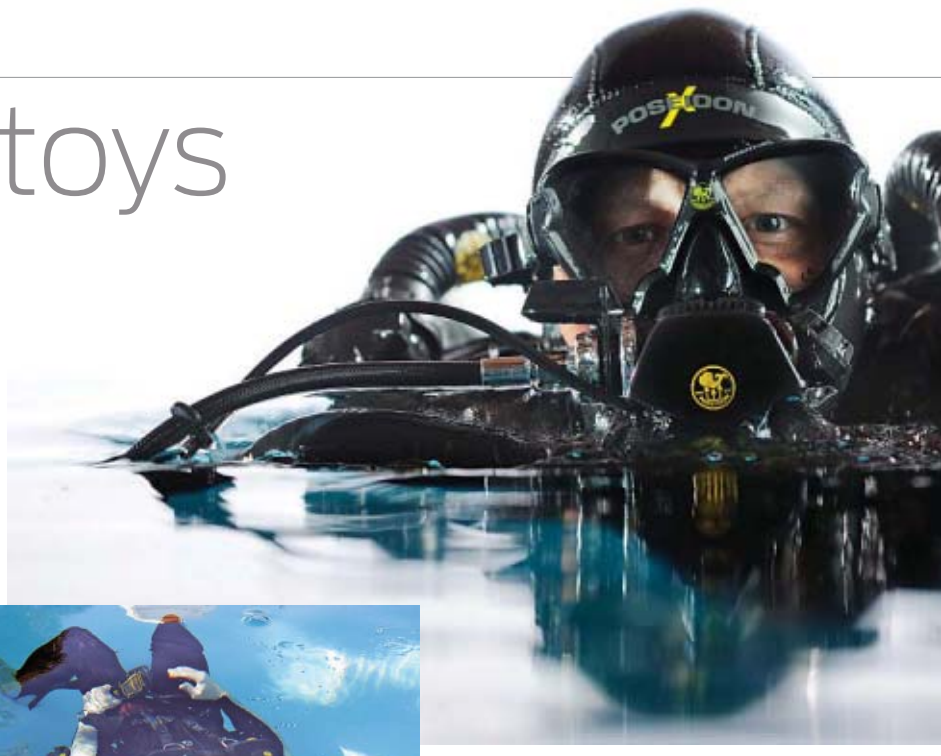
PHOTO: HEWLETT-PACKARD/SPACETIME

SpaceTime resembles a tiny version of the Mathematica or Maple analytical programs. Its creator, Chris DeSalvo, started out as a game designer, which perhaps explains how he managed to squeeze some astonishingly nice graphics and even animated displays onto such tiny screens. There are even sliders that let you vary a parameter and see the effects on a plotted function. SpaceTime is very easy to use, remarkably powerful, and the price is right.

Give copies to the students in your family and maybe they'll create animated Möbius strips on their cellphones instead of texting their friends from the back row of math class.

—Kenneth R. Foster

tools & toys



WINNER: POSEIDON DISCOVERY

The world's leading designer of scuba gear brings closed-circuit rebreathers to the masses

THIS MONTH, Swedish scuba manufacturer Poseidon Diving Systems plans to introduce an electronically controlled closed-circuit rebreather (CCR) called Discovery, which promises to change mainstream sport diving the way Microsoft Windows changed computing. Rebreathers, which have been around for decades, greatly increase dive time but at an enormous cost in complexity, training, and setup time. Poseidon's new system is designed to do away with all that. In October, the company gave me the system for a 30-minute test splash during a trade show in Las Vegas.

FIRST BREATH: Closed-circuit rebreathers, long the scuba technology of choice for professionals, may soon be available to amateur divers.

PHOTOS: TOP, POSEIDON DIVING SYSTEMS; BOTTOM, KARL SHREEVES

To see what sets Discovery apart, let's review some scuba basics. The conventional scuba equipment that Jacques Cousteau introduced in 1943 has an open circuit. The regulator supplies air from the tank, and your exhaled breath vents into the water as bubbles. Your body uses only a fraction of the oxygen in each breath; the rest is wasted. At higher pressures, each breath takes more from your cylinder, so you use up your air faster just when you need it the most—on your deepest dives.

A rebreather with a closed circuit gets around the problem by salvaging oxygen in your breath. You exhale into a counterlung, a gas bladder that expands and contracts as you breathe. The air then passes through a chemical-absorbent canister that removes carbon dioxide. Sensors analyze the oxygen content and direct the system to add either pure oxygen or regular air, whichever is needed to keep the oxygen concentration within its proper boundaries. The resulting gas goes to a second counterlung, then back to you when you inhale.

Closed-circuit rebreathers can give you seven times as much dive time as standard scuba equipment, regardless of depth. They also make it easier for your body to adapt to changes in water pressure, because they adjust the ratio of nitrogen to oxygen as you go up or down. The downside is complexity. It can take up to an hour, even for experienced divers, to set up and check a CCR compared with a few minutes for an open-circuit system. Then, underwater, CCR divers must decipher multiple readouts—including sensor readings, supply pressures, decompression status, oxygen exposure status, oxygen partial pressure, and scrubber life; recognize the combined effects of all those variables on dive time; and make what are in effect tens of thousands of implicit decisions. Even with electronic systems, problems aren't always obvious.

So until now, sport use of CCRs has been limited to a relatively hard-core cadre of "tec" divers who are willing to deal with these hassles and risks. Even many professionals have stayed with the simplicity of open-circuit scuba.

Discovery may change all that. It is the culmination of 20 years of design and development by Bill Stone, arguably the most innovative and experienced CCR engineer alive, famous for leading several milestone cave-diving projects.

Since the mid-1980s, Stone and other divers have used limited-production rebreathers that use computer controls to improve operation and make the device easier to use. He has taken his Cis-Lunar Mark III, IV, and V models, designed for science and exploration, to depths in excess of 120 meters—edgy stuff.

The Discovery Cis-Lunar Mark VI, though, is the first to use sophisticated predictive modeling to make many of the complicated decisions that divers have had to make themselves, after undergoing many hours of training; it is designed for mainstream divers going no deeper than 40 meters. Though the Discovery is vastly simpler to use than its limited-production predecessors, its inner workings are much more complex—just as even the

earliest Windows software had many more lines of code than MS-DOS. The result is a CCR design that's an order of magnitude more sophisticated than what came before it.

The heart of Discovery is a set of 8-bit microprocessors distributed around the rig to provide computing power where it's needed. Discovery not only monitors all subsystems but also collects breathing and environmental data to update its models in real time. That data is applied against a 160 000-entry decision table, gathered from thousands of hours of human test dives. The upshot is a system that takes on the decisions that burden conventional CCR divers—and, at times, Stone says, makes better decisions than humans.

Consider an emergency requiring a quick ascent or descent. Maybe you need to get to the surface quickly or dive down to a fellow diver in trouble. These rapid changes are problematic with a conventional CCR because you can't change your oxygen-nitrogen ratio or breathing-gas volume quickly enough. You're left with either too much or too little oxygen—and either situation is life-threatening. According to Stone, however, Discovery's predictive modeling recognizes the abnormal descent or ascent and adjusts the mix of breathing gases based on where the diver will be rather than trying to keep up with where the diver is.

Under Stone's guidance, I tried a beta unit in a swimming pool. Setup took a mere 10 minutes, compared with an hour for conventional rebreathers. You just change out the scrubber canister, attach two filled gas cylinders, and turn it on.

Underwater, the harness and weight distribution felt comfortable and tight immediately; normally it takes one or two dives to get any scuba rig "tuned" to an optimal fit. Dry, the unit weighs around 15 kilograms, which is a bit lighter than a typical open-circuit rig. I understood the display without any real instruction. Stone told me to expect some alarms due to some software revisions they're working on. This allowed me to see the warning icons, feel the mouthpiece vibration, and switch to open-circuit bailout. No issues here.

Discovery also did well at handling rapid breathing, a common problem in all scuba gear, open or closed, especially at greater depths. At its worst, you feel like you're breathing through a soda straw while running a marathon. I huffed and puffed as hard as I could, simulating rapid breathing, but Discovery kept up.

When I surfaced, Stone asked me how the hoses felt, referring to the tendency for many CCRs to restrict comfortable head movement. I realized I hadn't even thought about the hoses.

My dive lasted only 30 minutes and didn't go deeper than about 2.5 meters, so I wasn't able to see how Discovery performed at depths that would truly test the system's capabilities. Still, I'm left with the impression that this may indeed be the first CCR for casual recreational divers. —Karl Shreeves

LOSER: EYES WIDE SHUT

Display glasses still aren't ready for prime time

I COULD STOCK a computer-peripheral museum with all the input and output devices I've accumulated over the years. Drawing tablets, three-dimensional mice, dial boxes, rotatable monitors, touch pads—if it purports to make using software easier or games more enjoyable, I have probably tried it and consigned it to a plastic bin in my basement.

That's where the Vuzix iWear AV920 personal-display eyewear will be going. These display glasses, said to be compatible with iPods, Xboxes, PS3s, DVD players—any audiovisual device at all!—sounded wonderful: "a wearable virtual 62-inch big screen," "crystal-clear high-resolution 2-D and 3-D," "lightweight and ergonomic design ensures long use in perfect comfort." What's not to love?

But the AV920 doesn't deliver. It's made of flimsy soft plastic, yet its edges are so badly finished that they scratch behind the ears. Its stereo earbuds are mounted on stiff rubber arms that are hard to bend into shape and were too short to reach my ears. And, oh yes, the sound quality is unremarkable.

VUZIX

Worst of all, the thing works only with iPods that have better screens than it does. In fact, the "virtual 62-inch big screen" turns out to be 640 by 480, which the world hasn't called "high resolution" since Windows 3.0. With their US $350 price tag, I can't help but compare these virtual-reality glasses unfavorably to the $500 1080p HD televisions at my local Costco.

Playing *Soulcalibur IV* on the floor instead of on my couch, tethered to the Xbox 360, was downright unenjoyable. And the glasses didn't work with my computer; the company wants me to buy another model to do that. The personal-display industry has made great strides in recent years. Unfortunately, these strides have not been great enough to make display glasses more desirable than traditional displays. Save your money for something useful, or risk adding to your own peripheral museum.

—*Harry Teasley*

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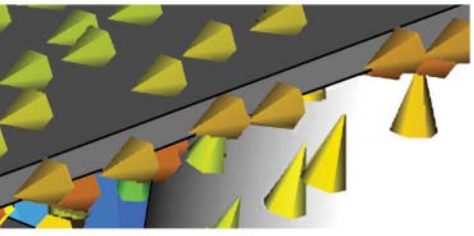

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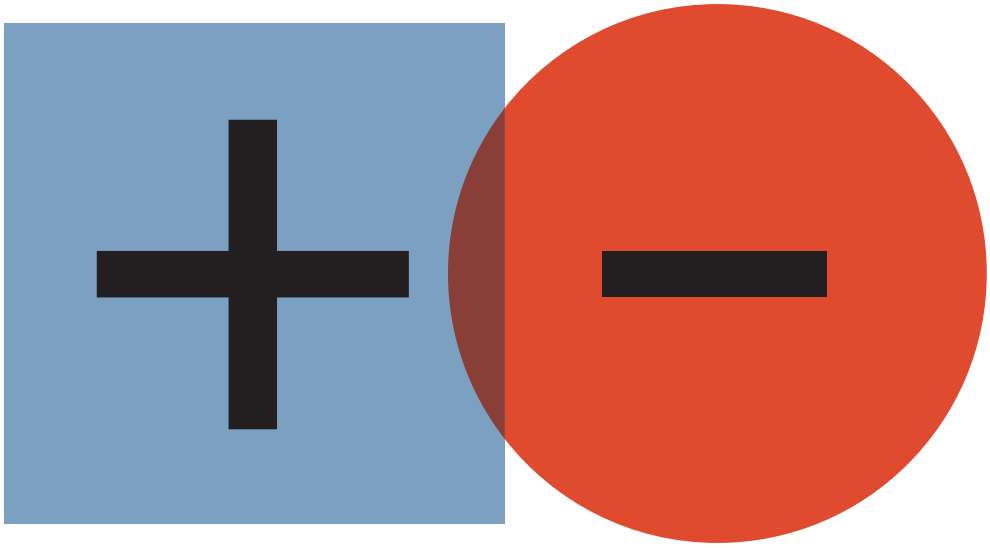


WINNERS & LOSERS VI

OUR PAST EXPERIENCES with this annual special issue suggest that some of you are going to go to your computers in the next day or two and compose a little message to us. We're not sure exactly what it will say. But to paraphrase: "Just what the heck do you people think you're doing by giving a thumbs-up or thumbs-down on the technology projects of good, hardworking, decent folk?"

We're engaging in a reality check. And we're also indulging in yet another magazine list. Magazines love lists, because they attract the eye and provide a convenient platform for scattered insights. *Forbes* ranks billionaires, *U.S. News & World Report* ranks colleges, *The Economist* runs "league tables," and *Playboy*...well, never mind.

Lists are fun, but sometimes they're just a little too easy: Bill Gates is rich, Harvard's a fine school, and China's economy is hot. Tell us something we don't know.

This year's Winners & Losers issue, our sixth, aims to do just that. We judge a range of projects so near to commercialization that we might be proved wrong in real time. That would mean eating crow, but you risk it if you hope to grow a backbone strong enough to hold up your head. Most people in our business refuse to run that risk; instead, they pontificate on what's already happened. They find all sorts of reasons why, in retrospect, something succeeded or failed.

The late, great, short-lived satirical magazine *Spy* used to make fun of such journalistic bombast in a section it called "Ten Years Ago in *Spy*." Of course, that would have been seven or eight years before the magazine was even founded, and of course, every item was eerily prescient.

Imagine how we might apply *Spy's* formula to our Winners and Losers: "For all its technical prowess, Sony's new Betamax

WINNERS & LOSERS 2009

videotape format will clearly lose the race," we might say we'd said, back in 1975. "It's a dark horse, but Linux could well have legs," we could remember opining, back in 1992. "Intel has put tremendous resources into designing the Itanium processor," we might claim to have opined in 2001, "but we think it's just not powerful enough." And we could flatter ourselves for having written, last year, that "financial derivatives—especially credit default swaps—are snake oil, and no sane investor would touch them."

To avoid this conceit, for Winners & Losers we consider only projects that haven't yet come to pass. We use information in the public record and the insights we gather from people close to the research itself. We make sure every project has commercial ambitions, that it's in a late stage of development, and that it faces milestones in the coming year. That way, if we turn out to be wrong, you'll remember our mistake and call us on it. When we truly can't decide whether a project's a winner or loser, we put it in a category we call You Tell Us. We've posted it on our Web site so that you can vote on it, thumbs-up or thumbs-down.

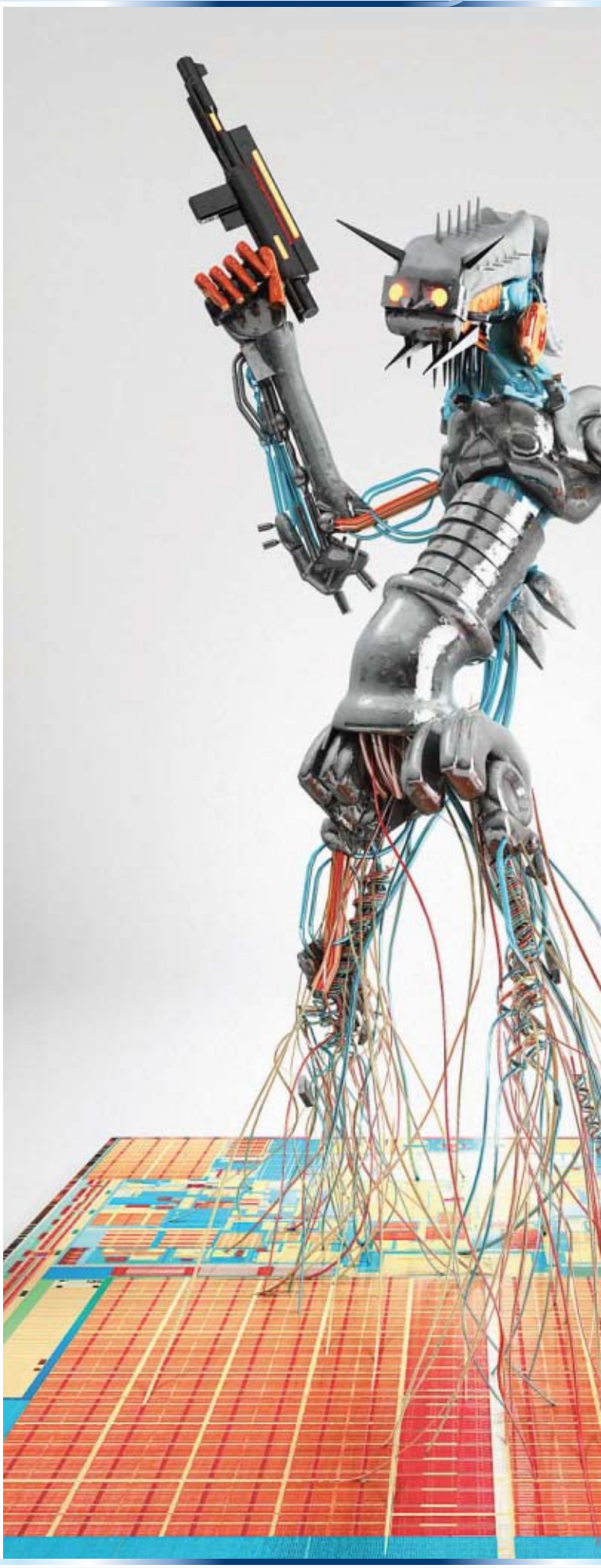
Of course, we have to resist putting all the stories in that in-between limbo. It can indeed prove tempting to do so, especially when we find ourselves having to label the work of earnest, smart, likable people as losers. Sometimes we wake up in the night, sweating, alive to all our loser's seemingly good points—his adorable children, plucky spouse, ironic sense of humor. We find ourselves seeing the good points about antigravity metals, flying automobiles, home nuclear reactors. Worse, we see our own condemnatory words inscribed in some future magazine "list" story covering stupid statements, right next to Lord Kelvin's famous judgment that "heavier-than-air flying machines are impossible." Or Bill Gates's assertion in 1988 that "OS/2 is destined to be the most important operating system, and possibly program, of all time."

So we try hard to make it through the dark nights of the soul. Decisiveness is a virtue, particularly in those who presume to give advice. Give us a one-armed journalist, we say, because then we won't have to read lots of stories with the words "on the one hand...and on the other hand...."

It comes down to this: if we never took a stand, especially on projects we deemed badly conceived, we'd end up in technology's amen corner, along with most of the world's tech journalists. In that corner every new technology is wonderful, every new initiative promising, every start-up visionary. That's nonsense. Most tech projects fail, and few of the supposed successes ever make much money.

But you knew that. You're an engineer.

—Philip E. Ross



POWER UP: Larrabee's new architecture will enable next-generation three-dimensional games and amplify high-end physics simulations.
ILLUSTRATION: BRYAN CHRISTIE DESIGN

Winner Semiconductors

Multicore Made Simple

INTEL'S LARRABEE IS A CHIP EVERY DESIGNER ALREADY KNOWS HOW TO PROGRAM

BY BRIAN SANTO & SALLY ADEE

Chips base on Intel's Larrabee architecture aren't on the shelves yet, but the design is already a hot property because it promises to beat the chips that game designers now use to model graphics.

And the market for such graphics capability goes beyond video games. Consider *Monsters vs. Aliens*, which DreamWorks Animation plans to release later this year. In classic B-movie style, the film will be in three dimensions, but this won't be your daddy's 3-D. Because the digital stereoscopic system delivers a different perspective to each eye so deftly, it won't strain your eyes or turn your stomach. That's why the technology can show you giants battling not just for minutes at a time but for the entire hour, and why it'll dominate the market as its '50s-era forerunner never could.

