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THE MAGAZINE OF TECHNOLOGY INSIDERS
11.08

WEAPONS ACQUISITION

SPENDING TOO MUCH, GETTING TOO LITTLE

F-22 FIGHTER:
$137 000 000

HOW "DOUBLE VISION" WILL SAVE CHIP MAKING

THE MEDITERRANEAN'S NEW RING OF POWER

HIGH-TECH HOLIDAY GIFTS

IEEE

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EASY AS AED: Engineers foolproofed the defibrillator so that anybody can use it [top left]; Fatima Mansouri [top right] helped link Morocco's power grid with Europe's; the U.S. Marine Corps' Expeditionary Fighting Vehicle [bottom] is expected to take 20 years to field.

COVER: U.S. AIR FORCE

THIS PAGE, CLOCKWISE FROM TOP LEFT: CARDIAC SCIENCE; ANA NANCE; U.S. MARINE CORPS

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TOP: GENERAL MOTORS
BOTTOM: H&S PRODUCTION/
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AVAILABLE ONLINE 1 NOVEMBER

THE R&D 100: STILL SPENDING BILLIONS

Economies crater from time to time, but companies must continually spend more money on R&D [above] or be left behind when the inevitable upturn comes. Despite spending growth in India and China, this year's list of the world's top 100 spenders is dominated by firms from the U.S., Japan, Germany, and the UK. Who topped the chart? Which U.S. telecom giant boosted spending by 341 percent? Which German colossus slashed spending by 32 percent? Read the list, then use our interactive **R&D 100 Graph-o-matic** to compare spending across companies, industries, and countries.

ONLINE FEATURES:

NEW BLOG: Starting this month, Senior Editor William Sweet and veteran energy journalist Peter Fairley analyze cutting-edge alternative-energy technologies and provide perspective on climate-change issues in their new blog, ***Energywise***.

TECH GIFT GUIDE SUPPLEMENT: Exclusive video and Web-only reviews of the hottest holiday gadgets for geeks of all ages.

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IEEE HONORS INNOVATORS

From the microprocessor to the World Wide Web, the contributions of this year's recipients of IEEE medals and awards have had a major impact on our daily lives. Check out highlights from the IEEE Honors Ceremony.

TWO NEW IEEE MILESTONES

The newest IEEE Milestones recognize the Edison West Orange labs in New Jersey and the Japanese word processor in Tokyo.

IEEE ENERGY CONFERENCE

The first conference of its kind, the IEEE Energy 2030 Conference will bring together experts from a broad range of disciplines to discuss the technology, policy, and economic framework required for the creation of a global sustainable energy infrastructure by 2030. The conference will be held 17 and 18 November in Atlanta.

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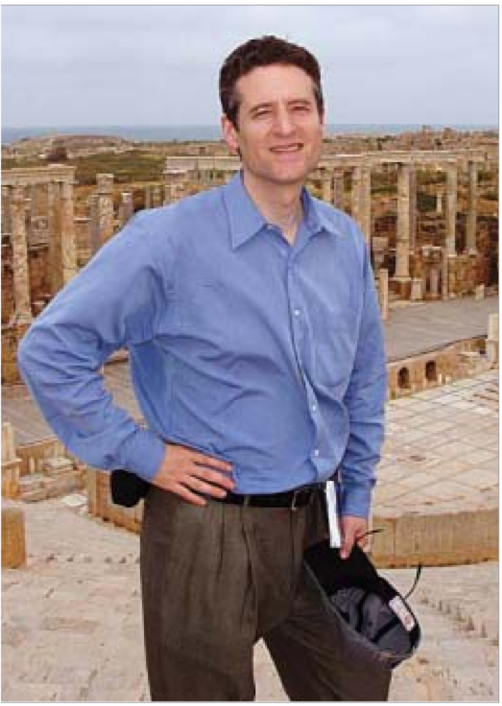
back story



PETER FAIRLEY

The Ties That Bind

SOME 2000 years ago, North Africa was an integral part of the Roman Empire. Those early ties with Europe are apparent from the Roman ruins that remain there, including those of Leptis Magna, in Libya. The spectacular theater of this ancient city was one of the few tourist sites that Contributing Editor Peter Fairley [above] was able to take in during his journeys.

Fairley spent two years planning his fieldwork in North Africa to investigate the region's role in the emerging Mediterranean Electricity Ring, or MedRing. But a week before he was to leave home, a promised Algerian visa evaporated amid that country's deteriorating security situation. So he quickly had to redirect part of his focus from Algeria to Morocco. "It gave me ulcers," Fairley says. His revised itinerary turned out for the best, however, opening his eyes to some of the vast differences within the region.

