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SPECIAL REPORT

winners & losers

2010

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PIXEL QI'S new display is like three screens in one. **46**

ILLUSTRATION: BRYAN CHRISTIE DESIGN

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WHAT HAPPENS IN VEGAS WON'T STAY THERE

Can't make it the Consumer Electronics Show in Las Vegas this month? No problem: You can live vicariously through *IEEE Spectrum*'s Tekla Perry, Steven Cherry, and Josh Romero as they trawl one of the world's largest and most lavish tech shows, in search of the tastiest gadgets. There'll be e-readers galore, along with a mind-bending assortment of 3-D TVs, smartphones, touch-screen netbooks, and vagus nerve stimulators (just kidding about that last one). Will it be enough to fill the gaping hole in our collective soul? You can bet on it.

ONLINE FEATURE

WINNER OR LOSER? YOU TELL US

AVAILABLE STARTING 1 JANUARY

EVERY YEAR, our search for the best and worst yields a few maybes. And now we invite you to decide whether they're winners or losers. This latest crop includes a car that flies using a parasail, a battery-powered, self-balancing unicycle [right], and a totally hands-free gaming controller.

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SNOOPING EMPLOYERS: Not only have Facebook, LinkedIn, and Twitter become popular sites for people to stay in touch with friends and colleagues, these social networking sites are also becoming an employer's favorite tool for screening potential candidates. Learn how to use these sites to your advantage from the webinar "Snooping Employers: How Employers Get Background Information on You Prior to the Interview," sponsored by IEEE-USA.

NEW BIOMETRICS CERTIFICATION: Do you want to prove your credibility in the biometrics field to employers? IEEE has developed a new certification program for biometrics professionals that includes training and an exam.

AEROSPACE CONFERENCE: The IEEE Aerospace Conference, being held from 6 to 13 March in Big Sky, Mont., will cover space missions, systems and architecture, spacecraft and launch-vehicle systems, and remote sensing.

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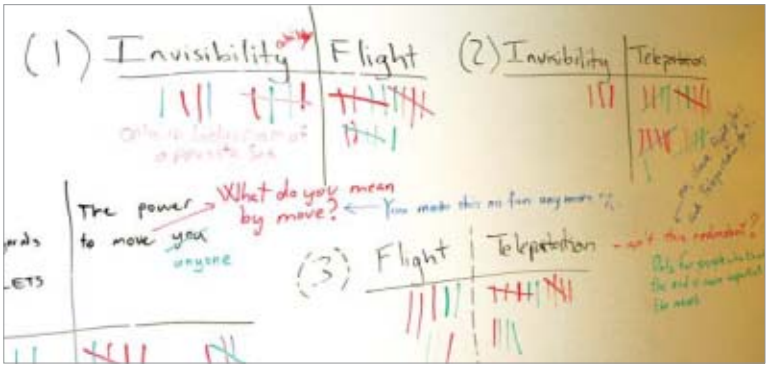
back story



What's Your Superpower?

On a typically cloudless day in Mountain View, Calif., Google engineers are brainstorming feverishly, making emphatic notations on a whiteboard. Arcane tech problem? New business plan? Latest twist in the plot to rule cyberspace? No, these engineers are arguing the relative merits of superhuman powers. The choices? Invisibility versus flight, invisibility versus teleportation, flight versus teleportation, and the power to kill from 200 meters versus the power to move people with your mind.

The engineering mind-set knows no boundaries. Therefore, a traditionally short conversation ("Would you rather have the power of invisibility or the power of flight?") rapidly spins off new and philosophical threads enumerating hidden caveats and analyzing cost-benefit scenarios. Under the black-markered "The power to move you," someone uses a blue marker to replace "you" with "anyone." "What do you mean by move?" asks a red marker. "You made this no fun anymore," complains a blue marker, underscoring that point with a frowning face.

The superpower issue is not merely theoretical. When users complete a Google profile, they are asked to choose their preferred superpower. According to the whiteboard, Google engineers overwhelmingly prefer flight (16) to invisibility (9). The preference is even stronger for teleportation (21) over invisibility (3). But when flight and teleportation square off, they are more evenly matched: Teleportation wins 14 to 8.

Last October, Associate Editor Sally Adee visited the Googleplex to report on Google's planned Chrome operating system [see "Chrome the Conqueror," in this issue]. Three days before leaving, she put herself on a list to get an invitation from Google to try the preview version of Wave, Google's new e-mail/chat/collaboration tool. Knowing the list was long, she used her journalistic clout to cadge a Wave invitation ahead of the queue.

So what's your superpower, Sally? "Being able to wheedle an early Wave invite out of Stephanie Hannon," she sheepishly admits. (Hannon is the project manager for Wave, in Sydney.) "It's not flight, it's not teleportation, and it may not even be ethical, but it's all I've got." ❑

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 Reflections column is in *IEEE Spectrum,* Vol. 47, no. 1 (INT), January 2010, p. 27, or in *IEEE Spectrum*, Vol. 47, no. 1 (NA), January 2010, p. 31.

SALLY ADEE

contributors

MARK ANDERSON covered two winning technologies in this issue. In "A More Cerebral Cortex" [p. 58], he describes a hot-rodded smartphone chip with the power of a PC processor, designed by Intrinsity. Even during breaks, the brains of Intrinsity's engineers were still running at full speed, Anderson noted. The engineers turned the lunchroom's wall of windows into a dry-erase board, covering it in equations and circuit diagrams. In "Optical Lasers in a $100 Cable. Really" [p. 24], Anderson reports that optical cable technology is overtaking copper, even in home electronics.

NICHOLAS EVELEIGH got creative with some glass jars to produce a photographic bar chart for The Data [p. 80]. To illustrate the demand for rare earth metals, "I combined potting soil and Singapore curry powder to create a realistic reddish earth material," he says. Eveleigh first worked for *IEEE Spectrum* over 10 years ago. He was using his dining room as a studio, and an assistant had to hold Eveleigh's cat, which kept jumping into the shot. That cat is now 17 years old. "I haven't seen him jump in a long time," Eveleigh says.

CHIN-YEE LAI designed this month's cover, her first for a magazine. "That's why I was excited to do it," she says. She's been designing book covers for 14 years and enjoys "anything new and different." Before going freelance, she worked for several publishers, including Random House, Vintage, W.W. Norton, and HarperCollins. She also did a brief stint as deputy art director for gardening with *Martha Stewart Living* magazine.

JOE LERTOLA produced thousands of information graphics for *Time* magazine during his 25-year tenure there. In March 2009 he joined Bryan Christie Design's team of artists. He and his colleagues created the three-dimensional illustrations of the winners in this issue. "The goal was to use lighting, color, transparency, and reflections to create a celebratory mood," he says.

JOSH McKIBLE, a.k.a mckibillo, created the whimsical illustrations for this month's losers. Originally from New York City, he now lives in Japan. A frequent contributor to *Spectrum*, McKible spent eight years as a magazine art director before returning to his first love, drawing. His work has since appeared internationally in numerous editorial, advertising, and graphic design projects.

RICHARD STEVENSON got a Ph.D. at the University of Cambridge, where he studied compound semiconductors. Then he went into industry and made the things. Now, as a freelance journalist based in Wales, he writes about them. His story on NanoGaN [p. 52]—a feisty start-up headquartered in Bath, England—is the third article he's written for *Spectrum*.

CLOCKWISE FROM TOP LEFT: PENNY LEVERITT; CHRISTINE CHAN; MCKIBILLO; KATHARINE STEVENSON; SIMON LEE; DARCY EVELEIGH

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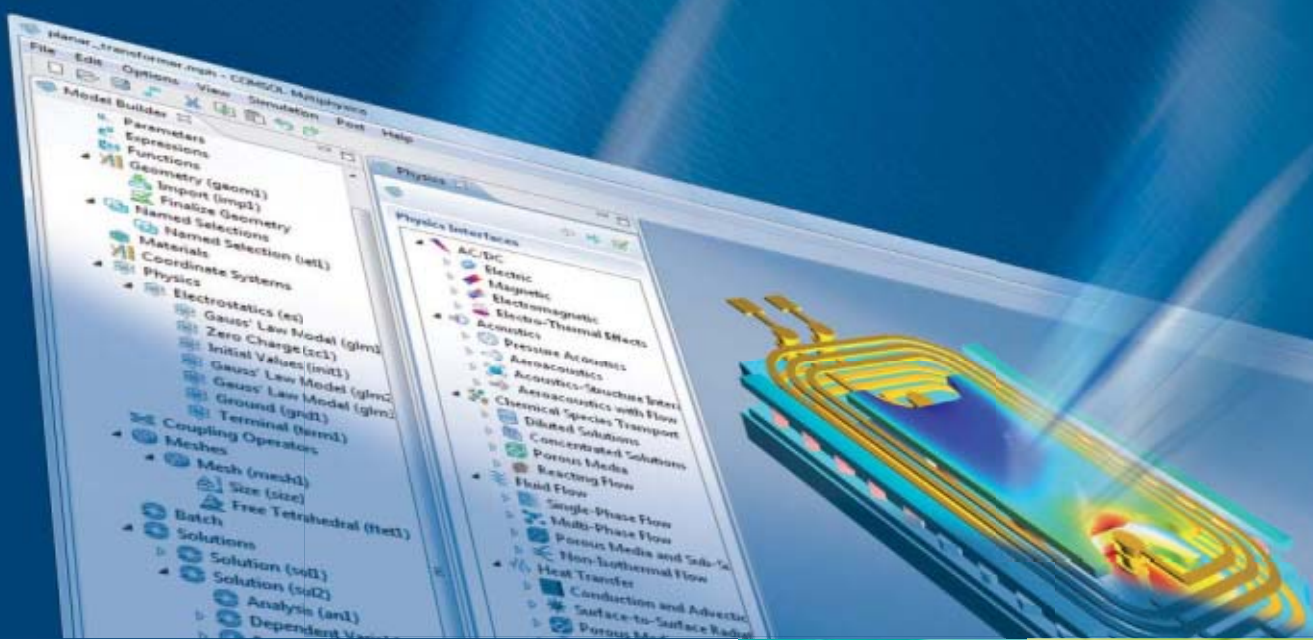

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Target Practice

TRY TO remember when search engines were new, hybrid cars were unavailable outside of Japan, and MP3 players were clunky bricks (1998, in other words). Today we've got Google, the Prius, and the iPod. And they seem to have been absolutely inevitable, don't they?

Historians have a term for that kind of thinking: determinism. And some even think they've found a remedy for it: counterfactual thought experiments. They try to imagine what would have happened had a single event gone differently—if, say, Lee had won at Gettysburg in 1864, or if Babbage had completed his stored-program computer at about the same time.

In this year's Winners & Losers issue—our seventh—we submit ourselves to a similar exercise. We strive to free our minds of bias. And then we peer into a messy, bubbly brew of technology ferment and try to see if it's going to yield fine wine or plain old vinegar.

To make the game consistent and fair, we also follow some hard-and-fast rules. We do not evaluate projects that have been fully unveiled; that'd be like shooting first and then drawing the bull's-eye neatly around the bullet hole. Nor do we predict the distant future or evaluate blue-sky projects designed mainly to stimulate thought; that'd be like shooting blanks. Nor do we spend time on government projects that eschew the market altogether; that would be shooting fish in a barrel. Finally, we never aim our guns at an entire category of technology, such as lithium-ion batteries or organic LED displays, because that would be to praise or blame many—or none at all.

Instead, we examine only particular projects meant to achieve quantifiable (and preferably commercial) goals, although we take into account social, environmental, and other interests. We require that a project be serious, have real financial backing, and be advanced enough to reach the market or at least hit some major milestone within a year of our publication date. This proviso ensures that we set ourselves up as targets—in this life, not just posthumously.

As you can see from the summary updates of winners and losers from earlier issues, we have very rarely been far wrong but sometimes just a bit off target. Undoubtedly, one fine day we will be spectacularly wrong. We'll probably condemn some hallucinogenic idea as a loser, only to watch it become the next Google or Prius or iPod. Future historians and e-ink–stained wretches will chortle over our sanctimonious censure. We will stand alongside such worthies as Lord Kelvin, who said no heavier-than-air craft would ever fly, and Digital Equipment Corp. cofounder Ken Olsen, who declared, in an auditorium full of people in Boston, that "there is no reason for any individual to have a computer in his home." It's a risk we're willing to take.

Finally, by consulting our experts and by employing the tools of journalism (tools not all that different from those of the historian), we choose five projects that we think will succeed and five that we think will fail. We work hardest on the losers. A project might qualify as such because it cannot reach its stated goal or because its stated goal cannot successfully juggle commercial, environmental, or other imperatives. Charles Babbage's computer was wondrously conceived and—within the limits of Victorian tooling—excellently executed, but it just didn't make economic sense at the time. Of course, not all the candidates for loserdom require us to sweat a great deal. There are a lot of crazy projects out there, waiting to be exposed.

We are indebted to our panel of expert advisers—Kenneth R. Foster, Robert W. Lucky, Nick Tredennick, and T.J. Rodgers—who have offered their opinions on some of these projects, as well as to our anonymous band of peer reviewers who examined the articles and corrected more than a few of our errors.

—PHILIP E. ROSS

ON THE COVER

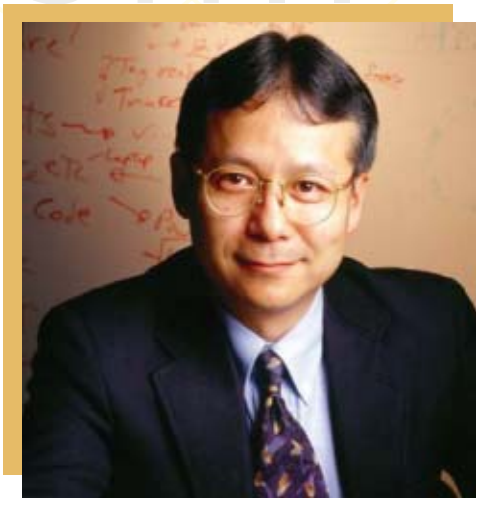
For this year's Winners & Losers cover, *IEEE Spectrum* asked three talented firms to submit designs. The entries [from left] are from Chicago-based Thirst, New York City–based WSDIA, and book designer Chin-Yee Lai, of New Jersey. All three design firms submitted provocative work. Thirst and WSDIA employed an open-source programming language, Processing, to create the wirelike textures. In the end, the *Spectrum* staff voted for Lai's design (rendered by Bryan Christie Design) for its simplicity and elegance. It is her first magazine cover.

JAPAN NATIONAL TOURISM ORGANIZATION PRESENTS:

The Nature of Science

HIROSHI ISHII

One of MIT's leading Japanese-American Scientists discusses his projects, his upbringing, and all the advantages of planning meetings in Japan



IEEE Spectrum recently had a chance to interview professor Hiroshi Ishii, associate director of media arts and sciences at MIT's Media Lab, one of the United States' leading havens of innovation in the field of communications technology. As a native of Japan, Ishii discussed how his childhood influenced his career path in the field of communication technology, as well as the advantages of Japan as a setting for international meetings.

The Tokyo-born engineer employs a uniquely dynamic approach to the traditionally empirical world of science, favoring artistic interpretations as an alternative to tested pragmatic methods. As the first Japanese faculty member to join the Media Lab team at MIT, Ishii's work continues to be widely recognized not only in the science and engineering worlds, but also in the art and design worlds, earning him praise an accolades from esteemed members of the community.

A Curious Nature

Examining Ishii's work brings forth an observable natural influence as he describes the surroundings upbringing. In an interview with Recruit's Rikunabi-Next, Ishii explains how ambient media first made a lasting impression throughout his youth.

"We had an abacus that served as a communication tool between my mother and me. The clicking sounds the abacus made when my mother was using it taught me that it was not the right time to ask her to play with me. This experience lead me to coming up with the concept of "ambient media" in Media Lab."

Ishii adds, "There was a huge impact on me after I touched an abacus for the first time since I was a child, which made me realize that tangible interfaces, such as an abacus, are direct and straight; opposite of graphical user interfaces such as those that are available on personal computers and cell phones."

Ishii would spend his adolescent years traveling all around Japan as he cultivated an appreciation for the arts, architecture, and nature of his home country. He would soon conclude that the aesthetics of Japanese art, architecture, and nature would inevitably influence his work in a profound way.

A Cultural Influence

There is still an undeniable Japanese influence on Ishii's work. When asked about Japan's current role as pioneers of new technological endeavors, he notes that since the land has limited natural resources, its inhabitants have always had to work hard to create new industries based on strong tradition of arts and engineering. For example, Japan has been at the forefront of the semiconductor, electronics, car, and robotics industries, all of which combine strong senses of engineering and aesthetic design. The professor's forward-thinking nature combined with his Japanese roots has introduced unorthodox methods of scientific approaches throughout his intellectual circles, an attitude seldom witnessed throughout the tried-and-true practices of the scientific world. His research undoubtedly reflects the elements of his Japanese childhood; traditionally, the Japanese culture as a whole has an intrinsic grasp of the artistic characteristics of the world. It is this kind of balance between man and nature that directly correlates with his work as he attempts to develop a perfect harmony of the physical world and technology. "The balance between the advanced technologies and the beauty of tradition makes Japan very unique." Ishii observes. "Japan takes pride in its unique cultural heritage, yet maintains a cosmopolitan approach to innovation and engineering."

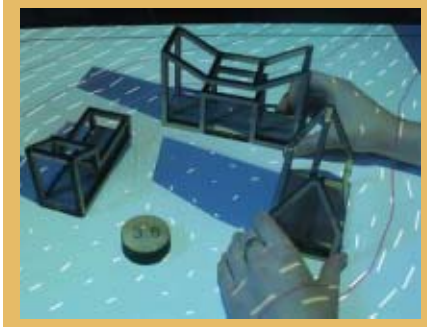
A Balance of Symmetry

The balance between tangible and virtual worlds thus became a juxtaposition that Ishii would examine throughout his career. Tangible Bits, Ishii's vision of human-computer interactions, seeks to eliminate the traditional graphical user interfaces which require screen, mouse and keyboard, to achieve seamless coupling of

physical and digital worlds. In a 2004 article with MIT Spectrum, Ishii notes, "An engineer just makes things work. But the artist asks profound, provocative questions: What feelings does this evoke? How does this relate to the whole? What does it mean? We need to look at the entire picture…Division is dangerous"

It is therefore quite apparent that Ishii's work is more ethereal than purely empirical. The ability to visually represent the environmental impact of a project with his Urban Planning Simulation ("Urp"), for example, evokes not only a practical development but also a certain emotional aspect that causes users to actually see and feel their influence on the urban environment. The Urp takes surface computing to a new level, allowing researchers to manipulate every day objects on a special tabletop that features all relevant data, right at the users' fingertips. So if an architect, for example, wanted to visually represent and alter his designs, material costs, and measurements in one tangible interface, the Urp would provide the space. Similarly, Ishii has further advanced the field of urban and landscape design with his "SandScape" project, wherein users can alter the topography of a sand-based model as the changing variables are captured in real-time by a laser scanner mounted above it. The ability to manipulate such a dynamic material while simultaneously logging its computational data has had tremendous positive ramifications on the efficiency and perspective modern urban design, which can be partly attributed to Ishii's application of nature in technology.

Photo credit: Webb Chappell



The Urban Planning Simulation ("Urp") allows users to manipulate physical building models to explore shadow and wind flow.

The SandScape allows users to design landscape manipulating sand-based topography and simulating shadow, water drainage, and other aspects.

A Nucleus of Commerce

Since more than a dozen companies in Japan sponsor MIT Media Lab, Ishii returns to his home country three to four times a year to attend meetings and conferences. "Too many great international conferences organized by IEEE and ACM are happening in Japan, and I wish I could attend them all", Ishii says. "I often attend those conferences to give keynote speeches, and I always enjoy their hospitality and high standard of professional services. The extensive, efficient public transit system makes it easy to navigate from one venue to the next in large cities. You can easily find the best route and estimated time to travel with trains and subways using online web service."

As media research and development continues, Japan has undoubtedly emerged as a capital of technological innovation. "At conferences in Japan one is able to enjoy the fruits of international collaboration and ingenuity while appreciating how local influences have shaped the course of Japanese engineering industries."

Tokyo Night Cityscape with Mt. Fuji in the background

Kanazawa Castle in Winter

forum

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IS SOLAR THE SOLUTION?

Deepak Divan and Frank Kreikebaum's article ["Organic (But Not Green)," November] began with great promise. But several of the authors' statements about solar photovoltaic power plants were puzzling, such as the claim that PV power plants are totally emissions free. The authors also claim that "a photovoltaic system covering [one] square kilometer, with a typical commercially available system efficiency of 15.5 percent, could power 12 000 homes or 60 000 electric vehicles." What commercial PV farm achieves a sunlight-to-grid efficiency of 15.5 percent? And why is the equipment needed to convert sunlight and wind into electricity considered "renewable"? Also, a general question: The solar energy reported to the California Energy Commission in 2008 represented only 0.24 percent (746 gigawatt-hours) of that year's total, down from the peak in 2002 of 0.3 percent (864 GWh). If solar is as capable as the article implies, then why does its contribution to California's energy needs remain so small?

Ed Johnson
IEEE Life Member
Sunnyvale, Calif.

The authors respond: We are not projecting from what is being achieved today but rather exploring the impact of scaling up currently available solutions to a global scale. We took the best high-volume, commercially available solar cells with 18.5 percent efficiency, added the efficiencies of the power conversion and grid-interface elements, and then took the average U.S. level of solar radiation energy of 4 kilowatt-hours per square mile per day to compute how much energy such a source could yield. In the overall calculation, we assumed that the energy required to make the solar cells, the panels, and other equipment is derived from sustainable solar energy (and also that the processing of biofuels is energized by biofuels). Thus solar cells are sure to be free of carbon emissions.

We realize that the current penetration of solar and wind energy remains small. This is due in part to high costs and a relatively slow adoption cycle, something we expect to change in the coming years. Our intent was to raise a flag about the scalability of biofuels. Our fear is that as biofuels come down in cost, their global proliferation will be difficult to contain—with, as we have shown, some dire consequences.

COMPUTERS THAT MATTERED

The timeline in "The Recession's Silver Lining" [October] shows the IBM 701 Defense Calculator as a "vector of change." Not true! The vector of change in the computer field was the ENIAC, the world's first electronic digital computer. It was completed and doing productive work, both military and scientific, in 1945, seven years prior to the IBM Defense Calculator. J. Presper Eckert Jr., an IEEE Medal of Honor winner, and John W. Mauchly, inventors of the ENIAC, gave a course in 1946 on computer design at the Moore School of Electrical Engineering at the University of Pennsylvania, where they had supervised ENIAC's design and construction.

Theodore Bonn
IEEE Fellow
via e-mail

As much as I enjoyed "The Recession's Silver Lining," the infographic "Vectors of Change" contained an error that warrants correction. The infographic states that in 1988 the NEC Ultralite was "the first MS-DOS–based portable computer in a notebook size." In fact, that distinction probably belongs to the Data General/One ("DG One"), introduced in 1984 but first produced in 1983. There was also the GRiD Compass 1100 (1982); the Gavilan SC (1983), which was marketed as a laptop; and the Sharp PC-5000. However, the GRiD did not run MS-DOS until well after launch and had an 80- by 24-character/320- by 240-pixel screen in a clamshell design. The Gavilan and Sharp both had tiny text-only screens. But whatever one's definition, the NEC Ultralite was a latecomer.

William J. Conner III
IEEE Member
Hingham, Mass.

Editor's note: The infographic "Vectors of Change" was not intended to represent these devices as being the first of their kind but rather the first to dominate markets. Michael Geselowitz of the IEEE History Center elaborates: "Most historians would consider the ENIAC a 'vector of change' in the history of the computer. There are others as well. The case for the IBM 701 could be made because it was the first production computer from IBM that went on to dominate the industry. I agree that the earlier DG machine was in 'notebook form,' but it weighed 9 pounds. The NEC Ultralite was just that. Also, the term *notebook* came into use around the time of (and perhaps with) the Ultralite. Prior to that, notebooks were called portable computers, among other names."

more online at spectrum.ieee.org

PLUGGING IN: Some utilities worry that charging cars at night could damage weak points in the distribution grid.
PHOTO: DAN SAELINGER/ GETTY IMAGES

Speed Bumps Ahead for Electric-Vehicle Charging

Plugging in cars, even overnight, will strain local grids and could boost pollution

As major automakers like Nissan, Mitsubishi, General Motors, and others prepare to roll out mass-produced plug-in hybrid electric cars in the United States late this year, electric utilities are both salivating at the business opportunity and quietly fretting over potential outages that could mar the electric-vehicle rollout. The myth that thousands of EVs will seamlessly fold into the power grid by charging at night, using otherwise idle generating plants and power grids, is breaking down. Utilities worry that EV charging could black out the neighborhoods of some early EV adopters and give the emerging technology a black eye. Policy experts worry that the change in the grid's use could unintentionally muck up their green energy plans.

The urgency was palpable in comments by Saul Zambrano, director for clean air and transportation at San Francisco–based Pacific Gas & Electric Co. (PG&E), at a California Energy Commission conclave in October: "You've got to manage the runway. And from our perspective, we think the runway is getting short relative to the launch of these vehicles."

The EV wave looms largest for California utilities and their state regulators, thanks to the state's long-standing efforts to mandate zero-emissions vehicles and its abundance of wealthy green consumers. Californians buy 12 percent of new cars in the United States but 24 percent of its hybrid electric vehicles. According to the California Energy Commission, close to 5500 plug-in hybrid and pure battery EVs could be cruising the state next year, and state rules require large automakers to sell 20 000 more annually starting in 2012.

A few thousand EVs won't crash the California grid, but they could cause local trouble, explains Doug Kim, director of EV readiness efforts at Rosemead, Calif.–based Southern California Edison (SCE), PG&E's neighbor to the south. Kim expects EV buyers to be concentrated in certain communities. Star-studded Santa Monica is already on his watch list. "We need to make sure that our local neighborhood circuits, including the transformers, are robust enough to support those additional loads," says Kim.

update

CHARGE IT: Plug-ins could upset some regions' green energy plans.
PHOTO: JAMES S. WOOD/AP PHOTO

EVs need lots of power, especially when charged quickly. Utilities bet that most buyers will want a 240-volt charger that can "fill the tank" of a modest-size EV in 2 to 3 hours, four times as fast as a standard 120-V charger can. Such "AC Level 2" chargers, as defined by the Society of Automotive Engineers' emerging J1772 standard, draw up to 6.6 kilowatts. Turning one on is like adding up to three homes to a neighborhood, and that's with the air conditioning, lights, and laundry running.

Turning on two or three Level 2 chargers could burn out the street-level transformers that are the distribution grid's weakest link. Most utilities employ undersized transformers, which are designed to cool overnight. Without time to cool, sustained excess current will eventually cook a transformer's copper windings, causing a short and blacking out the local loads it serves.

Ironically, electricity rates designed to discourage charging during the daytime threaten to intensify the night-charging challenge. For instance, customers with an AC Level 2 pay SCE a whopping 28 cents per kilowatt-hour to charge between noon and 9 p.m., but just 10 cents thereafter. That scheme protects the grid while it is normally peaking, but it invites new problems if EV owners plug in en masse at 9 p.m. "All of a sudden you've got an artificial peak and you've got transformers popping," says Zambrano, describing the nightmare scenario for the energy commission meeting.

SCE and PG&E are working with the Electric Power Research Institute to predict likely problem areas, and Kim and others are seeking to strengthen the grid before trouble starts. California's Public Utility Commission, meanwhile, is examining how utilities might use the smart meters they're installing to choreograph charging and avoid an early-evening EV-charging peak. The communication gear needed to allow smart meters to control EV charging can be integrated into vehicle chargers and will come standard in GM's Chevrolet Volt plug-in hybrid sedan.