Graphics like these don't happen with commercial off-the-shelf graphics chips, and that's where Intel's Larrabee comes in. It's an architecture, now in late development, for a multicore general-purpose graphics-processing unit (GPGPU), one of many in a new category that's sometimes called a hybrid because it combines the functions of a multicore central-processing unit (CPU) with those of a graphics-processing unit (GPU). The idea is to do the jobs exclusive to each kind without wasting time on inter-chip chatter. But Larrabee has critical advantages over the other designs. First, Intel claims that it'll provide greater speed at a lower cost. Second, Larrabee is based on Intel's *x*86 architecture, which millions of developers know like the backs of their hands, and it can be programmed in C and C++, languages they know like the roofs of their mouths. Finally, Larrabee is backed by the full weight of Intel.

Though graphics applications are what Larrabee's intended for, they won't be all it ends up doing. Chips based on the Larrabee architecture may one day allow your computer to watch a sporting event, identify the players, pick out the most significant, and generate highlight reels automatically. They may enable your laptop to sift through thousands of digital photos, correctly identify the people in each one, and label them so you can find exactly the snapshots you want. They may even be able to help researchers manage and then visualize vast amounts of data in such fields as genetics, geophysics, finance, and computational neuroscience.

To understand what's at stake requires a bit of history. During the PC's first 15 years or so, its every task was handled by a CPU, the increasing sophistication of which can be seen in the evolution of computer graphics. In the early years, computer characters and images were constructed out of giant pixels—think of the first several iterations of the game character Mario. In the 1980s, Mario was a vaguely humanoid clump made of squares; by 1996, Super Mario 64 had become a 3-D character limned by smooth curves, drawn in perspective. Computer animation had gained more detail; color palettes had become richer. Virtually all CPUs and software have evolved to the point where it's no longer imperative to spend US $200 on a separate graphics card; without one, you can still get pretty good 3-D graphics.

WINNERS & LOSERS 2009

The improvements came mainly by force: CPUs just got faster. They could handle the job because CPUs can, in principle, do almost any job. Rendering graphics was just one more thing they could handle—right up until computer graphics got a third dimension. At last CPUs had come up against a task for which their general-purpose design was poorly suited, and rendering slowed to a crawl.

The problem was that CPUs are designed to perform tasks one after the other, through the repetition of four main steps: the CPU fetches an instruction from the program memory, decodes it, executes it, and returns the results to memory for access later on. But generating the triangular building blocks for 3-D graphics, and updating them every time the screen refreshes, puts a great strain on computer resources. Accessing the memory from which the next instruction must be plucked is often slow, and that means the CPU sits idle as it waits for the instruction to be returned.

The computer industry solved the problem a number of years ago by off-loading most of the repetitive stuff to a companion processor optimized to handle such tasks—the GPU. It has two main advantages: parallelism and hardwired instructions.

SNAPSHOT:

Cores Aplenty

Goal To dominate the general-purpose graphics-processing unit (GPGPU) market.

Why it's a winner It uses the *x*86 architecture, which every software developer can already program using C and C++, instead of relying on some arcane proprietary language.

Who Intel Corp.

Where Teams are distributed, but the base is in Hillsboro, Ore.

Staff "Loads," according to a secretive spokesman

Budget "Enough," according to the same secretive spokesman

When Prototypes and test chips available late 2008; scheduled for commercialization by late 2009 or early 2010

Parallelism allows a GPU to retrieve many instructions from memory at the same time. Say you want to look for every mention of the word *supercalifragilisticexpialidocious* in a 400-page book. Using the CPU method, you'd be doing the equivalent of reading every single page until you found the word. With the GPU method, you'd rip the book into 400 pages and hand it out, four pages each, to 100 friends.

Hardwiring speeds things up by formulating frequently used instructions with dedicated circuitry rather than with software. It's like signing your name with a rubber stamp instead of a pen. Hardwired instructions made GPUs faster at processing graphics, and GPUs became every gamer's object of desire. But you still had to have that CPU, because GPUs are chips of much brawn but very little brain. They need a CPU to tell them what to do.

2 TERAFLOPS
PERFORMANCE OF LARRABEE'S SINGLE GRAPHICS CARD, DUE TO BE RELEASED IN 2009

Another way to think of it is to describe the GPU as the specialist and the CPU as the generalist. The specialist will get the task done much more quickly than the generalist—provided you give him the right task. For a GPU, the right task is any book that can be ripped into 400 independent pages. Graphics is one such task, and for its sake—particularly in game applications—the GPU became common.

Meanwhile, as game designers cried out for new capabilities and vendors answered by hardwiring them in, GPUs began to groan under the weight of the accreted wiring, much of it a pointless legacy from forgotten applications. In the end, GPU vendors simply could not provide the desired functions without fabricating a new GPU version every few months. Something had to give.

So GPUs needed to become programmable—in other words, more like CPUs. Thus was born the general-purpose graphics-processing unit: the GPGPU.

Nvidia and archrival AMD pounced on the task. AMD had acquired graphics legend ATI in 2006 to compete in the GPU market, and a few months later it released its Stream Processor line of GPUs. Meanwhile, Nvidia had already begun to augment its GPU chips with features normally associated with CPUs, including cache memory. But you can't treat a GPU like a CPU, because GPUs are constructed differently. So in November 2006, Nvidia announced its proprietary software developer kit, CUDA (Compute Unified Device Architecture), which allows application developers to do non-graphics work on a graphics chip. CUDA was the companion language for Nvidia's high-performance GPGPU line, Tesla, which the company introduced in June 2007. Tesla was targeted at the high-performance computing market: simulations for the oil, gas, and finance industries—anything, in other words, that required high computational power. AMD's competing kit, Close to Metal, accompanied the Stream Processor chips, but it was no match for CUDA. Thus, thanks to its head start, Nvidia is now the leader in the GPU market, right ahead of AMD.

"Three years from now, the GPU and the CPU will be a single chip," says Nathan Brookwood, an industry analyst with Insight 64, a semiconductor market research group. "The question is, what is that chip going to look like?"

There are two schools of thought. Nvidia's approach is to retrofit a GPU to give it some CPU functionality. The problem is the same problem GPUs have always faced, says David Kanter, the guru behind Real World Technologies, a leading semiconductor and technology analysis site: "When you get into situations where you do need control logic, your performance drops off a cliff."

Intel's approach is to make a more parallel CPU, one that can play traffic cop to a huge horde of programmable GPUs. This means building the thing pretty much from scratch, except for the foundation in the *x*86 architecture.

To call Larrabee a multicore chip is a bit of a misnomer; it's a "many-core" chip. Many core, to oversimplify it, is to a GPU what multicore is to a CPU. These are not split hairs: Larrabee architects laid out their design differently from that of traditional GPU structures. Where most GPUs organize their processor cores as discrete blocks, Larrabee's architecture

has the core processors situated in line (rather than in parallel, as is typical with GPUs) and connected in a ring shape, with all those cores sharing access to the cache memory.

That approach sidesteps a typical GPU problem, in which one core processor modifies a block of memory without the other cores being aware of it, which slows down the work flow as they wait for that block of memory to be freed up.

And Larrabee's been designed on a clean slate; many of the old hardwired instructions are gone. For example, it used to be that every time some new graphics technique was hardwired into a graphics chip, every single game suddenly had that one feature. Take "lens flare": typically, it's an undesirable photographic artifact, but in the early '90s it was modeled as one of the first special effects for computer graphics. Before long everyone was using it, and that's how 1995 became the year of lens flare.

But these new tricks had a price; anything hardwired into the circuitry of a GPU could be done only in that one way. That's not the case with Larrabee—all the instructions can be carried out by any software a developer can throw at it. Of course, Nvidia and ATI GPUs have also been highly programmable for at least five years. The difference is that a Larrabee chip will also be able to handle the nongraphics aspects of the software, like the complex physics of natural hair or cloud movement.

"In many ways, Larrabee is like the Cell processor," says Insight 64's Brookwood. But because of its arcane structure, the Cell processor is very hard to program. "It drives game developers nuts," he says. "Larrabee will have the same capabilities, but it'll be easier for a programmer to get his head around."

And Real World's Kanter questions Nvidia's interpretation of the "GP," or general-purpose, part of a GPGPU. To be sure, he says, "Nvidia packs a ton of execution resources onto a single chip to go after the graphics market." But while the 240 cores of a recently released Nvidia Tesla GPGPU sure are brawny, they may not have the brains to compete with Larrabee. "From a microprocessor-engineering perspective, a core is something that can get its own instructions, figure out what the instructions mean, and then do it," Kanter says. "What Nvidia is calling a core is really just the 'do it' part, so their 240-core chips are not competitive with what Larrabee will offer."

EXPERT CALL "It's a Moore's Law solution looking for a billion-transistor problem."
—*T.J. Rodgers, founder and CEO, Cypress Semiconductor Corp.*

MANY-CORE MONSTERS: *Monsters vs. Aliens* creator DreamWorks will be the first Intel customer to test-drive Larrabee technology.
IMAGE: DREAMWORKS ANIMATION

But most of all, Brookwood says, Larrabee stands to benefit from the existential problems of CUDA. At this point, proprietary approaches are frowned upon—and CUDA is proprietary language for proprietary hardware. "Software developers write stuff they want to be able to run on a lot of different platforms," he says. "If I educate all my programmers in CUDA, I can't jump ship to a better solution later, because I'm locked into Nvidia." Prior efforts to create an open GPU computing language resulted in Open Computing Language, which is being pushed heavily by Apple, and AMD's high-level Brook language. But Brook is obscure and OpenCL isn't quite ready for prime time.

Intel can fill that void with Larrabee for one very important reason: it's based on the *x*86 architecture most modern programmers cut their teeth on.

To be sure, there are lingering questions. Larrabee isn't yet a chip or even a prototype, just a planned prototype. The first test chips came out only a few weeks ago, and the product won't reach store shelves until late 2009.

"This is the elephant that's *not* in the room," scoffs Andy Keane, general manager of Nvidia's GPU Computing business unit. He says that by the time Larrabee enters into mass production, it will already be obsolete. Nvidia has already sold hundreds of thousands of its CUDA-enabled GPGPUs, and "by the time Intel starts selling their Larrabee chips," Keane says, "we will have millions of our chips in laptops." In an effort to make CUDA as familiar to programmers as C++, Nvidia launched the CUDA Center of Excellence program, which provides high-end equipment and support to universities in exchange for CUDA integration into the curriculum. To that end, last July Nvidia donated $500 000 and an $800 000 64-GPU CUDA technology cluster to the University of Illinois at Urbana-Champaign for computational biophysics research.

And it's still tough to benchmark Larrabee, because Intel has not released key specifications, including clock speeds and even the number of cores. "It's too soon to declare it a winner, in my opinion," *Microprocessor Report* senior analyst Tom Halfhill says. And Brookwood stresses that few applications have been written yet that can take advantage of many-core architectures.

But there *is* an elephant in the room, and its trumpeting can already be heard: the *x*86 cores that will populate the Larrabee-based chips. This is the architecture today's developers grew up with; it's what they learned to code using the most ubiquitous programming languages, a capability that Intel says none of the competing products will have. A chip as programmable as

WINNERS & LOSERS 2009

an *x*86 CPU could tilt the field to Intel's advantage.

Better yet, it means application programmers will be able to avoid CUDA. "CUDA is proprietary," says an IT researcher at a major financial institution, who asked that his name be withheld. "[Larrabee] is regular *x*86—now you don't have to write into a special language to take advantage of it," he says. "Their proposition is that you can run a GPGPU without having to adopt a new programming paradigm."

So who will win—Nvidia, whose Tesla chip was first to market and is now present in hundreds of thousands of laptops, or Intel, whose Larrabee has so many admirable attributes that won't be real for another 12 months?

IEEE Spectrum has spoken to people inside and outside Intel, on and off the record, and we believe that Larrabee is a winner—because of the one feature that it alone offers: C++ programmability. That really handicaps the race. After all, once Larrabee and its software development environment are out, the tools will be ones that programmers are already familiar with. That means they'll write software to run on *x*86, which will enable lots of third-party organizations to write more software and sell it to other developers. Lather, rinse, repeat.

Intel hopes that all the advantages of Larrabee chips—low price, high performance, ease of programming, greater flexibility—will lure in enough game developers to establish some momentum in the market, attracting a good portion of the many other *x*86 developers who are out there.

"Some people think that's our secret agenda," says Stephen Junkins, lead software architect for Larrabee's software tools and technologies. "It's not much of a secret. We want to get it to smart people and let them pound stuff out on it." ❑

LOSER Power & Energy

WIZARD OF WATTS: Randell Mills, founder of BlackLight Power, says his reactor liberates energy from hydrogen in a totally new way.
PHOTO: DAVID YELLEN

Hot or Not?

BLACKLIGHT POWER SAYS IT'S DEVELOPING A REVOLUTIONARY ENERGY SOURCE—AND IT WON'T LET THE LAWS OF PHYSICS STAND IN ITS WAY

BY ERICO GUIZZO

Imagine that you could make hydrogen atoms do something that quantum mechanics says they can't: slip into an energy state *below* the ground state, the collapse releasing 100 times as much energy as you'd get by just burning the hydrogen. If you could harness the heat to produce power, using hydrogen from water as fuel, you'd consume no oil, create no fumes, and solve the problems of energy and global warming forever.

Of course, first you'd have to overturn a century's worth of physical theory, prove your point experimentally, and demonstrate its feasibility in a prototype power-producing system. Yet this is precisely what a company called BlackLight Power says it has done. The company, based near

Princeton, N.J., has raised US $60 million, equipped massive labs, hired two dozen employees, gotten some high-profile executives to serve on its board, and attracted a devoted following of fans to online discussion boards.

Last year BlackLight announced that it had a prototype reactor capable of putting out 50 kilowatts of thermal power using a tiny amount of hydrogen. The company said that the device releases energy in one short burst and that it's working to make the reaction continuous. It also said it planned to scale up for pilot operation sometime this year, estimating that its technology could produce electricity for under 2 cents per kilowatt-hour. That's on a par with nuclear and coal power plants and considerably better than gas and petroleum plants.

Is this real, or just fodder for a science-fiction TV show?

Ask experts in atomic physics and you'll hear that a new form of hydrogen is just fantasy.

"This is scientific nonsense—there is no state of hydrogen lower than the ground state," says Wolfgang Ketterle, an MIT scientist and a Nobel Prize laureate in physics. "Hydrogen is the most abundant element in the universe, and it's had time enough to find its ground state."

Anthony Leggett, a professor of physics at the University of Illinois at Urbana-Champaign and also a Nobel laureate, says that quantum mechanics is "consistent with just about everything we know about atomic physics, so the onus is firmly on anyone who wants to discard it to prove his case." He adds, "I don't see that [BlackLight] has got anywhere near doing this."

But turn to Randell Mills, the founder, chairman, chief executive, and president of BlackLight Power, and he'll tell you that this lower-energy hydrogen, which he calls hydrino, is very real indeed.

"We produce hydrino on demand," he tells *IEEE Spectrum*, adding that his team has isolated and characterized hydrino's properties using spectroscopy and has even created hydrino-rich materials it can provide for analysis.

Mills is unfazed by the criticism, having faced down the physics establishment since he first put forward his hydrino theory some 20 years ago. A graduate of Harvard Medical School, he veered into physics after taking some courses at MIT in the late 1980s. His theory has been evolving since then. Not only does it explicitly reject quantum mechanics as it is currently understood, it also attempts to explain physics and chemistry "from the scale of quarks to cosmos," as Mills puts it. Unlike quantum theory's statistical approach, his theory is completely deterministic.

You can read about it all in his magnum opus, *The Grand Unified Theory of Classical Physics*, a 1771-page work that he's self-published on his Web site. It claims to offer explanations with no "spookiness or weirdness" for quantum phenomena like entanglement, as well as some extraordinary predictions: that under certain conditions electrons acquire antigravity properties, which Mills calls "the fifth force," and that the mysterious dark matter permeating the universe consists of large hydrino agglomerations.

Mills says he's published numerous papers describing his theoretical results in peer-reviewed journals. But critics counter by saying that the papers appeared in publications that focus on speculative work and that his theory has deep flaws that he hasn't addressed.

Mills first tried to make something of his theory in the early 1990s, when he started a company called HydroCatalysis Power, which experimented with heat-producing electrolysis cells. A few years later he shifted to electrical discharges in gases, changing the company's name to BlackLight Power, a reference to the emissions of ultraviolet light he observed. More recently he's focused on a solid-fuel design, which he says is the most promising configuration for producing power.

All the while Mills has proved himself a terrific salesman. He has raised capital from various sources, including utilities Conectiv Energy Supply and PacifiCorp and private investors like former Johnson & Johnson president Jim Lenehan.

BlackLight's current prototype reactor consists of a steel cylinder containing 1 kilogram of an industrial chemical called Raney nickel—a powdery, porous nickel-aluminum alloy that traps hydrogen gas—coated with a few grams of sodium hydroxide. According to Mills, when you raise the cylinder's temperature, the reactants form sodium hydride. This material acts as a catalyst, absorbing just the right amount of energy—a multiple of 27.2 electron volts—to produce sodium ions and hydrinos while generating lots of heat.

The company reports that after an input of 1396 kilojoules, it obtained an output of 2149.1 kJ—a 753.1-kJ difference that raised the temperature of the reactor from 85.6 to 518 °C in just 35 seconds. Then, according to Mills, comes the best part: if you inject more hydrogen into the reactor, it will combine with the sodium atoms and regenerate the sodium hydride catalyst, which then produces more hydrinos and energy. To obtain the additional hydrogen, Mills says, a fraction of the output energy could be diverted to

SNAPSHOT:
Water Into Watts

Goal To develop a power-producing reactor that unleashes energy by inducing hydrogen atoms to transition to an energy state below the ground state.

Why it's a loser Most experts don't believe such lower states exist, and they say the experiments don't present convincing evidence.

Who BlackLight Power

Where Cranbury, N.J.

Staff 25 full-time employees and 20 consultants

Budget US $60 million

When Pilot plants projected for mid- to late 2009

electrolyze water. "A billion-watt power plant would consume about 1 liter of water per second," he says.

Mills also claims that the hydrinos, far from being mere waste products, will themselves constitute a pot of gold. Hydrino compounds, he says, have unique properties and could be used in semiconductor devices, high-voltage batteries, synthetic diamonds, anticorrosive coatings, and rocket fuel.

This past October, BlackLight announced the "independent validation" of its solid-fuel reactor by a group led by Peter Jansson, a professor of engineering at Rowan University, in Glassboro, N.J. The Rowan group performed its own experiments and reported that the significant energy release could not be explained by "conventional chemistry" and may support BlackLight's claim that it has found a novel technology for producing energy.

EXPERT CALL

"Remember when two professors in Utah said they'd produced nuclear fusion in a jar? Here we go again."
—*T.J. Rodgers*

In a statement after the report was issued, Michael H. Jordan, former CEO of Westinghouse Electric and a board member of BlackLight, said that the company's technology "will go down as one of the most important advances in the field of energy in the last 50 years."

But critics have raised questions about the replication. They point out that the Rowan group simply borrowed reactors from BlackLight instead of preparing their own from scratch and that Jansson has been a collaborator of Mills's. And they say there isn't enough detail to tell whether BlackLight ruled out all possible sources of error in its calorimetry tests, which used temperature measurements of water surrounding the reactor to derive the energy input and output.

"Calorimetry experiments are notoriously touchy—it's easy to fool yourself," says Joshua Halpern, a professor of chemistry at Howard University, in Washington, D.C. He notes that it was the controversy over calorimeter experiments that undermined claims for cold fusion in the late 1980s. Small variations in temperature data and water flow can wildly distort results.

OLYMPIC-SIZE POOL

ENOUGH WATER TO POWER SEATTLE FOR A MONTH—IF HYDRINOS EXIST

And even if there's an energy release, he says, the chemical reactions could be much more complex than what BlackLight accounted for. The heat, he says, may come from other reactions—for instance, between hydrogen gas and oxidized nickel, a highly exothermic process. "Raney nickel," he says, "can ignite after certain hydrogenation reactions."

William H. Green, a professor of chemical engineering at MIT, says that the BlackLight concept is "inconsistent with experiment," because many people have made sodium hydride before without seeing it decompose into sodium and an anomalous form of hydrogen. And then there's the issue of turning the burst of energy into a continuous process that could be harnessed for power production. BlackLight hasn't explained in detail how it plans to feed hydrogen and a catalyst into the reactor to keep the process going. "For a useful large-scale energy process, one cannot be consuming nickel or the sodium compounds, both of which take a lot of energy to produce," Green says.