Fairley observed firsthand that parts of Casablanca, Morocco's main economic hub, could easily be mistaken for a bustling European capital, whereas Tripoli, in Libya, suffers from decades of isolation under Muammar al-Qaddafi's rule.

More recently, in the wake of Libya's renunciation of terrorism and abandonment of its efforts to obtain weapons of mass destruction, the country has been working to rebuild links with the international community. Some of those ties, as Fairley details in his feature article, run at hundreds of kilovolts: they are electrical interconnections of the Libyan grid with countries to the east and, very soon, to the west. Completing these interconnections will be a key step in bringing about the MedRing's long-awaited closure.

With greater electrical stability, the countries of North Africa may gain a measure of economic security, as more reliable electrical supplies begin to improve the quality of life. Further in the future, the intercontinental ties might allow North African organizations to sell "green" electricity northward: there are rich potential sources of wind and solar energy along the Mediterranean's southern flank and ready markets for it across southern Europe. Fairley hopes that the increasingly robust connections with Europe may even eventually strengthen democratic institutions within North African countries. "Despite the patina of democracy," Fairley explains, "for the people who live there, it's a dangerous place to be critical." ❑

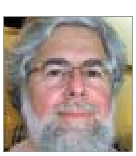
CITING ARTICLES IN IEEE SPECTRUM

IEEE Spectrum publishes two editions. In the international edition, the abbreviation INT appears at the foot of each page. The North American edition is identified with the letters NA. Both have the same editorial content, but because of differences in advertising, page numbers may differ. In citations, you should include the issue designation. For example, the first Update page is in *IEEE Spectrum,* Vol. 45, no. 11 (INT), November 2008, p. 9, or in *IEEE Spectrum*, Vol. 45, no. 11 (NA), November 2008, p. 13.

contributors

ROBERT N. CHARETTE, an *IEEE Spectrum* contributing editor, is a self-described "risk ecologist" who investigates the impact of the changing concept of risk on technology and societal development. In writing the cover story, "What's Wrong With Weapons Acquisitions?" [p. 26], he spent over 18 months interviewing dozens of industry and government defense-acquisition experts. "Everyone knows the acquisition process desperately needs to change," he says. "Unfortunately, no one I spoke to believes it will change until there is a major national crisis." Charette writes Spectrum Online's Risk Factor blog.

ANNA DEMIAN is a New York City–based independent art director and illustrator. Over the past five months, she has created illustrations and information graphics for several feature articles in *Spectrum*, including this month's "Weapons Acquisitions" [p. 26]. Demian holds a B.S. in biology, and her work is influenced by a lifelong interest in science and the natural world.



DANIEL DERN has amassed quite a collection of small, now outdated computers in his quest for the perfect portable machine. In this issue, he writes about Toshiba's new Qosmio laptop [p. 20]. "Technology is interesting both for its own sake and the uses it gets put to—what we can do with it and what difference it makes in business, our lives, and the world," Dern says. "Plus, we get to play with cool stuff."

MARK W. KROLL, an electrical engineer, and **BYRON GILMAN**, a chemist, share a long history of developing medical devices. In 1991, they realized that with available technology they could build a simple, automated external defibrillator to treat cardiac arrest. But first they needed a creative mechanical engineer to round out the team. They chose **KARL KROLL**, who, coincidentally, is Mark's brother. Together the three founded Survivalink Corp. to deliver the device. They chart the creation of the first self-testing, single-button AED in "Idiotproofing the Defibrillator" [p. 34].

CHRIS A. MACK considers double-patterning lithography in "Seeing Double" [p. 40]. Dr. Mack (yes, even his mother calls him Dr. Mack) is recognized worldwide as a leading expert in lithography. He is an adjunct faculty member in the electrical and computer engineering and the chemical engineering departments of the University of Texas at Austin.

ANA NANCE photographed Fatima Mansouri, network project manager at Morocco's state-owned electric utility, for "Closing the Circuit" [p. 46]. She then spent the rest of the day wandering around Casablanca, getting shots of the city. Since it was Ramadan, the normally bustling Old Medina was completely empty, she says. Nance regularly shoots for Spain's highest-circulation newspaper, *El Pais*, as well as *Marie Claire* and *Bon Appétit*.