AC LEVEL 1
1.4 kilowatts
6 kilometers per hour of charge

0.7

Equivalent number of California homes at peak power

AC LEVEL 2
*3.3 or 6.6 kilowatts**
19–38 kilometers per hour of charge

1.5–3

Equivalent number of California homes at peak power

**Some configurations provide more power. Source: California Air Resources Board*

California's regulators also envision smart charging to help EVs synchronize with the state's wind farms, which tend to provide most of their energy overnight. That would help EVs secure something that remains hotly contested by energy experts: their environmental benefit, something that is both complex to calculate and regional.

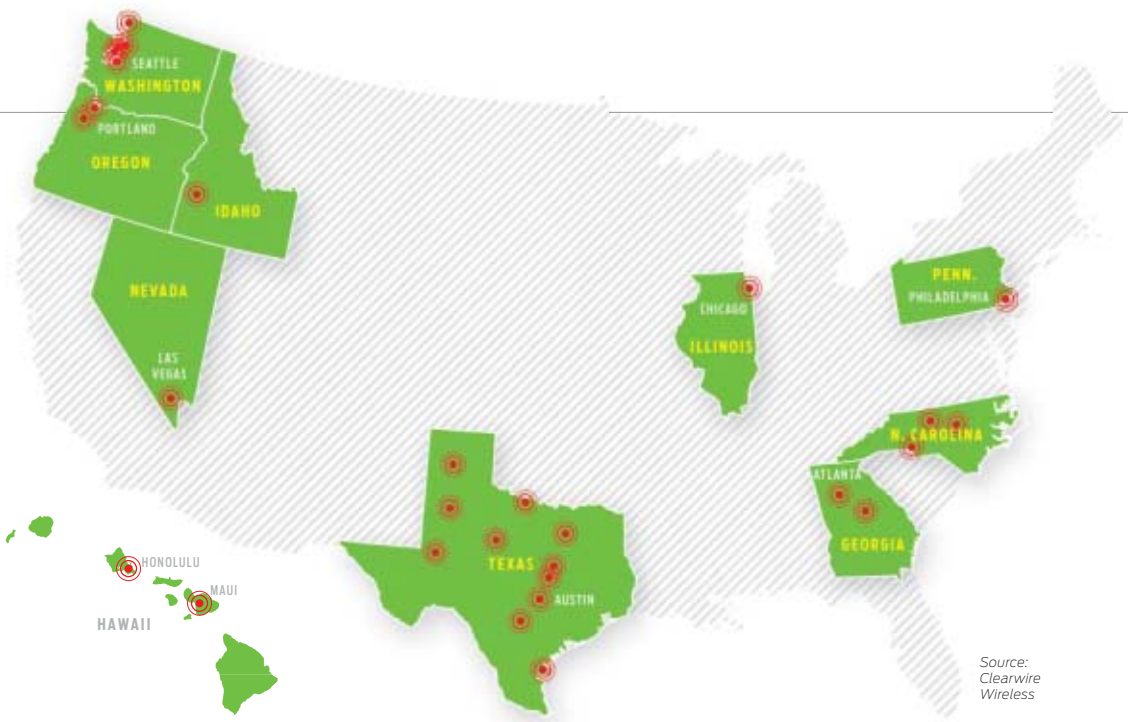
For their part, regulators at the California Air Resources Board predict that a kilometer's worth of EV charge should result, on average, in just 43 percent as much carbon dioxide as burning a kilometer's worth of gasoline. They consider EVs a key tool in their goal to reduce greenhouse-gas emissions to 1990 levels by 2020.

But things are different for the United States as a whole. Whereas carbon-heavy coal provides just 16 percent of California's electricity, it meets fully half of U.S. power demand. That U.S. reliance on coal-fired power (along with the energy intensiveness of battery manufacturing) negates the EV's on-road efficiency advantage over gasoline-powered cars, according to the U.S. National Resource Council.

The effects of EVs are even more vexing farther up the coast from California. Thanks to hydropower, British Columbia's power sector released the equivalent of just 22 metric tons of CO_2 per gigawatt-hour in 2007—squeaky clean relative to the U.S. average of roughly 600 metric tons per GWh. However, taking advantage of that low-carbon energy to charge EVs overnight may be pricey, according to a study of British Columbia's grid readiness released in November by the Pacific Institute for Climate Solutions.

British Columbia is in a bind because provincial utility BC Hydro imports cheap coal-fired power from Alberta to meet its nighttime demand, saving up hydroelectric energy for lucrative daytime exports to California and elsewhere. Shifting to hydropower at night to make EV charging green would mean forgoing a significant income stream that keeps power costs low for British Columbia consumers. And the loss of the province's hydropower exports could make it harder for California to meet its carbon-emissions goals. "The BC Hydro mandate for carbon-neutral power generation by 2020 can be either facilitated or aggravated by the growth of [plug-in vehicles]," according to the energy systems engineers at the University of Victoria who wrote the report.

—Peter Fairley



Source: Clearwire Wireless

4G in the U.S.A.

WiMax is spreading in the United States, but it could soon be overshadowed by a rival technology

FOURTH-GENERATION wireless got its official start in the United States one year ago when Clearwire Wireless made Portland, Ore., the first city to be covered by its WiMax wireless "last mile" broadband connection. Twelve months later, the shape of wireless's future is now clearly outlined: WiMax has the early lead but will eventually be overtaken by another technology.

With a series of recent rollouts, 30 million people in 29 U.S. cities now have access to Clearwire's WiMax service. The company's third-quarter financial results indicate that 173 000 subscribers had signed up as of September. That makes the United States one of the most successful WiMax markets in the world, according to Emmy Johnson, principal analyst at Sky Light Research, a Scottsdale, Ariz., research firm that specializes in wireless technologies.

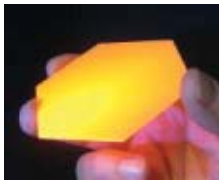
In South Korea—where WiMax debuted commercially with an early version of IEEE 802.16, on which the service is based—"there were probably about 200 000 subscribers as of June 2009," says Johnson. In Malaysia, Packet One Networks had about 80 000 at the end of August; in Russia, Yoda Communications has at least 100 000 customers and perhaps as many as 200 000, a success that came about almost by accident. "Because of some laws there, Yoda couldn't charge for six months. So they let people subscribe for free. Lots signed up, and many stayed," Johnson says. It also helped Yoda that Taiwanese manufacturer HTC Corp. had just released a sexy new handset.

These early successes are much needed, because WiMax is in a desperate race to gain ground before most of the world's mobile operators begin to upgrade to a rival 4G technology, Long Term Evolution (LTE), beginning in 2013. A few carriers, notably Verizon Wireless, will be even quicker. LTE is the 4G successor to two hitherto incompatible standards: GSM, which rules Europe and most of Asia, and CDMA, which has large pockets of strength in North America, Korea, and China.

Clearwire and other WiMax services may have a three-year head start, but LTE has the power of incumbency: the revenue streams and allegiances of a huge base of existing customers. Robert Syputa, a senior analyst at telecommunications research firm Maravedis, in Montreal, says that LTE will also have a device advantage. "Verizon, along with DoCoMo and to some extent China Mobile, are pushing the handset makers. It sounds very aggressive, with new chips available the first of the year—Qualcomm says it will rush the product along." Verizon in particular is trying hard to eliminate WiMax's time-to-market advantage.

Sky Light's Johnson says, "WiMax will be a much smaller play than LTE; it might thrive in the markets it establishes early or even merge with LTE. The world is going toward LTE."

Where does that leave the folks at Clearwire? "They could also deploy LTE," Syputa says. "They're an operator, they have spectrum; they'll deploy what works." —STEVEN CHERRY



news briefs

Dot Light

The phosphors used to make the cold light of white LEDs look more natural also sap their efficiency. QD Vision, a Watertown, Mass., start-up, is producing filters for LED lighting using quantum dots. The filters keep LEDs' efficiency high but make their light look more incandescent.

PHOTO: QD VISION

commentary

Cat-Brain Fever

Two simulations and an angry e-mail reveal the conflicting goals of supercomputer brain modeling

IT'S NOT every day that a leading scientist calls for another leading scientist to be "strung up by his toes" in an open letter. But that's just what neuroscientist Henry Markram called for in a dispute with IBM computer scientist Dharmendra Modha. Their altercation shows that the motivations behind brain simulations are not always clear, even to the main characters.

At the 2009 Supercomputing conference in November, Modha's team from IBM and Lawrence Berkeley National Laboratory reported the creation of supercomputer software that simulated 1.6 billion neurons and their 10 trillion connections, or synapses—about the equivalent number to those in a cat's brain. (It is *not*, as some have called it, a simulation *of* a cat's brain, however.) The team, led by Modha, won the Gordon Bell Prize, a major award in supercomputing. A few days later, Markram, who leads a brain-simulation project at Switzerland's École Polytechnique Fédérale de Lausanne, sent an open letter to IBM and the press refuting Modha's claims and calling the work a hoax.

In Markram's letter, he fulminated that awarding the Bell prize "for such nonsense is beyond belief." He said that the sophistication of the neurons Modha simulated was trivial compared with what would be necessary for an actual simulation of a cat brain.

Markram's letter made waves. Some scientists applauded it, while others decried his tone as unprofessional. Many were cynical, calling all efforts (including Markram's own) at reverse engineering the brain equally spurious. But before getting caught up in the drama, it's important to understand why Markram may have missed the point.

ISTOCKPHOTO

US $200 000 Price of a ticket to space on Virgin Galactic's recently unveiled *Spaceship Two*. The craft is twice the size of its predecessor and is designed to carry two pilots and six passengers.
Virgin

Reverse engineering the brain is the goal, but different groups have different motives for doing so, and Markram and Modha may represent opposite extremes. Generally, for Markram and other neuroscientists, the goal is to understand how the summed activity of the 100 billion neurons in the human brain lead to phenomena like consciousness and neurological disorders. For computer scientists, the goal is to understand the brain's unique and appealing architecture—and from this architecture, to create new kinds of electronics.

Markram took issue with the fact that Modha's simulation did not use biologically realistic neurons. His own "Blue Brain" simulation at EPFL re-creates about 10 000 neurons, each with an exquisite level of biological realism, on an 8192-processor IBM Blue Gene L.

But when you understand Modha's motivation, biological realism at that level is beside the point. Modha's work is not about creating a conscious brain. It is about addressing three major roadblocks on the way to brainlike computing: speed, scaling, and parallelism.

Consider the fact that the Blue Gene P on which Modha did the work has 147 456 processors. "It's fairly impressive that he showed good scaling up to the size of that machine," says Ben Chandler, a computer scientist and cognitive scientist at Boston University, which competes with Modha's team for funding from the U.S. Defense Advanced Research Projects Agency. "I don't think [other neural simulation environments] can handle 147 456 processors or 144 terabytes of memory." Modha's team was able to use each of the processors more or less equally to do the work of the brain simulation, getting only a 0.3 percent deviation in workloads across cores.

Distributing the work uniformly across the machine means that all the processors were able to complete their work at roughly the same time, allowing the simulation to run reasonably close to real time.

The distribution of work also helped the simulation take advantage of the supercomputer's memory resources. "Part of the reason neural simulations are so difficult is the memory-intensive nature of biological computation," says Chandler.

Modha's cat-*scale* simulation is exactly what the Gordon Bell Prize celebrates: a milestone in computing. It deserves its accolades in full.

—Sally Adee

200 milliseconds The time it takes a new electromagnetic pulse generator to punch a hole in press-hardened steel car frames, according to its developers at the Fraunhofer Institute for

Taiwan's DRAM Plan Fails

Good riddance, say manufacturers

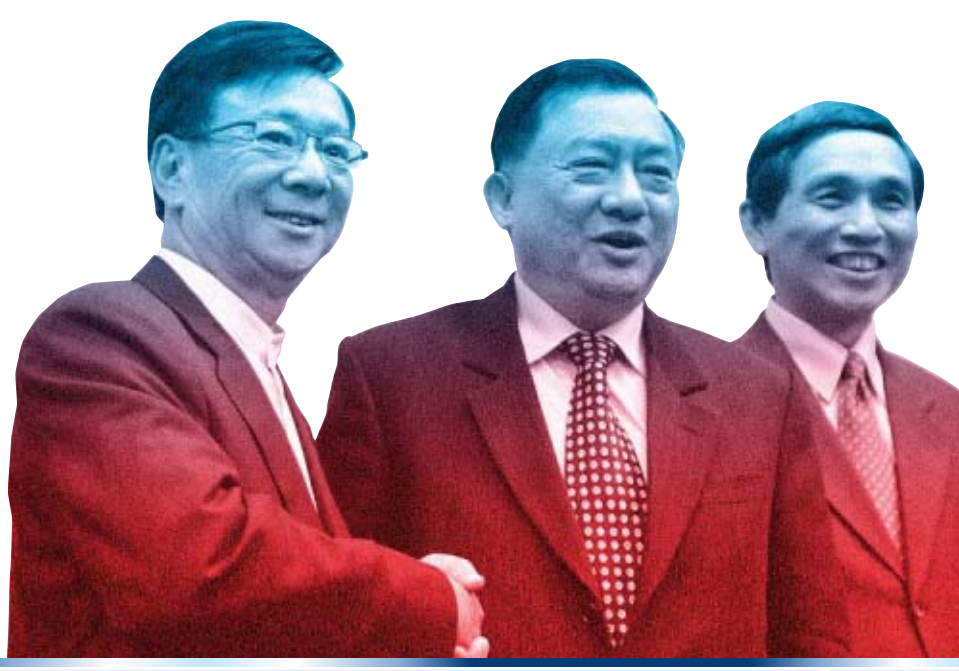
TAIWAN'S PLAN to restructure its dynamic RAM industry seems to have met its end—not with a bang but with a whimper. The plan was to consolidate the industry and acquire new technology under the banner of a new company, Taiwan Innovation Memory Co. (TIMC), created in March 2009. In mid-November, the country's lawmakers rejected the cabinet's request for the National Development Fund to invest NT $5 billion (about US $150 million) in TIMC—all but ending what had turned out to be a pretty unpopular project.

The plan had its origins in 2008's disastrous downturn. Then, DRAM makers around the world found themselves in a financial bind following an orgy of overcapacity and plummeting prices. Manufacturers in Europe, Japan, Korea, and Taiwan turned to their governments for help, although it was too late for Germany's Qimonda, which went under early last year.

Taiwan accounts for less than 15 percent of the global DRAM market by revenue, but it is home to six of the 10 major manufacturers. Through various deals, foreign firms such as Elpida, Memory, Micron Technology, and Hynix own stakes in several Taiwanese manufacturers and have transferred DRAM technology to them partly in exchange for a portion of their output.

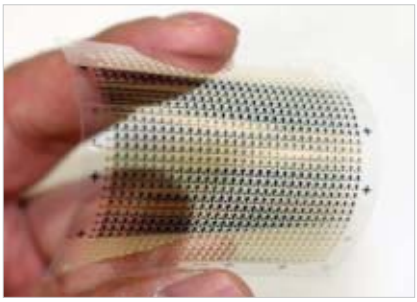
None of Taiwan's six DRAM firms agreed to be folded into TIMC. And improved DRAM prices in 2009 have left manufacturers in less dire straits. According to Taiwanese market research firm DRAMeXchange Technology, contract prices for DDR3, expected to soon become the most popular memory for new computers, rose sharply in the third quarter of 2009—by 36 percent—and spot prices were up 24 percent.

Officials of the executing agency, the Ministry of Economic Affairs, still see a need for restructuring. "Although we've seen the prices bounce back, root problems have not yet been solved," Minister of Economic Affairs Yen-shiang Shih told reporters. "The plan aims



John Hsuan [left] of TMIC with government officials Chii-ming Yiin [center] and Yen-shiang Shih *PHOTO: PICHI CHUANG/REUTERS*

Machine Tools and Forming Technology, in Chemnitz, Germany. It takes an industrial laser seven times as long.



news briefs

Flexible Flash

University of Tokyo engineers have invented the first flexible flash memory device. It was built on plastic using an organic semiconductor. The engineers say that flexible flash would be a good fit for storing the input to large-area sensor arrays. *PHOTO: SCIENCE/AAAS*

to remove major obstacles, including our local makers paying dozens of billions every year to acquire key technologies from foreign partners."

Some analysts agree that this is just a temporary reprieve for Taiwan. "They're not having to face the music as soon as they thought," observes Jim Handy, of Objective Analysis, which does market research for the semiconductor industry. "Consolidation can be put off in good times," but the need for it—namely to be able to afford the rising cost of equipping a fab for new generations of products—will reappear with the next downturn, he says.

At press time, the Taiwanese cabinet had yet to officially call off the reconstruction plan. John Hsuan, who was tapped to lead TIMC, says he personally would not feel bad about a possible halt to the plan. "I will just accept whatever final decision the government makes," he says.

TIMC has already made some progress on the technology front. Under a deal struck in March, TIMC is expected to hold 10 percent of the shares of Tokyo-based Elpida and collaborate on the migration of technology from Elpida to TIMC. There are signs, however, that the deal may not last. Elpida recently announced technology and production deals with Taiwan's ProMOS Technologies and Winbond Electronics.

—Yu-Tzu Chiu

US $220 million The fine that Taiwanese manufacturer Chi Mei Optoelectronics agreed to pay for conspiring to fix the price of LCD panels.
Six companies have pleaded guilty so far, and nine executives have been charged.

update

The Littlest SRAM

New lithography trick makes smallest memory cell

A NEW TYPE of lithography that uses an electron beam to spark a chemical reaction could provide a way to build incredibly tiny transistors, which the chipmaking industry will require in a few years. Researchers from Taiwan and the University of California, Berkeley, say they've made static RAM that anticipates 16-nanometer chip features using a new process called nanoinjection lithography.

Hou-Yu Chen and his colleagues from Taiwan's National Nano Device Laboratories presented their work last month at the International Electron Devices Meeting (IEDM) in Baltimore. They say their technique may provide an alternative to lithography that relies on extreme ultraviolet light (EUV), which is still beset by problems and could be extremely expensive.

"This is the smallest SRAM made," says Chenming Hu, a professor of microelectronics at UC Berkeley. "There are a lot of concerns about the scalability of SRAM going forward." The device the team made was a six-transistor SRAM in a 0.039-square-micrometer cell. The previous record holder was based on 22-nm features in a 0.1-μm² cell.

SRAM occupies an ever-increasing percentage of a chip, taking up as much as 80 percent of chip area in some designs, Hu notes. "The size of the SRAM cell becomes critical to the cost of the chip, so SRAM is always the most taxing circuit for testing process capability," he says. Shrinking the SRAM, in other words, is key to shrinking the chip's circuitry as a whole.

Standard lithography uses a set of masks to create a pattern in a photoresist that's exposed to ultraviolet light. The Taiwan team's process eliminates both the masks and the photoresist, relying instead on a gas of organic molecules studded with atoms of platinum. A 4.6-nm-wide electron beam is fired at the gas, causing a chemical reaction that deposits the platinum on the silicon chip in the desired pattern, while the rest of the gas flows away. With this hard mask deposited on the silicon, the researchers then use chemicals to etch away exposed silicon and thereby create the desired circuits. The platinum pattern is then chemically removed.

Eliminating the masks and the photoresist cuts the patterning process from five steps to one, greatly simplifying production. The researchers say that EUV masks are projected to cost around US $3 million a set and the EUV lithography machines about $60 million apiece. So the nanoinjection lithography could also be significantly cheaper. Hu says the technique also allows for finer lines and closer spacing than typical electron-beam lithography.

The team built its SRAM based on the nanowire structure known as a FinFET, a field-effect transistor that's shaped like the fin on a fish's back and protrudes vertically from the silicon. Hu, who invented the FinFET, says the shape is important when the dimensions are so small, because a gate dielectric can be applied to the entire periphery of the fin, preventing the current leakage that troubles small transistors.

The process, of course, could be used to build other circuits on a chip besides SRAM. Hu says the work is in a fairly early stage and needs to be developed further before researchers know if it can be applied to full-scale chip manufacturing for a reasonable cost. One major concern is that the process provides relatively low throughput. The researchers say their technique is mainly an alternative to EUV and e-beam lithography for low-volume fabrication.

—NEIL SAVAGE

A version of this story ran online in December 2009.

ISTOCKPHOTO

Formfitting, Self-Powered Artificial Retina

Researchers at Stanford University have developed a silicon retina that has two advantages over others in development. First, it gets its power and data from light entering the eye rather than through external wires. And second, the implant can be bent to conform to the curvature of the back of a person's eye. See http://spectrum.ieee.org/biomedical/bionics/artificial-retina.

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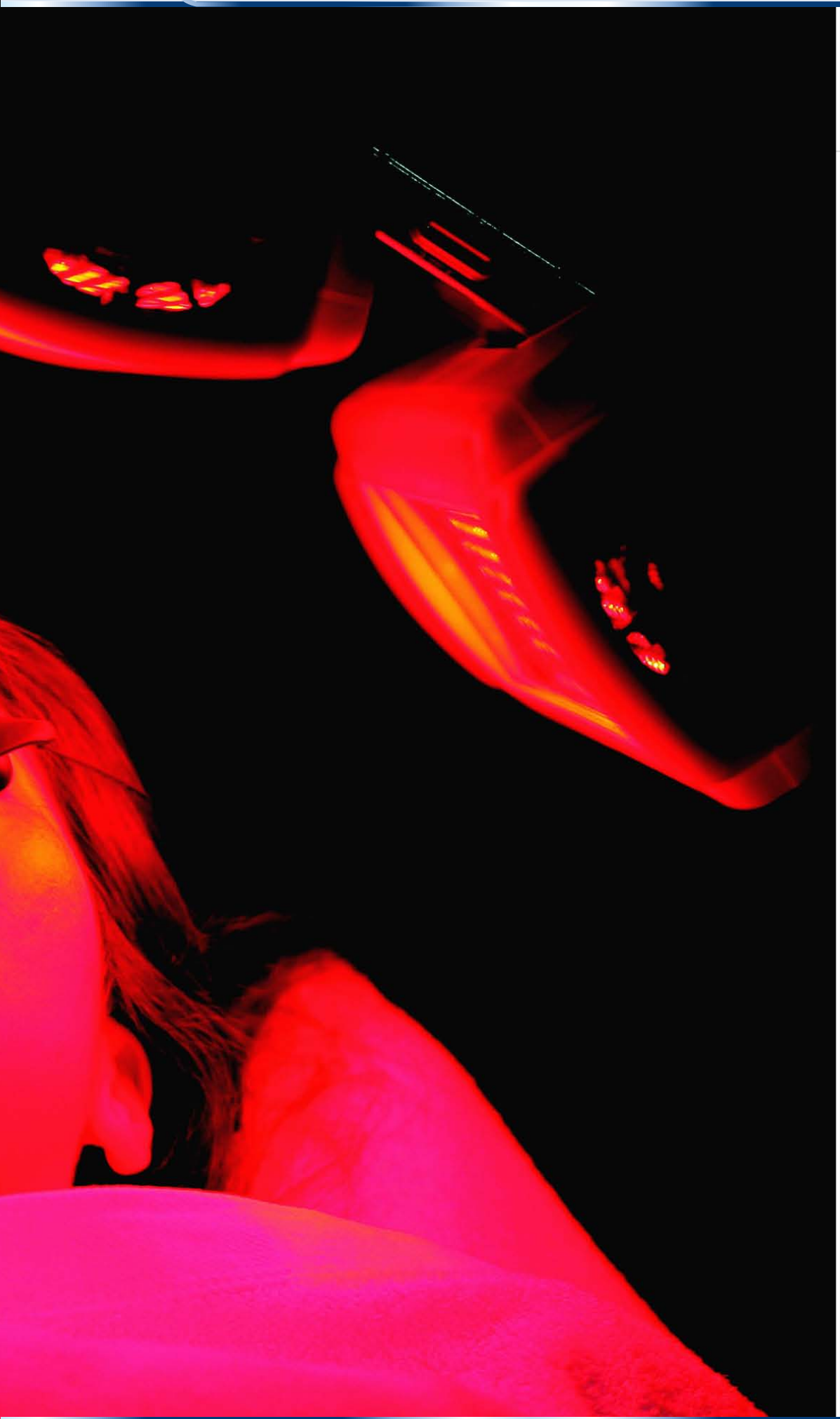


the big picture

YOU'VE GOT THAT GLOW
A light-therapy machine called ReGen, produced by Energist, in Swansea, Wales, uses high-intensity LEDs, which the company claims will soften skin, smooth wrinkles, and erase blemishes. Each of the four light boxes has a 255- by 70-millimeter panel containing 1024 LEDs. At wavelengths of 415 nanometers, they glow blue; when they're set at 630 nm, they're red. A third mode—which produces purple light by mixing blue and red—is claimed to combine the benefits of both treatments. Twenty minutes twice a week is supposed to reduce the signs of aging.

PHOTO: MICHAEL CARONNA/REUTERS

SPEED OF LIGHT: Data centers are the early adopters of optical cables, but homes will soon need their higher speeds as well. PHOTO: ZARLINK

OPTICAL LASERS IN A $100 CABLE. REALLY

As homes go high definition, copper will give way to active optical cables

Visitors to this year's Consumer Electronics Show in Las Vegas will surely be stunned by the lush colors and sounds of high-definition movies as displayed on today's screens. What they'll likely overlook is the technology that makes the new HD world possible, one that aims to replace the old paradigm of electrons over copper wire.

Instead we'll get our data through what's called active optical cable, or AOC. It has the same shiny plugs on either end as regular consumer electronics cable, but instead of electrons it pushes photons produced in tiny lasers.

The tip of a cable can now accommodate optical components as sophisticated as those in an Internet router of a few years ago. And the cables themselves can be a tenth as wide as conventional cables and far lighter as well.

According to Tom Rossi of Solutions by Design, a Silicon Valley database consultancy, the next four years will see a tenfold growth in the market for AOC, at prices as low as US $100. Last summer Rossi wrote a first-ever survey of AOCs for Information Gatekeepers, a Washington, D.C., research firm. He estimated that 2 million AOCs worth $200 million would end up being sold in 2009 and predicted that the market would reach $2.6 billion by 2013. That's when consumers will begin to see AOC versions of high-definition multimedia interface (HDMI), USB, and DisplayPort cables at their local electronics stores.

AOCs are already used in high-end computer data centers. They usually adhere to the InfiniBand standard, a bidirectional serial link fast enough to communicate among supercomputer processor nodes or between a supercomputer and its storage devices. According to Stan Swirhun, senior vice president at Zarlink Semiconductor, in Ottawa, a 20-meter, 40-gigabit-per-second InfiniBand AOC costs about $200.

That's not all that much higher than what the market will bear for most consumer applications. Wander over to the video section at Best Buy and you'll find copper HDMI cables that go as high as $170. And the cost of the most expensive part of an AOC—the solid-state laser and photon detectors on either end that convert between electronic and photonic signals—is dropping.

"Today's data centers are establishing the model for tomorrow's home IT requirements," says Robin

LASER TAG: Optical lasers can now fit inside the tips of an ordinary data cable, as with this 5-gigabit-per-second cable from Zarlink. PHOTO: ZARLINK

Crandell, marketing vice president of Berlin-based MergeOptics. "When you add up the computing power in the home, along with the associated storage and high-speed interconnects, it's kind of like a mini data center."

At the 2008 Consumer Electronics Show, Luxtera, based in Carlsbad, Calif., debuted a DisplayPort AOC that could carry video at up to 10 Gb/s as far as 4 kilometers. Conventional copper can't do much better than 5 Gb/s over distances greater than 5 meters. And HDMI, USB, and DisplayPort standards are approaching 5 Gb/s. "At short distances and lower speeds, the competition is copper," said Zarlink's Swirhun. "At longer distances and at greater speeds, there's no real competition."

Nevertheless, copper wire has hardly breathed its last, says Darren Crews, a platform engineer at Intel. "Copper is everywhere. There have been and are huge investments to move that technology forward." Crews led the division at Intel that created an InfiniBand AOC design, which was eventually sold to Emcore Corp., in Albuquerque.