Mills dismisses the criticism as small practical issues that his company has been able to deal with. He says BlackLight did account for all conventional chemical reactions and that the most exothermic of them—the formation of aluminum oxide—produces only 1 percent of the heat measured. As for making the operation continuous, he says his company is pursuing two approaches. One would be to continuously feed hydrogen into the reactor in such a manner that the reaction would proceed without any significant degradation of the catalyst. The other would use a batch operation, in which some catalyst is successively retrieved, recycled, and reinserted for a new cycle.

Mills says BlackLight has operated the reactor continuously for two hours and that it's investigating a new type of fuel that yields 10 times as much energy per weight as the sodium hydroxide–doped Raney nickel. He insists the company has disclosed the experiment in detail in a paper available on its Web site, only retaining "some know-how in order to maintain our technical lead." He says BlackLight is "open to host validators" and is "willing to supply the fuel under an academic license or commercial license." Eventually, he contends, others will be able to make the fuel themselves.

"Based on the response to our announcement," Mills says, "it appears that the engineering and business communities are ready to take advantage of this unprecedented opportunity and engage at this point in the development."

Critics, however, remain unconvinced. They say that BlackLight has made similar claims before, announcing that it was on the brink of commercializing its revolutionary technology but failing to deliver.

"This claim has been around for several years, and I know of no hard evidence provided by BlackLight Power to substantiate their claims," says Stanford physicist and Nobel laureate Douglas Osheroff.

"I would say without reservation that if Mills were proved right, it would revolutionize physics and solve the world's energy problems overnight, and he would easily win a Nobel Prize and become a multibillionaire," says John Connett, a mathematician at the University of Minnesota, in Minneapolis, who's tracked Mills's ideas for several years. "But extraordinary claims require extraordinary proof, and at this point it appears to me that the proof side of the equation is very sadly lacking." ❑

WINNER Electricity

Hot Rocks

GEODYNAMICS IS TURNING AUSTRALIA'S NATURAL RADIOACTIVITY INTO THE COUNTRY'S FIRST GEOTHERMAL POWER PLANTS

BY SANDRA UPSON

Four kilometers down below the orange earth of Australia's Cooper Basin lies some of the hottest nonvolcanic rock in the world—rock that the geothermal industry had never seriously considered using to make electricity. But next month Geodynamics, an eight-year-old company based in Milton, Queensland, will prove otherwise when it turns on its 1-megawatt pilot plant here. The company has done more to harness this unconventional form of geothermal energy than anyone else in the world.

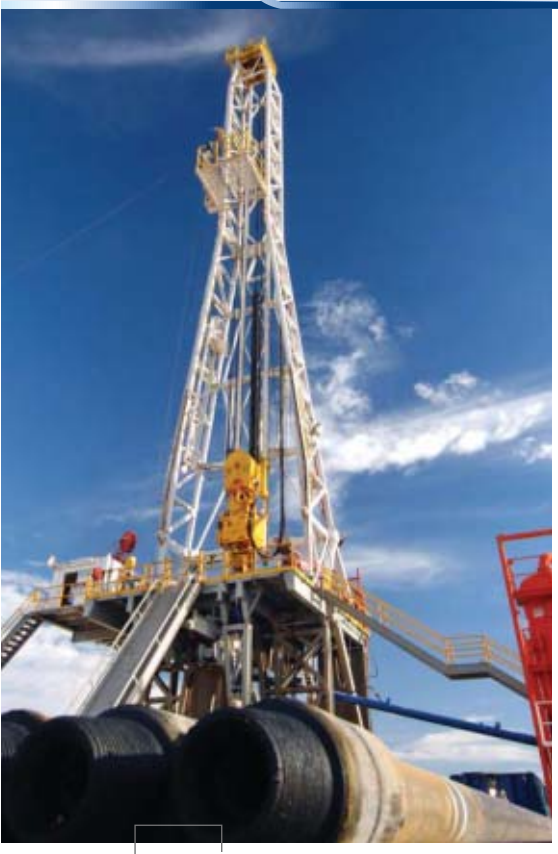
Geodynamics picked a place in the middle of Australia with a smattering of trees, a mostly dry riverbed, and a town with a population of about 14. Even in the best circumstances, building a geothermal power plant is a risky endeavor: drilling costs money, and divining what's going on in the depths of the Earth is still something of a black art. Here, geothermal companies must clear yet another hurdle. The world's 10 000-MW collection of geothermal power plants exploits existing underground reservoirs of water and steam. Australia's geoscientists, by contrast, must create their own.

This very experimental technology is known as an engineered geothermal system, or EGS. If it works—and the finances and expertise at Geodynamics' disposal suggest that it will—heat from deep under the outback could contribute a few gigawatts of clean round-the-clock power, up to 20 percent of Australia's capacity today. And if it works here, many other countries will want to give it a whirl.

In the last few years, the concept of geothermal energy has undergone a dramatic reshaping to include a broad range of geological conditions not normally deemed useful. In the United States, for example, EGS could potentially contribute as much as 100 000 MW of electricity in the next 50 years, according to an MIT report released in 2006. Today conventional geothermal capacity in the United States amounts to about 3000 MW, less than half of a percent of the country's total electric capacity. In famously geothermal Iceland it comes to 450 MW—about one-fourth of the island's total. Australia's use of geothermal heat is basically nil.

DREAM STEAM: A new kind of geothermal system in Australia's desert holds great promise for clean electricity generation.

PHOTO: GEODYNAMICS



GRANITE GRINDER: When Geodynamics couldn't find a drilling rig to lease, it bought one, becoming the first geothermal company to do so. *PHOTO: GEODYNAMICS*

SNAPSHOT:

Power From The Rock

Goal To build Australia's first geothermal power plant, a 50-megawatt facility.

Why it's a winner The company has made several key breakthroughs working in what are totally new geological conditions for the industry; its success could revolutionize the renewable energy field in Australia.

Who Geodynamics

Where Australia's Cooper Basin

Staff About 45

Budget About US $200 million for a 50-MW plant

When A pilot plant will start up this spring; a commercial facility should be running in 2011

If the three dozen geothermal ventures now trolling the Australian continent are any indication, that situation is about to change. But there's a catch. Only a couple of EGS projects have ever produced power, and those are in Germany and France, where the rock is considerably more pliant than Australia's granite underpinnings. That hasn't stopped Geodynamics, whose managing director, Gerry Grove-White, contends that the system he is shepherding into existence is the first with real commercial promise. "None of those hold the prospects of ours, with our massive [geological] resource and much higher temperatures," says Grove-White, a power engineer and former executive at Tata Power, India's largest private utility. The reasons for his optimism have everything to do with the unique conditions into which Geodynamics has plunged itself.

Today virtually all geothermal systems are in volcanic regions, near the boundaries of tectonic plates. When two plates heave into each other, one tends to buckle under the other, creating openings in the mantle through which magma can seep up, heating the rock above. Mining the underground heat, however, requires a carrier. Today's systems rely on rainwater, which collects in fractures in the crust and drips several kilometers down, pooling in cracks and porous rock. A geothermal company drills a well, builds a power plant above it, and starts pumping water. The water comes to the surface and explodes into steam, which turns a turbine, which drives a generator, producing electricity. The hotter the rock and the larger the buried reservoir of water, the better the system should perform.

Now eliminate from that picture much of the water and shrink the fractures where the water pools to millimeter-wide slivers. Move the system to the middle of a desert, 500 kilometers from the closest grid connection. Those are the circumstances that Geodynamics chose to face in the Cooper Basin.

Australia's granite is a natural nuclear pile, warmed by the decay of uranium, thorium, and potassium isotopes. The result is some of the hottest nonvolcanic rock in the world, with temperatures in the range of 200 to 300 °C not uncommon a few kilometers below the surface.

Geodynamics was offered a rare glimpse of the deep Earth and its temperatures thanks to an Australian oil and gas company called Santos, which has been drilling its way through the Cooper Basin for decades. Where it didn't find fossil fuels, Santos did uncover remarkably hot granite, and its abandoned wells have served as windows into the underground. "In our case, figuring out where to drill was easy. We went right alongside wells that Santos had drilled in the past," says Grove-White.

Geodynamics' first big stroke of luck came early, when it drilled a well and hit hot water that seemed to be trapped in place rather than leaking down into harder-to-reach crevices. "Nobody had ever realized that such conditions existed—an environment a long way away from volcanoes and full of high-temperature waters," says geoscientist Doone Wyborn, who is Geodynamics' executive director.

Granite generally fractures horizontally in this geological environment, so the lack of downward cracks wasn't a complete surprise; even so, more water seemed to be pooling than anyone had anticipated. The discovery made all the difference, because it meant that water injected into the ground would stay there to soak up heat rather than trickling uselessly away. Even better, such water-holding conditions might well apply in much of the rest of the continent, whose geological conditions are more uniform than just about anywhere else.

"Now it turns out that virtually none of the systems we're looking at are dry," says John Garnish, an EGS consultant based in the UK. That was pretty good news for Geodynamics, which subsequently abandoned the idea of diverting large quantities of water to the desert of a drought-ridden nation. "Frankly, if it was hot *dry* rock, I wouldn't be here," says Grove-White, who joined the company two years ago.

Guts, as much as luck, produced the company's second big break. When the spike in oil and gas prices spurred exploration, making drilling rigs scarce and thus hard to lease, Geodynamics bucked the leasing trend by buying a rig

from a vendor in Houston. It happens to be the largest and most powerful rig in the country. "For them to own their own rig is brilliant. Having it at their disposal is a key factor in their success in today's market," says Brian Anderson, an assistant professor of chemical engineering at West Virginia University.

The rig allows Geodynamics to drill more cheaply than its Australian peers can—but even so, at US $50 000 or more a day, the cost of operating a rig puts a major dent in any rock driller's business plan. "Drilling under high temperatures and high pressures, in hard rock like granite and at great depth, makes this one of the most difficult onshore drilling projects in the world," says Ralph Weidler, whose company, Q-con, in Bad Bergzabern, Germany, helped Geodynamics develop the reservoir.

But drilling wells is just the beginning. The pockets of water in the Cooper Basin are far smaller than the large reservoirs found in volcanic regions, so Geodynamics set out to create the reservoir for itself. The company needed to enlarge the cracks so that they could hold more water. It also had to intercept those cracks with a second well so that the brine could be returned to the ground, allowing the plant to operate continuously. The engineers used a massive pump to cram 20 000 metric tons of water down a well and through the fractures in the rock, prying them open. They inferred the location and the movement of the cracks from the innumerable tremblings registered by an installed network of seismometers.

The process of wedging open those rocks went better than anyone had expected. The geoengineers had generated a horizontal pancake of long, widened cracks 2 km in diameter. "If you compare it with other EGS sites, [Geodynamics'] fracture area is absolutely amazing. It's humongous!" says Anderson.

The moment of truth came in mid-March, when the engineers trekked out to the tiny town of Innamincka to find out how thoroughly the fractures had connected the wells. They switched on the pump to see how much hot brine they could pull out of one well. "We could see pressure variations at one from the way we controlled the other," says Grove-White.

EXPERT CALL "Even assuming solutions to technical difficulties, extracting geothermal energy from granite layers seems unlikely to be cost-effective without subsidies."
—*Nick Tredennick, IEEE Fellow; editor,* Gilder Technology Report

As expected, the drop in pressure as the water rose converted it to steam, and it came billowing out of the well in a big white blast. The temperatures at the bottom of the well were measured at a heartening 244 °C. The rate of water gushing up from the well, a key part of a geothermal project's economic credibility, held solidly at 27 kilograms per second—a very respectable starting point. Five months later, a four-day circulation test again produced sufficient quantities of water.

Geodynamics is the only firm out of the many drillers in Australia that has managed to artificially extend the fractures in a well, let alone complete a circulation test. For the company's engineers, one major challenge remains. In the coming year it must triple its flow rate to the 80 to 100 kg/s that's necessary for a large-scale plant. To do that the company must master the art of creating multiple tiers of nearly identical fractures between pairs of wells, a technique that's well known in the oil and gas industries but terra incognita to geothermal engineers.

10 000 MW
THE WORLD'S EXISTING GEOTHERMAL POWER CAPACITY

To push through, Geodynamics has strong financial backing, on the order of $228 million, secured in the past year. It signed a joint venture agreement with Origin Energy worth about $130 million in December 2007, and this past September Tata Power, Grove-White's alma mater, committed about $35 million. Another $64 million came from two Australian investment funds. "Finally people are starting to realize the potential is there. Once people registered that EGS could contribute so much more than conventional geothermal, the penny finally began to drop," says Garnish, the EGS consultant.

Ladislaus Rybach, the president of the International Geothermal Energy Association, is a stalwart supporter of EGS, but he urges industry watchers to keep their expectations in check, pointing out that it took three decades of research to produce the paltry 1.5 MW of fractured-rock power in Germany and France. But he, too, notes that Geodynamics is in a unique position. "The main obstacle is that whatever you want to do in EGS takes a lot of money in hand. Only the Australians so far have managed to create this environment," Rybach says.

In spite of a dismal global economic climate, other factors are also contributing to a favorable future for geothermal start-ups. In Australia, a carbon-emissions trading scheme is expected to put a price on carbon dioxide within two years. A geothermal plant would be able to trade its carbon credits to other companies that burn fossil fuels, making it cost-competitive. More broadly, in September Google.org, the philanthropic arm of the search giant, offered its own endorsement of Geodynamics' strategy by committing $11 million to two American companies to jump-start the technology in the United States. (Google also swung around a satellite to generate a more detailed tree-by-tree map of the Cooper Basin on Geodynamics' behalf.)

Geodynamics will need the money and good will. In March it will begin the process of extending parallel levels of fractures between another pair of wells and then begin planning the construction of a 50-MW geothermal power plant, also in the Cooper Basin. As the only known source of clean, uninterrupted base-load power, geothermal energy could make an enormous difference. For that alone, it is well worth banking on. ❑

WINNERS & LOSERS 2009

LOSER Interfaces

Mental Block

EMOTIV SAYS ITS GAME CONTROLLER WORKS AT THE SPEED OF THOUGHT, BUT IT DOESN'T *BY DOUGLAS HEINGARTNER*

Controlling objects with just your thoughts has been a dream of sci-fi from "Star Trek" to *Star Wars*, but in the past few years that dream has inched closer to reality. Brain-computer interfaces have allowed wheelchair-bound quadriplegics to move cursors on screens and monkeys to control robot arms.

Now a San Francisco–based company called Emotiv Systems is trying to bring the technology to PC game applications. It had planned to release its Epoc headset, a plastic frame dotted with 16 electrodes, in time for Christmas, but now the company says only that it'll put the thing on sale "soon," for about US $300.

How the Epoc works isn't entirely clear. The company says that it relies exclusively on brain waves, but independent observers say that it might instead be picking up other sorts of signals. In either case, the headset couldn't let you manipulate fast-moving characters in *Grand Theft Auto* just by thinking about it.

Such a hair-trigger response would require some pretty significant breakthroughs in electroencephalography (EEG). Researchers have been using this form of brain-wave monitoring since the 1920s, largely because it is simple and cheap to operate. Still, scalp EEG sensors like Emotiv's are far less accurate than experimental setups that insert electrodes into the brain through holes drilled in the skull, as was done with the monkeys who were taught to control robot arms.

Worse, EEG signals are weak, noisy, and slow. "Video gamers spend lots of money buying fast computers and fast graphics cards," says IEEE Fellow Kenneth Foster, a bioengineering professor at the University of Pennsylvania who has long studied the medical applications of EEG. "Why would they then hook themselves up to a computer that allows them to do the equivalent of typing one or two words a minute with a 50 percent error rate?"

The mainstream media has hyped the technology with breathless headlines like "Next-Gen Vidgame Gear Reads Minds" (*Variety*) and "Control GTA With the Power of Your Mind" (T3.com). But

EMOTIV SYSTEMS

EXPERT CALL "On the brain-machine interface, I'm not sure I trust either the technology or my brain."
—*Robert W. Lucky, IEEE Fellow; former vice president, applied research, Telcordia Technologies*

that's not how brain-computer interfaces work.

"It's not that someone's thinking about doing something and the computer records the person's thoughts," said Foster. "It's just that through a training sequence, you can be taught how to fire those neurons near where the electrode is."

Think of it this way: learning to steer a cursor with EEG is like learning to wiggle your ears—it's not done well, but it's amazing that it is done at all.

Or maybe it isn't being done. Professor Klaus-Robert Müller, cohead of the Berlin Brain Computer Interface at Berlin Technical University, surmises that the headset senses not EEG per se but rather the potentials generated by contracting muscles, like those in the gamer's clenching jaw or moving eyes.

"These signals are at least 10 to 100 times stronger than EEG, so if the Emotiv uses facial expressions for controlling computer games, then great," Müller says. "But if they say it's using thoughts, then I object. If you have a small car and you put a Mercedes label on it, that doesn't make it a Mercedes."

But Tan Le, Emotiv's cofounder and president, insists that the Epoc is a pure EEG device. "There are no additional biofeedback measures used by the headset," she says. She also maintains that Emotiv's patented algorithms have minimized lag. "The response time after training is virtually instantaneous."

She adds that the Epoc can be used with just about any video game now on the market, including the fast-paced ones. "A direction like 'push' can be assigned to 'drive' in a preexisting game. 'Rotate right or left' can be assigned to turning right or left," she said. "The user can indeed think 'lift,' and the rock will lift."

Non-EEG biofeedback devices have been around for a long time. Atari's MindLink headband, launched in 1984 to work with the then-popular Atari 2600 console, actually had nothing to do with brain waves, but it did read muscle motions in the user's forehead. In 1998, a Nintendo-compatible game called *Bio Tetris* let users influence play by adjusting their heart rates. Likewise, the Journey to Wild Divine system, launched in 2003, monitors heart rate and skin conductance via finger-mounted sensors and uses this data in a variety of relaxation games. And OCZ Technology's Neural Impulse Actuator, an Epoc-like headset launched earlier this year, modestly allows you to "play games using biosignals"—not thoughts.

To be sure, in the lab EEG readings have proved robust enough to allow people to play rudimentary versions of games like *Pac-Man* and *Pong* and to navigate though Google Earth. In *BrainBall*, a game launched by Sweden's Interactive Institute in 2000, two players try to move a ball by achieving a certain brain state, thereby "out-relaxing" the opponent.

You could argue, therefore, that Emotiv is doing us all a service by making an improvement—even just an incremental one—in a new kind of input control, much as Nintendo's Wii did last year, with its motion-sensing wands. And games specifically designed to take advantage of the biofeedback of Emotiv-like systems could lead to new gaming genres.

As Anton Nijholt, a professor of computer science at the University of Twente, in the Netherlands, and manager of an interdisciplinary consortium called BrainGain, puts it: "Hard-core EEG researchers are negative about Emotiv, because they say it doesn't use EEG-measured activity only. For a gamer, the answer to this is, 'So what?' As long as there is an interesting game, then who cares that part of the activity measured is coming from, for example, muscle contractions?"

You could also argue that the technology has legs. If such brain-computer interfaces work in games, they can also help rehabilitate disabled patients and perhaps monitor skilled workers, for example, by predicting when a pilot or a crane operator is in danger of losing concentration. Tan Le says Emotiv might look at applications in market research and advertising.

"If Emotiv has a technology where they can measure EEG and use it for gaming, that would be great," Müller says. "So far I haven't seen any scientific evidence, any studies, or any convincing demo. But I would be very happy if they have something that's beautiful and that works."

But a goal is one thing, an achievement quite another. "You can do a lot better with sensors that measure eye motion or things of this sort," says Penn's Foster. "Maybe in the long run we'll be able to have jet pilots control their jets by brain-wave activity, but it's a long way from now. It's an interesting technology, and there's a huge amount of research being done on this, but as far as any kind of practical gaming use, it just isn't there."

So why plunk down hundreds of dollars for a device that does badly what can already be done well—by a finger on a joystick? ❑

190 MS (0.19 SEC)
AVERAGE GAMER'S REACTION TIME IN PUSHING A BUTTON

SNAPSHOT:
Thinking Cap

Goal To develop a brain-machine interface for gamers.

Why it's a loser The brain-wave control system is hard to master and slow on the draw.