Emcore and Zarlink now dominate the AOC marketplace. But new companies, such as Avago, Finisar, Reflex Photonics, and Tyco, as well as MergeOptics and Luxtera, have quickly jumped in—attracted no doubt by a market that is increasing even more quickly than the data rates themselves.

—Mark Anderson

books

Is Facebook Making Us Narcissists?

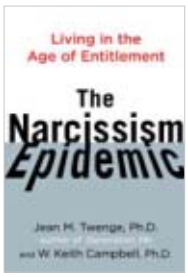
A new book argues we're much more self-absorbed nowadays, and technology is to blame

I tweet, therefore I am. Or is it, I tweet, therefore I am insufferable?

As if Paris Hilton weren't clue enough, we now have statistical evidence that young adults are a lot more in love with themselves than they used to be.

In *The Narcissism Epidemic: Living in the Age of Entitlement*, Jean M. Twenge, a professor of psychology at San Diego State University, and W. Keith Campbell, a social psychologist at the University of Georgia, look to the Narcissistic Personality Inventory, which measures self-regard, materialism, and lack of empathy. They found that the number of college students scoring high on the test has risen by 30 percent since the early 1980s.

The authors blame the usual suspects—the self-esteem movement, indulged children, unjustified praise by teachers, celebrity culture, reality shows, easy credit. But they also cite social networking tools, such as MySpace, YouTube, Twitter, and Facebook.



The Narcissism Epidemic: Living in the Age of Entitlement
By Jean M. Twenge & W. Keith Campbell; Free Press, 2009; 352 pp.; US $26; ISBN: 978-1-4165-7598-6

"Using Facebook doesn't mean you're a narcissist," says Campbell. "But the ones who scored highest on the narcissism test tended to have more friends, wall posts, glamour shots, and self-promoting statements. For them, social media is a tool to express their narcissistic tendencies. It allows them to get attention from lots of 'friends' rather than develop deep, more emotional connections."

Naturally, the book has its own Web site: narcissismepidemic.com. —*Susan Karlin*

Narcissistic Personality Quiz: http://psychcentral.com/quizzes/narcissistic.htm

Divine Circuitry, or Circuitous Divinity

Will the world undergo a "cataclysmic shift" on 21 December 2012—the end of history, as the ancient Mayan calendar would have it? A number of books say it will. The latest—and the one with the thickest technological wrapping—is *Fractal Time: The Secret of 2012 and a New World Age* by Gregg Braden.

Braden worked as a computer scientist for Phillips Petroleum, Martin Marietta Defense Systems, and Cisco Systems before turning his attention to spiritual matters. His latest book—and what he must imagine to be his last—merges the laws of fractal patterns (smaller shapes or patterns representative of the larger whole) with ancient cyclic views of the universe. —*S.K.*

Fractal Time: The Secret of 2012 and a New World Age
By Gregg Braden; Hay House, 2009; 256 pp.; US $24.95; ISBN: 978-1-4019-2066-1

Fractal Time: The Secret of 2012 and a New World Age: *http://www.hayhouse.com/details.php?id=4021*
Gregg Braden: http://www.greggbraden.com

tools & toys

THE GREENING OF TELEVISION

Your giant LCD uses just as much energy as your old CRT. That's about to change

THAT BIG liquid-crystal display in your new TV may be twice as efficient as the old cathode-ray tube was, but because it's much larger, it may be using as much energy as your old set—or even more.

Blame that profligacy, in part, on the Energy Star 2.0 efficiency guidelines set by the U.S. Environmental Protection Agency back in 1996. Although they limited to 1 watt the power a TV could draw in standby mode (what most of us think of as "off"), they didn't bother counting the watts when TVs were operating. That'll change in 2010, the effective date of Energy Star 3.0, which calls for cutting the draw of a 42-inch (107-centimeter) TV from 208 W to 115 W. Come 2012, it'll drop to a mere 81 W.

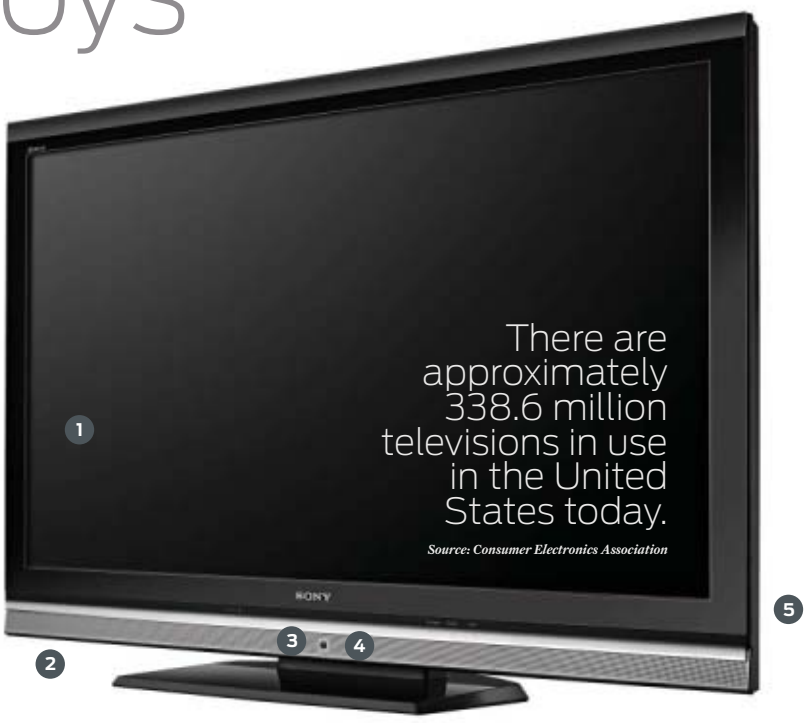
Energy Star guidelines are voluntary. But on 18 November of last year, California became the first U.S. state to set mandatory limits on the energy consumption of TVs; those that don't meet California standards cannot be sold in the state. Under the standard, a 42-inch television will be limited to consuming 183 watts by 2011 and 115 watts by 2013.

Most LCD manufacturers already meet or exceed the Energy Star targets, and they are coming up with all sorts of ways to cut back on power consumption, like automatic backlight dimming and video mute. (And some old features, long lost, are coming back again, like the mechanical on-off switch. Without this feature, the TV is always in standby mode and consuming power, albeit just fractions of a watt.)

Lots of new models are touting green features. Sharp's 32-inch green TV, Aquos DH77, claims an average operating consumption of 55 W and a low-power standby option of 0.6 W, thanks to what it calls the eco-button on the remote (essentially a dimmer switch.) LG's new entry-level high-definition television, the LH 30, consumes between 55 and 127 W, depending on the mode of operation, which the company contends makes it the most energy-efficient 42-inch LCD to reach the market so far. In June, Vizio announced the EcoHD line of TVs, which beat Energy Star 3.0 by 25 percent. Samsung plans to have all its 37-inch and larger LCDs backlit with LEDs rather than fluorescent tubes by 2010 and is forecasting a 2010 average power consumption that's 50 percent lower than that of its 2008 TVs.

Perhaps the greenest of the green is the Sony Bravia Eco TV. It packages all of Sony's eco-friendly features into one unit. A 40-inch Bravia, when on, draws 90 W, which is on the low end for an LCD television of that size, says Katharine Kaplan, EPA team leader for Energy Star product development.

—TEKLA S. PERRY



SONY BRAVIA ECO TV

1 BACKLIGHT: A bank of hot cathode fluorescent lamps (HCFLs) in the backlight consumes as little as half the power of a conventional, cold-cathode set. (HCFLs are larger than cold-cathode fluorescent lamps and have shorter life spans.)

2 AUDIO ONLY: A sound-only mode allows listening from another room or using the TV for audio-only programming.

3 AMBIENT LIGHTING: A light sensor matches the television's brightness to the room's lighting—bright to compete with daylight, much dimmer for a darkened room.

4 SLEEP MODE: A motion sensor in front of the television turns the screen off if no motion is detected for some specified period, then turns it on again when the viewer returns.

5 MECHANICAL ON-OFF SWITCH: An Energy Star–compliant LCD television must draw no more than 1 watt when the television is not on, to let it respond to the remote. Turning this switch to "off" cuts that to zero.

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careers

ANIMAL WRIGHT: Israeli robot researcher Amir Shapiro [top] builds snakelike robots (like the one draped around his neck) that can twist like screws. He also makes robots that scale walls [bottom] by releasing tiny amounts of glue, much as a snail leaves a trail of mucus. *PHOTOS: TOP, DANI MACHLIS/BEN-GURION UNIVERSITY; BOTTOM, TOMER AVRAMOVITCH AND AVISHAI SINTOV*

ROBOTICS' WILD KINGDOM

An engineer looks to nature to make robots that slither through pipes and climb walls

ISRAELI ROBOTICIST Amir Shapiro takes his engineering cues from members of the animal kingdom, though his choices might seem unexpected: snakes and snails. Oh, and cats, too.

In the field of biomimetics—the use of technology to mimic nature—there's a subspecialty that mimics animal locomotion, and several research centers have worked on robots that mimic the undulation of a snake. But Shapiro's team has gone a step further (no pun intended) by combining two concurrent wave motions to create a slithering movement.

"These three-dimensional snakes have two sets of motors that give us two traveling wave motions, in the vertical and horizontal directions," says Shapiro, who heads the robotics lab in the mechanical engineering department at Ben-Gurion University of the Negev, in Beersheba, Israel. "We combined the two perpendicular traveling waves for a screwlike motion that moves the snakebot forward. So it's going forward and around at the same time." This lets it wriggle through small holes and pipes, a trick that could help workers find and rescue people buried under collapsed buildings.

Today the robot is under remote control, but Shapiro plans to make it autonomous. "The idea is to have sensors on the robot—tactile sensors to see where the contact points are, scanning sensors at the head of the snake, a laser scanner, or a camera—and then design adaptive algorithms that can change the motion pattern, the amplitude, phase, and wavelength according to the terrain."

Shapiro, 38, displayed an early affinity for machines. He attended a technical high school, then served as a project engineer designing armored vehicles during his mandatory military service. From there, he went to Technion-Israel Institute of Technology, in Haifa, where he earned bachelor's, master's, and Ph.D. degrees in mechanical engineering. Smitten with robotics because it combines several engineering disciplines, he did a postdoctorate at the Robotics Institute at Carnegie Mellon University, in Pittsburgh, developing his snake robots, before joining the Ben-Gurion faculty.

In 2004, the Israeli military asked him to craft wall-climbing robots for intelligence gathering. His team came up with a tracked robot that scales concrete walls by releasing melted glue, which holds it in place until it can move forward and release more glue. Shapiro's inspiration was the mucus trail that a snail leaves behind. For rough walls, he designed a robot whose four legs carry fishhooks, allowing it to climb like a cat.

He has also equipped a robot with compliant magnetic wheels so that it can clamber on the submerged hulls of cargo ships, perhaps one day replacing the divers who now check for contraband and bombs. "A robot can do it safer, better, easier, and much less expensively," Shapiro says. "A good scanning algorithm can make it very efficient."

His latest project is a robot that shoots arrows attached to strings, which it uses to pull itself along a wall or ceiling. So what animal inspired that?

"That one," he says, laughing, "came from Spider-Man." —S.K.

JOINT VENTURE: Palestinian engineers find it easier to teleconference with their Israeli colleagues than cross the military border that separates them. PHOTO: G.HO.ST

ENGINEERING PEACE

Palestinian and Israeli software engineers are finding the coexistence that eludes the politicians

An unusual summit between Israelis and Palestinians took place 15 months ago at an unnamed gas station along Route 1 between Jericho and Jerusalem, in the West Bank. The "diplomats" were engineers and software designers from Global Hosted Operating System, or G.ho.st, the first-ever high-tech Israeli-Palestinian joint venture. The gas station was a place where employees from its offices in Ramallah, in the Palestinian National Authority, and Modi'in, Israel, could meet without getting permits or waiting in long lines to cross the border.

In the technology sector, at least, a quiet little trend of cooperation is emerging. A handful of Israeli companies are outsourcing to Palestinian engineers, aligning the bottom line with lofty ideals. Some Israel-based branches of multinational companies, such as Cisco Systems, Intel, and the software consulting firm Equiom, are doing the same thing.

"At first, it was strange for both of us—you could feel the tension on both sides," says Montasser Abdellatif, G.ho.st's marketing and communications manager. "But we avoid talking about politics. We're helping to create more jobs in a small industry where a lot of educated people can't find good jobs. And the bottom line of any start-up company is putting out a good product, so we're optimistic about that."

Each year, 3000 computer scientists graduate from the 11 universities within the Palestinian National Authority and enter a workforce suffering from a 21 percent general unemployment rate. With wages that are a third of Israel's, cultural familiarity, good English-language skills, and a shared time zone and currency (the Israeli shekel), the Palestinian National Authority is in many ways ideal for outsourcing—particularly for software, a business that can be conducted over the Internet. Telecommuting is practically a necessity, as Israelis are not allowed into Palestinian territories, and Palestinians must wait months to get permits to enter Israel, only to wait again on long lines at the border. "This could only happen with an IT company," says Abdellatif. "You don't have to rely on transportation or logistics."

Jonathan Levy, president of Nuvoton Technology Israel, a silicon-chip design firm that invests a year in training new employees, hesitated to set up design teams in China for fear that their English skills would be weak and their long-term commitment to a low-profile company would be weaker still. G.ho.st CEO Zvi Schreiber referred Levy to Murad Tahboub, a G.ho.st equity partner who runs Asal Technologies, an outsourcing firm in Ramallah. It located all the engineers Levy needed.

"We were the first Israelis some of the Palestinian engineers had seen out of uniform," says Levy. "It was a big gap for us both. But as soon as we had personal meetings, everyone's fear disappeared. We've since heard that salaries are going up in China very significantly."

Meanwhile Galil Software, a service company in Nazareth, is trying to narrow the cultural gap within Israel itself by helping Arabs already living there find jobs in the country's high-tech industry. CEO Inas Said estimates that fewer than 16 percent of the 2500 Israeli Arab engineers enter that arena because few Israeli Arabs serve in Israel's army, where early work relationships are often formed. Roughly 90 percent of Galil's engineers are Israeli Arabs.

"When we first started this engagement, we worried that customers would consider it risky," adds Levy. "But they said, 'This means if I use your chip, I'm contributing to world peace.' It creates an emotional value as well as technical one." —S.K.

BY ROBERT W. LUCKY

Driven to Distraction

I USED TO feel that the ultimate aim of communications research was telepresence—creating the perfect illusion of being where you're not. However, now I'm thinking that we did too good a job of creating this illusion and that the law of unintended consequences is taking hold. Sometimes you need instead to enforce the perfect sense of being exactly where you are at the moment—like when you're behind the wheel of a car hurtling down the highway. Maybe instead of *tele*presence (*distant* presence) we need *plesio*presence (*near* presence).

The problem is technological distraction. It's becoming serious, and there is no solution in sight. Laws against using phones in cars aren't working, because the problem isn't that you're putting a phone to your ear; it's that you're putting your brain somewhere else. So are we technologists helpless? Now that we've created technological distraction, can we create technological *traction*?

Why is talking to the passenger next to you different from talking to someone on the phone? We need to better understand the psychology of cellphone conversations. And not just in cars. There's an illusory cone of privacy that surrounds people's all-too-public conversations everywhere.

I often travel in the quiet car on Amtrak trains, where cellphone conversations are forbidden. Like my fellow occupants, I'm alert to anyone breaking the rules. I can nearly always tell when someone is talking to a "cellmate" rather than a seatmate. It simply sounds different. I can't explain how I know, I just know, and apparently so do the other passengers. Perhaps there are some useful clues there for the psychologists.

While this much-needed research in the cognitive area is going on, we might as well go ahead and try some things. First, we need to detect when someone is using a cellphone in a moving vehicle. There could be a monitor in the car, but this would be either relatively ineffective or hugely expensive, given the number of older vehicles still on the road. Instead, we could detect cellphone users through base-station handoffs, triangulation, or Doppler shift of the received signals. That's the easy problem. The hard problem is what to do when we do detect it.

We could, of course, just block calls to and from moving vehicles, but this probably wouldn't be allowed. Doctors and other people would cite emergencies or other urgent circumstances in which calls must be permitted. Maybe we could simply make the conversations unpleasant by adding static to simulate the old analog long-distance calls, randomly adding the screech of chalk on a blackboard, or inserting a simulated satellite delay. Most deviously, we could introduce an echo delay that makes it almost impossible to talk. But I'm not sure whether such annoyances would help or hurt the sense of telepresence. They might draw the brain further into the call instead of pushing it back out.

A milder alternative would be to query the user at the beginning of a call, the way software does when it thinks you're about to overwrite a file. "Are you sure you want to do this stupid and dangerous thing?" the cellphone might ask. Or maybe we should limit calls to some small amount of time, then prevent you from redialing until you stop the car. Whatever we do to inhibit calls from moving vehicles, it would have to be mandated by law, as it would surely be unpopular. Everyone believes that he or she alone can use a cellphone faultlessly; it's the other driver who's the problem.

So here's my big idea. Remember the early days of high-occupancy-vehicle lanes, which you can use only with a passenger? Some people bought dummies to put in the passenger seat. Suppose we took these dummies and instrumented them so that a cellphone voice came out of their mouths, lips moving in sync with the words. Every now and then the dummy would nod its head, look at the road, glare at the driver, and say, "Watch the road, dummy!"

Maybe you have a better idea. I sure hope so. ❑

ILLUSTRATION: CRISTIANA COUCEIRO; CAR: SUPERSTOCK/GETTY IMAGES

SPECIAL REPORT

Winners & Losers

Our annual exercise in prognostication forces us and our contributing panel of experts to make predictions that will be tested while the writers still live

WINNERS	LOSERS
GOOGLE CHROME OS	CHEVROLET VOLT
IBM & RUSSIAN RAILWAYS	QUANTUM SUPERCOMPUTING
PIXEL QI DISPLAY	SWITCHGRASS BIOFUEL
NANOGaN WAFERS	nanoUV LITHOGRAPHY
INTRINSITY'S HUMMINGBIRD	BAD VIBE DETECTOR

FROM LEFT: KENNETH R. FOSTER; STEPHEN LACKO, CYPRESS SEMICONDUCTOR CORP.; GILDER PUBLISHING

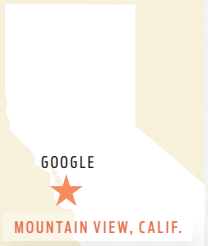
EXPERT CALLS : INDUSTRY LEADERS WEIGH IN ON OUR PICKS

KENNETH R. FOSTER
IEEE Fellow;
bioengineering professor,
University of Pennsylvania

ROBERT W. LUCKY
IEEE Fellow; former
vice president,
Telcordia Technologies

T.J. RODGERS
IEEE Member;
CEO, Cypress
Semiconductor Corp.

NICK TREDENNICK
IEEE Fellow;
editor, *Gilder Technology Report*



GOAL
A fast operating system—freed from legacy software—that boots up in under 7 seconds

WHY IT'S A WINNER
Google has nearly limitless resources and the entire open-source community at its disposal.

STAFF Because Chrome OS is an open-source project, the company says the staff is theoretically limited only by the number of software developers in the world.

BUDGET "Less than a googol"

WHEN Fourth quarter of 2010

WINNER ⁞ COMPUTING

Chrome the Conqueror

Google's new online operating system could be the Windows killer ⁞ BY SALLY ADEE

IS GOOGLE GOD? ¶ There's a test for that: omnipresent, omniscient, and omnipotent. Omnipresence? Check. There's Gmail, Google Maps, Google Calendar, Google Earth, Google Mars, Google Apps (the word-processing, spread-sheeting service). They're all everywhere, all the time.

Omniscience? The eponymous search engine is perhaps as close to a complete index of the sum total of human knowledge as has ever existed. (There's even the PowerMeter application, which can tell when you've been naughty or nice with your electricity usage.)

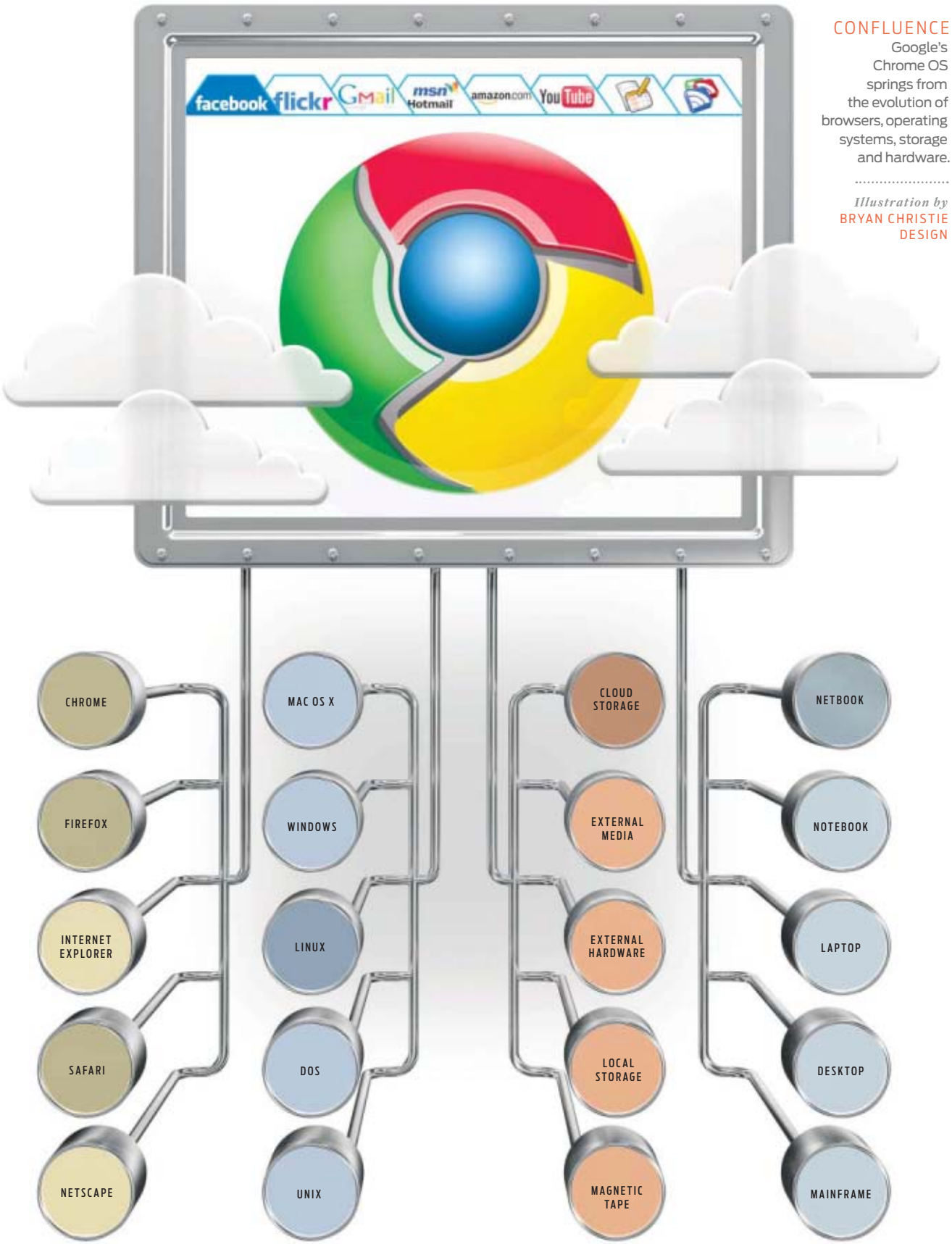
Omnipotence? That's a tough one. Google could annoy you in myriad ways if it wanted to. It could frustrate your flailing attempts to find out where the hyoglossus muscle is. Gmail could gobble up your feverish love letters; Maps could send you down an endless series of side streets long ago blocked by freeways and housing developments. Off you go to the howling wastelands of Yahoo Search and MapQuest.

But, really, why should Google bother with you when, with its superpowers, it can take on much bigger game? Like, say, Microsoft?

Last year saw the introduction of Google's Chrome browser, a variant of which can live inside Microsoft Internet Explorer. Ouch! Then came another smack with the unveiling of Google Wave, a sort of supercharged e-mail and messaging application that merges those functions and seamlessly adds other niceties—social networking, automatic translation, and other services. And later this year will come the most punishing blow of all: an entirely Web-based operating system, Google Chrome OS, which will live in ultraportable netbooks.

Although you'll never hear it from Google, the Chrome suite looks an awful lot like a dagger aimed straight at Microsoft's heart.

WHO NEEDS 500-GIGABYTE hard drives and a 6-megabyte L2 cache when lots of input ports and a fast wireless connection will do? That's the rhetorical question that has lately prompted the meteoric rise of the netbook, a barebones laptop that gets most of its muscle from online services. Google, in Mountain View, Calif., is the first software company to truly capitalize on the promise of these machines: to allow casual users to live entirely in the cloud, without realizing they're there.



CONFLUENCE
Google's Chrome OS springs from the evolution of browsers, operating systems, storage and hardware.

Illustration by BRYAN CHRISTIE DESIGN

Chrome OS has no built-in applications—no iCal, no Outlook, no TextEdit, no Word. You just turn on your netbook and you're on the Web, in what we now call the cloud, where all your stuff lives: all your photos on Flickr, a long trail of your daily foibles and frustrations on Twitter, your purchasing history on PayPal, your prolix unpublished novel on LiveJournal, your music collection on Rhapsody, and the stuff that might be a little embarrassing if your coworkers came across it on Facebook. In fact, cloud computing is what makes Google's strategy possible. "There's only a browser," says Linus Upson, a director of engineering at Google, who is in charge of Chrome OS. "And all it does is get you onto the Web really, really fast."

Cloud computing has become an everyday transaction. Those computer users who don't need to store sensitive documents locally can put everything up in the cloud without missing a beat. Nearly any application you desire—for e-mail, social networking, maps, shopping, even music—no longer needs to be stored on your computer. A significant number of people no longer use their computers for much that isn't Web-based. So why not make it as easy as possible to open your laptop, press the on button, and be where you want to be?

As an increasing number of applications become virtual—Microsoft is even taking Office 2010 into the cloud—you can use them without using a lick of your own computer's resources. Experts call the new paradigm "appliance computing," likening your netbook to your television: Your TV doesn't care whether it's fed an HD or a standard signal as long as the hardware can make sense of it. At last year's Supercomputing conference, Nvidia showed off precisely that idea: A featherweight netbook with only rudimentary graphics capabilities displayed completely photo-realistic three-dimensional rendered images courtesy of a server 500 miles away. Your Web apps—Gmail, Google Calendar, Google Docs, YouTube—are just small-scale versions of that concept.

EXPERT CALLS

"No more managing, tracking, and backup—my data and applications will be available instantly from any Internet-connected terminal. Thank you, Google."
NICK TREDENNICK

"I will admit that Google is a deity, but even they have bad-hair days. They can't have my data in their cloud. I don't trust them."
ROBERT W. LUCKY

But first, some untangling of terms, because Google insists on sowing confusion by naming the OS after the browser. The new technology is called Chrome OS, an operating system that is mostly a Web browser, but it's not Chrome, which actually is a browser. Confused? You're not alone. Google punted on the naming conventions, but the company insists that it all makes sense. And it does. But it requires a little bit of explaining.

Chrome OS is Google's stab at reinventing the operating system. To understand why, you need a little background in what makes an operating system in a regular computer and why it's in need of an upgrade.

LOSER ⁞ AUTOMOTIVE

Discharged

General Motors' Volt hybrid car is a courageous design, but it won't make money ⁞ BY PHILIP E. ROSS

SOMETIMES A PROJECT fails even though the technology it pioneers is destined to conquer the world. Take Babbage's steam-era computer, Pioneer Electronics' LaserDisc home video system, or Apple's Newton—technically brilliant, yet business failures all.