Who Emotiv Systems; investors include Technology Venture Partners, Epicure Capital Partners, and the Australian Federal Government

Where San Francisco

Staff Info not available

Budget US $6.3 million raised so far

When Originally Christmas 2008; now unspecified

WINNERS & LOSERS 2009

WINNER Robotics/Neurointegration

The Revolution Will Be Prosthetized

DARPA'S PROSTHETIC ARM GIVES AMPUTEES NEW HOPE *BY SALLY ADEE*

It's October at Duke University, in Durham, N.C., and Jonathan Kuniholm is playing "air guitar hero," a variation on *Guitar Hero*, the Nintendo Wii game that lets you try to keep up with real musicians using a vaguely guitarlike controller. But the engineer is playing without a guitar. More to the point, he's playing without his right hand, having lost it in Iraq in 2005. Instead he works the controller by contracting the muscles in his forearm, creating electrical impulses that electrodes then feed into the game. After about an hour he beats the high score set by Robert Armiger, a two-armed Johns Hopkins University engineer who modified *Guitar Hero* to train amputees to use their new prostheses.

Armiger's research is part of a nationwide effort to create a neurally controlled prosthetic arm. That arm has been the focus of much media attention, but that focus obscures the truly groundbreaking research typical of the Revolutionizing Prosthetics 2009 (RP2009) program.

The U.S. Defense Advanced Research Projects Agency (DARPA) is pouring at least US $71.2 million into the program in the hope that it will let amputees do what most people take for granted: make gestures, test the water in a teacup, turn a key, even peel the shell off an egg. Words like *bionic* and *thought-controlled* have been thrown at the project, but they don't do justice to the sheer ordinariness of its purpose. DARPA isn't looking for a superstrong "Six Million Dollar Man" arm; it just wants an arm that moves exactly like a real one does.

Yet even making just a garden-variety arm requires a herculean effort, not only in the field of mechatronics but in neuroscience, electrical engineering, cognitive science, signal processing, battery design, nanotechnology, and even behavioral science. This four-year project is wildly ambitious even by the standards of the Pentagon's mad-science wing. After the program concludes at the end of 2009, many of the arm's various technologies will go into FDA clinical trials and then out into the world.

But some of the RP2009 technologies have already begun to filter out. In October, a Canadian hospital announced that it had used part of the control mechanism of the DARPA arm to steer regular, nonrevolutionized prosthetic arms in two patients. Simply borrowing that one technology has made huge improvements in commercially available prosthetic devices.

DARPA's device is the world's first truly neurally controlled prosthetic arm. To keep it from being the last, its designers are explicitly creating it with other designers in mind. The program's engineers want a quasi–open source platform for hardware and software, so that the RP2009 specifications will replace the Babel-like confusion of scattered prosthetic-arm designs with a platform everyone can use to finally push the technology into the 21st century.

The Revolutionizing Prosthetics program has been testing control technologies on volunteers around the country: at the Rehabilitation Institute of Chicago; at OrthoCare, in Oklahoma City; and at the Johns Hopkins University Applied Physics Laboratory (APL), in Laurel, Md. RP2009 team leader Stuart Harshbarger says the investigations will likely extend later this year to the Salt Lake City Veterans Affairs hospital, one of the military's major rehab centers for amputees.

Such centers are reeling under the burden posed by the wars in Iraq and Afghanistan, where improvements in body armor have saved the lives but not always the limbs of many soldiers who would have died in earlier wars. The number of such amputees stood at 1214 on 1 August 2008, compared with 4809 deaths and 33 116 injuries, making for a ratio of amputations to deaths that's roughly twice as high as in any previous war.

Those numbers have turned amputee research from a backwater to a high priority. In 2005, DARPA set up the prosthetic-arm project and put it in the hands of Geoffrey Ling, a neuroscientist

ARMED AND READY: Jonathan Kuniholm wears a prototype of the prosthetic arm created by the DARPA Revolutionizing Prosthetics project. PHOTO: MIKE McGREGOR

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PROSTHETICS REVOLUTIONARY: Jonathan Kuniholm is an engineer at Duke University, one of dozens of institutions partnering on the Revolutionizing Prosthetics project.

PHOTO: MIKE MCGREGOR

trained at Georgetown University, in Washington, D.C., who is also a colonel in the U.S. Army.

Ling split the program into two distinct parts. The part headed by Dean Kamen's New Hampshire–based Deka Research and Development Corp. had a 2007 deadline for creating a sophisticated mechanical limb by making the most of existing technologies, using noninvasive control mechanisms.

The complementary four-year program has a 2009 deadline to reinvent prosthetics from the ground up so that they can be biologically controlled. The goal is to restore sensory feedback to amputees so that they can again perceive heat, cold, pressure, and the position of a limb in space. All these faculties must fit inside a package that has the look, weight, strength, dexterity, natural movement, and toughness of an arm [see illustrations, "Custom Built"].

Ling tapped APL to oversee this nationwide "Manhattan Project" for prosthetic arms. Over 30 universities and research institutions are collaborating on the project, all of them leaders in their fields. "I thought it was going to be like herding cats," says Harshbarger, Ling's APL counterpart, who directs the 2009 effort. But countering stereotypes of academic competitiveness, these 300-odd researchers have been working together in lockstep, project first and egos last, to make the endeavor succeed.

Creating an arm that actually interfaces with an amputee requires an encyclopedic understanding of countless disciplines including power management, neural integration, and anatomy. APL built two mechanical prototypes, both of which were marvels of modern engineering. The Rehabilitation Institute of Chicago (RIC) developed surgical techniques to reroute existing nerves in amputees so that they interface with the electronics in the prosthetic arm. Chicago-based Sigenics developed implantable electrodes to wirelessly transmit the electrical signals from residual muscles directly to the prosthetic limb. Researchers at the University of New Brunswick, in Canada, developed signal-processing algorithms to decipher the noisy biopotentials from the reinnervated muscle in real time. Researchers at the University of Utah developed brain-penetrating electrodes to tap nerve impulses at their source. Johns Hopkins University has developed what it calls the Virtual Integration Environment, in which an amputee can practice by "driving" a virtual arm with nerve signals.

The result is a system that will patch together delicate nerve surgery, signal-processing algorithms, injectable electrodes, and a virtual-reality training environment to connect an amputee to an artificial arm that he can control intuitively with his own nerves and muscles, as intuitively as you control your own arm. By the end of 2009, two crucial components of the technology should be in clinical trials: injectable myoelectrodes that let amputees wirelessly use the signals from their residual muscles to drive the limb, or if they choose a more invasive path, drive it using electrodes implanted directly into peripheral nerves.

At the end of the 1979 *Star Wars* sequel *The Empire Strikes Back*, a deft stroke of Darth Vader's light saber slices off Luke Skywalker's hand. In the next scene, Luke is on a medical ship, and a robot is putting his new prosthetic hand through its paces: a needle pricks each of his fingers in turn, and each time Luke winces in response. The throwaway scene shows a state of the art in prosthetics that in 1979 was out of the question. Even then it was relatively easy to make a prosthetic hand look convincing, but if you were to stick a needle in one—or chop it off—the wearer wouldn't know unless he was watching you do it. Prosthetics were designed for form, not function. Mechanical designs for futuristic robot arms have been floating around for at least half a century. Yet despite years of sci-fi promises, prosthetic-arm research has stagnated.

Upper-arm prosthetics got their last big overhaul in 1912, in the form of a hook that could be opened by shrugging against a strap across the back. That turned what had been a purely cosmetic sleeve-stuffer into a machine with a limited ability to manipulate objects. Another big investment, after World War II, gave the world the myoelectric hand, but it did not change the fact that prosthetics were unintuitive and cumbersome. Today the hook has been prettied up with a molded plastic hand and semirealistic skin tones, and

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the arms are lighter and stronger. But they can't do a whole lot more.

Traditional upper-body prosthetics provide at best three degrees of freedom: you can open and close the hook, bend and straighten the elbow, and on sophisticated models you can rotate the wrist. And even those simple movements require training, concentration, and effort, which is why the resulting motion is neither fluid nor precise. Contrast that with the human arm's subtle dexterity and more than 25 degrees of freedom of movement, not to mention its ability to discern hot from cold. With three degrees, you can't even open a door—a doorknob requires what's called off-axis rotation, and that requires two extra degrees of freedom in the elbow and wrist—and you can completely forget about tying your shoes or checking your e-mail. Within a year of being fitted, many amputees put their artificial limbs in closets to collect dust and learn to live without them.

Why so few advances? In part it's because upper-body amputations are rather uncommon, unlike lower limb amputations. That's why there's been far greater demand for high-tech leg prostheses (notably the carbon-fiber transtibial artificial limbs on which sprinter Oscar Pistorius recently threatened to break records set by able-bodied men). The disparity has led Deka's Kamen to grouse that today's prosthetic arms use "Flintstones" technology.

But the main problem is that it's just harder to make a really useful artificial arm than it is to make a comparably useful leg. To fulfill the minimum requirements of daily living, a leg needs springiness and four degrees of freedom; an arm-and-hand system needs about 22 degrees of freedom, as well as the ability to feel heat, texture, and force and to use that information to make dexterous movements.

In 2003, Ling was stationed with the 44th Medical Brigade in Afghanistan, where he soon found himself bandaging many more children than soldiers. "Every day some little Afghani kid came in missing part of his limb," Ling says, often after the child had inadvertently found one of the many land mines still littering much of Afghanistan, some of them dating back to the Soviet occupation. Between surgeries, Ling developed his own ideas of what a prosthetic arm should be—a system that could replace a hand, a forearm, even the entire limb and shoulder, to restore to the amputee a fully functional arm. When he returned to the United States, Ling created the Revolutionizing Prosthetics program.

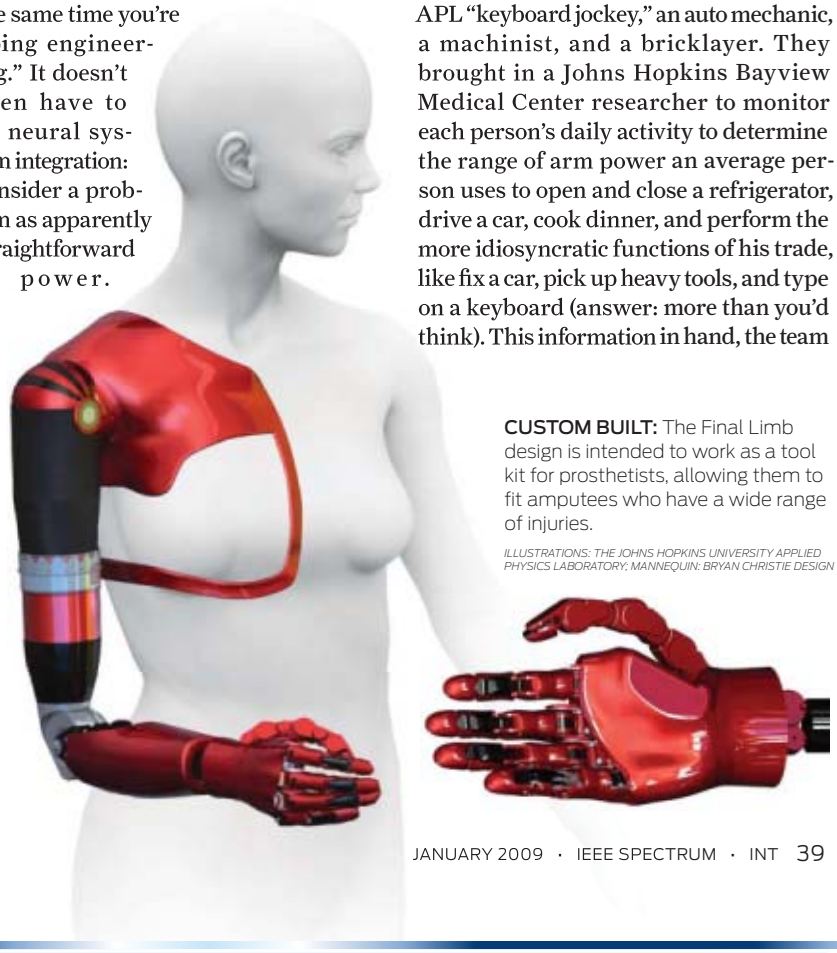
EXPERT CALL "Reaching high for too many things has doomed other projects. I hope that doesn't happen with the robotic arm."
–Nick Tredennick

Making the arm is the easy part, and it's not at all easy. Microprocessors have become small and powerful enough, and research has yielded materials light enough, to meet the limb's 3.6-kilogram (8-pound) specification, the weight of an average female's arm. But even that might be too heavy—the natural arm is connected to the bone, but an artificial limb relies on sockets and straps, which make even a "normal" weight feel awfully heavy by the end of the day.

But at least that's a problem an engineer can tackle—how to make something lighter. "When you're working on the neural system," says APL director Richard Roca, "you're doing scientific discovery at the same time you're doing engineering." It doesn't even have to be neural system integration: consider a problem as apparently straightforward as power. Power consumption has improved but not enough to allow a lightweight battery to indefinitely power a mechanical arm. Harshbarger's goal is a battery that can last for 18-hour shifts.

The research was going ahead at full speed before it became clear that no one knew how much power an actual arm requires per day. Convinced that the answer had long since been published in someone's doctoral thesis, APL systems engineer James Burck searched the literature, only to come up empty-handed.

So before they could continue their work, the APL team had to determine the daily power usage of an average arm. They asked for volunteers from a wide range of occupations—a self-described APL "keyboard jockey," an auto mechanic, a machinist, and a bricklayer. They brought in a Johns Hopkins Bayview Medical Center researcher to monitor each person's daily activity to determine the range of arm power an average person uses to open and close a refrigerator, drive a car, cook dinner, and perform the more idiosyncratic functions of his trade, like fix a car, pick up heavy tools, and type on a keyboard (answer: more than you'd think). This information in hand, the team



CUSTOM BUILT: The Final Limb design is intended to work as a tool kit for prosthetists, allowing them to fit amputees who have a wide range of injuries.

ILLUSTRATIONS: THE JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY; MANNEQUIN: BRYAN CHRISTIE DESIGN

WINNERS & LOSERS 2009

SNAPSHOT:
Arms Race

Goal To create a neurally controlled prosthetic arm with 22 degrees of freedom.

Why it's a winner It has accomplished every goal so far, and even though the project is incomplete, its associated technologies have begun to improve existing prosthetics.

Who U.S. Defense Advanced Research Projects Agency; Johns Hopkins University Applied Physics Laboratory (systems integrator); Rehabilitation Institute of Chicago; 30 research institutions around the world

Where Laurel, Md., and 30 other locations around the world

Staff 300 and counting

Budget US $71.2 million to date

When Third-generation prototypes under development, scheduled for clinical trials late 2009; commercially available (in some form) the following year

was able to determine a specification for a battery that would last 18 hours and be recharged as easily as a cellphone.

But the most power-efficient arm in the world is no good if you can't control it. So APL partnered with RIC to develop a groundbreaking technique for controlling a mechanical arm with an amputee's own nervous system.

Todd Kuiken, director of RIC's neural engineering center, created a portal to the nervous system by rewiring the shoulder. The procedure, called targeted muscle reinnervation surgery, redirects the residual nerve bundles that once connected the spinal cord to the 70 000 nerve fibers in the arm. After an amputation, these nerves remain in place, and they continue to work—they just aren't connected to anything functional. The pectoral muscles also remain intact, but they too are no longer driving an arm. So Kuiken surgically threaded the residual nerves from their original locations into the chest, where they innervated, or grew into, an area of pectoral muscle slightly smaller than a compact disc.

Next, Kuiken taped electrodes over the chest patch, where they could pick up the electromagnetic signals from muscles and send them to paired electrodes inside the prosthesis. There, signal-processing algorithms could translate the signals into the user's intended movements. With Kuiken's surgery, amputees were able to control the DARPA prototype with their own muscles, as if it were an extension of their own flesh.

Then came an unexpected and very lucky break: the researchers found that the redirected nerves restored not only muscle function but also sensation. The skin on that patch had been rewired with the nerves from the arm and hand; therefore, the patients sensed a touch on their chests as if someone were touching their missing hands—even if it was just a tap. The Hopkins team exploited this discovery with a device called a tactor, built at Northwestern University. By placing the tactor on the chest next to the electrodes, they created a complete feedback loop. In the end, the combination of Kuiken's complex rewiring scheme and the brain's natural plasticity simulated a real arm's ability to sense touch, heat, and cold.

But soon the researchers found themselves with an intractable problem. The goal is to create an arm for unconstrained daily use—ideally, Ling says, you'd want to just "strap it on and go." But few people would submit every day to the punishing routine of having 20 electrodes and an array of tactors taped to areas of the chest, then having those electrodes connected to the correct wire. It would take hours to suit up. Also, Kuiken wants more electrodes than that CD-size patch of skin can accommodate. "I'm running out of real estate," he says.

70 000
NUMBER OF NERVE FIBERS IN A HUMAN ARM

To solve all these problems, the researchers figured it was time to get some of those electrodes under the skin and to make the control mechanism work wirelessly. To that end, they plan to implant rice-size devices called Injectable MyoElectric Sensors (IMES) into the muscles, to magnify the electromagnetic signals from muscle twitches. Pending FDA approval, these devices, developed by RIC researchers Richard Weir and Jack Schorsch and Illinois Institute of Technology biomedical engineering professor Philip Troyk, will go into clinical trials at the end of 2009. Also in the queue for clinical trials are much more invasive needlelike implants that bypass the muscles by going directly into the peripheral nerves. The ultimate goal is penetrating brain electrodes to tap the signal directly at the source. But that's still a few years away.

DARPA is often accused of funding science-fair research projects that fail to find real-world applications. This isn't one of those projects. The fruits of the Revolutionizing Prosthetics program are already improving existing prosthetics. Targeted reinnervation surgery has already been adopted in Canada, where in October Jacqueline Hebert, clinical director of the adult amputee program at the Glenrose Rehabilitation Hospital, in Alberta, announced that two patients had successfully undergone the surgery and were now starting to control their prosthetics with the newly innervated muscles. "The patients have visible muscle contractions in their arms when they think of opening and closing their hands," Hebert says. One patient is beginning to have sensory reinnervation as well.

The success of the procedure suggests that it could soon be a mainstay of rehabilitation. Otto Bock Healthcare Products, in Vienna, is the transition partner for DARPA, meaning that it will manufacture the devices after DARPA has stopped funding.

But the eventual, overarching goal is more than just an arm or even a system of devices that includes an arm. It is to give shape to the new generation of prosthetic arms. Take the game of air guitar hero, for example: later in 2009, the software that let Kuniholm play *Guitar Hero* will go open source. Harshbarger thinks DARPA will eventually make all or most of the RP2009 software and hardware interfaces open source. Within the next year or so, the Johns Hopkins Virtual Integration Environment hardware specifications should be available, so that down the line, as Kuniholm says, "anyone can build a better elbow without having to build a whole new arm." ❑

LOSER Automotive

That Sinking Feeling

IN THE TEETH OF A GLOBAL RECESSION, AN AQUATIC-CAR COMPANY RAMPS UP TO ENTER A MARKET THAT'S NEVER MADE MONEY *BY STEVEN CHERRY*

In 1961, the world's first mass-produced aquatic car came to market. The Amphicar, built in West Germany around a state-of-the-art Leyland Motors engine, could go 113 kilometers per hour on land and 7 knots on the water, and it cost a modest 11 200 marks (about US $20 000 today). Yet in seven years it sold a mere 4000 units.

For a boat, it was a good car; for a car, it was a good boat.

So what makes Gibbs Technologies, of Troy, Mich., think the prospects for an amphibious car are any better today? That's the $64 000 question. Or, more accurately, the $85 000 question, because that's the least it'll cost to get behind the wheel of an Aquada, the spiritual successor of the Amphicar.

Like its predecessor, the Aquada is a technical marvel. And it too might sell several hundred units in its first year—whatever year that turns out to be. As recently as last June it was expected to be 2009, but in October, company president Neil Jenkins told this reporter it would be "later than 2009." It's just the latest of a long series of delays.