Better yet, take General Motors' Chevrolet Volt, a car known as a plug-in hybrid because it will get most of its power from the wall socket in a garage. The Volt is bold, cool, and technically feasible. It appeals to early adopters, and it's catnip for the automotive fan mags. To cap it off, a little creative accounting gives it the sheen of sky-high mileage, the better to offset GM's gas-guzzlers and thus meet future fuel efficiency targets.

GM, stung by the failure of its EV1 all-electric car of yesteryear, has put its considerable corporate muscle into the Volt, building the car into a game-changing breakthrough. But to succeed on those terms, it'll have to become a mass-market car—anything less wouldn't make enough of a difference to a company that, even in its postbankrupt state, still remains the second-biggest automaker in the world. And at a projected price of US $40 000, cosmic success just isn't going to happen.

"The first year's volume, by GM's own calculations, is 10 000 units, and you can't save a company with that. That's chicken feed. You'd need a vehicle that sells 400 000 units," says John Wolkonowicz, an auto industry analyst at IHS Global Insight, in Lexington, Mass.

Chrome OS is based on Chrome, a free, open-source Web browser Google introduced in 2008 to compete with Apple's Safari and Mozilla Firefox. Google is working with equipment manufacturers to create special hardware around the Chrome operating system, based on Linux, which will run on *x*86 and ARM chips. Chrome OS–compatible netbooks are expected to appear by the fourth quarter of 2010, just in time for the holiday shopping season.

So if the whole operating system runs inside a browser, why can't any computer use it right now? Well, at press time, there were still some pesky technical challenges that Google engineers had to solve, which is why they released the first open-source version of the code in November. Among the issues: How much storage do you build into a machine that isn't intended for off-line use? How do you come up with a smarter way to let users print to any printer without worrying about drivers? Can

GOAL
A plug-in hybrid car the masses will buy

WHY IT'S A LOSER
The car can't save enough on fuel to justify its US $40 000 price

STAFF
Reportedly 300 people

BUDGET
Reportedly more than $1 billion

WHEN 2010

"There are not enough idiots who will buy it," Johan de Nysschen, the president of Audi of America, told auto blogger Lawrence Ulrich.

The idea behind the Volt is wonderful. The car doesn't have to trade off power between motor and engine from second to second according to some exquisitely complicated mechanism or scheme. Instead, the Volt makes electricity the main course. Today's hybrids put the motor and engine in parallel so that they juggle their power contributions to the wheels according to many different parameters, including speed, battery charge, and the load on the engine. But the Volt links the power plants in series. That way the motor powers the wheels, and the engine merely engages, when needed, to recharge the vehicle's enormous lithium-ion battery. How enormous? If you drive no more than 65 kilometers (about 40 miles) and have an electric socket handy at both ends of your commute, you won't burn a drop of gasoline.

Plenty of tech-minded people love the concept, hence the aftermarket for conversions of standard-issue hybrids to plug-ins (see "Plugging Away in a Prius," *IEEE Spectrum*, May 2008). But these are unusual folk: They don't mind buying a standard hybrid for $25 000 and throwing in $30 000 to make it into something else. These are the people who tile their roofs with photovoltaic cells, harvest the energy they expend on their StairMasters, or live underground in hobbit holes to conserve heat. We love these people—they make up a significant portion of our readership—but they have little in common with the typical auto buyer, who is mainly concerned with overall costs.

In a study published recently in the journal *Energy Policy*, four engineers at Carnegie Mellon University, in Pittsburgh, found that the Volt won't save enough on gas to cover the higher purchasing cost. They assumed that the plug-in would achieve 50 miles per gallon (4.7 liters per 100 kilometers) when operating on gasoline and asked how much more mileage you could eke out by adding enough batteries to enable the vehicle to get most of its power from the grid.

They assumed (from reports about the Volt) that the car would achieve 250 watt-hours per mile (402 watt-hours per kilometer) when operating on electricity, that gasoline would cost about $3 per gallon ($0.79 per liter), that electricity would cost $0.11 per kilowatt-hour, and that the car would cover 150 000 miles (roughly 241 000 kilometers) over a 12-year life. Result: a lifetime savings of $4875, ignoring charging costs. By discounting that sum at 10 percent over 12 years, to cover the cost of borrowing money, the authors arrived at a net savings of $3000 in fuel costs over the life of the vehicle. That's what you'd save by running on wall current instead of gasoline.

people with no intention of ever having a Google account happily get by using a Chrome netbook?

THE SAME BASIC PAIN POINTS that users hate about bad browsers—sluggishness, complexity, malware, and the constant crashing—have also been the most common complaints about operating systems. That's how the Chrome operating system grew out of the Chrome browser, says Upson.

The rationale for the Chrome browser was that the vast majority of users don't need duplicate commands or such dubious features as the Home button—that house-shaped icon that takes you back to the first page that loads each time the browser is opened anew. Really, how many computer users even know what that button means? Research has shown that button to be worse than useless—inexperienced users often end up having their home pages set for them by enterprising Web sites, their browsers doomed to perpetually redirect them to GetRichByGamblingInNigeria.com. So Google built a basic, no-frills browser chassis and let third-party developers build optional extensions for the people who need to pimp their browsers with bells and whistles.

Naturally, critics complain that the Chrome browser is too plain, while conceding that it runs much faster than other browsers and takes up less memory. That's a particular plus for Windows users, whose other applications grind to a halt when an application like Firefox or Internet Explorer 6 hogs memory.

Like the browser, Chrome OS will rely on HTML 5, the latest incarnation of the predominant language used to structure Web pages. HTML 5 will make Chrome OS more powerful, mainly by improving access to rich media. Right now, in order to look at video in older browsers, you need a plug-in—a piece of software that augments your browser's basic capabilities. Think

OTTBEKMCW

"So if the extra batteries cost more than about $3000 up front, there is no way to make up the cost in future fuel-cost savings unless electricity prices drop or gasoline prices rise considerably," says Jeremy Michalek, one of the authors of the study and a professor at CMU.

He and his colleagues assume a base price for lithium-ion batteries of about $1000/kWh, meaning that the Volt would require a battery pack costing $16 000—or $13 000 higher than economic considerations can justify. Sure, battery costs may fall, and the federal government may give as much as $7500 in tax credits, shifting some of the burden from the car owner to the taxpayer. But it's still uneconomical.

Michalek doesn't deprecate hybrids; it's just that he prefers parallel designs, which can make do with smaller—and therefore cheaper—batteries. "With a lower-cost pack, there is less investment to recover in fuel-cost saving, less weight to lug around, and less risk from uncertainty of future gasoline and electricity prices," he says.

EXPERT CALLS

"We need to pursue any reasonable approach to wean the United States from its addiction to oil. If the Volt is not a commercial success, maybe its successor will be."

KENNETH R. FOSTER

"Lithium-ion batteries degrade substantially in just a few years. Owners will face decreasing range and, ultimately, the need to replace and recycle the car's giant, expensive battery."

NICK TREDENNICK

GM declined to respond to *IEEE Spectrum*'s requests for an interview. But in the company's blog, FastLane, GM's vice president for global program management, Jon Lauckner, attacked the CMU study as unrealistic, saying that its estimate of the cost of the batteries "is many hundreds of dollars per kWh higher than the actual cost of the Volt pack today. Moreover, our battery team is already starting work on new concepts that will further decrease the cost of the Volt battery pack quite substantially in a second-generation Volt pack."

So let's assume for a minute that the pack ends up costing just $8000, about the same as the hoped-for tax break, and that the Volt and other plug-ins eventually sell by the millions. That'll cost the government tens of billions of dollars a year in subsidies, so the bailout of Detroit will go on and on. And it won't just be a bailout for Detroit: GM's rivals will also be standing in line for those subsidies. Indeed, Daimler, Fiat, Mitsubishi, Nissan, and mighty Toyota, father of the Prius, are coming out with all sorts of electric-drive vehicles, just in time to take the shine off GM's tail fins.

The Prius offers a sobering view of what the Volt is up against. It is easily the most extraordinary tech success story that the auto industry has had in decades, yet Toyota took a long time to reach the break-even point. "I don't think they're making money on it even now," says IHS Global's Wolkonowicz.

GM can't afford to lose money on the Volt, not even in the short run, because it doesn't have a stable of great new products waiting in the wings to help defray the Volt's start-up costs. Look at GM's market share, which has been falling not just for years but for decades.

Archrival Toyota is experimenting with plug-in hybrids—although apparently not serial hybrids—and says the technology is promising but unripe. "We are indeed committed to the technology, but we are being open about the tech progress—and the key issue is battery technology," spokesman John Hanson told *Spectrum*. "For the plug-in to become a mass-market success, we need a breakthrough in battery technology that will deliver three things: higher energy density, lower cost, and higher overall performance than lithium."

The Volt is a fine idea, but it just can't do what GM is asking it to do. ❑

Quicktime, which lets you watch YouTube videos of skateboarding cats, or Adobe Reader, which lets you look at a PDF document right in your browser window. But HTML 5 displays rich media without the assistance of plug-ins. Chrome not only won't need them—it might not even support them.

So what does Google get out of all this? After all, apart from the netbooks (which by some estimates will sell for between US $400 and $700), Google is giving the entire Chrome suite away for free. Recall that Google makes its money from the ads that people see during the course of their everyday Web surfing. So if these people surf more, Google profits more. "We noticed that when people can use the Internet faster and more easily, they are able to use the Internet more," says Chrome OS engineer Upson. "And that means Google makes more money."

To that end, Google's main bragging right is "power button to Web" speed, or how fast you can get from having a shut-down computer to reading your e-mail. Google Chrome, the company promises, will do it in 7 seconds. Contrast that with even the best computers, which can take 45 seconds to boot up. Where does that big difference come from? A computer that runs many applications has a lot of chores to do when you hit the on button. Among these are loading the firmware (a kind of software that deals with the most basic operations, which allow a device to function—for example, by making it aware that its various components exist so it can start delegating tasks to them), initializing various drives and ports, and looking for any external devices. Some of these don't exist anymore, but the legacy firmware will spend time checking for them anyway. Raise your hand if you remember Zip drives.

That eats into the boot-up time before the operating system has even loaded. But even after it does load, you're still not out of the woods. The next obstacles are the auto-start applications that have been configured to fire themselves up the moment the system starts: virus protection, office reminders, updaters, self-

monitors, and so on. These applications grow on your hard drive like ivy. If you don't prune them mercilessly, within a few years they'll have clogged up your system's memory and your once blazingly fast computer will creak like an old rocking chair.

GOOGLE TRASHED most of these processes. By getting rid of all software except the browser, engineers were able to prune a tremendous amount of legacy software. Virus protection? Part of the browser. Calendar reminders? In the cloud; subtract a couple of seconds. Google's partners will replace the hard disk drives in the new Chrome netbooks with solid-state drives (the kind that are on your mobile phone). That means no moving mechanical parts—subtract a few more seconds. An operating system that's also a browser means you'll never have to double-click an application icon again—subtract another second. And so on.

Not surprisingly, Microsoft isn't too happy about all this. The software giant can't complain about an unseen OS, which leaves it to talk up Windows 7. A Microsoft spokeswoman told *IEEE Spectrum* in a canned statement that people have purchased Windows 7 twice as often as they purchased any of Microsoft's previous operating systems.

Microsoft's confidence may stem from a misconception that Chrome will be bound to the netbook. However, given the open-source nature of the code, Chrome's migration into other hardware is just a matter of time. In late November, Google cofounder Sergey Brin intimated that Google Chrome OS will not stay in the netbook ghetto for long. Eventually, he said, the operating system will also be available on notebooks and desktops. "There are no technical limits," he said.

FAST, SECURE, FREE—is that where the Web is headed? If it is, it wouldn't be the first time. Consider the story of Microsoft's "free" Hotmail. In 1999, Hotmail offered users 2 MB of free storage, but for most users spam quickly devoured that allotment if they weren't vigorous about maintaining their pittance of free space. Disingenuously, Microsoft (or MSN) made available a paid upgrade if you couldn't live on that pittance: Various plans charged users between $19.95 and $59.95 a year to upgrade to between 10 and 100 MB. In 2004, Google blew a hole in that business plan with Web mail that gave away shocking amounts of storage: 1000 MB, a number that kept growing at such a rate that users couldn't keep up with supply (it now stands at 7384 MB). Lo and behold, in 2004 Microsoft announced that it was upping its free storage offering to 250 megabytes at no charge. Now it's all free—even Yahoo offers theoretically unlimited free storage.

Where Are They Now?

2009 WINNER

"Manhattan Project" for a next-gen artificial arm

UPDATE Apparently, there have been major advances in prosthetic arms resulting from clinical and home trials that were part of a Defense Advanced Research Projects Agency/Veterans Affairs collaborative effort. In September, a DARPA spokesman teased *IEEE Spectrum* with talk about a "major event" scheduled for early next year.

VERDICT We were right!

And yet, even a plan as seemingly bulletproof as "let me give you this great thing for free" has its skeptics. "I think we still have a long way to go before cloud computing becomes something that we can all use on a day-to-day basis," says Mike Halsey, an IT support engineer and teacher based in Sheffield, England, and the author of the *Windows 7 Power Users Guide*. "What about playing music or video on the move, or editing photos on one service when they're stored on another?" Halsey asks.

Halsey's particular beef is that the cloud is not yet reliable enough to support Google's Web-only vision. "It's certainly not ready for the mainstream as things stand," Halsey concludes. Let's say you're in the clouds (you're stuck on an airplane without Wi-Fi), and yet, ironically, cut off from your access to The Cloud. The thought of a $400 brick sitting in your lap for the entire 6 hours you spend on a flight between New York and Frankfurt might give you pause. A Google spokesperson told *IEEE Spectrum* that Google has no plans to mitigate the issue by installing off-line applications—a word processor, say, or an e-mail client—as insurance against the times when no Internet connection is available.

So the cloud is still the kink, but the cloud will improve. And so will Google, right along with it. It's worth pointing out that many companies store sensitive documents in the cloud right now, and some of them use the enterprise version of Google Apps. Here's the predictable scenario: The programs will evolve with use, as more developers test-drive Chrome's capabilities and more geeks customize it with every extension you can possibly imagine. In the end, Google's user base will expand the extensions to areas that not even Google can imagine. People will spend even more time surfing, and out of the corners of their eyes they will see ads from Google, making a rich company even richer. And that means the benevolent deity will continue to make fast and fun toys.

But before you sign your entire life over to Google, you might consider a minor sticking point. "Google has been able to treat users really well because it's been so profitable," says Siva Vaidhyanathan, a cultural historian and media scholar, who is an associate professor of media studies and law at the University of Virginia. He is working on a book called *The Googleization of Everything*. Google's benevolence, Vaidhyanathan says, isn't something we should get too used to. "Henry Ford thought he was saving the world, too," he says. "It's really important to be suspicious about any egalitarian claim by any corporation. Corporations are, and should be, in the business of business. Any claims of making the world better should not be important to those of us who use the services and products. In fact, we are Google's products, because Google actually sells us." ❑

RAINER FACKLAM

EUROPE DIRECT High-speed lines connecting St. Petersburg to Helsinki and Moscow to Nizhniy Novgorod are under development.

WINNER | TRANSPORTATION

Russia Reinvents Its Railroad

IBM overhauls Russian Railways' software infrastructure | BY SANDRA UPSON

IT'S NO EXAGGERATION that the backbone of the Russian Federation is its railways. With 85 500 kilometers of track and 664 600 railcars transporting people and goods across 11 time zones, Russian Railways is practically a force of nature.

As Russia's fourth-largest revenue earner, the state-owned railroad, based in Moscow, is also an economic force. It employs 1.2 million people, and many millions more rely on the trains to make their living. A brand-new high-speed line now shuttles between Moscow and St. Petersburg in just three and a half hours. At the tiniest whistle-stop, hawkers greet trains with boiled potatoes and pickles, local growers offer buckets of berries, and taxi drivers mill about, ready to scoop up travelers.

If the railroad drives the economy, data drives the railroad. No freight train on the 170-year-old railroad moves without documentation of its contents, the contract for their delivery, and the route map that defines the train's journey. All that information gets tracked by a string of data centers, aided by an optical-fiber network that mirrors every kilo-

GOAL A redesign of the company's IT infrastructure that consolidates data centers and adopts new automation software

WHY IT'S A WINNER The project will substantially improve the efficiency of one of the world's largest, most vital rail networks.

STAFF Hundreds of employees at both IBM and Russian Railways

BUDGET Info not available

WHEN Major tasks of consolidating the data centers will take place from 2010 through 2014.

Illustration by BRYAN CHRISTIE DESIGN

meter of track. In total, the data centers manage the movements of the 1.3 billion passengers and just as many tons of freight that pass through the country's far-flung depots each year.

It's strange, then, that Russian Railways' investment in information technology has been minuscule—just 0.6 percent of its total budget, according to Alexey Illarionov, the company's chief information officer. That's between an eighth and a quarter of what a typical transportation company spends, he adds.

No more. In an effort to catapult its operations into the 21st century, Russian Railways has struck a technical partnership with the U.S. computer giant IBM, based in Armonk, N.Y. With IBM's help, the railway is at last overhauling the hardware, software, and communications architecture that underpin its operations. The overhaul will centralize the management of data into new comput-

ing hubs, restructure the collection of information on the railroad's field operations, and integrate new automation software to help the railway strategize how to deploy its assets. When the redesign is completed in 2014, the company will do business in a fundamentally new way.

IN HIS MASSIVE OFFICE at company headquarters in Moscow, behind a hulking desk and flanked by a wall-blanketing map of Russia, sits Illarionov, the man behind the transformation. "For most companies, IT is pretty straightforward," he says in Russian, settling in with a brief tug at the lapels of his wheat-colored suit. "We have a very broad set of tasks—for us it's a complete mix."

Illarionov wants the railway to shake off the last vestiges of Soviet-era planning and become a more nimble, modern operation. The first step, he says, is to do away with the railways' diaspora of data centers. Currently there are 17 of these regional branches, each managing the data for a subsidiary railway—an arrangement that made sense back when the regional railways made a lot of operational decisions on their own. Now these centers just slow down operations, making it harder to monitor activity in real time. It's also a managerial nightmare. "Maintaining 17 separate, data-intensive centers and making sure I have a well-trained, well-equipped staff for each has been a burden," Illarionov says. Eventually, there will be just three data hubs, located in St. Petersburg, Moscow, and Yekaterinburg, which sits on the border between Europe and Asia.

That's just the beginning. Ultimately, the new computer network will unify hundreds of discrete software applications into one integrated data environment. "The plan has a simple landscape," Illarionov says, looking down at his desk and swirling his black coffee in its cup. The scale of the project, however, is "colossal," he says.

He ticks off three of the biggest challenges his team and IBM are grappling with. First, to break down the historical divisions between the regional lines, they must write software to redistribute the computing tasks to the three new hubs. Second, Illarionov still works with paltry sums, a problem complicated by the fluctuating valuation of the ruble, which makes budgeting a rather strenuous exercise.

EXPERT CALLS

"Congratulations to IBM on its huge IT win. Congratulations to the Russians on their new IT system. However, I wouldn't short the stock of any shipping company that's currently five times as efficient as the Russian railroad."

T.J. RODGERS

"I'm skeptical about overhauls of gigantic business operations, particularly state-owned businesses, where the connection between incentives and outcomes is weak."

NICK TREDENNICK

LOSER ⋮ COMPUTING

Does Not Quantum Compute

D-Wave Systems' quantum computers will likely be costlier and slower than conventional ones

BY ERICO GUIZZO

D-WAVE SYSTEMS, a Canadian start-up, recently booted up a custom-built, multimillion-dollar, liquid-helium-cooled beast of a computer that it says runs on quantum mechanics.

That's right. D-Wave, a 55-person company operating out of an office park in Burnaby, B.C., claims to have built that almost mythical machine, that holy grail of computing, the stuff of sci-fi novels and technothrillers—the quantum computer. Such a system would exploit the bizarre physics that apply on ridiculously small scales to compute ridiculously fast, solving problems that could stymie today's supercomputers for the lifetime of the universe.

Now, building a practical quantum computer has proved hard. Really hard. Despite efforts by some of the world's top physicists and engineers and the likes of IBM, HP, and NEC, progress has been slow. Ask the experts and they'll tell you these systems are a decade—or five—away.

Yet D-Wave believes it can build them now. It has raised some US $65 million from investors that include Goldman Sachs and Draper Fisher Jurvetson, enlisted collaborators from Google and NASA, amassed 50 patents, and transformed its offices into a world-class quantum lab.

Is Schrödinger's cat really out of the bag?

To put things in perspective, consider that one of the most celebrated feats in quantum computing is the factoring of the number 15 (yep, that'd be 3 times 5). The problem is that today's state-of-

MCKIBILLO

the-art quantum systems can juggle only a handful of quantum bits, or qubits—the fundamental units of information in quantum computers. Whereas a conventional bit can be in one of two states, 0 or 1, a qubit can be 0, 1, or a superposition of 0 and 1. By linking and manipulating qubits, you can carry out quantum algorithms that solve problems in fewer steps and thus faster than with regular computers. With enough qubits—hundreds to thousands—quantum computers would be able to crack some of the hardest codes, search databases superquickly, and simulate complex quantum systems such as biomolecules.

Rather than build a multipurpose quantum computer, D-Wave says it is building a specialized one, designed to solve specific math problems that have applications in science and business. Its current system has 128 qubits, which the company claims are enough for a research device, one that probably won't beat a powerful PC. To solve larger problems and outperform conventional computers, D-Wave plans to scale up to tens of thousands of qubits in the next two years, eventually reaching millions of qubits.

But experts are skeptical that D-Wave's quantum computer is really, well, quantum.

"If this were the real thing, we would know about it," says Christopher Monroe, a quantum-computing researcher at the University of Maryland, in College Park. He says D-Wave hasn't demonstrated "signatures" believed to be essential to quantum computers, such as entanglement, a coupling between qubits.

Paul Benioff, a physicist who pioneered quantum computing at Argonne National Laboratory, in Illinois, notes that even the best prototypes can't keep more than 10 qubits in entangled states for long. "Because of this I am very skeptical of D-Wave's claims that it has produced a 128-qubit quantum computer," he says, adding that talk of reaching 10 000 qubits at this point is "advertising hype."

Anthony Leggett, a physicist at the University of Illinois at Urbana-Champaign and a Nobel laureate in physics, says that D-Wave has made claims that "have not been generally regarded as substantiated in the community."

But it's all for real, says Geordie Rose, the cofounder and chief technology officer of D-Wave. "We are making good progress," he says, explaining that they are currently testing three 128-qubit systems, to be installed at institutions that will use them for research.

D-Wave's system uses a chip with little loops of niobium metal containing Josephson junctions—two superconductors separated by an insulator. When the chip is cooled to very low temperatures, tiny electrical currents flowing around the loops exhibit quantum properties, and you can use the direction to represent the states of a qubit: Counterclockwise represents 0, clockwise represents 1, and current flowing both ways represents a superposition of 0 and 1.

D-Wave's superconducting qubits are not new, and other groups use similar devices. But whereas most groups are trying to build the quantum logic gates from which all computing operations can be derived—an approach known as the gate model—D-Wave has adopted a different approach, called adiabatic quantum computation. Here's the gist: You initialize a collection of qubits to their lowest energy state. You then ever so gently (or adiabatically) turn on interactions between the qubits, thus encoding a quantum algorithm. In the end, the qubits drift to a new lowest-energy state. You then read out the qubits to get the results.

With enough qubits, D-Wave believes it could beat today's best methods for approximating the solution to difficult optimization problems in financial engineering, logistics, machine learning, and bioinformatics, either by getting the same answer faster or getting a more exact solution.

And herein lies the $65 million question for the company. By its own admission, D-Wave will have to go bigger than 128 qubits. But can its system scale up?

Qubits are fragile entities, and stray magnetic fields and other environmental disturbances easily destroy their quantumness, or coherence. David DiVincenzo, a leading quantum computing expert at IBM's T.J. Watson Research Center, in Yorktown Heights, N.Y., says that "there has yet to be an established methodology for how [adiabatic quantum computation] could function fault tolerantly," that is, with effective error correction.

Umesh Vazirani, a computer scientist at the University of California, Berkeley, says D-Wave hasn't taken into account the need to control the rate of the adiabatic process. "Running the adiabatic algorithm without this 'tuning' gives no speedup," he says.

For its part, D-Wave hasn't backtracked. Rose, the CTO, says the company is working on new experiments and simulations that should confirm whether its system operates as a quantum computer.

D-Wave's investors are happy with the company's progress. "Quite happy," says Steve Jurvetson, a director at Draper Fisher Jurvetson.

Hartmut Neven, a Google scientist who is using D-Wave's computer to design and test image-recognition algorithms, says the company is taking a "very sensible approach" and has "a very good chance at getting it to work."

Rose says the collaboration with Google shows that the company is tackling real-world problems, even if it's at the proof-of-concept level. "Our ultimate objective is to build systems with spectacular performance on these sorts of problems," he says.

But when asked whether things are still on track to reach tens of thousands of qubits in the next couple of years, Rose dodges the question. "Right now we are concentrating all our resources on getting the 128-qubit systems up and operational and delivering them to customers," he says.

Which means D-Wave still has a long way until it can build a quantum computer that can solve large real-world problems—and that companies would pay good money for.

Looks like Schrödinger's cat is still in the bag after all. ❑

D-WAVE SYSTEMS

BURNABY, B.C., CANADA

GOAL
A commercial quantum computer that can solve optimization problems faster than ordinary computers.

WHY IT'S A LOSER
There's no convincing evidence that it works like a quantum computer; even if it does, its algorithms aren't likely to go faster than those of classical ones.

STAFF 55 full-time employees and 60 collaborators

BUDGET
US $65 million

WHEN A 128-qubit system is "available for purchase"; 1000-qubit systems expected by 2010–2011

EXPERT CALLS

"This will never work—if you define 'never' as 'not in 20 years.'" ROBERT W. LUCKY

The greatest difficulty, though, arises from the fact that Russian Railways' hundreds of software engineers are developing more than 400 projects in parallel, all of which will have to interact with the consolidated data platform. As any computer programmer knows, writing and debugging just one chunk of code takes time and great care. Seamlessly integrating that software with code written by others is exponentially harder. "The scale of transformation—the number of people involved and the huge number of applications we are forced to consolidate—makes this IBM project unique," Illarionov says.

Consider a few of the many tasks the network must perform. On the most basic level, it must calculate payroll for 1.2 million employees. It must also continuously track the locations, routes, and contents of 624 900 freight cars as they chug across Europe and Asia. In addition, it has to keep tabs on 39 700 passenger carriages crisscrossing the landscape and the round-the-clock ticketing of the 1.3 billion people who ride them every year. Amid those terabytes of data, the railway's databases must also tally the spare parts that the cars, locomotives, and signaling systems may require and keep tabs on the work crews who perform repairs on trains and tracks.

The fruit of these herculean labors could be truly sweet, for Russian Railways and for Russia. By operating its infrastructure more efficiently, the railway will be able to move more passengers and potentially lower its rates for transporting freight, perhaps attracting more Asia-to-Europe traffic along the Trans-Siberian Railway. Lower transport prices could in turn increase demand for the vast stores of raw materials in Russian mines—including nickel, cobalt, diamond, and coal. And for IBM, the project represents a visible foothold in an emerging market that the company views as pivotal to the future of its hardware business.

SHOWCASING ITS BIG IRON is part of IBM's goal. The new data hubs will each be stocked with a handful of powerful IBM System z10 mainframe servers, introduced in 2008, each packing the computing power of 1500 ordinary servers, according to the company. IBM dominates the market for these behemoths, but that's not hard, because most of its competitors have left the business. In all, mainframe-related revenue accounts for almost half of IBM's operating profit, according to financial analysts at Sanford C. Bernstein & Co.

The geriatric machines that the new mainframes will replace include Soviet-built clones of IBM's Cold War–era computers, called ES EVMs (the transliterated Russian acronym for "unified system of electronic computing machines"). Starting in the late 1960s, Soviet computer scientists began reverse engineering IBM's hugely successful System/360 and System/370 mainframes, and Soviet electronics makers copied the components. The machines worked well, but Anton Efremov, who heads the travel and transport team at IBM's Russia division, is glad to see those old computers go. "When I was trying to sell hardware during the '90s, I had to compete against the secondhand market of IBM clones," he explains. By replacing some of those machines, the company will gain an increase in performance by a factor of 10 000, if not more.

Each data hub will consist of two identical sets of servers, one for actual operations and the other as backup. Should one or even two of the hubs go down in a natural disaster or an attack, there would still be enough computational power to keep the network up. "What we're doing now is coming up with the microdesign for how we would continue, how we would distribute the workload between data centers, and what would be the critical processes," Efremov says.

Once all three hubs are in place, the tricky task of shifting the data and computing from the regional centers will begin. Such handoffs are perilous, and the railroad will still have to operate during the transition. So to avoid a misstep, Russian Railways will roll out the new network gradually, over three years. The calculations needed to manage passenger train movements, ticketing, and back-office operations for three of the country's regional railroads are currently being shifted to the three new hubs. By the end of this year, about half of the railroads' computing tasks will have migrated to the new hubs, and the following year cargo operations will have moved as well. Soon after, the backup servers at the three sites will be up and running, and in 2013 the vestigial data centers will likely be shut down. Some of the centers' workers will relocate, but others will lose their jobs. That's the irony of efficiency: By shuttering its far-flung data centers, Russian Railways will be pulling jobs out of those territories in order to serve them better.

To help manage all that data, Russian Railways software engineers are writing hundreds of new applications that, taken together, about 150 000 employees will use. The new software will encompass traffic management, digital document entry, and the sales systems for passenger and freight transport. These programs will replace applications that are at least a decade old; a few of them date back to the 1960s. A lot has changed in the programming world since that software came online, and the new system will reflect the latest thinking, espe-

RAINER FACKLAM

Where Are They Now?

2009 WINNER

Intel's Larrabee: a hybrid CPU and GPU

UPDATE In early December Intel put off indefinitely the commercialization of its stand-alone Larrabee graphics chip, which was to have blended the best features of CPUs and GPUs for such jobs as ray tracing, a technique used to create photo-realistic digital images. The move leaves the chips by Nvidia and AMD in command of the market. Interviewed last year, Andy Keane, then general manager of Nvidia's GPU Computing business unit, told *IEEE Spectrum* that by the time Larrabee's chip entered mass production, it would already be obsolete. He may have been right.

VERDICT We were wrong!

cially in terms of integration. "It will not be artificially assembled from different pieces but designed from the very beginning to operate as a whole software complex," Illarionov says.

In addition to in-house software, the network will rely on several IBM software packages, including one called Maximo, which helps companies manage and monitor their assets. In Russian Railways' case, those assets include not just the tracks, cars, and locomotives but also the electricity and telecommunications lines.

The new software environment will eliminate the enormous paper trail that now follows most day-to-day activities along the tracks. By moving to electronic transactions, the company hopes to cut down on a major source of error and speed up the availability of information. Of course, it also means many more bits and bytes to move around. Illarionov estimates that the IT infrastructure will eventually register more than 120 million digital transactions per day on a wide variety of activities. That's at least 20 times as many transactions as a large telecom operator handles, he says. Right now, his team is conducting a pilot project that's logging 2.5 million transactions daily.

Data security will be a bigger challenge for the new system. "One of the things you really struggle with when you move from paper to electronic is how to validate it: How do you know these are real requests and that the data is accurate?" says Randolph Resor, a policy analyst at the U.S. Department of Transportation. "If the data isn't accurate, the system is worthless." That's why each one of the 120 million transactions in the railroad's network will have a digital signature, an encrypted bit of code that ensures the transaction is valid. For an operation as sprawling as a transcontinental railroad, that simple innovation will be essential to keeping the electronic documents flowing.

Among other things, the new scheme should result in a tighter, more efficient use of the tracks. "Your timetable is very critical. You've got to make sure you're running the right numbers of train sets at the right time of day," says Nigel Davies, a vice president for business development at Interfleet Technology, a rail technology consultancy based in Derby, England. "If your systems are out of date, as in Russia, then the number of trains you can run in a span of time is limited." In other words: Railways make money by keeping things moving.

Tracking everything electronically will also avoid a most unpleasant phenomenon: the disappearing freight car. The car itself hasn't vanished, of course, but if the tracking system doesn't know where it is, it may as well have. Such a mistake can be costly, and it can be dangerous. In a previous job, Resor investigated a missing U.S. freight car carrying caustic acid. During the month when the car went rogue, the acid ate through its walls, leached out, and sent two dozen people to the hospital.

THE STORIED TRANS-SIBERIAN RAILWAY, efficient at last, may finally start to compete successfully with oceanic shipping between Asia and Europe. According to Forrest Van Schwartz, managing director of the Global Transportation Consultancy, in Madison, Wis., transporting goods from mainland China to Europe by way of Russian railroads currently costs five times as much as moving containers by sea from Beijing, around Singapore, through the Suez Canal, and past Gibraltar to Europe's ports. Part of the problem, he surmises, is that too many railroad employees are doing jobs better done by technology. "It's as much a social, keeping-people-employed program as it is a transportation company," Van Schwartz says.

That may be so, but the company is also an integral part of life in Russia. The Trans-Siberian made Russia's Far East accessible to the Western world for the first time, and during World War II the rail lines were essential for transporting soldiers and military equipment to the front lines and for ferrying supplies and people to safer locations deeper within the country. After the collapse of the Soviet Union, the railroad again became a lifeline. Struggling factories sometimes paid their workers with their own wares, forcing them to become off-hours salespeople. In Vekovka, outside Moscow, workers from a crystal factory walked the train station's platforms with vases and chandeliers hoisted above their shoulders, hoping to catch the eye of a seated passenger.

Even now, the railroad is the only means of transport for countless Russians and for the coal, timber, and valuable minerals in distant corners of the country. Roads quickly become impassable in the frigid winters, and commercial air traffic is limited in most places, leaving few options for traversing the 17 million square kilometers that make up the world's largest country. Opening the arteries that allow people and exports to flow can only be good for the railway and the people it serves. ❑

RADICAL RAILROADS

To some readers, railroads may still evoke the chugs and puffs of industrialization or robber barons in top hats. These centenarian networks are indeed ripe for reinvention, but they were also some of the first innovators when it came to data management. "Railroads were probably the original users of IT," says Edward Burkhardt, the president of Rail World, a Chicago-based company that specializes in railroad restructurings. "They always had huge amounts of data to manipulate, long before any IT came along." Masses of clerical employees kept track of millions of transactions one way or another, sending cargo shuttling along the steel rails. The hunt for an automated way of tracking cargo eventually led to the invention of bar codes, which were initially developed as electronically readable labels for freight cars. Throughout their history, railways have forged ahead, with information technology at their side. —*S.U.*

ISTOCKPHOTO

PIXEL QI CORP.

SAN BRUNO, CALIF. (& TAIPEI, TAIWAN)

GOAL
A commercial LCD that offers e-paper's power savings and readability in sunlight

WHY IT'S A WINNER
It supports both color and full-frame video, which makes it versatile enough to use in computers.

STAFF Info not available

BUDGET Info not available; completed venture finance round in March 2009

WHEN Displays began shipping to device manufacturers in December 2009; products should reach consumers by early 2010.

WINNER ⁞ COMPUTING

The Take-Anywhere, Do-Anything Display

Pixel Qi's screen gives you color when you want it, power when you need it ⁞ BY JOSHUA J. ROMERO

I'M WATCHING A CLIP from *Slumdog Millionaire* on what looks like a standard netbook computer, a scene in which deep blue body paint gives way to luscious saffron-yellow cloth. The picture quality is fine, if nothing special. But then I push a small white button at the side of the display, and it does something I've never seen before: The backlight disappears, and the image turns black and white, remaining visible thanks to the overhead lights in the room. I hold up an Amazon Kindle by way of comparison. Both displays have the same crisp gray-scale text I've come to expect from e-paper.

"You can easily cheat in a demo like this," says Mary Lou Jepsen, the creator of the prototype screen, "but most movies are shot in very dark conditions, which is hard to display." Jepsen, who has brought her new liquid crystal display to *IEEE Spectrum*'s New York City offices, seems confident that her new technology is good enough to take on any challenge. When we step into the bright September sunlight, her new LCD easily outperforms the other screens she brought along for comparison. In black-and-white mode, it's nearly as bright as the E Ink display on the Kindle, but it also provides seamless video playback. And the expensive indoor-outdoor LCD in her small Toshiba R600 laptop is so dim and washed out that it doesn't stand a chance.

It seems that at last we have a screen that gives you what you want, when you want it. If you need to extend your battery's charge or work outside, you can have perfectly good black-and-white text. If power and sunlight are not a problem, you can watch a full-color movie. It could be the most versatile display ever made, and it comes from Pixel Qi Corp., Jepsen's company in San Bruno, Calif. Jepsen has both an electrical engineering degree and a Ph.D. in optics, and she's had plenty of experience in the display field—first with Microdisplay Corp., a

LCD PIXEL DESIGN

TRADITIONAL TRANSFLECTIVE In traditional pixels, light is lost to absorption when it passes through color filters. In the reflective part of the pixel [bottom], the light must pass through the color filter twice.

PIXEL QI DESIGN Most of the pixel real-estate is reserved for reflection. The reflective part of the pixel renders only black and white, so there's no light lost to color filters.

REFLECTIVE BLACK AND WHITE When the backlight is turned off, the display relies on ambient light alone and looks like e-paper. It uses much less power than a typical LCD and can still handle video playback.

TRANSFLECTIVE COLOR For most applications, this combination mode provides a practical mix of power savings and color images.

TRANSMISSIVE COLOR In completely dark situations—working on an overnight plane or reading in bed—the backlight can be turned up, making the display behave just like a traditional LCD.

Illustrations by BRYAN CHRISTIE DESIGN

company she started in 1995 that built liquid crystal on silicon chips for high-definition TVs, and later at Intel, as chief technology officer of the display division.

But she first developed the idea of a dual-mode display while working at the nonprofit One Laptop Per Child Association, which aims to provide educational computers to the poorest children in the world. Jepsen, a cofounder of the organization, was given the task of creating a screen that would use very little power and could be read outdoors, without sacrificing color or video capability. It also had to be inexpensive. Gaining unprecedented access to the big Taiwanese LCD manufacturers, Jepsen was able to create just such a display.

In 2008 she left OLPC to found Pixel Qi, with the goal of creating a similarly versatile screen for mainstream users and manufacturers. In late May 2009, Pixel Qi introduced the first prototype of the 3Qi display and began mass production in December; it expects multitouch tablet PCs featuring the display to ship in early 2010. John Ryan, Pixel Qi's chief operating officer, says it costs slightly more than a standard LCD screen, but Jepsen maintains that it'll still be inexpensive enough to go in products priced as low as US $200.

Pixel Qi's first production display is a 10-inch screen with 1024 by 600 pixels in the full-color mode. It's the first LCD screen that's optimized for mobile computing, in which the most common activity is the reading of text—in e-mail, code, or on a Web site. In adequate light, you can easily read and write without wasting any battery power on the backlight.

The design thus runs counter to the tendency in the LCD world to continually improve video quality for the more lucrative television market. For several years, laptops have generally offered the option of a glossy "cinema" display, and while that's great for watching movies in the dark, it's virtually useless for working outside, or even in front of a big window.

It's in such bright light that the Pixel Qi screen shines. When switched to its reflective mode, the 3Qi triples its resolution to 200 dots per inch, as compared to the 167 dpi of a Kindle. True, the contrast ratio is lower, but in our unscientific comparison, it didn't make much difference. And if you find yourself in poor lighting, you can set the 3Qi's backlight to its lowest setting, which increases contrast and also adds color.

EXPERT CALLS

"I've seen Jepson's displays for One Laptop Per Child, and I've really been impressed with both the technology and its performance."
ROBERT W. LUCKY

"I want one!"
KENNETH R. FOSTER

But computers, unlike e-readers, require more than just legibility. Because the 3Qi is an LCD at heart, it can easily provide real-time visual feedback—things as simple as an animated, mouse-controlled cursor or letters that appear as soon as you type them. Such simple functions don't work well with slow-refreshing e-paper. On the Kindle, for instance, "turning a page" takes nearly half a second.

"For the really big markets, you've got to have color, you've got to have video—that's what the customer demands," says Jason Heikenfeld, a professor of electrical engineering at the University of Cincinnati, who studies displays in his Novel Devices Laboratory. That's why he believes dedicated e-readers will be limited to their current small market unless they become more versatile. "Pixel Qi is not e-paper, but it's doing the things that e-paper will have to do" to expand beyond its current niche, he says.

The Pixel Qi display consumes far less power than traditional LCDs, drawing a peak of about 2.5 watts, of which

MCKIBILLO

LOSER ⋮ ENERGY

Biofoolish

DuPont Danisco Cellulosic Ethanol makes biofuel from switchgrass, but the environmental benefits are highly questionable

BY DAVID SCHNEIDER

OF ALL THE POSSIBLE biofuel crops that can be grown in the United States, perhaps the most attractive is *Panicum virgatum*, otherwise known as switchgrass. A hardy perennial native to North America, it needs little fertilizer and water, and pests don't seem to like it much. So it holds out the shimmering promise of one day producing vast quantities of fuel in "carbon neutral" fashion, absorbing as much carbon dioxide in growth as it releases when burned.

Compared with sugarcane or corn, though, switchgrass is tricky to use, because it provides cellulose—the natural polymer that gives plants their rigidity—rather than simple sugars. So you need to do some elaborate processing, first to

break down the cellulose and then to ferment the resulting sugary brew so that it turns into ethanol, which can be served neat or blended with gasoline. As yet, nobody has succeeded in producing switchgrass ethanol on a commercial scale, and the economics of doing so remain fuzzy.

One company that believes it's on the verge of success is DuPont Danisco Cellulosic Ethanol (DDCE), based in Itasca, Ill. Founded in May 2008 by DuPont and Danisco, DDCE has just completed a pilot ethanol plant in Vonore, Tenn., which is slated to open officially in a few months. The facility, built in partnership with the University of Tennessee, will be able to produce almost a million liters (250 000 gallons) of ethanol per year from either switchgrass or corncobs. DDCE then plans to build a much larger plant in Tennessee with a capacity of nearly 60 million L a year. Meanwhile, it's taking advantage of more than US $70 million in state support to enlist farmers to start growing the grass now. The company is thus positioning itself on the cutting edge of a new "grassoline"-based economy.

"We're doing scale-up and commercialization," says Vonnie Estes, vice president of commercial development and marketing for DDCE. "Once we get it up and going, it'll be competitive with gasoline—I have no doubt."

Perhaps she should have doubts. Here's one: Will it be possible to transform the half billion or so cars and trucks in the United States so that they can use more homegrown ethanol and less gasoline? Even Estes sees that hurdle. "That's one of the big issues—creating the market," she says.

But even if a market does emerge and DDCE's production process proves highly profitable, this technology can't be considered a winner. Why? Because it will fail to satisfy the main premise for adopting it in the first place: to benefit the environment. A simple thought experiment sheds light on the dark side of grassoline.

Suppose you replaced all the gasoline the United States now uses with switchgrass-derived ethanol. How much land would that take? The United States consumes 522 billion L of gasoline a year. Because of the difference in energy density, you need about 1.5 L of ethanol to replace a liter of gasoline. So the yearly requirement for ethanol would be about 780 billion L. A hectare of switchgrass can supply about 4700 L of ethanol a year, so the United States would need to devote roughly 170 million hectares (420 million acres) to it.

That's an enormous quantity of land—almost as much as the country now devotes to farming. And even if you covered all that land with switchgrass, it wouldn't produce enough fuel to supply the country's diesel trucks and buses, its jet aircraft, or the homes and businesses that use petroleum for heating fuel.

Carpeting the continent with enough switchgrass to displace all that petroleum use is theoretically possible—but it would be an environmental catastrophe on many counts. For one, it would devastate what's left of the already besieged wilderness. And according to estimates that Timothy Searchinger of Princeton University and his colleagues published in the journal *Science* in 2008, it would also exacerbate the world's greenhouse-gas problem, not help solve it. That's because even if switchgrass agriculture were limited to established cropland, we'd end up having to convert forests and other land to agriculture just to feed ourselves. That in turn would release huge amounts of carbon dioxide into the atmosphere. Many of the wonks now working out carbon-emissions policy have missed this simple fact, an oversight that Searchinger and his colleagues pointed out in another piece in *Science* this past October.

Biofuel can't be considered carbon neutral, Searchinger

GOAL
A process that transforms a hardy native grass into transportation fuel

WHY IT'S A LOSER
It would damage the environment more than it would help it.

STAFF About 35

BUDGET
US $140 million

WHEN Pilot plant officially opens in early 2010.

the backlight accounts for about 2 W, says Jepsen. Turn off that light and slow the refresh rate, and you can maintain a static image—such as the page you're reading now—with just half a watt. That's still more power than is needed by electrophoretic displays, the generic term for the kind made by E Ink. Electrophoretic screens are bistable, which means that the pixels can maintain a static image powerlessly. But e-paper also requires a higher operating voltage than the Pixel Qi screen, which means that if future e-paper displays offer faster refresh rates, their power advantage will likely wane.

The prototype 3Qi display gives Jepsen's off-the-shelf Acer netbook an extra one to two hours of battery life, depending on what she's doing. But there's a lot of room for improvement, she says, in the ways a netbook or tablet PC can take advantage of the new screen. "Look for dramatic power savings in 2010 for devices using our screens," she says, hinting that they should be an order of magnitude better.

Pixel Qi has also beat E Ink to color. In the *Spectrum* conference room, Jepsen cranks the backlight all the way up to show off the color and video playback. The video is perfectly

says. "Even the strongest advocates in the biofuel industry would agree that it's not," he says. But biofuel advocates downplay that and other environmental risks.

Estes argues that switchgrass would be planted mainly on fallow farmland. "Where we're looking at growing these crops, there isn't anything growing there anyway," she says. Her collaborator Kelly Tiller, director of external operations for the University of Tennessee's office of bioenergy programs, notes that planting switchgrass "has good wildlife benefits" and that it stores carbon in the soil. And she points out that there are some places where switchgrass could be grown with no environmental costs at all: within highway medians, for example, or along power-line rights-of-way. And, she asks, what are the alternatives? "There is no perfect solution. This is a sustainable bridge while we develop new technologies," she says.

The benefits to wildlife and the carbon storage Tiller is talking about are, however, only valid if your baseline is traditional farming. But as Searchinger and his colleagues pointed out in their 2008 *Science* article, truly excess cropland eventually reverts to forest. And when that happens, you'd get all the wildlife-friendly, carbon-storing benefits that ensue. If you plant switchgrass there instead, those benefits are lost. "You have to look at what you give up," says Searchinger. As for growing switchgrass along highways or under power lines, that's all good, but it would put just a small dent in the problem.

What's more, if switchgrass proves highly profitable, what's to prevent farmers from raising it everywhere? Strict U.S. regulations may save forests from being replaced by fields of switchgrass, but elsewhere in the world trees would inevitably be chopped down, either to make way for biofuel feedstock or to grow the crops that switchgrass displaces elsewhere. For this reason alone, DDCE's project is destined to be a loser, even if it one day proves a commercial success. ❑

EXPERT CALLS

"If we required that all the energy for today's corn-based ethanol plants—including trucking, lighting, power generation, and distillation—come from the plants' own ethanol production, there'd be little ethanol left over."

T.J. RODGERS

"To be more than a niche solution, switchgrass would have to be raised on a huge scale, increasing food prices and thus creating massive humanitarian problems."

KENNETH R. FOSTER

watchable, although it probably wouldn't be your first choice if movies were the primary application. The colors don't look as saturated as they would on a glossy cinema display, but at least the blacks in dark scenes are very black. In other words, the Pixel Qi screen offers an excellent compromise for a class of gadgets defined by their low-cost versatility.

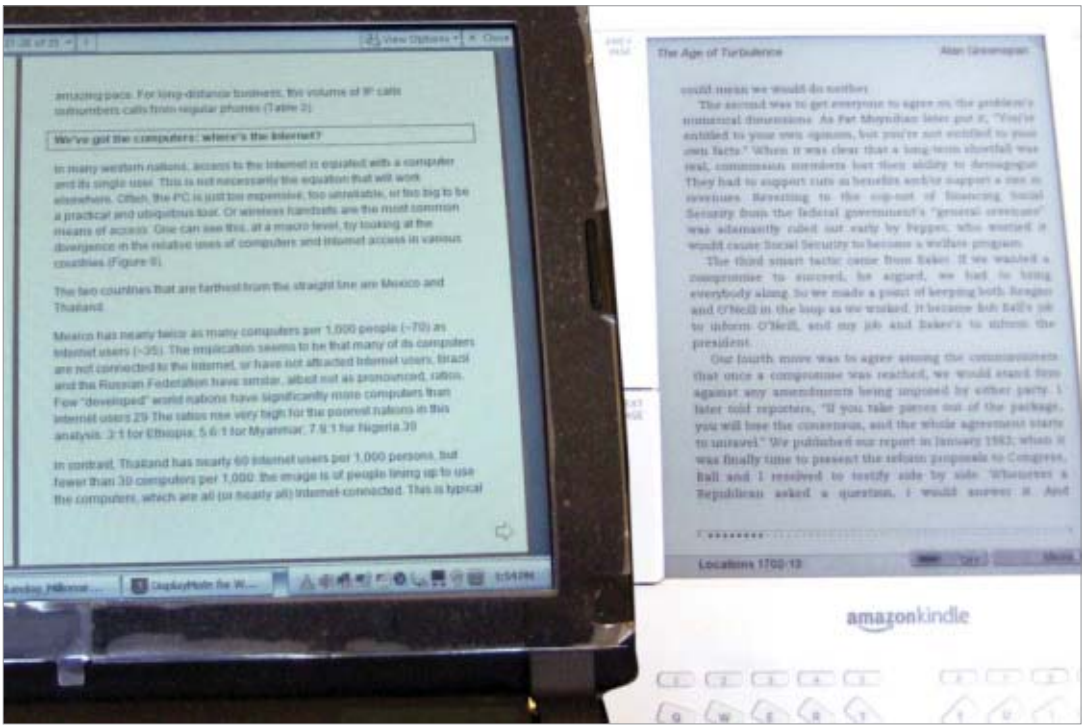
The root of that compromise is a technology dating to the 1970s, in which transmissive light (from a backlight) and reflected light (from the surroundings) combine to create a "transflective" image. But unlike conventional transflective LCD screens, such as the ones in Jepsen's Toshiba laptop or an iPhone, the Pixel Qi screen really excels in the reflective mode. Most reflective screens have poor performance because the light gets absorbed or reflected in the many layers that make up an electronic display. With paper, the gold standard of readability, "the ink is right on top, immediately interacting with the light that hits it," explains Jim Larimer, a consultant who used to develop display technology for NASA. "[Jepsen] is very good, and she's worked out a tough problem."

To improve the reflective mode, Pixel Qi reengineered and tweaked nearly every light-absorbing layer in the LCD—polarizers, optical retarders, filters, masks, electrodes, and the liquid crystals themselves. A conventional transflective screen divides each square pixel into rectangular red, green, and blue subpixels, then further divides each subpixel into transmissive and reflective areas. In the reflective subpixels, you lose light as the rays pass through the numerous optical layers on their way in, and again after they reflect off a mirror and make their way out. That's why an iPhone screen outdoors looks washed-out, with very little contrast. Pixel Qi sidesteps one source of loss by ditching color filters. In each of the rectangular subpixels, nearly all the available area is devoted to reflection. Because each subpixel is basically a mirror, the screen's reflectivity is about as high as it can get.

To allow for the transmissive mode, each subpixel contains a pinhole that lets colored light pass through. The big technical question is just how Pixel Qi squeezes so much light through such a tiny pore. Jepsen won't say how she does it. Perhaps part of the answer can be gleaned from her patent application for the old One Laptop Per Child display. The application indicates that you can improve efficiency by using a colored backlight—for instance, a red light-emitting diode to illuminate red subpixels—rather than straining white light through color filters.

"It's a bit like an orchestra of all these layers and films and fluids and surface treatments to get the light to do magic for us," says Jepsen. The payoff, though, is obvious: Because it leaves most of the screen area for reflectivity, the Pixel Qi display looks much better in natural light than any other LCD.

"For [Jepsen's] new product, I think they emphasized more on the outdoor readability to compete with e-readers," says Shin-Tson Wu, a professor of optics at the University of Central Florida, in Orlando, where he leads the Liquid Crystal Displays Lab. Wu was impressed with a demonstration he saw in a hotel room earlier this year. "Bright light was streaming through the windows, and the display just looked great. I think it's a wonderful product."



PIXEL QI VS. E INK
Both displays use ambient light to display grayscale images. The E Ink display [right] uses power only when refreshing the image, so it has lower power consumption. The liquid crystals in Pixel Qi's display [left] require constant refreshing but also allow for video playback. E Ink offers better contrast, while Pixel Qi has slightly higher resolution.
PHOTO: PIXEL QI CORP.

To be sure, new display technologies have had a spotty record, often taking longer to get to market than promised. Take the organic LED, that ultrathin, crisp, and perpetually hyped display technology. It was demoed and talked up for two decades, and by the time it began to trickle into real products, the original patents had all run out. Electrophoretic displays pioneered by E Ink took nearly nine years to get ready for prime time. "New display technologies take on average 20 to 30 years to get into mass production," says Jepsen. "It's way too long."

THAT'S WHY JEPSEN chose LCDs, a technology with a huge manufacturing infrastructure already in place. She even mandated that it should be possible to fabricate Pixel Qi's display on existing LCD lines, using available materials. So far, this pragmatic approach seems to be paying off. Jepsen's prototype passed early reliability testing, and the industry doesn't so much as cock an eyebrow when she says it's easy to make, that many companies are gearing up to make it, and that it'll get made in a matter of months. "I have very strong evidence that at least one major OEM [original equipment manufacturer] is ready to implement the Pixel Qi display in a netbook, as long as technical specs are met and business commitments are honored," says Dave Blakely, an electrical engineer by training and the director of technology strategy at the design firm Ideo.

JEPSEN IS ALREADY LOOKING at ways to improve her screens, such as adding touch-sensitive overlays and flexible back planes. Pixel Qi has yet to demonstrate a touch screen but has confirmed that the first consumer device will feature one. It remains to be seen if the added cost and the extra light absorption of such an interface might ultimately hurt the technology's two biggest selling points. But manufacturers have already overcome similar hurdles to create other touch-based e-readers.

Jepsen's display needn't do everything. It's enough that its mix of capabilities doesn't restrict it to niche environments or uses. "Ultimately, something like a Kindle will be short-lived. People are not going to want to have five different gadgets," says Heikenfeld. "Pixel Qi might be doing very well for a really long time."

"A display that combines the best of high-end LCDs—especially when you're watching entertainment or playing a game—combined with some of the best features of an e-reader?" says Blakely. "It's incredible. It's dynamite." ❑

TO PROBE FURTHER In October 2000, IEEE Spectrum *bet against reflective LCDs in "A Bright New Page in Portable Displays."*

Where Are They Now?

2007 WINNER
Innovative Silicon's Z-RAM

UPDATE Innovative Silicon has changed course. Its zero-capacitor RAM technology was meant as an embedded memory for silicon-on-insulator chips, but they haven't succeeded as quickly as ISi had predicted. Therefore, the company is developing Z-RAM in three-dimensional devices built on ordinary silicon. Korean dynamic RAM firm Hynix Semiconductor has licensed the technology, and ISi expects products within two years.