Founder Alan Gibbs built his first aquatic vehicle in 1995, began design work on the Aquada in 1997 in Detroit, moved to the United Kingdom a couple of years later, and in 2004 announced that the first Aquada would soon roll off the production line. That June, billionaire adventurer Richard Branson tore across the English Channel in a prototype in 100 minutes. A £150 000 version (then about $270 000) was to be sold in the UK that September, but supplier problems kept the car from going into production. The company spoke of getting a left-hand-drive version into European showrooms by the end of 2005. That didn't happen either.

The year 2007 found Gibbs Technologies in the Detroit suburb of Troy, promising a U.S. model in 2009. This time, the company got cold feet. "A number of items cropped up," Jenkins says, "which really said that while it was ideal for a European climate and the European market, there were some things that needed changing for the U.S. So we're in the process of engineering those changes and implementing them. It won't be 2009. I don't actually have a date for you yet." He also conceded that the new features would drive the Aquada's price even higher.

Fortunately, Alan Gibbs doesn't need to sell cars to put food on his table. He's not even relying on venture capital, having made several fortunes himself, first in manufacturing—television sets, refrigerators, masonry bricks, brassieres, and a lot of other things—then in merchant banking, car dealerships, and a pay television network.

You might even argue that with very few takers the car could still justify itself as a loss leader—a sexy product that casts a halo over Gibbs Technologies' other, more marketable offerings. These include the Quadski, a combined all-terrain vehicle and jet-ski-style boat, and the Humdinga, a light amphibious truck.

CIRCA 1750

SOLDIER, SCIENTIST, AND REPUTED SORCERER RAIMONDO DI SANGRO INVENTS AN INTERNALLY PROPELLED AMPHIBIOUS CARRIAGE.

PHOTO: GIBBS TECHNOLOGIES

The Aquada's image might even buff Gibbs's military business. In July, Gibbs announced an extensive partnership with mammoth defense contractor Lockheed Martin to make amphibious military vehicles that match the Aquada's 45-km/h water speed. Today's versions still dog-paddle along—at 7 knots, or about 10 km/h—the way their predecessors did 60 years ago in World War II. Ravi Vaidyanathan, a professor of systems engineering at the Naval Postgraduate School, in Monterey, Calif., says that Gibbs's speed on both land and water "could be very useful for 'rivering'—if the vehicle could also go off-road."

Yet if all you want is image, you don't need to mass-produce the Aquada; just give a single car—like Branson's prototype—to Columbia Pictures for use in the next James Bond movie.

You can just picture it. Bond barrels through a haze of bullets on Chicago's Lake Shore Drive as enemy agents corner him by the Lake Michigan shoreline. Just before plunging into the water, he hits a button on the dashboard. A hydraulic system retracts the wheels into their wells. Bond's foot hits the accelerator again, and the already spinning propeller bites down, throwing a jet of water out the back at 100 cubic meters per minute—enough to generate a metric ton of thrust. Hapless SPECTRE agents can only stare angrily from the shore as the Aquada speeds away at 65 km/h. In the next scene, our hero steers with one hand, a dry martini in the other, as he smiles back at the bikini-clad beauty water-skiing off the rear of his aquacar.

EXPERT CALL

"I imagine running out of gas in the middle of the river and slowly sinking into the muck below."
—*Robert W. Lucky*

Making a water jet that pulls a water-skier isn't hard, of course, but designing one that does so while powering a boat weighed down with a car's guts is quite another. Thus the 2.5-liter V6 engine, which puts out 130 kilowatts (175 horsepower) and 240 newton meters (177 foot-pounds) of torque—every bit of which is needed to haul around three independent bilge-pump systems and drive a 90-centimeter-long 40-kilogram water jet. According to Jenkins, that's half the length and a third of the weight of any other jet with a comparable level of thrust—just one of the many design challenges the company had to overcome.

Of course, another big challenge was just staying afloat. To that end, the designers omitted doors. Instead, you step up and into the vehicle on a rail that runs along the side, which deflects spray from the interior. It also helps the vehicle corner on the water, together with two additional rails underneath. A hydraulic strut lifts and retracts the wheel and tire assembly into the wheel housing.

SNAPSHOT:
Water Wheels

Goal To produce a commercially successful aquatic sports car.

Why it's a loser Comparable sports cars can be had for far less. Few will pay a US $60 000 premium to drive across a river.

Who Gibbs Technologies

Where Auburn Hills, Mich.

Staff 100 and hiring more

Budget Info not available

When Any year now

Most of the Aquada's innovations, such as sensors that don't let the wheels retract until the hull is surrounded by water, would have been difficult to imagine and impossible to implement in 1960, when the Amphicar was being designed. And certainly there are more people who might find an amphibious car useful today.

Back in 2004, an enthusiastic Richard Branson, fresh from his record-breaking Channel crossing, announced plans to use the Aquada as part of the limousine service for his Virgin Airlines, which picks passengers up at home. "But unlike our other limos," Branson was quoted as saying, "when the Gibbs Aquada hits traffic on its way to or from central London, the driver simply heads for the nearest slipway and takes to the Thames before rejoining the roads on the final leg of the passenger's journey." Unfortunately, the Aquada is far from a limousine. There's only one seat up front—in the middle—and two in the back. A Ford Mustang has more room, at one-fourth the price.

What about other riverine locales, such as New York City, where you have to cross the Hudson to reach New Jersey? Jenkins says he's talked with city officials and believes that amphibious crossings will be allowed. Commuters who now must take the George Washington Bridge would thus be able to save $6 to $8 a pop on tolls, enough for the car to pay for itself—in 44 years.

So does the Aquada's prospect for success all come down to price? Of course it does. Alexander Edwards, president of the automotive division at Strategic Vision, a large analytical firm, thought that at $39 000 or so, there were "a fair number of people entering the luxury market that might think this is an interesting option." But that's less than half the price Gibbs is contemplating. Tom Libby, a senior director at J.D. Power and Associates, agrees. "If it comes in too high, volume will be very, very low," he says.

On top of all that is the slight friction in the credit markets that you may have been reading about lately. That friction, and the economic contraction it has set off, will surely cut down on the number of people shopping for luxury cars. What does that do to Alan Gibbs's plans?

So far, he's sticking to what he said last year, when he predicted he'd sell 100 000 units a year in the United States, including all Quadskis, Humdingas, and military vehicles. He says he expects to ramp up to 1500 employees three years from now, from the 100 or so he has today. He plans to move his headquarters to Auburn Hills, Mich., and he's shopping around for a manufacturing site.

I wish Gibbs well. In fact, as I contemplate another bout with the George Washington Bridge's toll collectors, I would dearly love to be wrong in labeling the Aquada a losing proposition. But like most car buyers about to walk into a car showroom, I don't have an extra $60 000 to throw around. ❑

QUANTUM DOT-COM: Japanese start-up QD Laser's Yasuhiko Arakawa [left] and Mitsuru Sugawara oversaw the 15-year effort to commercialize a temperature-stable semiconductor laser.

PHOTO: BRUCE OSBORN; PHOTO-ILLUSTRATION: BRYAN CHRISTIE DESIGN

Winner Telecommunications

Quantum Leap

QUANTUM-DOT LASERS FROM JAPAN'S QD LASER WILL MAKE HIGH-SPEED "FIBER TO THE HOME" NETWORKS SIMPLER, CHEAPER, AND MORE POWER-EFFICIENT *BY JEAN KUMAGAI*

Suppose you had a dog whose personality fluctuated with the weather. On cool, crisp mornings, he's a champ, fetching, rolling over, and shaking hands at your slightest command. But as the sun climbs higher and the day warms up, he becomes less and less responsive, and you have to ply him with doggy treats to get him to obey. And during heat waves? Forget about it—he barely plays dead unless you double or triple his kibble ration.

While you could excuse such behavior in Fido, something remarkably similar goes on all the time with the semiconductor lasers used in CD and DVD players and in optical communications. These tiny devices are incredibly sensitive to heat. Even a small rise in temperature causes the electrons within to move around faster and migrate out of the laser's active layer—the thin slice of semiconducting material where the electrons recombine with positively charged holes to make light. As a result, the laser's light output fluctuates, and it needs stronger and stronger electrical currents to keep lasing. At 85 °C, the device might need two

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or three times as much current to produce the same amount of light as at 25 °C.

To get around that shortcoming, developers of semiconductor lasers must either cool them or introduce extra circuitry that maintains the device's output even as the temperature fluctuates. But those workarounds increase both the cost of making the lasers and the power they consume. Ever since this problem came to light, researchers have been hunting for a semiconductor laser that is inherently stable.

SNAPSHOT:

A Laser That's Right On the Dot

Goal To commercialize a reliable and inexpensive semiconductor laser that's also immune to temperature changes.

Why it's a winner These high-speed, low-power, temperature-stable lasers are equally applicable to optical networking and consumer electronics.

Who QD Laser, a joint venture of Fujitsu and Mitsui Venture Capital Corp., and University of Tokyo

Where Tokyo and Atsugi, Japan

Staff 30 scientists and engineers

Budget US $14 million

When Spring 2009

One promising technology, first proposed 27 years ago, is the quantum-dot laser. Such a device tightly confines the electrons and holes within many nanoscale blobs, or dots, of semiconducting material. With enough dots—millions or billions, that is—lasing will occur and steady output maintained, regardless of external temperature. While researchers can now grow these devices using standard molecular-beam epitaxy equipment, mass-producing them has been very tricky.

The Japanese start-up QD Laser, of Tokyo, a joint venture of Fujitsu and Mitsui Venture Capital Corp., has finally succeeded. Its quantum-dot lasers use inexpensive substrates made from gallium arsenide (GaAs) and boast an industry-leading density of 60 billion dots per square centimeter [see images, "Collecting the Dots"]. Compared with the conventional indium-phosphide lasers now used in optical networks, QD Laser's devices will consume just half the power while transmitting up to 10 gigabits of data per second at a wavelength of 1.3 micrometers. Best of all, they will generate the same output at any temperature from –40 to 100 °C.

To mass-produce the GaAs laser chips, QD Laser has partnered with one of Japan's leading consumer-electronics firms, which will use the same production lines on which it currently cranks out conventional red lasers for DVD and CD players, video-game consoles, and other products. (QD Laser says it will reveal the name of its partner later this year.) The initial shipments of laser chips are destined for an unnamed optical equipment vendor, which sometime this spring will begin offering the world's first optical transceivers incorporating a quantum-dot laser. Fujitsu will almost certainly buy the transceivers for use in optical LANs and fiber-to-the-home networks.

The quantum-dot laser has long been envisioned as a successor to the quantum-well laser, itself an improvement on earlier laser designs because it confined the injected electrons to an extremely thin layer—no more than tens of nanometers thick—of active material. That way, it required less current to induce lasing. But like the "bulk" semiconductor lasers it superseded, the quantum-well laser is sensitive to temperature.

In the active layer of a bulk semiconductor laser, which you can picture as a fat, rectangular slab, the electrons and holes move in three dimensions, and that makes their interactions hard to control. In a quantum-well laser, they can move in only two dimensions, but electrostatic fields tend to build up, pulling the electrons away from the holes. In both cases, an increase in temperature makes the electrons more unruly.

Researchers began looking at ways to confine the electrons even further. In 1980, Yasuhiko Arakawa, a 28-year-old associate professor at the University of Tokyo, had an epiphany. "I thought, if we fix the position of each electron by confining it in a small box, the energy distribution will not be affected by temperature," Arakawa recalled in a recent interview at his office at the University of Tokyo. Each "box" would be a semiconducting nanosize crystal into which electrons and holes would be injected. The box would effectively prevent the electrons and holes from being thermally excited to higher energy states.

He presented his quantum-box laser idea at the annual meeting of the Japanese Society of Applied Physics in March 1981. Then, collaborating with another professor, Hiroyuki Sakaki, he published a paper on the topic in the 1 June 1982 issue of *Applied Physics Letters*. The two researchers followed up with a series of experiments in which they confined electrons using 30-tesla magnets and demonstrated that the devices worked the same over a wide temperature range. "But I thought it would be impossible to fabricate such nanostructures until the 21st century," Arakawa says.

The quantum-box laser concept

didn't exactly set the world on fire. Some people found it interesting but not particularly useful, while others concluded that the boxes would be structurally unstable. His early work "attracted almost no one to the field," says Arakawa, now an IEEE Fellow. Today, he adds, thousands of researchers worldwide are working to advance the field.

31 PERCENT OF SOUTH KOREAN HOUSEHOLDS HAVE BROADBAND "FIBER TO THE HOME" CONNECTIONS.

Just three years after Arakawa and Sakaki's paper, a research group at France's Centre National d'Etudes des Télécommunications (CNET) noticed a strange phenomenon in the "superlattices" they were trying to build out of extremely thin alternating layers of indium arsenide and gallium arsenide. Studying their handiwork under an electron microscope, they noticed that some of the indium arsenide had formed tiny regular blobs atop the underlying layer of gallium arsenide. Each blob, it turned out, was a quantum dot. The French team didn't actually produce lasing from their weird structure, but it was a start.

In 1994, a team at the Tokyo Institute of Technology and a collaboration of the Technical University of Berlin, Russia's Ioffe Physico-Technical Institute, and the Max Planck Institute of Microstructure Physics independently demonstrated the first quantum-dot lasers. (At that point, the *quantum-dot* versus *quantum-box* terminology was still in flux, with the German-Russian team using the former term and the Japanese using the latter. Eventually, Arakawa says, the world settled on *quantum dot*. "Now even I call them quantum dots," he says.)

But it's one thing to create an experimental device in the lab and another thing to mass-produce a laser that operates reliably, can be manufactured cheaply, and performs a useful function.

QD Laser's president and CEO, Mitsuru Sugawara, and his colleagues began chipping away at the problem of commercialization in 1994. Sugawara was then a research physicist at Fujitsu, aiming to develop a temperature-stable laser that emitted at 1.3 µm, the best wavelength for optical communications. "We weren't interested in quantum dots per se," Sugawara recalled in an interview last fall.

Like the CNET group, he and his team had been working on superlattices when they noticed quantum dots forming spontaneously, Sugawara says, "like water beading up on a waxed car." After realizing what they'd done, they set to work on building a laser. "We knew that to produce lasing, we had to increase the density of the dots, so we started to study how to grow them intentionally," he says. Five years later, in 1999, they demonstrated their first quantum-dot laser with a wavelength of 1.3 µm.

In a perfect world, the Fujitsu group would have continued to make steady progress, and a commercial quantum-dot laser would have hit the market years ago. In the real world, the IT bubble burst, and corporate priorities shifted. "My boss told me that if we didn't stop our research [on quantum dots], he'd be fired," Sugawara says.

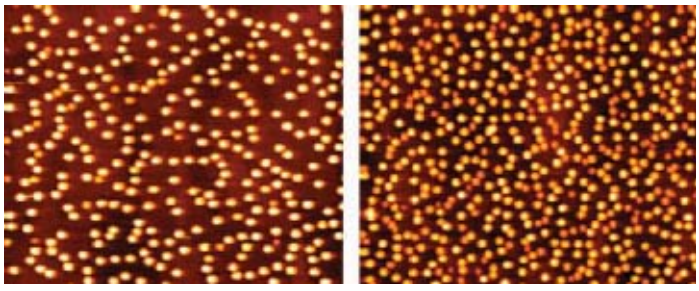
Eager to keep Japanese R&D on quantum-dot lasers alive, Arakawa stepped in. By then his pioneering work on nanostructure devices had made him quite influential in Japan's scientific circles. In 2001 he persuaded the Japanese government to include quantum-dot research in a national project on photonic networking. Fujitsu participated, along with Hitachi, Mitsubishi, NEC, and a number of other Japanese companies.

The Fujitsu group resumed its efforts to increase the dot density, mainly by stacking the quantum-dot layers. In 2004, they built a stack of 10 layers containing 30 billion dots per layer and capable of transmitting data at 10 Gb/s.

"At that point, we could think about starting up a venture company," Sugawara says. Though it had nurtured the early stages of research, Fujitsu wasn't the best place to commercialize the results, he says. The company's main business is building high-end servers and optical networking systems for government and business customers. It has no expertise in the commodity chip-making methods that Sugawara envisioned using for the quantum-dot lasers.

In April 2006, Fujitsu and Mitsui Venture Capital formed QD Laser, providing the start-up with an initial US $2 million. Fujitsu agreed to let QD Laser use its 40 or so patents on quantum-dot technology; Arakawa signed on as the company's technical advisor.

Although QD Laser's official headquarters are in a central



COLLECTING THE DOTS: One of QD Laser's achievements, as shown in these atomic-force microscope images, was to double the dot density in its quantum-dot lasers, from 30 billion [left] to 60 billion [right] dots per square centimeter.
IMAGE: QD LASER

WINNERS & LOSERS 2009

Tokyo high-rise, most of the company's staff, including Sugawara, are based at Fujitsu's facility in Atsugi, about 45 kilometers southwest of Tokyo, and research goes on there and at Arakawa's labs at the University of Tokyo. There are currently 30 scientists and engineers involved, including five at the University of Tokyo.

EXPERT CALL "If high-density quantum dots of uniform size can be manufactured cheaply, this is a winner." —*Nick Tredennick*

After its founding, the start-up continued to work on boosting the lasers' dot density. "We thought we could keep adding more layers, but we realized that wasn't enough," Sugawara says. Using proprietary techniques, researchers at QD Laser and Tokyo University eventually succeeded in doubling the dot density, from 30 billion dots per square centimeter to 60 billion. Sugawara brings out two atomic-force microscope images of quantum dots. The first shows a sparsely dotted surface. "Everyone can make this density," he says. Then, pointing to the second image, which is crowded with dots, he says, "but only we can make this."

QD Laser isn't the first company to bring a quantum-dot laser to market. That distinction belongs to Innolume, a start-up based in Dortmund, Germany, and Santa Clara, Calif. Since 2007 it has sold quantum-dot "comb" lasers, which can emit tens to hundreds of colors over a range of wavelengths. The devices are potentially suitable for optical computing, laser television, and biomedical applications. But Innolume has yet to find a wide market for its products.

QD Laser will do better because its corporate backers have the muscle to see that it does. Fujitsu has already agreed to replace the standard indium-phosphide lasers in its optical networking systems with QD Laser's gallium-arsenide lasers. But even Fujitsu had to be convinced that the new devices would be as reliable as existing lasers. "The communications market is very conservative," Sugawara notes. To make its products more palatable to optical equipment makers like Fujitsu, his company spent months tailoring the quantum-dot laser's output power and performance so that they matched those of a conventional laser. The resulting laser can seamlessly replace an indium-phosphide laser in an optical transceiver, with no significant redesign required.

With telecom giant Nippon Telegraph and Telephone Corp. adding 3 million fiber-to-the-home connections each year, Sugawara thinks his company could claim 5 to 10 percent of the Japanese market by 2011. QD Laser is also working on lasers for long-distance communications of up to 20 kilometers.

At press time, the company was wrapping up reliability tests and planned to begin selling in the spring. Even as it tries to line up more optical equipment customers, QD Laser wants to branch out into the consumer-electronics market, which buys 100 times as many lasers, or about 2 billion devices a year. That's why the partnership with the Japanese consumer electronics maker holds particular promise.