VERDICT
We were wrong!

RAINER FACKLAM

GOAL
High-quality wafers of gallium nitride

WHY IT'S A WINNER
Its nanocolumn growth technique is efficient and produces GaN crystals with few defects.

STAFF About 10 people

BUDGET Already raised £750 000 (US $1.2 million); recently acquired by substrate company IQE, which will pay up to £3.6 million, depending on whether several milestones are met.

WHEN
Commercial production set for 2010

WINNER ⋮ LASERS

Crystal Method

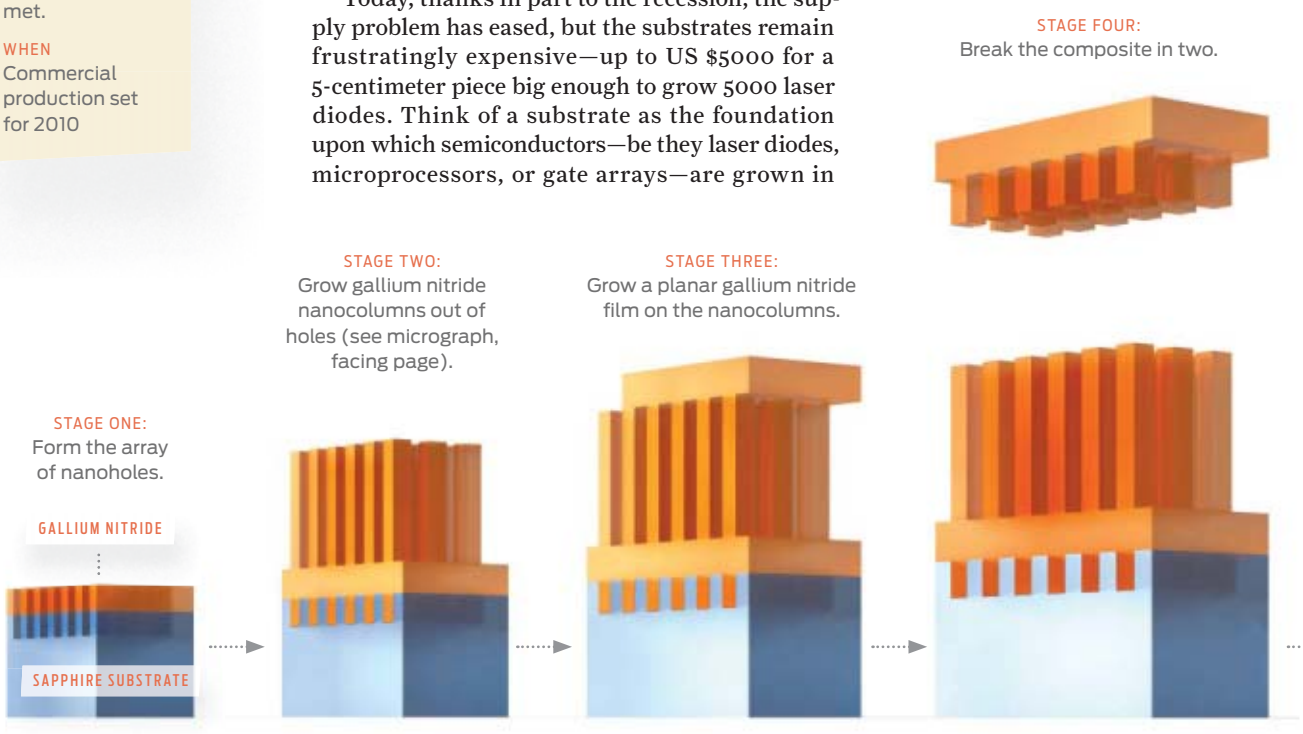
NanoGaN's substrates will grow better, cheaper lasers

BY RICHARD STEVENSON

IN MARCH 2006, Sony dashed the hopes of gaming fans by postponing the supposedly imminent launch of its PlayStation 3 console until November. Six months later, it pushed back the launch again. Later it revealed it couldn't live up even to that promise: Although the launch went ahead in Japan and the United States, European shops got the console only in the first quarter of 2008, and Sony's shipments in the first few months were only half as big as it had intended.

What went wrong? Sony would say only that it had had trouble manufacturing a new type of semiconductor laser that emits violet light, which has waves short enough to read the densely packed data of a Blu-ray disc. However, informed observers—including Shuji Nakamura, who invented this class of laser—had no doubt that the specific problem was a lack of decent gallium nitride substrates on which to grow the laser chips.

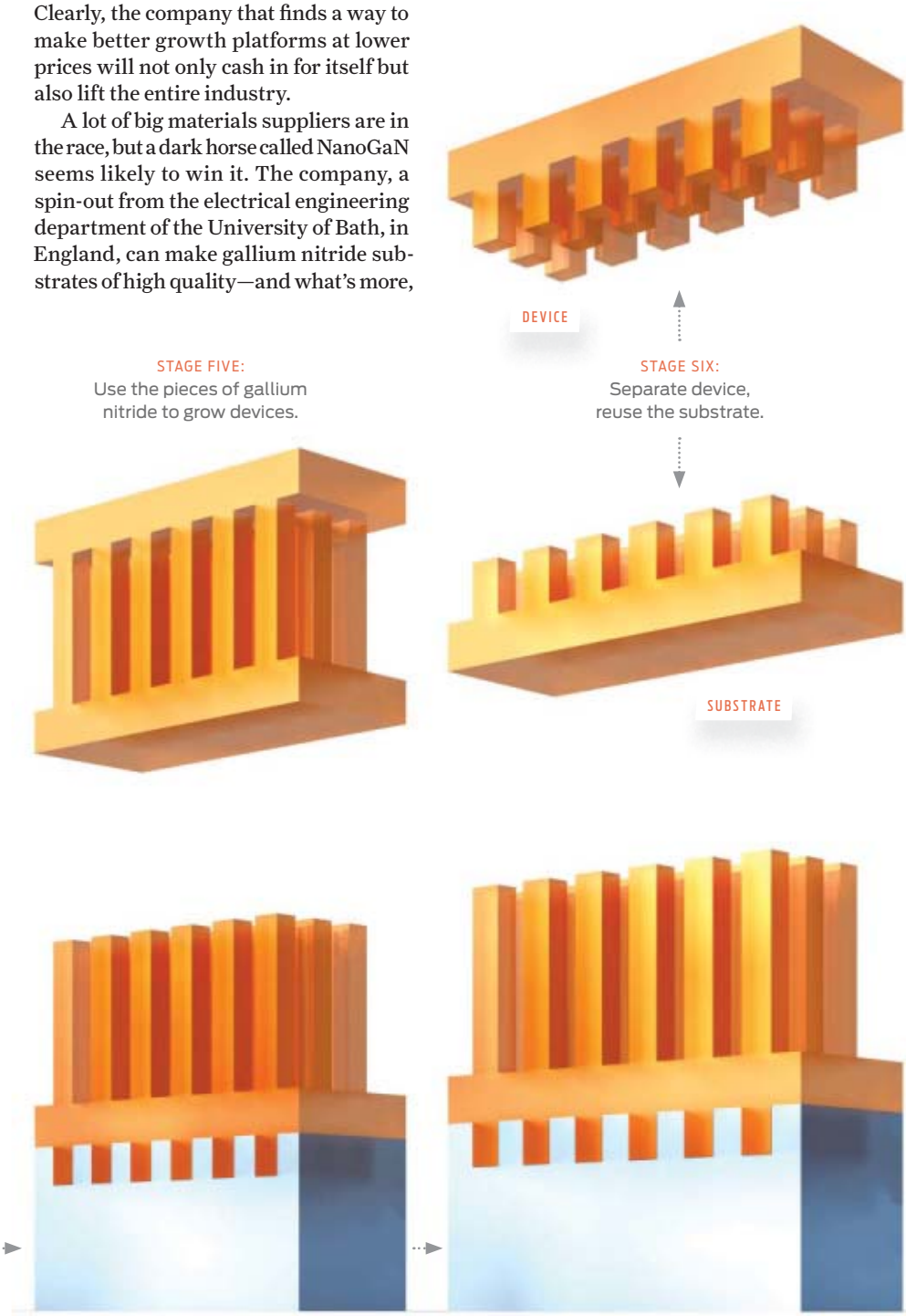
Today, thanks in part to the recession, the supply problem has eased, but the substrates remain frustratingly expensive—up to US $5000 for a 5-centimeter piece big enough to grow 5000 laser diodes. Think of a substrate as the foundation upon which semiconductors—be they laser diodes, microprocessors, or gate arrays—are grown in



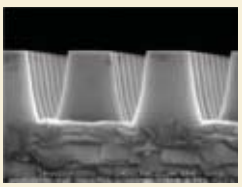
layers. In architecture, a flawed foundation imperils the entire building, and that's the problem here as well. Gallium nitride substrates haven't improved substantially, either, nor has the yield of the laser chips grown on those substrates. Clearly, the company that finds a way to make better growth platforms at lower prices will not only cash in for itself but also lift the entire industry.

A lot of big materials suppliers are in the race, but a dark horse called NanoGaN seems likely to win it. The company, a spin-out from the electrical engineering department of the University of Bath, in England, can make gallium nitride substrates of high quality—and what's more, it can recycle them, saving scarce and costly gallium.

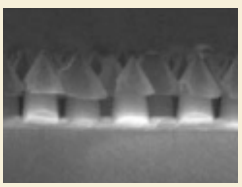
The company's founder, Wang Nang Wang, is a soft-spoken academic, but hardly the ivory-tower type. He's paid



A MICROGRAPHIC VIEW

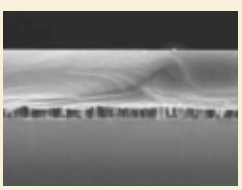


INITIAL SETUP
GaN nanocolumns grow out of holes in substrate.



INITIAL OVERGROWTH
A planar film of GaN begins to form at the top.

MEDIUM-STAGE OVERGROWTH



FULL COALESCENCE
High-quality planar film of GaN is complete.

PHOTOS: WANG NANG WANG

Illustration by BRYAN CHRISTIE DESIGN

his dues in industry, serving first as a consultant, then from 1993 to 2000 as chairman and president of Taiwan's Quantum OptoTech, and finally as the cofounder of Arima Optoelectronics Corp., now listed on the Taiwan Stock Exchange.

But his greatest achievement so far came a couple of years ago in the dimly lit warrens of a crowded basement lab in one of the University of Bath's EE buildings, in the middle of a campus that sits on one of seven lovely hills overlooking the center of Bath. In an interview there, Wang says that NanoGaN's substrate will do far more than provide a more efficient platform for the growth of the 5- to 8-milliwatt, 405-nanometer-wavelength lasers used to read discs in Blu-ray players and game consoles. It should also aid the production of much more powerful 150- to 200-mW violet lasers, which the industry needs for its next challenge: to read the four pairs of layers in a 200-gigabyte high-definition DVD. Future laser printers will use violet lasers instead of today's red ones, allowing them to double the print quality to 1200 dots per inch; a blue version of the lasers will still be used in tiny, portable color projectors.

The market analysis firms Strategy Analytics, Strategies Unlimited, and Yole Développement differ widely in their estimates of the current size of the market for gallium nitride substrates, from a low of $124 million to a high of $515 million, but all three firms agree that the rate of growth will average in the double digits over the next five years. If so, the market NanoGaN will be tapping into could be worth from $172 million to $800 million by 2013.

THE QUIRKIEST of all the semiconducting compounds has got to be gallium nitride. Researchers have struggled for more than a decade to produce a crystal big enough to be useful without introducing defects that sap its ability to turn electricity into light.

The brute-force approach for making a gallium nitride substrate is to take a crystalline seed and hold it in a solution of nitrogen in molten gallium. But success requires stupendous pressures and temperatures around 2300 °C. No one has managed to do that, but researchers at the Institute of High Pressure Physics at the Polish Academy of Sciences, in Warsaw, can get close, and the quality of their product is excellent. But the growth proceeds glacially, and the resulting crystals are irregularly shaped, with sides up to just 1 to 2 cm in length. They're too small to fit into standard processing equipment, which is designed for circular substrates at least 5 cm wide. So the Polish institute's material has been limited to research purposes. It isn't sold commercially, so you can't even put a price on it.

For production of 5-cm commercial substrates, today's leading manufacturers—the Japanese trio of Hitachi

EXPERT CALL

"I'm betting against Wang. However, if the wafer business doesn't pan out, with all those recipes and ovens he could open a restaurant."

ROBERT W. LUCKY

LOSER ⋮ LITHOGRAPHY

Dim Prospects for Bright Light

NanoUV's unproven light source won't shine in the next-gen lithography market

BY ANNE-MARIE CORLEY

USING ULTRASHORT LIGHT RAYS to print tiny features on integrated circuits has long been a dream of chipmakers, but suppliers of the necessary tools have been dashing that dream for a decade. The sources remain too weak to print more than a handful of wafers per hour, and critical parts still lack funding. As a result, Sematech, the chip-industry consortium, recently suggested that the expected rollout of the technology in 2013 might be jeopardized yet again.

"EUV's been this bride waiting at the altar," says G. Dan Hutcheson, CEO and chairman of VLSI Research, a firm in Santa Clara, Calif., that tracks the chip industry.

Here comes the latest bridegroom. Start-up nanoUV says it has created the world's brightest

MCKIBILLO

GOAL
A small, ultrabright light source for the EUV lithography industry

WHY IT'S A LOSER
The device combines too many new ideas with too few demonstrations of its reliability and reproducibility to attract ideal customers: EUV metrology and lithography toolmakers.

STAFF About 20

BUDGET €8.7 million (US $13 million)

WHEN Planning to ship multiplexed light sources in 2010

EUV light source. The trouble is, the company won't reveal to more than a handful of players how its technology works, making it hard to rack and stack against other options.

Hutcheson says that such a secretive strategy "doesn't work in this industry." Switching to a radically new chipmaking process can cost billions, he explains, and before companies write a check for the key ingredient, they want to be sure it performs. "There have been dozens of companies that don't disclose. They fail because of that," he says.

EUV, or extreme ultraviolet light, is a euphemism for soft X-rays, things that everybody in Silicon Valley knows are devilishly hard to make and focus. Whatever you call it, the radiation is attractive because its waves are around 13.5 nanometers—about as small as the features in the next generation of chips—so using them avoids the current need to print features far smaller than the wavelengths of light used to do it.

One big problem with such short rays, though, is that they get absorbed by pretty much everything, including air and glass. So you need special multilayer mirrors to focus them. A far bigger problem is that, after more than a decade of effort, nobody can yet make a decent light source. Cymer, Gigaphoton, and Xtreme Technologies, the leaders in this field, generate their EUV photons in hot plasmas that spit out fast-moving particles, making it hard to protect their light-collecting optics from the heat and debris.

We'll do you one better, proclaims little nanoUV. The company—headed by a Brit, based near Paris, boasting a Russian chief scientist, and backed by €8.7 million (US $13 million) of venture capital from the United Arab Emirates—says its technology replaces the vulnerable light collector with a lens that's indestructible because it, too, consists of plasma.

According to Peter Choi, nanoUV's president and director of technology, the source has two plasmas—a very hot, tiny one surrounded by a cylindrical one. The farther you move from the center, the cooler the outer plasma becomes, dropping to a positively brisk 10 000 kelvin at the rim. As the density

Cable, Mitsubishi Chemical Corp., and Sumitomo Electric Industries; Kyma Technologies of Raleigh, N.C.; and the French firm Lumilog—rely instead on a technique called hydride vapor phase epitaxy (HVPE). This growth process involves wafting gaseous compounds containing gallium and nitrogen onto a heated substrate—usually sapphire, an oxide of aluminum. There the gallium and nitrogen combine to form a film of free-standing gallium nitride, which you can then peel off.

Unfortunately, the atoms in sapphire are spaced out a little differently from those in gallium nitride, creating a strain within the gallium nitride crystal. It's like building a stack of jumbo egg crates on a base of standard-size ones. The initial compressive strain, at the junction between the dissimilar materials, is then compounded by differences in the rates at which the materials expand in response to heat. In short, the gallium nitride bends, and it ends up with millions of defects per square centimeter.

NanoGaN circumvents these problems by taking a substrate, such as sapphire or silicon, depositing a thin film of gallium nitride, forming an array of nanometer-size holes in the surface of the gallium, then growing crystalline gallium nitride layer by layer in the holes. Up grows the crystal in the form of columns, each having a radius in the tens of nanometers.

Now, if you let those columns grow in the standard way, they'd still be plagued with the standard types of defects: edge dislocations perpendicular to the growth direction, screw dislocations parallel to the growth direction, and a combination of these two, called mixed dislocations. The screw types are the real killers because they can propagate right into the device's core, leading to a reduction in the efficiency, output power, and lifetime of the laser.

Wang and his workers solved the screw-defect problem with a counterintuitive trick: You adjust the growth conditions so as to introduce more edge and mixed dislocations. These defects then cross paths with the screw dislocations, annihilating them. Then, having done that, you can reduce, if not eliminate, the other defects.

WITH A FOREST OF COLUMNS to serve as your foundation, you can build up a film of gallium nitride. Under the right conditions, the film will grow not only up the columns but also out, finally coalescing to form a plane. Because it grows on a material having the same crystalline structure, that planar film will have very little strain in it; with a little more vapor deposition, you can build that film into a good, clean crystal of gallium nitride. When it's ready, you can pull off a piece of high-quality, free-standing gallium nitride either by breaking the nanocolumns or by etching away a thin, sacrificial aluminum gallium nitride layer you'd built into the structure from the start.

Wang's technology has clearly been inspired by another technique called epitaxial lateral overgrowth. In that approach, you deposit a layer of silicon dioxide on a gallium nitride surface, then remove some of the silicon dioxide, forming stripes several micrometers wide. Then you grow gallium nitride out of the resulting trenches until it's level with the silicon dioxide layer, at which point it grows laterally, forming a continuous film.

With Wang's approach, however, the gallium nitride material above the columns is of superior quality, an improvement because the surface area of the gallium nitride is much greater in the array of nanocolumns than in the more sparsely distributed stripes, he says. Wang believes that because the surface area is much bigger, the growth process has a chance to annihilate a greater proportion of the screw-dislocation defects before they are fixed in the crystal structure.

Laser chip manufacturers can buy NanoGaN's substrates and just grow their own devices on top of the side that's covered in the planar film, incorporating everything into the laser diode product. But it would be much better for them if they built their devices on top of the other side of the substrate—the one that has the nanocolumns—so they can then pull off the substrate and return it to NanoGaN, to be refurbished for reuse. To reuse the substrates, you need to polish them: You add a few micrometers of gallium nitride to replenish lost material, poke holes in the surface, and grow new nanocolumns of gallium nitride in them.

Wang estimates that one piece of freestanding gallium nitride could be reused from 60 to 80 times. It's a big selling point for the company's technology. Some analysts believe that if we keep chewing up gallium at our current rate, we'll deplete all known reserves in a decade. That's a minority view, but pretty much everybody agrees that gallium will probably get scarce sooner rather than later.

THE NANOCOLUMN METHOD'S other great advantage is that it lets you make a really thin laser chip. That means you can get more heat out—which extends the chip's life—and channel more light in the direction you want it to go, to raise efficiency. That's a boon not only for state-of-the-art lasers but also for plain old LEDs.

And that's not all: Nanostructured gallium nitride will also make it possible to fabricate LEDs that efficiently emit light in the longer wavelengths of green. LEDs at such wavelengths today are disappointingly dim. The problem occurs in their active regions, where electrons and holes recombine to form light. In all nitride LEDs, the active region is a series of layers of indium gallium nitride, and green light demands a lot of indium. And therein lies the difficulty: It's hard to get enough indium into the active layer without compromising the quality of the material.

Recently, though, researchers have found that you can get a much brighter green laser by building the LED not along the standard crystalline cross section but rather on a bias. This method exposes one of the semipolar planes, so called because the internal electric field is far weaker, so the chance that electrons will recombine with holes to produce light is greater. But even more important, by growing crystals in this way you can get a lot more indium into the active layer.

Other companies do this by cleaving a gallium nitride crystal along a semipolar plane and growing all the nitride-based layers needed to make a device on the exposed face. NanoGaN instead mills its nanocolumns along the proper angle, exposing a semipolar plane on top of the bias-cut columns. The gallium nitride then grows on top of that plane, producing material that then coalesces to form a corrugated, rather than planar, film. Thanks to the corrugation, Wang believes it will be possible to create devices in which the active layer is three times as big as the one in a conventional LED. The concentration of indium isn't greater, but the area is. Such a structure should produce a far brighter green light than anything seen yet.

increases, the index of refraction decreases, which means the EUV rays bend more at the edges than in the middle, thus converging on a point. The device requires more input power than the leading light source candidates, Choi says, but because it's just a few centimeters long, hundreds of sources can be "multiplexed" in a many-headed "Hydra" pattern for greater output power and brightness.

The company plans to showcase two versions of its Hydra source (4- and 12-headed variants) at the SPIE conference on advanced lithography, to be held in February in San Jose, Calif. "What they claim to be able to do is revolutionary," says Gregory Denbeaux, an assistant professor in the College of Nanoscale Science and Engineering at the State University of New York, at Albany. "If it works."

But will it? So far, few outside of nanoUV have even seen the plasma lens. Company researchers don't publish in peer-reviewed journals, nor do they give demonstrations to people without first requiring them to sign a nondisclosure agreement. NanoUV won't even reveal which companies have agreed to take a peek in return for keeping mum.

Glenn Leedy, an inventor with several patents in semiconductor processes, says that after looking at what little information he could find on nanoUV's plasma lens, "it sounded rather magical to me."

Another skeptic is David Ruzic, a plasma expert at the University of Illinois at Urbana-Champaign. "It's not easy to bend EUV light to where you want it," he says, though he doesn't believe there's any "mysterious physics" in nanoUV's process. "The big question is whether or not it really works in practice, and with the reliability needed for a product."

Choi says nanoUV is playing its cards close to the vest because it doesn't want a bigger competitor to see its idea and "improve it better than we can." While the company holds a patent on the generic use of a plasma lens to collect light (WIPO Patent No. 2005038822), it doesn't "want to disclose how the lens works," he says.

At present, nanoUV's ultrabright technology isn't powerful enough to support high-volume manufacturing and will be useful only for inspecting patterning tools and lithography masks, says Vivek Bakshi, president of EUV Litho, an Austin, Texas–based consultancy specializing in EUV lithography. While such metrology tools are critical for EUV's success, the market for them isn't nearly as lucrative as for the high-power exposure tools that will actually print chips, Bakshi says.

Choi admits the company has struggled to find a toehold. It had planned to have a high-power, 100-source Hydra up and running for chip-printing

EXPERT CALLS

"The question is: What are they going to do with the X-ray 'lightbulb' when they perfect it? The real problem is the X-ray mask. The thin chrome of current masks cannot stop X-rays, and the thick quartz substrates do block them—hence the need for exotic masks. But the dimensional control and temperature coefficients are showstoppers for those masks."

T.J. RODGERS

"I doubt this will work, but if it fails at lithography, it could make a great *Star Wars* weapon for when we're invaded by aliens."

ROBERT W. LUCKY

tools by late last year. It didn't. "That's a business condition," he says, not a physics problem. "Someone needs to want it. We haven't been able to interest people enough to get involved with us."

That's because chipmakers tend not to bet everything on untried technology, points out lithography expert Chris Mack, especially when a company is using not just one but several new ideas, as nanoUV proposes. "Let's say the probability of a new technology being seamlessly integrated is one-third," Mack says. "You do that three times, and now it's one twenty-seventh. That's a pretty low probability [of success]."

"Multiplexing has not been tried before, the plasma lens has not been tried....These are new things," Bakshi adds. He's willing to give nanoUV the benefit of the doubt but warns that it has to start making more of its results public and inviting independent assessments so "customers will have more faith in the data." Bakshi himself has assessed every EUV source out there—except this one.

So where does that leave the little light source that...might? While nanoUV's determination to stand up to the big boys is admirable, history talks. "For every technology that really makes it, 10 to 20 fail," says VLSI's Hutcheson. "We haven't had a venture-funded group make it in 20 years, because of the nature of the industry." In short, nanoUV's current secretive strategy—regardless of its technology, which has its own challenges to overcome—is a loser. ❑

MAKING DREAMS COME TRUE takes cash—lots of it. But cash is a particularly scarce commodity now. Nevertheless, in February 2008, the University of Bath spin-out secured £250 000 (about $413 000) in seed funding from the university's commercialization fund, then got twice as much in first-round funding four months later. This past October, NanoGaN shored up its position through its acquisition by a leading specialty substrate company, IQE, in Cardiff, Wales. Wang has become the chief scientific advisor to the company.

To ramp up production as fast as possible, NanoGaN wants, reasonably enough, to replace its home-built HVPE vapor-deposition reactor with an industry-grade version. That'll take at least six months. Meanwhile, it has joined with another firm that already has such a reactor. Together the two firms should be able to deliver up to 300 substrates per month. By way of comparison, Sumitomo now dominates the industry by producing, according to industry sources, 700 to 1500 substrates per month; a rate of 300 per month would put NanoGaN in second place.

The company has recently simplified its manufacturing method, slashing the number of steps from 12 to 5. "When you reduce the steps you might compromise the yield rate," explains Wang, "but in our case the yield has improved and the quality has improved." NanoGaN is also looking to scale up from 2-inch to 4-inch (5-cm to 10-cm) substrates, which would mean they could be used in the more accurate tools used by silicon chipmakers.

In the meantime, potential rivals are working on other technologies for making better GaN substrates. One being pursued by Osaka University, in Japan, and by the manufacturer Ammono, in Poland, involves adding sodium to molten gallium in a nitrogen atmosphere. This technique suffers from the need to coat the reactor with a very expensive platinum liner that's etched away by the process materials, contaminating the gallium nitride. However, if the kinks can be ironed out, this method could make very high-quality GaN in mass quantities.

Just to be safe, Wang is also looking into this approach, with a partner in Taiwan. Still, he is confident that he has "10 years at least" before any rival technology can threaten him.

Now NanoGaN stands to beat the big boys by grabbing a healthy slice of the burgeoning market for the building blocks of lasers. By increasing the supply of this crucial component in game consoles, video recorders, and a host of other products, the company should help to cut the prices of all these electronic goodies. ❑

Where Are They Now?

2004 WINNER

Sumitomo's gallium nitride wafer

UPDATE Sumitomo Electric Industries, of Osaka, Japan, came up with the first practical way of making gallium nitride wafers for laser diodes, making possible Blu-ray and other products. We forecast great things for the project, and indeed, today Sumitomo is the clear leader in the field—although NanoGaN, described in "Crystal Method," bids fair to catch up to it.

VERDICT We were right!

RAINER FACKLAM

GOAL
PC smarts on a cellphone's power budget

WHY IT'S A WINNER
By hot-rodding a popular mobile processor core, the company has a chance to be the power behind many next-generation smartphones.

STAFF
99 engineers

BUDGET Info not available

WHEN 2010

WINNER ⁞ MOBILE CPU

A More Cerebral Cortex

Intrinsity boosts the brainpower of a cellphone chip to the level of a PC ⁞ BY MARK ANDERSON

IN SEPTEMBER, when Samsung boasted at a Taipei industry conference that it could make smartphone chips with PC-like performance, a company in Austin, Texas, took an offstage bow.