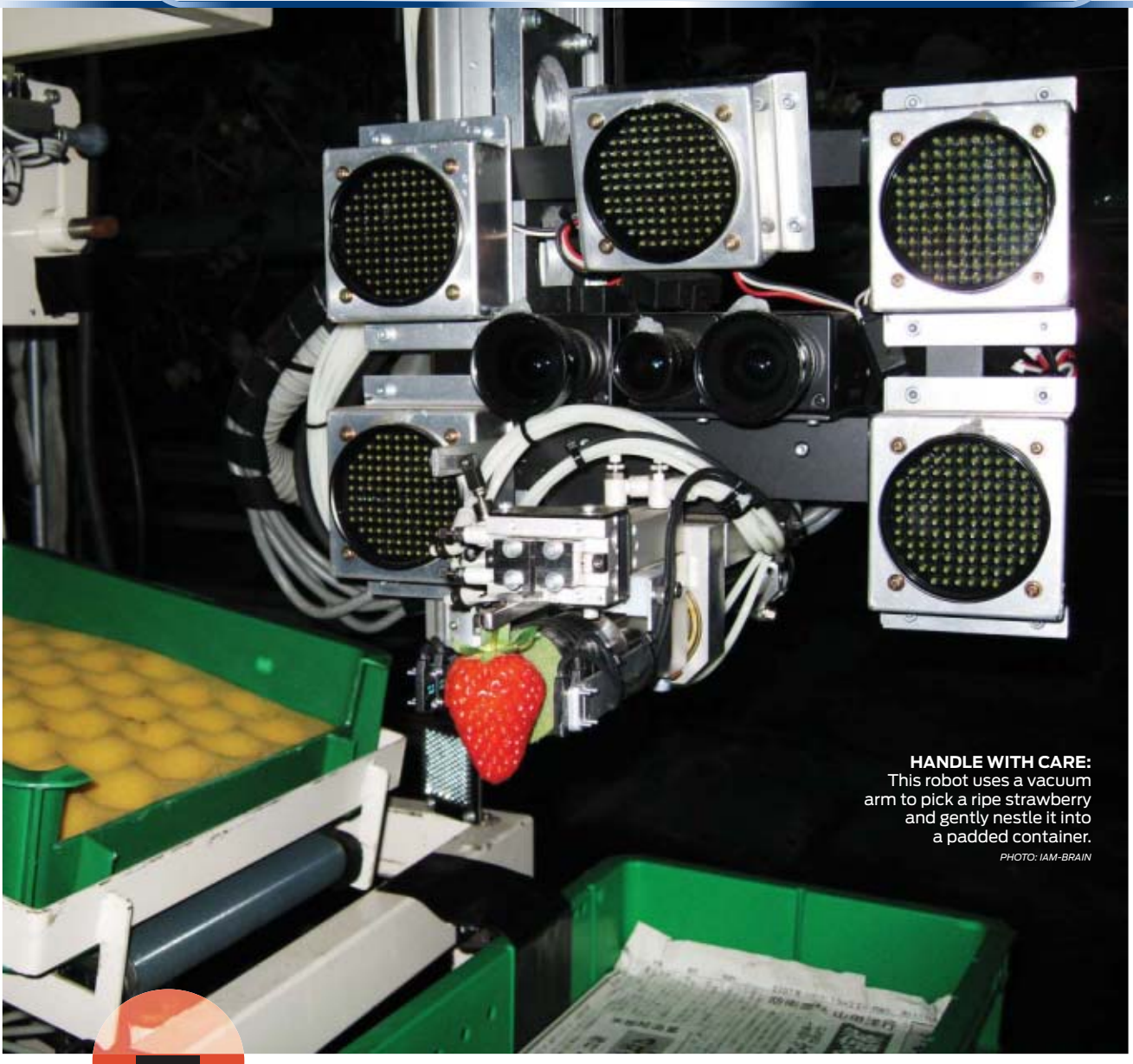
Back in 2006, shortly after his company was founded, Sugawara visited four of the major Japanese consumer-electronics makers to gauge their interest in quantum-dot lasers. Three said no thanks. But the fourth, Sugawara recalls, told him, "We've been waiting for you." The partnership is unusual in Japan, he adds, where there's little overlap between the optical-communications sector and the consumer-electronics makers. "We're one of the first companies to bridge the gap," he says.

For two years, QD Laser engineers worked closely with the consumer electronics firm to refine the fabrication process for the laser chips. QD Laser grows the 3-inch gallium-arsenide wafers in-house and then ships them to its partner, which can print about 50 000 chips on each wafer. Each 0.3-square-millimeter chip consists of a substrate of *n*-doped gallium arsenide, followed by a layer of *n*-doped aluminum gallium arsenide, the quantum-dot layer, and then layers of *p*-doped AlGaAs and GaAs. The company packages each chip in a can about 2 cm long. "Even though we're a small company, we can do mass production," Sugawara says.

QD Laser's partner would like to start incorporating quantum-dot lasers into its CD and DVD players and other products. By varying the size and concentration of the quantum dots, you can generate different wavelengths of light. To produce red light at 650 nm, for example, you could start with a 1300-nm quantum-dot laser and then pass it through a frequency doubler, which halves the wavelength. To make green light, you similarly start with a 1064-nm laser and double the frequency to get a 532-nm wavelength.

Quantum-dot lasers could also be used in laser TV sets, medical devices, and tiny portable projectors that fit in your cellphone. In the next couple of decades, Arakawa says, we'll see quantum dots showing up in quantum computers and other IT devices [for more on quantum computing, see "Dot to Dot Design," *IEEE Spectrum*, September 2007].

But why stop there? Quantum-dot researchers have been looking at ways to use quantum dots in biochemical sensors, solar cells, and other technologies. It's a future Arakawa modestly refers to as "quantum dots for everything." ❑



HANDLE WITH CARE: This robot uses a vacuum arm to pick a ripe strawberry and gently nestle it into a padded container.

PHOTO: IAM-BRAIN

LOSER Automation

Fruitless

A STRAWBERRY-PICKING ROBOT WON'T BE DISPLACING FARMWORKERS ANYTIME SOON

BY TEKLA S. PERRY

In California it's hard to drive anywhere without spotting people bending down to pick strawberries—some 10 million pint baskets a day during peak season. Because such farming isn't practical in labor-starved Japan, the government there is backing a more fundamental solution: robots.

Research began in 2003, with funding from the Institute of Agricultural Machinery Bio-oriented Technology Research Advancement Institution, or IAM-BRAIN. The first demonstration of a prototype came in 2005. Yet although the system may well qualify as a technical tour de force, it's hard to see how it makes economic sense, particularly outside of Japan.

To understand why it is such a fascinating technical challenge, you need to know a bit about the berry business. Strawberries ripen only on the vine, and they do so in dribs and drabs. A robot therefore must patrol rows of plants day after day. When the robot comes across a candidate plant, its machine vision has to do more than just tell red from green, because a strawberry goes through many shades of red before it is fully ripe. Finally, the robot has to pluck and place the berry very carefully; a little too much pressure will

bruise the strawberry, causing it to rot. In short, strawberries are not the low-hanging fruit for robotic harvesting technology.

"It's not what I would have started with; you have to get so many things right," says Joseph L. Jones, chief technology officer of Harvest Automation, a company in Groton, Mass., that develops robots for the agricultural market. "It seems you could start with something simpler—a winter squash, perhaps.

"There are no large-scale uses of agricultural robots doing anything, because it's really, really hard," Jones continues. "People working in agriculture use all our considerable talents to identify an object, our considerable manipulation skills to manipulate it, and we work under all conditions. Robots aren't up to that, particularly in an unstructured environment outdoors."

Sure, dumb mechanical harvesters have long ripped hard, unripened tomatoes off the vine to ripen and be sorted later on. And machine vision has gotten good enough to sort fruit passing on a conveyor belt. Robots being developed now will soon move potted plants around greenhouses. But such jobs are easier to do in these contexts than in a berry-growing greenhouse, let alone a planted field.

15 HOW MANY TIMES THIS YEAR'S CALIFORNIA STRAWBERRY CROP WOULD WRAP AROUND THE WORLD, LAID BERRY TO BERRY

The original prototype looked like a version of the multimedia cart used in high schools: it had wheels on the bottom and several layers of open shelves, with a laptop computer on the top shelf and a tall arm towering above it, much like the arm of an overhead projector that rises above that media cart. The robot cruised planted rows, illuminating berries with four polarized lights and examining them with three color video-graphics-array cameras. While it conceivably could have gone out in a field, it was designed for the greenhouse environment; outdoors, dust could obscure the machine-vision lenses.

The current version is optimized even more for the indoor environment. It runs on rails built into a specially designed greenhouse; a single arm reaches down to suck the fruit against a tube capped by a soft sponge while a clipper snips the stem. The arm, still holding the fruit by suction, then reaches down and gently places the berry into its own hole on a spongy tray.

When cruising the aisles of the greenhouse, the robot picks, on average, one berry every 10 seconds.

YOU TELL US

Not everything is a clear-cut winner or loser. Sometimes it's hard to tell whether we'll someday look back and say, "How did we ever live without that?" or "I guess it seemed like a good idea at the time." Here's your chance to weigh in now

THREE-WHEELER: The VentureOne hybrid leans into turns and sips fuel but seats only two.
ILLUSTRATION: VENTURE VEHICLES

That's nowhere near as fast as a human worker. On the other hand, the robot doesn't take breaks.

The target cost of the hardware components for one robot—estimated at 7 million yen (about US $72 000 at press time)—equals the seasonal wages of three to four workers. That's not bad—although that's Japanese workers, of course; the money would pay for far more labor in California, where the price of an individual strawberry runs as low as a dime, one-fifth the average price in Japan.

But the real expense comes in deploying the robot. Farmers would have to rebuild every greenhouse—raising the beds high enough to let the strawberries hang down for easy picking and installing tracks for the robot. It won't happen without government subsidies, says Kyoto University professor Naoshi Kondo, a machine-vision specialist who is working on the project under contract to SI Seiko. That's too bad, because robots would offer advantages beyond a mere savings of labor. Above all, robots collect a lot of data.

"We can code which bed a fruit is picked from, in which greenhouse. If a strawberry later has problems, we can trace it back to one spot and can know when it was harvested," Kondo says. Such a capability would have come in handy during the recent spinach, lettuce, and chili pepper health scares, which led to vast product recalls.

With the expensive requirement of greenhouse redesign as a major hurdle, does the project make any sense at all? Kondo himself says that at the moment, humans are better at picking strawberries because

SNAPSHOT: Robotic Reaper

Goal To develop a robot that can select ripe strawberries and pick them without damaging them.

Why it's a loser It works only in greenhouses, which would have to be redesigned to accommodate it. Besides, humans can do the job much more easily.

Who SI Seiko Co., Maekawa Manufacturing Co., AAI Japan, funded by the Institute of Agricultural Machinery's Bio-oriented Technology Research Advancement Institution (IAM-BRAIN)

Where Matsuyama City, Japan

Staff About a dozen

Budget Not public, estimated at over US $1.5 million to date

When Prototype available; scheduled for commercialization by 2010

Although fuel prices have fallen far from last summer's peak, the pain at the pump will not soon be forgotten. That's particularly true in the United States, still the world's biggest automobile market, where people have long enjoyed cheap energy and could therefore barely believe they were paying US $4 for a gallon of gasoline ($1.05 per liter).

Clearly, U.S. car buyers have abandoned hulking SUVs for smaller, fuel-sipping hybrid electric vehicles, sticking auto dealers with unsold gas guzzlers and lengthening the waiting lists for hybrids. But it's hard to say whether the swing in demand is wide enough to create a market for the new car from Venture Vehicles. The Contoocook, N.H.–based start-up will introduce the three-wheel VentureOne plug-in hybrid in 2010.

Though the 680-kilogram trike will be completely enclosed, it will qualify as a motorcycle—which makes sense because the driver and passenger sit in tandem. The vehicle should also lean into turns like a cycle, because at high speeds an electrohydraulic system—made by Carver Engineering, in Gravendeel, Netherlands—will tilt the cabin and front wheel up to 45 degrees while keeping the two rear wheels upright. That maneuver keeps the trike's center of gravity right over the front wheel, ensuring that *g* forces push the vehicle down into the road rather than turn it over.

Along with this neat trick, the VentureOne has such eye-grabbing stats as using 3.14 liters per 100 kilometers (75 miles per gallon) and going more than 30 km before the gasoline engine turns on to recharge the batteries. Nevertheless, will consumers plunk down about $25 000 for a car that seats only two people and stows nothing larger than a child's schoolbag?

It remains to be seen how the public will view this vehicle and the five other items we are inviting you to vote on. They include a biometric database that uses pattern-matching technology to identify people by their tattoos, a handheld device that unrolls into an e-book reader [see "Pocket Book"], and a giant microwave oven that its makers say can cook a tire until it turns into diesel fuel.

—Willie D. Jones

To have your say, go to http://www.spectrum.ieee.org/jan09/ytu09.

POCKET BOOK: The rollable screen on the Readius is cool, but it's a blah pale gray.
PHOTO: POLYMER VISION

WINNERS & LOSERS 2009

they are faster and more flexible.

"It's nifty the way it works," says Tony Grift, associate professor of agricultural and biological engineering at the University of Illinois at Urbana-Champaign, who recently visited Kondo. "And I think you could market it in Japan. In America, I doubt it. We aren't going to grow strawberries in greenhouses anytime soon."

EXPERT CALL "Imagine the robotic berry picker escaping and running wild. Sounds like a movie I've seen."
—*Robert W. Lucky*

"If you are interested in developing robots, it is a fascinating task," says John Billingsley, professor of mechatronic engineering at the University of Southern Queensland, in Toowoomba, Australia. "If you are interested in harvesting strawberries, it is not the way to do it." A better solution, he says, would be to just raise a lot of strawberries, harvest them all at once with a dumb mechanical device, and then sort out the good ones. "It would be cheaper to raise more strawberries than it would be to build expensive robots," he adds.

Billingsley suggests that the choice is similar to one that an engineer might make when designing a dishwasher. You could make a robotic dishwasher, he says, by taking a standard industrial robotic arm, putting it in front of a sink with a dishcloth in its grip, and programming it to do the task. However, that would make little sense because "it's so much easier just to bundle the crockery into a square box and squirt water at it," he says.

Labor shortages do mean that automation is coming to agriculture, says Billingsley, "but it has got to be the right kind of automation." ❑

WINNER Remote Sensing

PENETRATING GAZE: Ryan Smith, CEO of ImSAR, holds his company's featherweight radar unit, which can provide real-time aerial images of the ground day or night, even through smoke or dense fog.

PHOTO: LANCE W. CLAYTON

Radio Eye in the Sky

IMSAR'S SYNTHETIC-APERTURE RADAR IS BOTH SMALL AND AFFORDABLE

BY DAVID SCHNEIDER

Other than having an oddly shaped protrusion in its baggage door, the Cessna 172 looks unremarkable, at least for one of its age—this single-engine plane was built during the Apollo program. But behind that lump is mounted a radar set far more sophisticated than anything NASA's astronauts ever took to the moon.

"That's a building," says Ryan Smith, chief executive officer of ImSAR, the radar's maker, narrating from the back seat as the plane taxis toward the runway of a small municipal airport near Salt Lake City. Strangely, he's not looking out the window as he says this; his face is instead glued to the laptop perched on his knees.

Good thing Smith is there to interpret, because the signal trace he is pointing to on his computer screen shows nothing more than a vague swell in a sea of seemingly random noise. Could this radar, about the size and weight of a paperback dictionary, really turn that hash into a detailed image?

Lifting off into the bright desert sky, Smith clicks a button and the laptop begins to paint the scene below and immediately to the left of the plane. From an altitude of 300 meters, the radar scans the ground up to roughly a kilometer away, producing a black-and-white image of the terrain the plane has just flown over.

The houses, roads, and shopping malls beneath appear stark and eerily otherworldly in the radar's 10-gigahertz light. But the scenery is remarkably well resolved, with each pixel on the laptop's scrolling image representing about a meter on the ground. The picture would look no different had it been obtained at night or through thick fog or smoke. The magic that makes it possible to see the world in such sharp focus using an antenna that's smaller than a clipboard is called synthetic-aperture radar, or SAR.

It takes a while to get your mind around the idea of imaging with radar—especially if your experience with radio detection and ranging is limited to

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peering at a boat's radar screen, which indicates the position of other vessels as just blips and perhaps can show the general shape of a distant coastline. But radar can produce crisp images, too, at least when it's used to look sideways out of a plane.

Normally, say, if you were using a dish antenna, you'd expect the angular resolution to be no better than the wavelength being sensed divided by the aperture of your instrument. A plain-vanilla 3-centimeter-wavelength radar with a 30-cm antenna, for example, would provide at best an angular resolution of 0.1 radian, or about 6 degrees. With such a device, you might be able to resolve two objects 1 meter apart as long as they were no more than 10 meters away. But a pair of reflectors positioned a kilometer away could be resolved only if they were separated by a football field.

SAR does an end run around this fundamental limitation of physics. Because the antenna is carried in a line that is roughly perpendicular to the direction it is facing, you can "synthesize" an aperture that is much broader than the physical antenna by combining measurements collected as you fly along—and thus obtain much improved resolution in the direction of motion. Surprisingly enough, SAR can obtain spatial resolutions that for the most part do not depend on the distance to the target.

How can that be? The complications of SAR data processing are enough to make most people's heads spin, but it's easy to grasp in a general way why image resolution does not degrade with distance.

That the resolution perpendicular to the flight line is constant is not at all hard to understand. A radar—for instance, one that emits short pulses—can measure the round-trip travel time of the early-arriving reflections just as accurately as it can the later ones, assuming those are not so faint as to be lost in the noise. Figuring out why the resolution parallel to the direction of flight doesn't fall off with distance requires more insight.

The key is to realize that distant objects are in view of the moving radar for a longer period than closer ones. Therefore the length of the synthetic aperture used to scan an object is proportional to the distance to it. And as the aperture grows, the angular resolution that can be obtained improves, canceling the usual loss of resolution caused by geometrical spreading of the antenna's several-degree-wide beam.

Of course, to combine the many measurements and synthesize a multitude of different apertures requires serious computing power. But if all the data processing is done right, you can, in theory, compress the spatial resolution of the image in the along-track direction to a value that's half the physical size of the antenna employed. Real-world systems, of course, have a hard time achieving that limit. In any case, the ultimate resolution in both along-track and sideways directions doesn't depend on distance. This is a remarkable result, and it distinguishes SAR from other kinds of remote sensing, including using your eyes.

Synthetic-aperture radar was first pioneered in the 1950s, although it didn't really come into vogue until decades later. One challenge for SAR pioneers was that so much data pro-

SNAPSHOT: Sideways Glances

Goal To develop the world's smallest synthetic-aperture radar system.

Why it's a winner It crams a roomful of electronic equipment into something the size of a shoebox.

Who ImSAR

Where Salem, Utah

Staff About 20

Budget Info not available

When First field deployments expected in 2009

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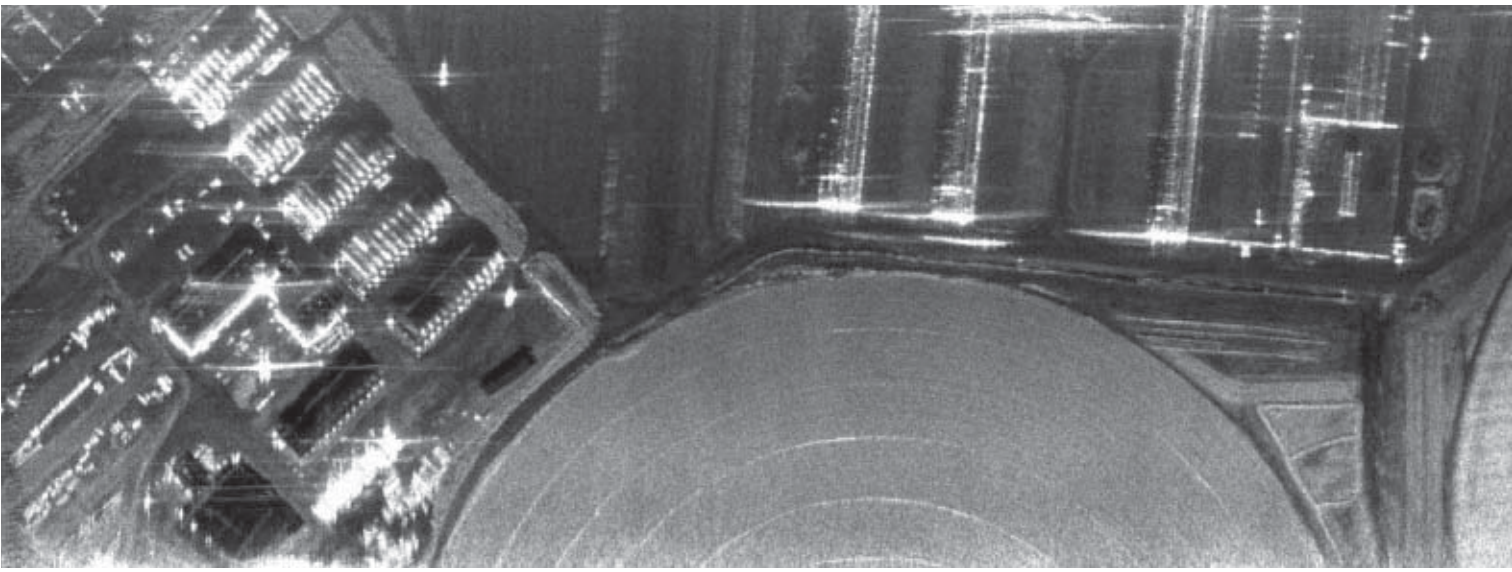

10-GHZ LIGHTING: ImSAR's imaging radar makes this Utah landscape appear stark and quite alien. Yet enormous detail can be discerned with nothing but radio illumination.
IMAGE: IMSAR

cessing was necessary that it had to be done long after the measurements were acquired. This was even the case when NASA conducted a series of SAR missions in the 1980s using the space shuttle. One surprise finding from those experiments was this technique's ability to map not just the surface of the Earth but also the subsurface—at least in places like the Sahara Desert, where the ground is so dry that the radar waves can penetrate without significant attenuation. The shuttle imaging radar could therefore peer beneath the dunes.

But the SAR systems flown in space and on aircraft in the past have been frighteningly large and complicated, not to mention expensive. Only recently have systems become small enough to carry on typical private aircraft.

For example, the special SAR equipment that Denver-based Intermap Technologies uses for three-dimensional terrain mapping fits on a Learjet. And Rockwell Collins is now in the process of commercializing a SAR system developed by researchers at Sandia National Laboratories that weighs only 12 kilograms. ImSAR has carried this evolution further still, reducing the package to something smaller than a shoebox, including the GPS and inertial-measurement units required to obtain precise navigational data. The company has also shrunk the price, charging less than US $100 000 for its system.

At that size and that price, the radar becomes practical for diverse applications. The U.S. military is keen to put it on small unmanned aerial vehicles (UAVs), for example. And many others—such as law-enforcement agencies, emergency rescue services, even fishermen—might soon use it to obtain SAR images from small planes.

This diminutive unit, fittingly dubbed NanoSAR, is an outgrowth of the thesis work that Ryan Smith did for his master's degree while a student at Brigham Young University, in Provo, Utah, which is just down the road from ImSAR's offices. At BYU, Smith investigated ways to make SAR instrumentation ever smaller—which had been one of the research thrusts of David Long, who with fellow professor David Arnold founded a radar lab at BYU in the early 1990s.

In particular, Smith abandoned the usual system of having the radar set send out a short-duration pulse and then listen for the echoes. Instead, he worked on a technique that transmits radio waves continuously while modulating the frequency with a sawtooth pattern that ramps up linearly. Previous efforts in the BYU radar lab had used this linear-frequency, continuous-wave (LF-CW) approach for other projects—a radar altimeter, for example—but at the time there were only vague hints in the technical literature that it might be appropriate for SAR.

LF-CW proved advantageous in making a SAR system small and relatively inexpensive, for two reasons. First, the approach reduces the instantaneous power levels that the electronics must handle. Second, the device mixes the received signal not with a local oscillator—as receiver front ends normally do—but with a copy of the transmitted waveform. The result contains comparatively low frequencies—the difference between those present in the incoming and outgoing waves. The signal can therefore be digitized and numerically processed with relative ease.

Even before he graduated from BYU in 2002, Smith went to work for Wavetronix, a company Arnold had established in nearby Lindon, Utah, to build radar sensors for monitoring highway traffic. But after leaving school, the idea of putting together a tiny SAR package stuck with Smith, so he worked on it on the side. "I set up a lab in my basement," he recalls.

WINNERS & LOSERS 2009

Smith had reasonable confidence that he could do the job with LF-CW, having modeled the problem and prototyped hardware for his thesis, but there was still a long way to go. "You can build all the models you want, but the world of physics has a lot of 'gotchas' you won't know until you're there," says Smith. And with a mortgage to pay and a family to support, he prudently kept his day job.

It wasn't lost on Smith that a SAR unit of the size he was working on could fit in a UAV, even one of the smaller varieties. So he started researching UAV manufacturers, and in 2004 he gave a presentation to InSitu, a Bingen, Wash., company (acquired by Boeing in July) that produces small UAVs, including its 12-kg, 1.2-meter-long ScanEagle. Seeing the obvious synergies, InSitu offered him funding to pursue his vision.

EXPERT CALL "It's time for the company to buy mil-spec parts and desert-camo paint and begin manufacturing."
—*Nick Tredennick*

That was Smith's Rubicon: he decided that he was going to leave Wavetronix and form a company of his own to build the world's tiniest SAR unit. For that, he enlisted the help of Logan Harris, another graduate of BYU's department of electrical and computer engineering, who was the chief technical officer of Wavetronix at the time. Together they worked with the occasional consultant while maintaining what eventually became part-time positions with Wavetronix. Only in 2007 did they commit fully to ImSAR. Since then the firm has grown to include about 20 full-time employees, including Adam Robertson, who, like Smith, studied SAR imaging in BYU's radar lab for his master's degree.

After completing that training in electrical engineering, Robertson obtained a degree in business administration and now serves as the company's NanoSAR program manager. Smith says it's critical to have people like Robertson in what are nominally the company's business roles. There's nothing worse, says Smith, than having someone with inadequate engineering knowledge attempting to sell a high-tech product, because potential customers will judge the technology by the person fielding their questions: "If you don't have the right answers, you're dead."

1904
THE YEAR A DEVICE FOR DETECTING OBJECTS WITH RADIO WAVES WAS FIRST DEMONSTRATED

ImSAR's business focus has so far been on working with InSitu to demonstrate the radar to military customers. ImSAR expects that the first battlefield deployments will come in the early months of 2009—though Smith, Harris, and Robertson are, naturally enough, tight-lipped on the details. They have to be especially mindful about what technical information they release, because SAR is on the list of "munitions" controlled by the U.S. government's International Traffic in Arms Regulations (ITAR).

Even so, some of the more obvious military applications of a UAV-borne SAR aren't hard to imagine. If the shuttle can use imaging radar to map subsurface features, then maybe a UAV can use it to detect buried explosive devices from the air [see "Countering IEDs," *IEEE Spectrum*, September 2008].

ImSAR's 10-GHz system penetrates soil less deeply than a longer-wavelength radar would, but it sometimes shows features that aren't at all apparent from just looking down at the ground. "We found some old settlements that had been abandoned who knows how many years ago, buildings and things," says Robertson, referring to the results of an earlier radar survey of some sagebrush-covered land nearby.

Even though these ImSAR engineers are closemouthed about their product's military uses, they gush about what's possible in other spheres, for while the technology falls under ITAR and thus demands a special license for export, it's available without restriction to U.S. customers. So ImSAR's unit should see some civilian deployments in 2009 as well.

UAV-borne SAR systems could, for example, help ice-breaking ships find openings in pack ice, even when visibility is too poor for conventional aerial imaging. And because the radar reflectivity of the ground depends on moisture content, this form of remote sensing could help farmers target their irrigation efforts more efficiently. It could also detect oil slicks, which change the surface characteristics of water in a way that shows up clearly in radar images.

Perhaps more important though will be the application of SAR imagery to search-and-rescue operations carried out in darkness or under other low-visibility conditions. The nearby snow-covered peaks overlook Utah's famous winter resorts, bringing to mind searches for skiers or snowmobilers lost at night. Would NanoSAR serve for that? "A human being in the snow might as well have a lightbulb on him when it comes to radar," says BYU's Long.

ImSAR's offices are close to a lot of recreational boating, too. And Smith's demonstration flight shows off what his NanoSAR system might do one day in a search for someone lost on the water.

The plane turns away from the towering Wasatch Range, flying now over the 400-square-kilometer Utah Lake, one of the largest freshwater bodies in the western United States. Off to the left, a water-skier preparing for some fun floats behind a small pleasure boat. Smith points to his laptop screen shortly after the plane passes over the scene. The boat stands out as a bright white spot in the radar image, which, because the surrounding water reflects the radio waves away, appears largely black. Even the mostly submerged water-skier is easy to pick out.

"We have a very clean radar," Smith boasts, later referring to what he has stored on his laptop that day as "some of the best SAR imagery ever collected." That may be an exaggeration, spoken by the understandably proud father of a newborn device. Nevertheless, the tiny package mounted behind that funny lump in the Cessna's baggage door indeed seems to be doing a bang-up job. ❑

SUGAR IN, FUEL OUT: Filling up with ethanol made at home may be convenient but costly.
PHOTO: E-FUEL CORP.

Brew, Baby, Brew

A BACKYARD STILL THAT TURNS SUGAR INTO ETHANOL FUEL MAY LOOK SWEET, BUT UNDER SCRUTINY IT TURNS SOUR

BY ERICO GUIZZO

Imagine filling up your car's tank with cheap ethanol from your very own backyard refinery. All you'd have to do is feed the machine with...sugar. Sweet!

That's the idea behind E-Fuel Corp., a start-up in Los Gatos, Calif., which recently began shipping its MicroFueler ethanol production system in the United States. The refrigerator-size machine's solid-state distillation system can produce up to 35 gallons (132.5 liters) of pure ethanol per week, enough to fill two average car tanks. The purchase price is steep—US $10 000, or a third less with a federal tax rebate—but the company contends that the operating costs are low enough to brew ethanol for as little as $1 per gallon (26 cents per liter). Assuming that gasoline averages $3 per gallon and electricity and spare parts cost about $500 per year, a MicroFueler running flat out would pay for itself in three or four years.

E-Fuel says that the arithmetic will get better, because sugar is vastly abundant and oil prices are likely to go up. Further, the company claims the machine will allow users to "greatly diminish their carbon footprint" because replacing gasoline with the homemade ethanol can cut carbon dioxide emissions by up to 85 percent. Finally, a home production approach would solve ethanol's main problem: distribution.

Its creators call the MicroFueler "revolutionary," "a game changer," and "the ultimate 'green machine.' " But is it?

"I'm not sure that the excitement is justified," says Donal F. Day, a professor at Louisiana State University's Audubon Sugar Institute, in St. Gabriel. He explains that it takes about 14 pounds (6.4 kilograms) of sugar to make 1 gallon (3.8 L) of ethanol and that raw sugar generally costs at least 20 cents per pound. "That comes to $2.80 for a gallon," he says, "and it's not counting a person's time and effort." A lot of effort: if you drove 30 miles (48 kilometers) a day and got 13 miles per gallon (18 liters per 100 kilometers), you'd have to lug your weight in sugar every week.

"Making ethanol at home does not make a lot of sense for one's own economics or the environment," says Robert W. Howarth, a professor of ecology and environmental biology at Cornell University, in Ithaca, N.Y. Even mass-produced corn ethanol, he says, is only marginally profitable in the United States, despite huge government subsidies. So it's hard to see how small-scale production using sugar could do any better.

WINNERS & LOSERS 2009

Howarth denies E-Fuel's environmental claims, saying that "ethanol is a poor fuel in many ways and very inefficient to make." On top of that, the E-Fuel scheme involves burning fossil fuel just to get feedstock to people's homes.

Daniel Sperling, director of the Institute of Transportation Studies at the University of California, Davis, says Brazil is probably the only place where sugar ethanol production makes sense environmentally and economically. That's because Brazilian producers cultivate high-yield sugarcane crops, use the cane waste as fuel to generate electricity, and have a vast distribution network. Ethanol home production in the United States "will always be a niche," he says, adding that even if it were possible to brew cheaper fuel at home, "not many people are really willing to go to all this effort."

SNAPSHOT:

The 200-Proof Solution

Goal To produce sugar-based ethanol at home for US $1 a gallon.

Why it's a loser The economics don't add up when all costs are factored in; transporting sugar to people's homes will burn lots of fossil fuel.

Who E-Fuel Corp.

Where Los Gatos, Calif.

Staff Info not available

Budget Info not available

When Started shipping in late 2008

Indeed, those interested in home ethanol production face some practical problems. Making the weekly maximum of 35 gallons of ethanol requires nearly a quarter of a metric ton of sugar every week. It also requires a fuel producer's permit from the Alcohol and Tobacco Tax and Trade Bureau, and maybe from state and local authorities as well. (Not that moonshiners would want the MicroFueler. For their purposes, a gas-fired distillery is good enough—and much cheaper.) Federal law also mandates that you keep the machine outside your house for safety's sake, so you'll have to think about the insurance implications and the opinions of your neighbors. Finally, you'll need to have your car tuned for a diet of pure ethanol, which means replacing some parts.

E-Fuel, naturally, stands by its claims. Its chief executive, Thomas J. Quinn, a Silicon Valley executive who has bankrolled the company, says the $1-per-gallon proposition is realistic because it's possible to obtain sugar for much less than 20 cents per pound. He explains that current U.S. farm legislation permits surplus sugar to be sold to ethanol manufacturers for 2 cents per pound, and that there's plenty of cheap, 2.5-cents-per-pound Mexican sugar that could be imported tariff-free. He also emphasizes that the MicroFueler can use discarded beer, wine, fruit juices, and other alcoholic or fermentable liquids.

Quinn expects the MicroFueler to sell 200 000 units worldwide, and he's already planning to market it in Brazil, China, and the United Kingdom. In the United States, he's establishing a network of dealers to distribute feedstock and help users set up their operations. He's also getting companies and governments to sponsor a carbon coupon program that lets customers buy discounted feedstock. "MicroFueler customers are not burdened with locating their own sources of feedstock," Quinn says. "They just need to pump ethanol into their vehicles."

70 KILOGRAMS OF SUGAR
THE FEEDSTOCK FOR THE ETHANOL NEEDED TO DRIVE FOR ONE WEEK

To be sure, the MicroFueler is a neat machine. Floyd Butterfield, the other cofounder of E-Fuel, designed it as a kind of cross between a gasoline pump and a washing machine that easily connects to standard home power and water supplies. You load sugar or other types of feedstock into the machine's tank and press a button; the machine does the rest. It uses sensors and a microcontroller to dispense special yeast and maintain the temperature at ideal conditions for fermentation. Then, in the distillation phase, it uses a single solid-state filter rather than the multiple distillation columns found in conventional systems.

EXPERT CALL "The backyard still reminds me of the lemonade stand I ran as a kid—a big moneymaker as long as I stole the sugar from our kitchen."
–T.J. Rodgers

E-Fuel is rather secretive about how it forces the liquid through this membrane system. All it says is that the nanoscale pores let the water pass while holding back the larger alcohol molecules. The result is 99 percent ethanol, a much higher purity than conventional distillers obtain.

Day, of the Audubon Sugar Institute, remains skeptical. He argues that if the main feedstock is sugar, the economics remain shaky. The prospects of getting hold of cheap sugar in the coming years are far from certain. In fact, U.S. prices will likely go up, now that two major hurricanes have hit the country's sugar-producing regions and high fuel costs have pushed many producers out of business. Prices also depend on politics—the subsidies and import limits negotiated between the government and the U.S. sugar industry. As for the cheap Mexican supply, Day says, "Tell me where it is and I'll go buy some."

There are just too many economic variables: sugar prices, gasoline prices, government politics, Mexican supplies, and so on. Last summer, with gas reaching $4.11 a gallon in the United States, home distillation might almost have seemed worthwhile. But as of late November, prices were down to less than $2. The current global economic slowdown may help keep prices at those levels, while sugar prices may increase, making ethanol home brewing a sweet deal turned sour.

"Brewing beer at home is also more expensive than just buying it," Day says. "But unlike fuel, at least you get to drink it." ❑

IEEE Executive Director

IEEE is the world's leading professional association for the advancement of technology with more than 375,000 members in 160 countries worldwide. IEEE's core purpose is to foster technological innovation and excellence for the benefit of humanity. If your personal vision is to make a solid contribution to a leading-edge organization you will find it with IEEE!

IEEE is seeking an Executive Director in Piscataway, N.J. who will serve as the Chief Operating Officer of IEEE, a 501 (c)(3) organization. He or She will have day-to-day operational responsibility for the direction of a 1000+ person staff working in seven locations, worldwide, and financial control of a $350 million budget. This individual will lead the staff in its work with the board of directors and a cadre of 40,000 volunteers in achieving the ambitious long and short-term strategic goals of the IEEE.

This individual will bring strategy and policy proposals to the Board; ensure that appropriate liaison is maintained with outside individuals and groups; and assure the success of other activities required to support the Institute's effective operation and its strategic and financial success.

First and foremost the qualified individual will be a visionary business leader who has directed $100m+ budgets, P&L, a large staff, and multiple aspects of corporate management at a senior level. This individual must be a mature decision maker who has built and sustained productive relationships with boards of directors and affinity business partners. The ideal candidate will be a master communicator who creates valuable touch points at all levels of staff, members, and volunteers. Prior experience with professional associations or similar not-for-profit organizations is a plus. Stature in either the engineering and technology professions and relevant academic degrees are desirable.

Interested parties may send a cover letter and resume to the search firm, Heiderick and Struggles, at IEEE@heidrick.com

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IEEE

Texas A&M University at Qatar

(TAMUQ) is a branch campus of Texas A&M University (TAMU) at College Station, Texas. TAMUQ began teaching undergraduate students in chemical, electrical, mechanical, and petroleum engineering in the Fall of 2003 and started conferring degrees in December 2007. The coursework undertaken by the students is materially identical to the programs offered at the TAMU main campus. The TAMUQ campus is situated within a brand new building and is part of Education City, Doha, Qatar, a consortium of educational and research institutions hosted by the Qatar Foundation (QF) for Education, Science and Community Development.

The electrical and computer engineering (ECE) department at TAMUQ currently offers BS degrees in Electrical Engineering but a graduate program in electrical engineering is currently awaiting approval. All formal instruction is given in English. More information about the ECE program at TAMUQ can be found at

http://ecen.qatar.tamu.edu/.

The ECE department at TAMUQ invites applications for faculty positions at all ranks with research specializations in the following and related areas:

Power Systems: Electric power generation, transport and distribution, electrical energy conversion, deregulation, forecasting, electrical installations, photovoltaic applications for buildings, electrical renewable energy technologies.

Electronics & Electromagnetics: Analog and mixed signal circuits and systems, design, implementation and application of CMOS wireless transceivers; CMOS sensors and circuitry, solid state devices (electronic/opto-electronic). Propagation, Antennas and RF Systems.

Applicants with interdisciplinary research and teaching interests are particularly encouraged. Applicants must have a Ph.D. or equivalent degree, or completion of all requirements by date of hire. For senior positions, applicants should have a proven record of scholarly contributions and a proven ability to attract research funding. For junior positions, candidates should have demonstrated potential for quality teaching and research.

Starting rank and salary will depend on qualifications and experience. The appointment also includes the following benefits: Fully furnished housing; coverage of local tuition fees for school-age dependent children; annual home leave allowance for family members; air tickets to Doha on appointment; and local transportation allowance. Fringe benefits include health and medical insurance as well as an enrollment in a retirement plan. Initial appointment will normally be on a two-year contract, but a local tenure process is currently under consideration for TAMUQ. Re-appointment will be subject to mutual agreement.

Applications, including full curriculum vitae with list of publications, statement of teaching, statement of research as well as the names, addresses (regular mail and E-mail), fax, and phone numbers of three references to should be sent to:

Dr. Costas N. Georghiades, Department Head
c/o Ms. Debbie Hanson
Department of Electrical and Computer Engineering
Texas A&M University
College Station, TX, 77843-3128.

Texas A&M University at Qatar is an equal opportunity/affirmative action employer and actively seeks the candidacy of women and minorities. The deadline for applications is January 15, 2009 but applicants will be considered until the positions are filled.

THE CHINESE UNIVERSITY OF HONG KONG

Applications are invited for:-

Department of Information Engineering

Professor(s) / Associate Professor(s) / Assistant Professor(s)

(Ref. 08/216(370)/2) (Closing date: February 16, 2009)

Applicants should have (i) a PhD degree; and (ii) a strong research record in security-related disciplines (e.g. systems security and cryptography). Apart from teaching, the appointees will actively undertake related research projects. Appointments will normally be made on contract basis for up to three years initially commencing August 2009, leading to longer-term appointment or substantiation later subject to mutual agreement. Further information about the Department is available at *http://www.ie.cuhk.edu.hk*.

Salary and Fringe Benefits
Salary will be highly competitive, commensurate with qualifications and experience. The University offers a comprehensive fringe benefit package, including medical care, plus a contract-end gratuity for appointments of two years or longer, and housing benefits for eligible appointees.