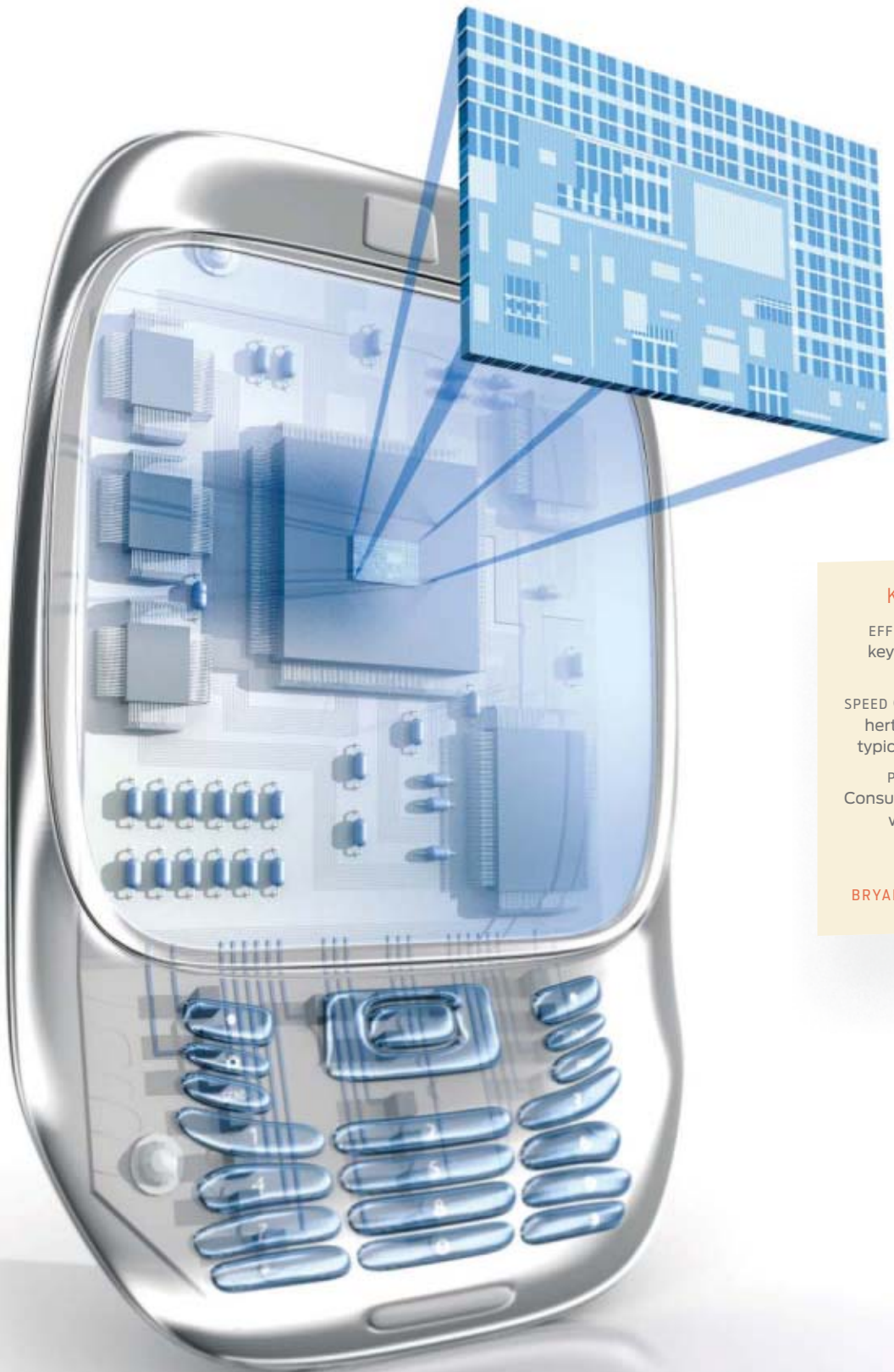
It was Intrinsity, a small chip designer, that had made the South Korean silicon giant's claims possible. It had taken the 650-megahertz ARM Cortex-A8—a CPU designed for smartphones, licensed to Samsung by ARM Holdings—and hot-rodded it into a 1-gigahertz processor dubbed Hummingbird. The result could, with Samsung's backing, power an impressive portion of the next generation of must-have mobile devices. Some even speculate that Apple itself will put Hummingbird in a coming upgrade to its iPhone. It's all happening very quickly for a start-up that still shares office space with a local magazine and a dentist.

Now that it's souping up a next-generation Cortex-A9 for an undisclosed partner, Intrinsity is bidding to carve itself a slice of the market for higher-priced smartphones, netbooks, and other portables. And what a market it is! Just as PCs supplanted minicomputers and laptops supplanted PCs, so smartphones and netbooks will replace laptops for many of their uses. Intrinsity and other designers stand to do well for themselves.

"WE'RE A SPEED SHOP that doesn't go and burn a lot of fuel in the process," says Intrinsity president and CEO Bob Russo. He and his 99 engineers grease the wheels of a CPU by trimming inefficiencies in the way logic gates are used.

For instance, when those engineers found that the conventional Cortex-A8 used 20 logical steps to perform some simple binary addition functions, they worked out a way to do the same job in four steps, saving computation time. Because this made some regions in the A8 speed up, the transistors in other regions needed to accommodate less traffic and therefore could be shrunk. Smaller transistors mean less power consumption—a critical element in a battery-powered device.

The key to this and many other performance tricks is the type of logic gate Intrinsity uses: 1-of-*n* domino logic, or NDL, part of its suite of technologies called Fast14 (named after the atomic



KEY FEATURES

EFFICIENCY Does some key calculations using fewer logic gates.

SPEED Operates at 1 gigahertz compared to the typical 650 megahertz.

POWER CONSUMPTION Consumes just 750 milliwatts at top speed.

Illustration by BRYAN CHRISTIE DESIGN

number of silicon). Russo says NDL can speed up a logical step by 40 to 60 percent. About a fifth of the A8's functions are benefiting from it, he adds.

Domino logic is a technology typically used in laptops and desktops, where power consumption isn't nearly as big a deal as it is in a smartphone. Domino logic does most of its work with *n*-channel metal-oxide semiconductor (NMOS) transistors, which use electrons to carry charge. In contrast, complementary-metal-oxide semiconductor (CMOS) logic uses equal helpings of both NMOS and *p*-channel metal-oxide semiconductor (PMOS) transistors, which are slower because they juggle holes—the absences of electrons in a crystal lattice. By relying on faster transistors than CMOS logic does, domino logic can speed computation.

Today firms such as AMD, IBM, and Intel use domino logic but only in certain circuits. That's because it consumes more power than CMOS logic, its circuit timing can be more difficult to manage, it's more sensitive to noise, and it generally requires more time and money to design and implement.

Fast14 puts a twist on domino logic, which lets it use power more economically. One of the most obvious differences is in the way it represents bits. In CMOS logic you can represent the numbers 0 through 3 on two wires as 00, 01, 10, and 11. In traditional "dual-rail" domino logic, you'd need four wires—two for the bits and two for their complements—so you have to switch twice as many wires every time the output changes, wasting power.

Intrinsity's 1-of-*n* domino logic saves power by switching less often. To represent 0 through 3, it uses four wires but switches only one at a time: Zero is represented by 0001, 1 by 0010, 2 by 0100, and 3 by 1000. That scheme means that many transistors will be turned off most of the time. What's more, the 1-of-*n* design lets engineers make more-complex functions in a single gate, reducing the number of steps needed to complete a logic function.

Indeed, Russo says, one of the qualities Intrinsity looks for when recruiting engineers is the ability to translate standard bit-based gates into faster 1-of-*n* domino circuits. The real art of integrating NDL into a processor core like the A8, he says, involves discovering which parts most need the NDL speedup at the expense of complicating that part of the design with 1-of-*n* logic. (As much of Intrinsity's NDL process is proprietary, Russo would say only that the trade-off isn't always worth the extra effort, which is why Intrinsity has used NDL "sparingly" in Hummingbird. It's a small tweak that makes a huge difference.)

Another key trick to Fast14 is the use of multiple slightly out-of-phase clocks. Mark McDermott, the company's vice president of engineering, likens it to a taxi's progress along a street dotted with traffic lights. An instruction such as "Call up memory register A and add it to the contents of memory

EXPERT CALLS

"Choosing to invent a funky new logic structure—without the required factor-of-three improvement—is not a sustainable strategy."
T.J. RODGERS

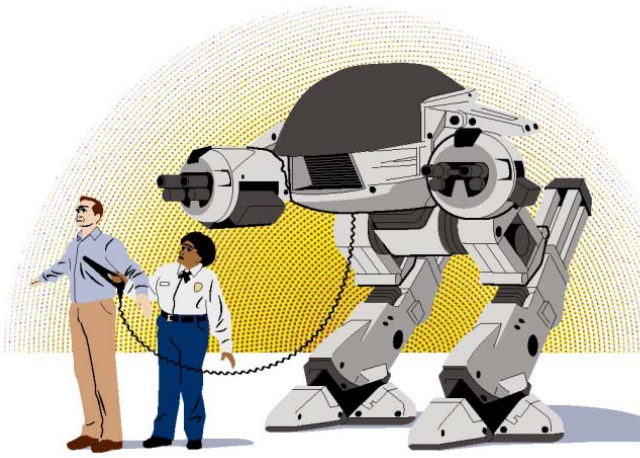
"Seems like a lot of work for a modest improvement in performance."
KENNETH R. FOSTER

"I'd say the company is a winner, but they seem to be relying on trickiness rather than fundamental technological breakthroughs. Is this a lasting solution for a business model?"
ROBERT W. LUCKY

LOSER ⋮ SECURITY

Bad Vibes

A quixotic U.S. government security system seeks to look into your soul ⋮ BY STEVEN CHERRY & ANNE-MARIE CORLEY



THE U.S. DEPARTMENT of Homeland Security (DHS), which operates airport security checkpoints in the United States, is spending upward of US $7 million a year trying to develop technology that can detect the evil intent of the terrorists among us. Yes, you read that correctly: They plan to find the bad guys by reading their minds.

Dozens of researchers across the country are in the middle of a five-year program contracted primarily to the Charles Stark Draper Laboratory, in Cambridge, Mass. They've developed a psychophysiological theory of "malintent"—basically, a hodgepodge of behaviorism and biometrics according to which physiological changes can give away a terrorist's intention to do immediate harm. So far, they've spent $20 million on biometric research, sensors, and a series of tests and demonstrations.

MCKIBILLO

This is no mere fantasy, DHS officials insist. And it isn't: It's a *noble* fantasy. And it's destined to be a noble failure. It's called the Future Attribute Screening Technology, or FAST.

"We're not reading minds," says Robert P. Burns, a deputy director of innovation at the Homeland Security Advanced Research Projects Agency and the FAST project manager. "We're just screening."

The underlying theory is that your body reacts, in measurable and largely involuntary ways, to reveal the nature of your intentions. So as you wait in line at the airport checkpoint, thermal and other types of cameras and laser- and radar-based sensors will try to get a fix on the baseline parameters of your autonomic nervous system—your body temperature, your heart rate and respiration, your skin's moistness, and the very look in your eyes. Then, as a security officer asks you a few questions, the sensors will remeasure those parameters so that the FAST algorithms can figure out whether you're naughty or nice, all on the spot, without knowing anything else about you. It's a bit like asking one of those RFID-based highway toll systems—the ones that automatically deduct the price of the toll from your credit card account—to determine whether the purpose of your car trip is business or pleasure.

The algorithms will scrutinize the output of the sensors, looking for several specific changes. For example, your pupils may dilate when someone asks you questions about matters on which you have malevolent intent, your heart may skip a beat, or you may suck in your breath. Of course, you may be having bad thoughts that have nothing to do with terrorism—if you're getting on a plane to meet your paramour, for example. But in that case, "you won't get noticed," maintains Daniel Martin, a psychologist and independent contractor who developed the initial malintent theory and is the director of research for FAST. "It only measures the signs of malintent in this specific context, in this situation," he says.

Martin and other backers say the system can tell whether a racing heart and sweaty skin are those of a nervous terrorist or merely a person who had to run to catch a plane. They say it can even distinguish among terrorists, garden-variety smugglers, and anxious travelers. But they won't reveal just how the system manages to discern the infinite and wondrous varieties of guilt and remorse that lurk in the hearts of men and women.

"If we laid out specifically [how the system works], the first thing someone will do is say, 'How do I counter that?' " Martin says.

Some of the research will eventually appear in peer-reviewed journals, says Burns. But he declines to say when and where. At an April 2009 meeting, 30 scientists met at Draper for a private peer review of the theory of malintent and the experimental protocols. Martin says the consensus was that the theory is generally correct. The DHS has also set up privacy panels to try to ensure that its system's operation won't violate passengers' rights; the program doesn't tie data to an individual's identity, nor does it store any of the information collected. "We dump the data once you're through security," says Burns.

Crucially, FAST will not measure you against some theoretical norm of, say, average heart rates for adult males. "Each person serves as his or her own baseline," says Martin. The system "will measure how people's signals change in response to stimuli." To top it all off, the profile of symptoms can't be faked.

"The signals are uncontrollable, even for a trained terrorist—you still give them off," says Burns. Even if there's a complete lack of signals—in other words, no change from the baseline—"that's also a sign" of something suspicious: that the person has been trained to suppress those signals.

At a September press conference at Draper, DHS researchers screened 30 volunteers with the FAST

GOAL
A sensor-based system that will discern a terrorist's evil intent from pupil size, skin moisture, fidgeting, and other biometric indicators

WHY IT'S A LOSER There are so many passengers and so few terrorists that the rate of false positives will make the system more trouble than it's worth.

STAFF Dozens of researchers

BUDGET More than US $20 million

WHEN A prototype by 2011

register B" is like telling the cabbie to go 50 blocks uptown and race through as many green lights as possible on the way. A regular processor core would use a route in which every light was in sync, turning red or green at the same time. That way, the taxi driver would move only a handful of blocks before stopping. But when you add Fast14 to the processor, McDermott says, you stagger the traffic lights so that the taxicab can travel dozens of blocks before having to stop for a red light. Everything goes faster.

Intrinsity's engineers use these and other time-shaving tricks to ensure that the CPU stands idle as little as possible. "All it takes is one choke point, and that's going to set your frequency," says Intrinsity chip designer Brent Chambers.

WHAT'S CRUCIAL to Hummingbird's appeal is that it represents a modification of the ARM Cortex-A8 rather than a top-to-toe redesign. This means that makers of devices that now run on regular A8s can drop in a Hummingbird without changing a

system, offering some of them $100 bonuses for acting in a way that might "involve something malicious." They were told there was a mock explosive that would "cause a loud noise but won't cause too much harm."

Thermal cameras read each subject's body temperature. BioLidar tracked respiration and heart rate (think of a police radar gun that uses laser light instead of radio waves, and is sensitive enough to measure changes in the surface motion of the skin, particularly in the large arteries of the neck). An eye tracker determined a subject's pupil size, rate of blinking, and "gaze vector." A "fidget detector" had the subject stand on a Nintendo Wii's balance board, which people normally use to exercise at home. All the sensors but one were off-the-shelf. The exception was the government-developed eye-safe BioLidar.

In fact, the test subjects that journalists watched at the Draper press conference were actors; the real subjects had gone through the mock screening beforehand. In a control room, for the benefit of the assembled press, computer monitors showed faces overlaid with neon lines and dots that showed readings of temperature, moistness, and the like (what the squiggly graphs on a different screen were actually measuring remained a mystery to the journalists). Time charts also tracked the subject's voice and facial expressions each time a question was asked.

Paul Ekman, the author of *Telling Lies: Clues to Deceit in the Marketplace, Politics, and Marriage* (W.W. Norton, 1992) and other books on behavioral psychology, notes that a critical problem for research intended to identify malevolent intent is "designing an experimental test in which the stakes are anywhere near as high as they are for the terrorist."

DOES IT WORK? Officials didn't give a success rate for the September demonstration but have said the system is generally about "87 percent accurate."

Such a system would be useless in the field, says Bruce Schneier, an expert on applying technology to security problems and a frequent critic of airport screening systems. He notes that more than 700 million people board airliners every year in the United States, and there have been very few attacks. "Imagine an attack every five years," he says, "and a system with a very good 0.1 percent false-positive rate," meaning that of every 1000 people screened, one gets stopped but isn't a bad guy. "Over those five years, the system will still have 3.5 million false alarms." And that's for a system with far better performance numbers than the "87 percent accurate" system that DHS says it now has.

Kenneth R. Foster, a bioengineering professor at the University of Pennsylvania, who studies biotechnologies, says, "Mammography, which has about the same accuracy as that quoted for FAST, has the same problem. For every woman it finds with breast cancer, it scares the heck out of a dozen or more who do not. And breast cancer is a lot more common than terrorists in our airports."

EXPERT CALLS

"In screening large populations for exceedingly rare occurrences, false positives dominate outcomes; any researcher engaging in a modicum of quantitative analysis would reject the hypothesis immediately."

NICK TREDENNICK

"Surely this is a joke! They should equip the Transportation Security Administration screeners with Ouija boards, and if your pointer moves to the wrong square, they'll pull you out of line and imprison you."

ROBERT W. LUCKY

Burns says an acceptable level of false positives "depends on the operational application." He also notes that no one would be arrested or even kept off a plane because they failed the test. Rather, passengers who seem to have bad intent would be sent on to a secondary screening, the same thing that happens when a passenger's behavior sets off suspicion in the frontline security officers. The goal is to have "less than the current go-to-secondary-screening rate," Burns says, though he and other DHS officials wouldn't give the current rate of secondary screening. "It's an additional tool. Screening is not going away, so how do we make it better?"

DHS officials acknowledge the extent of the challenge they have set for themselves—and the likelihood of failure. "There's a high degree of technical risk," Burns says. "But if this works, it could be a game changer in terms of security."

"The theory of malintent is still being developed and vetted in peer review," Martin acknowledges. And, he admits, "we're still a number of years away from deploying it." Ah. Maybe that number has two digits. Or three.

Nope. DHS is determined to have a prototype by 2011. "We have to do it," Burns says. "We have a lot of people in line, and we have to get them through quicker. We have to identify the people of interest."

You can start by throwing out the entire FAST system. "FAST will never achieve the extremely low rate of false positives it needs," says Schneier. "But even if it did, it's useless against passengers who are unwittingly carrying bombs. Better to screen for bombs directly." ❑

thing. By substituting one chip, Russo says, the manufacturer can get either a device that runs faster or a device that draws less power at a slower speed.

"There's no one in the market right now who can deliver this kind of [clock speed] with this kind of power range," says Russo. "We've had a lot of interest from a lot of big companies to implement our technology in their designs."

Tom Halfhill, a senior analyst at In-Stat's *Microprocessor Report*, says that Hummingbird boasts some impressive performance enhancements. He says that Hummingbird's specs, published in July, imply that the chip will consume 750 milliwatts at 1 GHz, leaking current in the "very low

milliwatt range." Compare that, for instance, to Intel's Atom N270, a processor for embedded systems, which clocks in at a slightly faster 1.6 GHz but guzzles 2.5 watts. (Unfortunately, power usage comparisons to the unmodified A8 are not easy, Halfhill says, because the A8 runs on less power than a Hummingbird—385 mW—but only at 650 MHz. The proper comparison would be a Hummingbird dialed down to 650 MHz. But neither Intrinsity nor Samsung has released power specs for Hummingbirds running at such speeds.)

So how much does Hummingbird's beefed-up performance cost? "The value of the A8 in the iPhone 3GS is probably about US $15 to $18," says Will Strauss, a market analyst with Forward Concepts, in Tempe, Ariz. "The Hummingbird version will carry a premium price. It's probably going to be more in the $18 to $25 range."

The extra dollars add up fast, too: In 2008, 139 million smartphones were sold. If Hummingbird makes Intrinsity the leading hot-rodder of smartphone CPUs, the company will surely build more partnerships with powerhouse companies—and take more offstage bows—in the months to come.

HUMMINGBIRD FACES a host of competitors, but Intrinsity has the advantage of having made a great career move. Not only does the company wring superior performance from a chip, it has chosen the right chip to wring it from. "The A8 is likely to be the dominant engine in smartphones" by the middle of 2010, Strauss says.

Probably Hummingbird's closest competitor in 2010 will be Qualcomm's top-to-toe redesign of the A8, dubbed Snapdragon, with two cores running at up to 1.5 GHz.

But raw power, says *Microprocessor Report*'s Halfhill, isn't everything. Equally important is the ease with which Hummingbird can be integrated into preexisting smartphone designs, such as the Palm Pre and the iPhone 3GS, that already use the A8.

"If you have a whole new microarchitecture, like Snapdragon, then that could possibly change the whole rest of the chip design—all the peripherals attached to it, the coprocessors," Halfhill says. "If you've got to redo the whole chip, then you're adding maybe another year to the project."

And if a company decides to add that extra year of design time, by the time it goes to market it could find itself facing other smartphones powered by ARM's dual-core next-generation Cortex-A9—it's rated at 2 GHz and expected as soon as mid-2010. (Remember, Intrinsity is now hard at work souping up that A9.)

"I think the Hummingbird looks pretty good against Snapdragon," Halfhill says.

Where Are They Now?

2006 WINNER

IBM, Sony, and Toshiba's Cell broadband engine

UPDATE Sony has sold 27 million PlayStation 3s so far; the world's most powerful supercomputer, Roadrunner, is a hybrid of Cell and *x*86 processors; IBM has incorporated Cell into blade servers; and Toshiba recently demonstrated a Cell-powered HDTV.

VERDICT We were right!

Then there's Intel, the world's biggest chipmaker, which is trying to break into the smartphone market with its Atom processor. But Intel faces an uphill climb, with 95 percent or more of the cellphones in the world running on ARM processors, Strauss estimates. Intel presents no great threat, though, because its refusal to license its technology means that any smartphone using the Atom line would have to begin at Intel itself. And Intel is no consumer products company.

ARM technology, however, has flowered precisely because so many third parties have had a chance to shape it as they saw fit. And fourth parties, too: Intrinsity didn't need any license to tinker with ARM's technology—it just had to license its own hot-rodding to Samsung.

The real fight, instead, looks to be between the Samsung/Intrinsity alliance and two key ARM processor makers: Texas Instruments and Qualcomm. The unmodified A8 powers TI's new OMAP3 family of processors, one prominent user of which is the new Nokia N900 smartphone. Unlike Qualcomm, however, TI doesn't hold what's known as an architectural license from ARM, which would allow the company to do a full redesign the way Qualcomm is doing with Snapdragon. TI has a license only to sell ARM products or ARM "look-alikes"—cores whose cycle-by-cycle operation is the same as that of an ARM core. One such look-alike is Hummingbird. In fact, Halfhill speculates that Intrinsity could possibly end up on two sides of Samsung's battlefield. Holding its own Cortex-A8 license, TI could itself turn to Hummingbird to speed up its next-generation OMAP3s, Halfhill says.

With the smartphone industry constantly shifting and allies and enemies often changing sides, Halfhill says the only sure thing about Hummingbird is that it's a well-designed core that should wind up in a number of smartphones, netbooks, and other portable devices in the coming year.

The marketplace is moving in Intrinsity's direction, Strauss adds, with an increasing number of mobile devices running off a shrinking number of chips or even a single system-on-a-chip, or SoC. And once a device maker designs an SoC around a processor core, it will want to be able to upgrade its device with the least possible disruption to the SoC design. That could mean just dropping in an amped-up processor core like the Hummingbird, or its successors coming out of Intrinsity's shop.

We judge Intrinsity's modified A8 a winner because it improves the performance-to-wattage ratio, as the market for mobile devices demands, and because it does so in an open-chip architecture that's on the ascendancy. In a year's time, you might well be holding a phone with a Hummingbird inside. ❑

RAINER FACKLAM

WINNER?
LOSER?

You Tell Us

It's usually not hard to spot technology's clear-cut winners and outright dogs. But every year IEEE Spectrum*'s editors cross rhetorical swords over a few candidate projects. In the name of peace, we thought we'd let you decide*

BY WILLIE D. JONES

NO MATTER WHERE YOU TRAVEL, the locals seem to drive like a bunch of maniacs. But now a company named Parajet, in Mere, England, wants to let you rise above the gridlock caused by the talkers, texters, eaters, shavers, and makeup artists who drive with a foot on the accelerator and eyes on everything but the road. Later this year, the company will introduce the SkyCar, a dune buggy–style car that turns into a paraglider on...well, the fly.

The two-seater takes to the air by deploying an asymmetrical parasail "wing" and then accelerating to at least 60 kilometers an hour. Its 104-kilowatt (140 horsepower) Kawasaki motorcycle engine lets it glide at its normal cruising altitude of 900 meters at speeds up to 161 km/h (100 miles per hour), the company claims. A tankful of biodiesel is enough for a 300-km flight. The car's also good for thrills on the ground—it goes from zero to 100 km/h in 4.2 seconds and can tackle dunes and rocky hills as well as any off-roader.

Parajet emphasizes that so long as you fly no more than 1220 meters (less than a mile) above the ground, you'll need no credentials beyond a driver's license. All you have to be able to do is steer a huge heap of metal by pulling on two cords.

Though the SkyCar sounds like a lot of fun, it remains to be seen how many people will spend US $80 000 just so they can skip traffic jams and get the chance to execute a rather difficult dismount in their company's parking lot. We're inviting you to vote on whether the SkyCar will be a success or a failure. There are also five other technology projects for you to consider at our Web site (http://spectrum.ieee.org/geek-life/tools-&-toys/you-tell-us). They include an electric vehicle project that uses battery-swapping stations to solve the nagging range problem, paper-thin batteries that can be used in smart credit cards, and a hands-free gaming controller that's Microsoft's answer to Nintendo's Wii. ❑

PARAJET

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 and the program is ABET accredited. The TAMUQ campus is situated within a 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 and teaching specializations in the following areas:

Telecommunication Networks

Power Systems

Electronics & Electromagnetics

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, with subsequent contracts being longer term. Re-appointment will be subject to mutual agreement.

Applications, including full curriculum vitae with a list of publications, a statement of teaching, a statement of research and the names, addresses (regular mail and E-mail), of three references should be sent to in a single PDF file electronically to **TAMUQ-Search@ECE.tamu.edu**, or in hard copy 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 February 15, 2010 but applicants will be considered until the positions are filled.

FIU FLORIDA INTERNATIONAL UNIVERSITY

CHAIRPERSON OF ELECTRICAL AND COMPUTER ENGINEERING

Florida International University (FIU) is seeking a dynamic and innovative leader to serve as chairperson of the Department of Electrical and Computer Engineering (ECE). FIU is one of the largest of 11 universities in the State University System of Florida, with a diverse student body of over 39,000. FIU is a rapidly growing research university located in Miami, a diverse and dynamic metropolitan area with a sizable electronic, biomedical and computing industry. FIU is a comprehensive Carnegie Research University in the High Research Activity Category and one of the fastest growing and largest public research universities in the United States. In recent years, the university has added a law school and has opened its first class of the new medical school. FIU currently offers over 190 Baccalaureate, Masters and Doctoral degree programs in 11 colleges and schools. ECE is the largest of six departments in the College of Engineering and Computing. The research areas presently are focused on imaging, signal processing, VLSI and embedded system design, antenna design, nanotechnology, telecom and networking, and renewable energy. ECE currently offers B.S., M.S. degrees in both Electrical Engineering and Computer Engineering, and the Ph.D. degree in Electrical Engineering. Both undergraduate programs are accredited by ABET. Undergraduate enrollment is currently about 550 and graduate enrollment is about 150, including 70 Ph.D. students. Diverse research centers are available for collaboration within the College (**www.cec.fiu.edu**) and at the university level (**www.fiu.edu**).

Qualifications: Applicants must have a Ph.D. degree in Electrical Engineering, Computer Engineering or a closely related field and must possess credentials that meet the qualifications for appointment at the rank of full Professor, as well as a substantial and sustained record of scholarly work and extramurally funded research, mentorship ability, professional service, ties to industry, and the demonstrated ability to provide leadership and vision to a growing academic department with strong research potential.

The position is available starting as early as August 1, 2010. Application processing will begin on January 31, 2010, and will continue until the position is filled. Application materials should include curriculum vitae, a list of at least five references, and statements on teaching, research and administrative experience, and overall vision. Inquiries and applications will be kept in confidence pursuant to the Sunshine Laws of the State.

For more information or to apply, please visit us online at **http://www.fiujobs.org** and reference position number 45252.

FIU is a member of the State University System of Florida and is an Equal Opportunity, Equal Access Affirmative Action Employer.

THE UNIVERSITY OF TENNESSEE
Mechanical, Aerospace, and Biomedical Engineering Department (MABE)

is seeking applications and nominations for a candidate with significant expertise in energy conversion and storage systems and device engineering for the position of Professor and Condra Chair of Excellence. Energy conversion and storage related to transportation – especially in automotive/truck/mobile applications including batteries and fuel cells – is of particular interest. Prior academic experience is desirable but not required. Applicants with outstanding industrial research accomplishments, a doctorate in engineering or a related field, a proven track record of developing research funding, substantial and active research program with archival publications in fuel cell science and engineering, an internationally recognized leader in fuel cell engineering, a team player, and ability to build multi-participant research sponsorship research programs to obtain major research sponsorship and recruit high-quality graduate students will be considered.

For further information, see

http://www.engr.utk.edu/mabe/deptjobopps.html;

http://www.ornl.gov;

http://www.ornl.gov/sci/eere

Please include a letter of intent outlining research/teaching goals/objectives; a current resume; the names, addresses and telephone numbers of at least four references. Preferred method of application or nomination is by e-mail to ***whamel@utk.edu***. Materials may also be mailed to Dr. William R. Hamel, Condra Chair of Excellence Search Committee, MABE Department, 414 Dougherty Engineering Building, The University of Tennessee, Knoxville, TN 37996-2210

The University of Tennessee is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA institution in the provision of its education and employment programs and services. All qualified applicants will receive equal consideration for employment without regard to race, color, national origin, religion, sex, pregnancy, marital status, sexual orientation, gender identity, age, physical or mental disability, or covered veteran status.

National Search for
Senior Leadership Position

THE UNIVERSITY OF OKLAHOMA

Norman, Oklahoma

is seeking
Applications for the
Combined Position of

DEAN

COLLEGE OF ATMOSPHERIC AND GEOGRAPHIC SCIENCES

and

DIRECTOR

NATIONAL WEATHER CENTER

For Complete Job Description
and Application Process:

http://ags.ou.edu/deansearch

The University of Oklahoma is an Affirmative Action/Equal Opportunity employer and encourages diversity in the workplace.

Assistant or Associate Professor, Bioengineering

Positions 0857, 1605, 1778

The Departments of Chemical and Bioengineering invites applications for several tenure-track positions at the Assistant or Associate Professor level in the areas of: Biomedical engineering, Biochemical engineering, Biodevices, Biosignal processing, and Advance Biomaterials test techniques. The successful candidates will develop and grow dynamic extramurally funded research programs in their areas of expertise related to Bioengineering, and actively participate in undergraduate and graduate teaching, advisement and mentoring.

Qualifications for the position include an earned doctorate in Bioengineering, Biomedical Engineering, Electrical Engineering or a closely related discipline. Applicants should have a strong record of graduate work in the area of interest: a record of academic achievement in the classroom and research; ability to work collaboratively and to communicate effectively.

For more information and to apply go to:

http://facultypages.ncat.edu/hr

North Carolina A&T State University
is a land-grant doctoral/research
intensive institution and AA/EEO employer.

The Institut national de la recherche scientifique, a university institution dedicated to research and postgraduate studies, seeks to fill two tenure track positions in ***Telecommunications****, from wireless to photonic communication at its Énergie Matériaux Télécommunications Centre. These positions are incorporated within an environment where about forty professors-researchers undertake leading-edge research and training in diverse fields of energy, materials and telecommunications. The Institute is located in Montréal.*

The Centre already benefits from a strong experience in the telecommunication sector and hosts many important laboratories. Research topics of interest for these two positions may include the use of novel microwave and/or photonic components, signal processing (for audio, speech, image, and/or video), and telecommunication systems and networks.

More information is available on the web site: www.emt.inrs.ca.

PROFESSORS-RESEARCHERS TELECOMMUNICATIONS

(Tenure Track)

Suitable candidates must have:

- A PhD degree in a relevant discipline (Electrical or Computer engineering, etc).
- An excellent record of research accomplishments that will enable her/him to successfully develop a strong independent research program in telecommunication.
- A strong experience in the telecommunication area.
- A demonstrated track record in teaching and supervising graduate students.
- The ability to work in a multidisciplinary team and within research networks.
- A proven ability to attract external funding and to collaborate with the industry.

Potential sources of funding include the Natural Science and Engineering Research Council (NSERC), the Canada Foundation for Innovation (CFI) and the Fonds québécois de recherche sur la nature et les technologies (FQRNT).

The work language is French. Candidates whose native language is not French are strongly encouraged to apply. INRS will provide all the necessary resources to make sure that the candidates learn the French language and integrate smoothly the Centre.

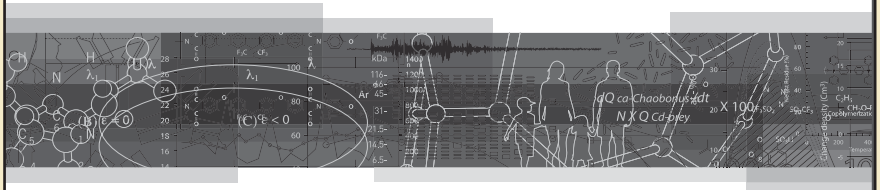
Salary and benefits are in accordance with the current collective agreement at INRS.

Interested candidates should submit a full curriculum vitæ by e-mail and registered mail, a statement of research interests (max. 3 pages), a statement of teaching philosophy, three representative publications, and the names and contact addresses of three referees before **February 19, 2010**, indicating competition **DS 09-05** to:

Dr. Jean-Claude Kieffer, Director
Centre Énergie Matériaux Télécommunications
800 De La Gauchetière West, Suite 6900
Montréal (Québec) H5A 1K6, Canada
kieffer@emt.inrs.ca

INRS is committed to equity in employment and diversity. The Institute welcomes applications from indigenous people, visible minorities, ethnic minorities, persons with disabilities, women, persons of minority sexual orientations and gender identities, and other who may contribute to further diversification.

WWW.INRS.CA



Centre - Eau Terre Environnement
Centre - Énergie Matériaux Télécommunications
Centre - INRS–Institut Armand-Frappier
Centre - Urbanisation Culture Société

INRS
Université d'avant-garde

BOSTON UNIVERSITY

Boston University

College of Engineering
Interdisciplinary Engineering Position

Tenured Faculty Position in Energy Systems

Boston University is committed to the development of broadly cross-disciplinary programs in energy and sustainability. Recently, the University created a new Clean Energy and Environmental Sustainability Initiative (CEESI) to spawn research and education at the intersection of energy technologies, energy economics, energy policy, and environmental science. In support of these commitments, the College of Engineering seeks to recruit a recognized leader in energy systems with emphasis in one or more application domains including but not limited to: electric power systems and markets; clean and renewable energy generation; cyber physical energy systems in the smart grid; distributed resource integration and adoption; building technology, micro-grids and load management. The successful candidate for this position will be an innovative leader in energy technology and policy, with potential for leadership and future positioning of the CEESI. This person will work closely with faculty in the College of Engineering and will be expected to have collaborative activity in energy related research and teaching activities in one or more of the Division of Systems Engineering, the Center for Information Systems Engineering, the Division of Materials Science and Engineering, the School of Management and the College of Arts and Sciences.

This position will be filled at the rank of tenured associate or full-professor appointment in one or more departments within the College of Engineering based on the individual's research and educational credentials. The individual should have a history of external funding in addition to being internationally recognized for distinguished contributions to the field of energy systems applied to one or more of the application domains mentioned above. The individual who assumes the position will find that collegial support from people in allied disciplines will provide a multiplier effect granting significant advantages to Boston University energy initiatives. Thus the successful candidate should be able to articulate a vision of the collaboration and leadership that will be needed to make Boston University a recognized leader in sustainability and energy.

The College of Engineering is comprised of three departments (Biomedical, Electrical & Computer, and Mechanical) and two graduate divisions (Systems Engineering and Materials Science and Engineering) consisting of 125 faculty, 75 staff, 1200 undergraduates and 500 graduate students. The College has risen rapidly in distinction over the past decade, being ranked in the top 40 by US News and World Report, and in the top 20 in research dollars per faculty member. The college recently completed a 187,000 square foot Life Science and Engineering Building. Significant resources by the College and University will continue to be invested in expanding engineering research and educational facilities. For more information, please visit the following web sites

http://www.bu.edu/eng
http://www.bu.edu/energy/
http://www.bu.edu/se/

Persons interested in being considered for this position should submit a brief letter of interest and current curriculum vitae to:

Michael Caramanis, Chair, Energy Systems Faculty Search Committee
energysearch@bu.edu

Applications will be accepted until the position is filled.

Boston University is an affirmative action, equal opportunity employer committed to increasing the cultural and intellectual diversity of its faculty.

Computer Science and Electrical Engineering

FACULTY POSITIONS

at the Catholic University of America

CUA

The Department of Electrical Engineering and Computer Science at the Catholic University of America invites applications for faculty positions at the Assistant and Associate Professor levels.

Qualified candidates must have a strong commitment to undergraduate and graduate education and the potential to develop an externally funded research program. Candidates at the Associate Professor level must have a strong record of scholarly and professional accomplishments.

The department will give priority to candidates at the Associate Professor level having expertise in high performance computing, including FPGA, GPU and multicore systems, and their applications in all fields of engineering. The department is also seeking qualified candidates for two positions at the Assistant Professor level in information forensics and security, as well as medical informatics.

Candidates must have earned a PhD in Electrical Engineering or Computer Science or a related discipline. Applications will be reviewed starting January 1st, and will be accepted until the positions are filled. Candidates should send a résumé and a list of three references to *Dr. Nader Namazi, Chair of Faculty Search Committee, Department of Electrical Engineering and Computer Science, The Catholic University of America, 620 Michigan Avenue NE, Washington, DC 20064;* ***facultysearch.cuaeecs@gmail.com.***

The Catholic University of America is an Equal Opportunity employer, and encourages applications from women and minority groups.

ILLINOIS INSTITUTE OF TECHNOLOGY

Electrical and Computer Engineering Department Chair Search

The Illinois Institute of Technology (IIT) is seeking a distinguished scholar for Department Chair of the Electrical and Computer Engineering (ECE) Department.

www.ece.iit.edu

IIT is a private research university in the heart of Chicago. IIT has entered an exciting period under leadership of a new president, provost, and dean of the Armour College of Engineering. IIT's recently developed strategic plan places engineering excellence among its highest priorities. As IIT's largest engineering department, the ECE Department is central to this vision, and it plays a leading role in interdisciplinary themes identified in the strategic plan.

The ECE Department offers bachelor, master and doctoral degrees in electrical engineering and computer engineering. It has 23 tenured/tenure-track faculty members, 281 undergraduate students, and 615 graduate students. The department received $4.5M in research awards in the most recent fiscal year.

Candidates for the position are expected to merit appointment as full professor and have a record of distinguished research and educational achievements.

For full consideration, applicants should submit a letter of interest outlining their qualifications and vision for the position, curriculum vitae, and the names and contact information of at least three references. Application materials should be submitted electronically to ***ece_search@iit.edu***. Review of applications will begin February 15, 2010 and will continue until the position is filled.

Direct questions and enquiries to the Search Committee Chair, Dr. Darsh Wasan, Vice President for International Affairs, at 312-567-3001 or ***wasan@iit.edu***.

Illinois Institute of Technology is an Affirmative Action/Equal Opportunity Employer.

THE GEORGE WASHINGTON UNIVERSITY

WASHINGTON DC

Tenure-track Faculty Positions in the Department of Electrical & Computer Engineering at The George Washington University

The Department of Electrical and Computer Engineering at The George Washington University invites applications for two tenure-track positions at the Assistant Professor rank in the areas of networking and security, and nano-electronics. Successful candidates may start as early as Fall 2010.

The department has a well-established and nationally recognized research program in the fields of telecommunications and networks, micro- and nano-electronics, computer engineering, and biomedical engineering, among others. In addition, the university has initiatives designating the areas of biomedical engineering, nano-technology and high-performance computing as areas of excellence, and has identified cybersecurity as an area of future growth. The George Washington University is located in the nation's capital with close access to many federal funding agencies and government research laboratories.

Responsibilities: Successful candidates will be expected to develop externally sponsored research programs, supervise masters and doctoral students, and contribute to the teaching and advising of graduate and undergraduate students.

Basic Qualifications: Applicants must have a doctoral degree in Electrical, Computer, or Biomedical Engineering, or a closely related field. ABD candidates will be considered, but must complete the degree by August 15, 2010. Applicants must 1) demonstrate strong research potential, as evidenced by publications in archived journals and conference proceedings; 2) demonstrate substantial potential to attract extramural research funding; and 3) demonstrate the ability to teach undergraduate and graduate level courses.

Preferred Qualifications: For the networking position, candidates in all areas of networking that complement the existing strengths of the department in wireless and optical communications and networking, and grid computing are encouraged to apply. Preference will be given to candidates with interests and expertise in network security and/or network systems. For the nano-electronics position, candidates in all areas nano-electronics that complement the existing strengths of the department in micro- and nano-electronics, and biomedical engineering are encouraged to apply. Preference will be given to candidates with interest and expertise in nano-sensors, bio-sensors and related applications. For both candidates, a strong background in designing and evaluating experimental systems will be an added advantage.

How to Apply: To be considered, applicants must send a letter containing (i) the position they are applying to, (ii) a brief statement of interest, (iii) a curriculum vita, (iv) a statement of research and teaching interests, (v) copies of at least three representative publications, and (vi) complete contact information of at least five references to:

Professor Mona Zaghloul, Chair
Department of Electrical & Computer Engineering
The George Washington University
Washington, DC 20052, U.S.A
http://www.ece.gwu.edu/

Only complete applications will be considered. Only electronic applications will be accepted and should be mailed to ***zaghloul@gwu.edu***.

Review of applications will begin on 2/1/2010 and will continue until the position is filled.

THE PETROLEUM INSTITUTE

ABU DHABI, UNITED ARAB EMIRATES

Institution: The Petroleum Institute (PI) in Abu Dhabi, United Arab Emirates was created in 2001 with the goal of establishing itself as a recognized institution in engineering education and research in areas of significance to the oil and gas and the broader energy industries. The PI's sponsors include the Abu Dhabi National Oil Company and four major other international oil companies, namely BP, Shell, Jodco, and Total. The Institute is affiliated with and has collaborative programs in place with the Colorado School of Mines, the University of Maryland at College Park, The University of Minnesota, and Leoben and Linz Universities (Austria). For more 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 Professor, Distinguished Professor
Professor, Associate Professor, Assistant Professor
Senior Research Associate, Research Associate

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.

Interested candidates should submit all materials online:

www.pi.ac.ae/jobs

Review of applications will begin immediately
and will continue until successful candidates are selected

Only short-listed applicants will be notified.

Boston University College of Engineering
Department of Biomedical Engineering

BOSTON UNIVERSITY

Tenured Faculty Position in Synthetic & Systems Biological Engineering

The College of Engineering is seeking an innovative individual to help lead the College's research and educational efforts in Synthetic & Systems Biological Engineering (SSBE). This interdisciplinary position will advance research and education at the intersection of systems and synthetic biology, systems engineering, bioengineering, nanotechnology, and medicine. This person will work closely with leading experimental, modeling, computational, and data generation faculty in the College of Engineering who are advancing engineering to address crucial challenges in synthetic and systems biology. The position will also couple with a University-wide effort in systems biology with faculty from Physics, Biology, Chemistry, Computer Science, and the Medical School, as well as the ability to partner with BU's new National Emerging Infectious Diseases Laboratory, a BSL4 facility at the Medical School.

This position may hold a tenured Associate or Full-Professor appointment in one or more departments based on the individual's research and educational priorities and expertise. The individual should have a strong history of external funding in addition to being internationally recognized for distinguished contributions to synthetic and systems biological engineering.

The College of Engineering is comprised of three departments (Biomedical, Electrical & Computer, and Mechanical) and two graduate divisions (Systems & Materials Science). The College has risen rapidly in distinction, being ranked in the top 40 by *U.S. News & World Report,* and in the top 20 in research dollars per faculty member. Its Biomedical Engineering program is ranked in the top 10 in the nation. The University recently completed a 187,000-square-foot Life Science & Engineering Building. Significant College and University resources will continue in the SSBE area. For more information, please visit the following websites: www.bu.edu/eng; www.bu.edu/eng/bme; www.bu.edu/abl/; www.bu.edu/ece.

Candidates should submit a brief letter of interest and current curriculum vitae to: Jim Collins, Chair, SSBE Faculty Search Committee (ssbesearch@bu.edu)

Applications will be accepted until the position is filled.

Boston University is an affirmative action, equal opportunity employer committed to increasing the cultural and intellectual diversity of its faculty.

Carnegie Mellon
Electrical & Computer ENGINEERING

Research and Tenure Track Faculty Positions

www.ece.cmu.edu

The Department of Electrical and Computer Engineering (ECE) at Carnegie Mellon has faculty openings (both research and tenure track). Exceptional candidates in all areas of ECE will be given serious consideration. Particular areas of interest include computer security, computer architecture, networking and communications, computer/neural interface, IC design and manufacturing, nano-enabled technologies, and energy systems. Applicants must have earned a doctorate in ECE or a related area.

The College of Engineering and the ECE Department are ranked among the top ten pro- grams in the U.S. at the undergraduate and graduate levels. The faculty have strong ties with many multidisciplinary centers and institutes such as the Institute for Complex Engineered Systems, Carnegie Mellon CyLab, Software Engineering Institute, Human Computer Interaction Institute, The Robotics Institute, and the Information Networking Institute. The department is home to several multidisciplinary centers and laboratories such as the Data Storage Systems Center, Center for Silicon System Implementation, Microelectromechanical Systems Laboratory, the Parallel Data Laboratory, and the Computer Architecture Lab.

A moderate teaching load allows time for quality research and close involvement with students and other faculty. We expect candidates for a tenure track position to have a strong commitment both to research and teaching at the undergraduate and graduate levels, while candidates for research track positions would focus primarily on research.

Applications should specify the position (research or tenure track) in which they are most interested, though candidates will be considered for both, and include a comprehensive resume, a list of three to five professional references, a statement of research and teaching interests (less than 2 pages), and copies of two research papers (journal or conference papers). The applicant is responsible for soliciting the reference letters to be sent to the address below. Send applications to:

T. E. (Ed) Schlesinger
Professor and Head
Electrical and Computer Engineerig
Carnegie Mellon University
Pittsburgh, PA 15213-3890

Carnegie Mellon is building a culturally diverse faculty and encourages applications from female and minority candidates. Carnegie Mellon is an Equal Opportunity Emplloyer.

Openings for Faculty Positions in Department of Information and Communications and Department of Mechatronics

Gwangju Institute of Science and Technology (GIST)

The Department of Information and Communications and Department of Mechatronics at the Gwangju Institute of Science and Technology (GIST) invite applications from the outstanding candidates for several faculty positions in all ranks. Level of appointment will be commensurate with the qualifications and experience. Applicants with outstanding research credentials will be considered at a senior level position.

The departments are looking for candidates who can drive new research initiatives in all areas of information and communication engineering: communication systems and computer networks, photonics, semiconductors and high speed electronics, signal processing, and computer science and engineering for Information and Communication, and opto-mechatronics, intelligent robotics/control, biomedical engineering, signal processing for Mechatronics.

More detailed information is available at **http://ewww.gist.ac.kr**

The successful candidates must have demonstrated excellence in research and teaching at the graduate level, and have the ability to independently lead research programs and to supervise graduate students in their respective fields of research interest. A Ph.D. qualification in Electrical Engineering, Computer Engineering, Mechanical Engineering or a closely related discipline is required for the appointment. The successful candidates will be strongly supported through an excellent start-up package to establish their research laboratories. The departments also offer opportunities for participation in the ongoing research activities and educational programs.

GIST is a research-oriented graduate school established by the Korean government in 1993. The Korea Ministry of Education, Science and Technology provides full financial support to students in order to produce world-class scientific and technologists with exceptional leadership skills. In its short 17-year old history, GIST has been recognized as a leading research institute for science and technology through its outstanding research achievements and successful globalization of its image as an advanced educational institution.

Applications are accepted on quarterly basis, and will be considered until the positions are filled. Please submit an application electronically to **academy@gist.ac.kr** or by regular post to; Section of Academic Affairs, Gwangju Institute of Science and Technology, 261 Cheomdan-gwagiro(Oryong-dong), Buk-gu, Gwangju 500-712 Republic of Korea. The application form can be downloaded from **http://ewww.gist.ac.kr**. For further information please contact the search committee, **openings@infcom.gist.ac.kr** and **mo@mecha.gist.ac.kr**.

NAVAL RESEARCH LABORATORY

ACOUSTICS DIVISION BRANCH HEAD

ACOUSTICS SIGNAL PROCESSING BRANCH

The Naval Research Laboratory's Acoustic Division is searching for a senior level research physicist/ engineer to lead a science and technology research team composed of experimental and theoretical physicists, mathematicians, engineers, technicians, and post doctoral students. The team is presently addressing: 1) the physics of random media acoustic signal propagation; 2) the impact of the random ocean media on the performance of phase coherent and incoherent signal processing algorithms; 3) the simulation of real time three dimensional shipping noise field; 4) the impact of environmental and computational uncertainty on the prediction of acoustic signal properties and signal processor performance and 5) the performance of acoustic communication systems in the dynamic ocean.

The selectee must be qualified for a US Navy Secret Level clearance. The position is at a NRL CCSD Level IV ($82,118-$127,604 plus 23.1% locality pay). Salary will be determined based upon selectee's background experience and leadership potential. Candidates must have a significant publication record in major peer reviewed scientific journals. Candidates with Ph.D. level educational backgrounds are preferred.

This position requires US citizenship or Legal Permanent Residency.

Interested applicants should email Dr. Douglas Todoroff at: ***douglas.todoroff@nrl.navy.mil***

2 Tenure-track Faculty Openings In EECS

The Min Kao Department of Electrical Engineering and Computer Science (EECS) at The University of Tennessee, Knoxville is seeking candidates for tenure-track faculty positions in two fields: 1) with background in Electrical Engineering, including device physics, RF/millimeter wave devices or bio-electronics, and 2) with background in Computer Engineering, including embedded systems, computational science, and next-generation networking and architecture. The Department currently enrolls approximately 400 undergraduate and 250 graduate students. Faculty research expenditures currently average about $10 M per year. The department is starting a new growth phase thanks to gifts from alumnus Dr. Min Kao and other donors plus additional state funding totaling over $47.5 M for a new building and endowments for the department. The University of Tennessee and Battelle manage the nearby Oak Ridge National Laboratory, which provides further opportunities for research.

Information about the EECS Department can be found at
http://www.eecs.utk.edu/.

Candidates should have an earned Ph.D. in Electrical Engineering, Computer Engineering, Computer Science, or equivalent. Candidates should have outstanding potential for establishing an independent research and teaching program in their field and should be capable of working with other faculty to further strengthen our existing research. Interested candidates should apply through the departmental web site at **http://www.eecs.utk.edu/jobs/faculty** and submit a letter of application, curriculum vitae, a research and teaching statement, and provide contact information for three references. Consideration of applications will begin on January 15, 2010 and the position will remain open until filled.

The University of Tennessee is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA institution in the provision of its education and employment programs and services. All qualified applicants will receive equal consideration for employment without regard to race, color, national origin, religion, sex, pregnancy, marital status, sexual orientation, gender identity, age, physical or mental disability, or covered veteran status.

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Positions at the Institute for Defense Analyses Center for Computing Sciences

IDA

The Institute for Defense Analyses Center for Computing Sciences (IDA/CCS) is looking for outstanding researchers to address difficult computing problems vital to the nation's security. IDA/CCS is an independent, applied research center sponsored by the National Security Agency (NSA). Emphasis areas for IDA/CCS technical staff include high-performance computing, cryptography, and network security. Members of the technical staff come from a diverse variety of backgrounds, including computer science, computer architecture, computer/electrical engineering, information processing, and the mathematical sciences; most have Ph.D.s. Special attention is paid to the design, prototyping, evaluation, and effective use of new computational algorithms, tools, paradigms, and hardware directly relevant to the NSA mission. Stable funding provides for a vibrant research environment, and an atmosphere of intellectual inquiry free of administrative burdens.

The center is equipped with a very large variety of hardware and software. The latest developments in high-end computing are heavily used and projects routinely challenge the capability of the most advanced algorithms and architectures. IDA/CCS research staff members have always been at the forefront of computing, as evidenced by lasting, visible contributions to areas as varied as multi-threaded architectures (e.g., Horizon), novel computing systems (e.g., FPGA-based Splash and Splash-2, Processing-In-Memory chips), design and implementation of operating systems (e.g., the Linux kernel), and programming language design and implementation for high-performance computing systems (e.g., Universal Parallel C and Cinquecento).

IDA/CCS research staff work on complex topics often engaging multidisciplinary teams; candidates should demonstrate depth in a particular field as well as a broad understanding of computational issues and technology. Because the problems of interest are continually evolving, IDA/CCS recruitment focuses on self-motivation, strength of background, and talent, rather than specific expertise.

Located in a modern research park in the Maryland suburbs of Washington, DC, IDA/CCS offers a competitive salary, an excellent benefits package, and a superior professional working environment.

U.S. citizenship and a Department of Defense TSSI clearance (with polygraph) are required. IDA/CCS will sponsor this clearance for those selected. The Institute for Defense Analyses is proud to be an equal opportunity employer.

Please send responses or inquiries to:
Dawn Porter
Administrative Manager
IDA Center for Computing Sciences
17100 Science Drive
Bowie, MD 20715-4300
dawn@super.org

the data

Rare Earth Metals

Supply and Demand

REST-OF-WORLD PRODUCTION
THOUSANDS OF METRIC TONS

CHINESE PRODUCTION
THOUSANDS OF METRIC TONS

Sources: IMCOA, U.S. National Geological Survey

The Rare-Earth-Metal Bottleneck

WHAT WOULD happen if the production of laptops, cellphones, and MP3 players suddenly halted? Oh, and no more hybrid electric vehicles and MRI machines? It probably won't happen, of course, but the fact that it could is scary enough. A single country, China, mines more than 95 percent of the world's supply of rare earth metals, found in permanent magnets, phosphors, lasers, capacitors, and superconductors.

That's not to say that China has all the deposits. In fact, most of the 17 elements in this group aren't rare at all. They got their name because the ores in which they're found are notoriously difficult to extract from Earth's crust. It's expensive to mine them in the United States, Europe, and other places with relatively strict environmental laws. China, with fewer such scruples, has been able to flood the market. In 1992, the price of ore containing these elements plummeted, and Molycorp Minerals, in Greenwood, Colo., the owner of the largest U.S. repository of rare earth metals, stopped digging.

As recently as 2004, China used less than half of the rare earth metals it produced. But according to an estimate by the Industrial Minerals Co. of Australia, in Mount Claremont, China's domestic demand will overtake its production in less than 10 years. Now Beijing is considering banning exports of some rare earth elements and limiting shipments of others to 35 000 metric tons a year, which would immediately threaten not just electronics manufacturing across the globe but also hybrid vehicles. A Toyota Prius, for example, requires about a kilogram of neodymium for its electric motor and as much as 15 kg of lanthanum for its battery pack.

In anticipation of China turning off its rare-earth spigot, Molycorp is gearing up to go back into full production. When mining restarts in 2012, the site is expected to turn out 20 000 metric tons of rare earth metals each year, says CEO Mark Smith. But the research site HardAssetsInvestor.com estimates that by then, annual world demand outside China is likely to exceed 60 000 metric tons. —*Willie D. Jones*

NICHOLAS EVELEIGH