Further information about the University and the general terms of service for teaching appointees is available at *http://www.cuhk.edu.hk/personnel*. The terms mentioned herein are for reference only and are subject to revision by the University.

Application Procedure
Please send full resume, copies of academic credentials, a publication list and/or abstracts of selected published papers, together with names, addresses and fax numbers/e-mail addresses of three referees to whom applicants' consent has been given for their providing references (unless otherwise specified), to *recruit@ie.cuhk.edu.hk* by the closing date.

The Personal Information Collection Statement will be provided upon request. Please quote the reference number and mark 'Application - Confidential' on cover.

Research Positions
Dept. of Comp. Sci. and Elec. Eng., Luleå University of Technology, Sweden.

LTU invites applications for two **postdoctoral research positions;** one in **control engineering**, and one in **digital communications/signal processing**. Applicants for the postdoctoral research positions, must have a Ph.D. in CS, EE, or related discipline, strong academic credentials, and an ability to perform research at the international level.

The **Control Engineering Group's** research includes methods and technology for the analysis, specification and implementation of control for complex dynamical systems. This includes modeling, simulation, estimation and fault detection. The **Signal Processing Group's** research in **digital communications** includes: channel coding, parameter estimation, coding and processing for audio/video data, adaptive algorithms, and blind signal processing.

CSEE has a history of research and education in the areas of computer networks, computer science and engineering, signal processing, control and electronics. See http://www.ltu.se/csee.

LTU has 14,000 students, mainly in the technical fields, with courses offered in Swedish and English by a diverse international faculty, see http://www.ltu.se. The university is located in the mid-sized coastal city of Luleå, a northern Sweden regional center for science, engineering and technology, more about the city of Luleå at http://www.lulea.se.

Questions to: Prof. Thomas Gustafsson, Head of Control Engineering, mobile: +46 70-5362034, email: tgu@ltu.se, or to James P. LeBlanc, Head of Signal Processing, tele: +46 920 492541, email: james.leblanc@ltu.se.

Applications, containing cover letter, detailed CV, a research statement, three professional references, and a selection of 3 publications must be marked with the appropriate reference number (ref num. **3024-07** for control, or ref num. **03241-08** for signal processing) and should be sent via email to: **registrator@ltu.se**.

Evaluation places emphasis on the applicant's scientific record, and ability to initiate research projects. To receive full consideration, applicants should submit materials by **March. 30, 2009**.

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

DEPARTMENT OF COMPUTING

The Department invites applications for Professors/Associate Professors/Assistant Professors in Database and Information Systems/Biometrics, Computer Graphics and Multimedia/Software Engineering and Systems/Networking, Parallel and Distributed Systems. Applicants should have a PhD degree in Computing or closely related fields, a strong commitment to excellence in teaching and research as well as a good research publication record. Applicants with extensive experience and a high level of achievement may be considered for the post of Professor/Associate Professor.

Please visit the website at ***http://www.comp.polyu.ed.hk*** for more information about the Department. Salary offered will be commensurate with qualifications and experience. Initial appointments will be made on a fixed-term gratuity-bearing contract. Re-engagement thereafter is subject to mutual agreement. Remuneration package will be highly competitive. Applicants should state their current and expected salary in the application. Please submit your application via email to ***hrstaff@polyu.edu.hk***. Application forms can be downloaded from ***http://www.polyu.edu.hk/hro/job.htm***. **Recruitment will continue until the positions are filled.**

Details of the University's Personal Information Collection Statement for recruitment can be found at ***http://www.polyu.edu.hk/hro/jobpics.htm***.

ABB

ABB Inc., global provider of power and automation products and systems, is looking for two Principal Engineers, one in Hardware and the other in Application, for its Distribution Automation R&D Technology Center in Allentown, Pennsylvania, USA.

More information about the positions are available at ***www.abb.com*** – please click careers to search for the two positions under North Americas. Upload your resume and cover letter for due consideration by January 31, 2009.

More information about
Distribution Automation is available at
www.abb.com/substationautomation

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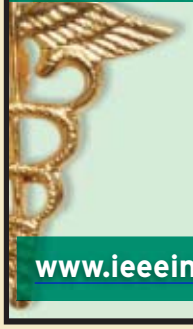

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UNIVERSITÄT DES SAARLANDES

Saarland University is seeking to establish several **Junior Research Groups** (W1/W2) within the recently established **Cluster of Excellence** *"Multimodal Computing and Interaction"* which was established by the German Research Foundation (DFG) within the framework of the German Excellence Initiative.

M2CI CLUSTER OF EXCELLENCE

The term "multimodal" describes the different types of digital information such as text, speech, images, video, graphics, and high-dimensional data, and the way it is perceived and communicated, particularly through vision, hearing, and human expression. The challenge is now to organize, understand, and search this multimodal information in a robust, efficient and intelligent way, and to create dependable systems that allow natural and intuitive multimodal interaction. We are looking for highly motivated young researchers with a background in the research areas of the cluster, including algorithmic foundations, secure and autonomous networked systems, open science web, information processing in the life sciences, visual computing, large-scale virtual environments, synthetic virtual characters, text and speech processing and multimodal dialog systems. Additional information on the Cluster of Excellence is available on **http://www.mmci.uni-saarland.de**. Group leaders will receive junior faculty status at Saarland University, including the right to supervise Bachelor, Master and PhD students. Positions are limited to five years.

Applicants for W1 positions (phase I of the program) must have completed an outstanding PhD. Upon successful evaluation after two years, W1 group leaders are eligible for promotion to W2. Direct applicants for W2 positions (phase II of the program) must have completed a postdoc stay and must have demonstrated outstanding research potential and the ability to successfully lead their own research group. Junior research groups are equipped with a budget of 80k to 100k Euros per year to cover research personnel and other costs.

Saarland University has leading departments in computer science and computational linguistics, with more than 200 PhD students working on topics related to the cluster (see **http://www.informatik-saarland.de** for additional information). The German Excellence Initiative recently awarded multi-million grants to the Cluster of Excellence "Multimodal Computing and Interaction" as well as to the "Saarbrücken Graduate School of Computer Science". An important factor to this success were the close ties to the Max Planck Institute for Computer Science, the German Research Center for Artificial Intelligence (DFKI), and the Max Planck Institute for Software Systems, which are co-located on the same campus.

Candidates should submit their application (curriculum vitae, photograph, list of publications, short research plan, copies of degree certificates, copies of the five most important publications, list of five references) to the coordinator of the cluster, Prof. Hans-Peter Seidel, MPI for Computer Science, Campus E1 4, 66123 Saarbrücken, Germany. Please, also send your application as a single PDF file to **applications@mmci.uni-saarland.de**.

The review of applications will begin on January 15, 2009, and applicants are strongly encouraged to submit applications by that date; however, applications will continue to be accepted until January 31, 2009. Final decisions will be made following a candidate symposium that will be held during March 9 – 13, 2009.

Saarland University is an equal opportunity employer. In accordance with its policy of increasing the proportion of women in this type of employment, the University actively encourages applications from women. For candidates with equal qualification, preference will be given to people with physical disabilities.

KHALIFA UNIVERSITY

KUSTAR is a world class research and teaching institution offering a wide range of employment opportunities. It is committed to attracting, developing and retaining a diverse workforce that strengthens the University's leadership in research and education. Staff diversity offers a blend of talents, experiences and differences that drive academic and professional success and excellence.

1. Assistant Professors

- Physics (KU-048/2008)
- Mathematics for Engineers (KU-049/2008)
- Computer Science (KU-050/2008)
- College English (KU-051/2008)
- Arabic and Islamic Studies (KU-052/2008)

Main Duties: (Teaching in engineering programs, developing curriculum, and establishing research programs in the area of specialization)

Required Qualifications:
Ph.D. in related fields from reputable University.
At least two years of post-doctoral lecturing experience.
Research potential.

2. Associate Professors / Professors

- Software Engineering (KU-044/2008)
- Computer Engineering (KU-045/2008)
- Electronic Engineering (KU-046/2008)
- Communication Engineering (KU-047/2008)

Main Duties: (Teaching undergraduate and graduate courses, leading in curriculum development, performing administrative work, and taking charge in establishing research programs in the area of specialization)

Required Qualifications:
Ph.D. in related fields from reputable University.
At least 8 years of post-doctoral lecturing experience.
Research experience demonstrated by quality publications.

3. Dean of Library *[Ref. KU-058/2008]*

Main Duties: Responsible for the leadership, creation, implementation and maintenance of all Library services for students, staff, and faculty. Working closely with other Deans, the incumbent will be responsible for the functioning of all areas. The incumbent will also instrumental in developing and implementing relevant library policies and procedures.

Required Qualifications:
MLS, MSIS or equivalent.
Minimum 7 years of professional academic library experience in similar capacity.

4. Director/HR *[Ref. KU-056/2008]*

Main Duties: Responsible for the implementation and functioning of all HR related functions. The principle role will be to implement strategies, tactics and policies that will contribute to the University's set goals.

Required Qualifications:
Graduate with a minimum of 7 years experience in an educational environment or equivalent.

5. Lab Engineer *[KU-053/2008]*

Main Duties: Developing laboratory experiments and setting equipment requirements in Physics/Electronics, assisting in teaching labs, and supervising labs usage.

Required Qualifications:
M.Sc. in Physics/Electronic Engineering or related fields.
Experience in lab supervision
Experience in relevant industry

6. Assistant/Associate Professors

- Computer Engineering (KU-057/2008)

Main Duties: Teaching in Computer Engineering, developing curriculum and establishing research programs in the area of specialization. Preferred areas of experience: Distributed Systems, Software Engineering and Computer Networks

Required Qualifications:
Ph.D. in Computer Science/Engineering from a reputable University
Post-doctoral lecturing experience
Research experience demonstrated by quality publications.

Notes:
Position Nos. 1 to 5: The openings from August 2009 for Abu Dhabi Campus.
Position No.6: The openings from February 2009 for Sharjah Campus

Salary & Other Benefits:
Highly competitive salary & benefits offered to the right candidates depending on qualification and experience.

Please send your CV, highlighting the reference number, to:

careers@khalifauniversity.ac.ae

For further information: **www.kustar.ac.ae**

Only the short-listed candidates will be contacted

جامعة كارنيجي ميلون في قطر
Carnegie Mellon Qatar
Member of Qatar Foundation

Computer Science Faculty Positions

Carnegie Mellon University in Qatar invites applications for teaching-track positions at all levels in the field of Computer Science. These career-oriented renewable appointments involve teaching international undergraduate students, and maintaining a significant research program. Candidates must have a Ph.D. in Computer Science or related field, substantial exposure to Western-style education, outstanding teaching record and excellent research accomplishments or potential.

Specifically, we are seeking candidates with expertise in cloud computing, Arabic language processing, human-computer interaction, databases, web technology and algorithms. Truly exceptional candidates in other areas also will be considered.

The position offers research support, highly competitive salaries, travel, housing and school allowances, as well as other benefits. Carnegie Mellon Qatar is located in Doha, a rapidly growing city with access to the Gulf Region and the world.

Carnegie Mellon is internationally recognized as a leader in research and higher education. In 2004, the university established itself in Education City, a state-of-the-art campus that is home to six top universities. Collaboration opportunities with internationally-known researchers and world-class businesses are abundant.

For further information or to apply, visit
http://www.qatar.cmu.edu/cs/positions/

The Petroleum Institute
Abu Dhabi, United Arab Emirates

Institution: The Petroleum Institute (PI) was created in 2001 with the goal of establishing itself as a world-class institution in engineering education and research in areas of significance to the oil and gas and the broader energy industries. The PI grants both BS and MEng degrees in electrical engineering with plans to start the PhD program by 2011. The PI's sponsors and affiliates include Abu Dhabi National Oil Company and four major international oil companies. The campus has modern instructional laboratories and classroom facilities and is now in the planning phase of three major research centers on its campus. The PI is affiliated with the Colorado School of Mines, the University of Maryland (College Park), and Leoben and Linz Universities. The PI is in the process of developing future working relationships with other major universities and research institutions around the world to capitalize on joint research areas of interest. For additional information, please refer to the PI website: **www.pi.ac.ae.**

FACULTY POSITIONS - ELECTRICAL ENGINEERING

The Electrical Engineering Department at the PI is seeking applications for the following positions:

Chaired and Distinguished Professor, Professor, Associate Professor, Assistant Professor

Applicants with research interests and experience in one or more of the following areas: instrumentation and measurements, smart sensors technology, condition monitoring, power quality, power systems, and with interest in applications in the Oil/Gas industry are especially encouraged to apply.

Program faculty will be expected to teach undergraduate and graduate courses, develop an active research program, and to engage in professional and institutional service activities. Opportunities to interact with PI industrial stakeholders and other local industries will be a key feature in the development of a research program.

Review of applications will continue until positions are filled.

Details are available on PI-web site: **http://www.pi.ac.ae/jobs**

PURDUE UNIVERSITY

Computer Engineering
in the School of Electrical and
Computer Engineering

FACULTY POSITIONS

The School of Electrical and Computer Engineering at Purdue University invites applications for faculty positions across the breadth of computer science/engineering at all levels. The Computer Engineering Area of the School (***http://engineering.purdue.edu/ECE/Research/Areas/CompEng***) has nineteen faculty members with active research programs in areas including AI, architecture, compilers, computer vision, distributed systems, embedded systems, graphics, haptics, HCI, machine learning, multimedia systems, networking, networking applications, NLP, OS, robotics, software engineering and visualization. We will consider outstanding candidates in any area of computer science/engineering, although for at least one position there is a preference for human-centered computing, visualization and HCI. All positions require a PhD in computer science/engineering or a related field and a significant research record commensurate with the position. Applications should consist of a cover letter, CV, research statement, names and contact information for at least five references, and URLs for three to five papers.

Applications should be submitted online at
https://engineering.purdue.edu/Engr/AboutUs/Employment/Applications

Inquiries can be sent to ***compengr@ecn.purdue.edu***. Review of applications will begin December 1, 2008. Applications will be considered as they are received, but for full consideration should arrive by 1 February 2009.

Purdue University is an equal opportunity, equal access, affirmative action employer, fully committed to achieving a diverse workforce.

Position Open

Toyota Technological Institute

Toyota Technological Institute has openings for either tenured or tenure-tracked faculty positions at the full professor level in the Department of Advanced Science and Technology.

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

RESEARCH FIELD

1. Fundamental computer science including theoretical computer science, algorithm, etc. or computer system including computer architecture, programming language, network computing, etc. **Inquiry:** Professor Seiichi Mita (Phone) +81-52-809-1820, (E-mail) smita2@toyota-ti.ac.jp
Deadline: March 14, 2009

2. Low dimensional science physics, chemistry, measurement and/or application of low dimensional and/or nano-structures. **Inquiry:** Professor Itaru Kamiya (Phone) +81-52-809-1769, (E-mail) trans@toyota-ti.ac.jp
Deadline: March 25, 2009

3. Spin materials for spintronics, spin memories, spin devices, and their applications. **Inquiry:** Professor Shuji Tanaka (Phone) +81-52-809- 1775, (E-mail) tanaka_mat@toyota-ti.ac.jp
Deadline: March 31, 2009

Starting Date: September 2009 or at the earliest convenience

DOCUMENTS

(1) A complete curriculum vitae with portrait; (2) A list of publications; (3) Copies of 5 major papers; (4) Brief description of research activities and future plan for research and education ***(3 pages)***; (5) Names of two references with phone/facsimile numbers and E-mail address.

The above should be sent to
Mr. Takashi Hirato
Toyota Technological Institute
2-12-1, Hisakata, Tempaku-ku
Nagoya 468-8511, Japan
Please be advised to write Application for ***(fill in the research field you would like to apply)*** *in red on an envelope.*

BAYLOR UNIVERSITY

Baylor is seeking candidates from all areas of electrical and computer engineering for two positions:

(1) a tenure-track position at the assistant/associate professor level, and
(2) a full time lecturer.

Candidates must have excellent verbal and written communication skills, a commitment to teaching excellence and professional activities, and is a follower of Christ. Tenure-track applicants must have an earned doctorate, and demonstrated research achievement with potential to acquire external funding. Further, the successful tenure track candidate will also be expected to contribute to the department's progress toward increased research activity and the development of a Ph.D. program. Lecturer applicants will have an earned doctorate; although, outstanding applicants with a master's degree will also be considered. The successful candidate for lecturer will have demonstrated laboratory experience and effective classroom skills. Both positions will contribute to the current state of teaching excellence.

Chartered by the Republic of Texas in 1845, Baylor University is the oldest university in Texas, has an enrollment of 14,000 students, and is a member of the Big XII Conference. The Baylor campus is located in Waco along Interstate 35, a major route for international commerce. The community offers an array of educational, cultural, recreational, and residential opportunities and is within easy driving distance of other major cities and universities in Texas.

Baylor offers ABET/EAC-accredited B.S. programs in Electrical and Computer Engineering, Mechanical Engineering, and Engineering. The University is in mid-course to achieve a 10-year vision called Baylor 2012 which will strengthen its academic and Christian character. As part of that effort, the ECE department has established new master's programs (Master of Science in Electrical and Computer Engineering, Master of Science in Biomedical Engineering, Master of Engineering, joint Master of Engineering/Master of Business Administration), with accompanying growth in its faculty, student body and facilities. Hallmarks of Baylor engineering include a commitment to engineering education in a supportive Christian environment, faculty collegiality, small class sizes, a near-100% pass rate on the FE examination, and a high U.S. News and World Report peer-group ranking.

Applications will be reviewed beginning immediately and will be accepted until the positions are filled. To ensure full consideration, however, applications should be received by Jan. 9, 2009. Applications must include: 1) a letter of interest that identifies the position sought; 2) complete current vita, 3) statement of teaching and, for the tenure-track candidate, research interests, 4) statement of Christian faith and service, and 5) the names and contact information for at least three professional references.

Additional information is available at

http://www.ecs.baylor.edu.

Send materials to Dr. Robert J. Marks II, Baylor University, One Bear Place #97356, Waco, TX 76798-7356, or by email to Robert_Marks@baylor.edu.

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

TEXAS A&M UNIVERSITY
The Department of Electrical and Computer Engineering

has openings for two tenure-track faculty at the assistant professor rank in the areas of power systems and power electronics. General areas of interest in the power systems area include systems aspects, such as stability, state estimation, steady state and dynamic modeling, deregulation and distributed generation. For the power electronics position, areas of interest include electronic power conversion and control, power supplies, inverters, power conditioning systems for Solar/Wind/Fuel-cells, electric power quality and harmonic mitigation. Candidates with expertise in the sustainable energy area will be given preference for both positions.

Applicants must have a Ph.D. or equivalent degree, or completion of all requirements by date of hire as well as demonstrated potential for quality teaching and research.

The Department of Electrical & Computer Engineering currently has 68 faculty members and its graduate program has been ranked in the top 20 in recent years. Further information about the department may be obtained by visiting

http://ece.tamu.edu.

Applicants should send a complete resume, including names and addresses of three references, to:
Dr. Costas N. Georghiades, Department Head
Texas A&M University
Department of Electrical and Computer Engineering
TAMU 3128 College Station, TX, 77843-3128.

The deadline for applications is February 1, 2009 but positions will remain open until filled.

Texas A&M University is an equal opportunity/affirmative action employer and actively seeks the candidacy of women and minorities.

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Your Next Computer Will Probably Be a Notebook

PORTABLE COMPUTERS used to be rare and expensive, but these days they make up almost half of all PC sales. In Western Europe, they represent well over half.

Businesses still buy a lot of desktop computers, but consumers now prefer notebooks, largely because prices have dropped precipitously, says Eszter Morvay, a senior research analyst for the global market intelligence firm International Data Corp., in Framingham, Mass. The drop began in 2003, when HP Compaq, the largest vendor, cut its notebook prices. Then Taiwanese manufacturer Acer targeted the European market, forcing HP, Dell, and other competitors to cut prices by about 15 percent per year.

"What was once a US $1600 purchase is now $600," says Morvay. "The price gap between desktops and notebooks has shrunk to close to zero." She predicts that by 2012, 80 percent of all new PCs sold will be notebook-size—or even smaller.

—STEVEN CHERRY

TIM HAWLEY/GETTY IMAGES

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