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CLOCKWISE FROM TOP LEFT: JAMES KEGLEY; SUSAN MACK; VIRGINIA ESTEBANEZ; ERNEST LILLEY; ANNA DEMIAN

spectral lines

Driving the DOD Toward Change

"DOD [the U.S. Department of Defense] is not receiving expected returns on its large investment in weapon systems. Since fiscal year 2000, DOD significantly increased the number of major defense acquisition programs and its overall investment in them. During this same time period, the performance of the DOD portfolio has gotten worse. The total acquisition cost of DOD's 2007 portfolio of major programs under development or in production has grown by nearly $300 billion over initial estimates. Current programs are also experiencing, on average, a 21-month delay in delivering initial capabilities to the warfighter—often forcing DOD to spend additional funds on maintaining legacy systems."

So begins the introduction to a report by the U.S. Government Accountability Office (GAO) to a U.S. Senate subcommittee with oversight of federal financial management in September, just as the world's financial markets began to crumble.

The facts contained in the report are appalling enough in their own right, but what's even worse is that the GAO has issued dozens of reports like these and trudged to the Hill dozens of times over the years to deliver the same bad news. Why does the problem continue to spiral out of control? Why can't it be contained?

Well, as Contributing Editor Robert N. Charette explains in our cover story, "What's Wrong With Weapons Acquisitions?" the reasons are myriad and messy. And as he points out, these defense-acquisition problems have existed for decades, but now the cost of every project that goes off the rails is staggering—and many projects do.

The two most obvious culprits in this debacle are politics and money. The DOD's base budget for FY 2008 was US $480 billion, while the budget for FY 2009 is $515 billion, a nearly 74 percent increase over 2001—and that's a lot of loot. This budget supports military readiness but doesn't even include the billions of dollars in expenditures—$189 billion this year alone—for the Global War on Terror. Lobbyists and members of Congress are all jockeying for part of the pot. And once DOD projects get started, they are very difficult to stop—even if they are obviously failing—because there are jobs and economic development and elections at stake. Defense contractors compound the problem by routinely promising the moon and then failing to deliver, leading to costly project delays and overruns.

But then there are also real engineering problems. Many of the projects the DOD takes on—large integrated "system of systems" defense efforts, for example—require brand-new technologies, which means that the course of their development is uncharted and unpredictable—and late and over budget.

Another issue, according to Charette, is the "gathering storm" problem. In the United States it's hard to maintain a skilled engineering and scientific workforce for big, complicated projects. And an economic environment like the current one, in which the big defense contractors may be looking at defense-contract cutbacks—and layoffs—won't help matters.

During our long prosperity, there really hasn't been much incentive to deal with the DOD problem, or others like it—and the federal government has plenty. Yes, there have been the requisite hearings and righteous (yet toothless) legislation, but no results. But now, with space for new digits added to the National Debt Clock and a national debt fast approaching $11 trillion, perhaps the will to change will begin to stir in both the public and private sectors.

The United States is certainly not the only country with weapons-acquisition trouble. Many others suffer from similar issues of bloat and bad management. But with a new president on the way, and a historically bad global economy running its course, this could be the time for verifiable oversight, true accountability, and rigorous project management to be finally given credence at the DOD. After all, a billion saved is a billion earned.

—Susan Hassler

DAN PAGE

forum

18 INT · IEEE SPECTRUM · SEPTEMBER 2008

Extremist Engineers

Why are so many jihadis engineers?

WHICH ACADEMIC pursuit has been the most prevalent among Islamic jihadis?

It's not the oddest question to come up at a dinner party, especially at the University of Oxford. But when it comes up between a Middle East expert and a sociologist, idle talk yields to a quest for data. That's how political scientist Steffen Hertog and sociology professor Diego Gambetta soon found themselves poring through records of 404 people from 30 countries engaged in political violence between 2005 and 2007. Their answer? Engineering.

Of the 178 whose academic focus could be ascertained, 44 percent of those were engineers—most of them in electrical engineering, civil engineering, and computer studies. The next-largest group, Islamic studies, had fewer than half as many, at 19 percent [see table, "Fields of Study"].

The authors acknowledge that the data underrepresent groups in South Asia, Southeast Asia, North Africa, and Iraq. They claim, though, that the sample population is "disparate enough—there are individuals from 30 nationalities, nine larger groups, and no fewer than a dozen smaller groups—to allow us to establish whether the puzzle holds true."

The findings garnered worldwide attention when they were published online last fall in a 90-page working paper. A catchy title didn't hurt: "Engineers of Jihad."

Hertog, now a lecturer in political economy at the University of Durham, in England, says that though he and Gambetta expected the paper to get noticed, they were surprised by accusations of "ethnic profiling."

"After all, the anecdote that engineers were overrepresented in radical Islamic movements in the Middle East has been around for decades," Hertog says. "But there was never a systematic study about how many were involved in political violence or radical Islam."

Curiously, the two have not heard from Islamists themselves. "Frankly, we hope we don't, after what the engineers said," Hertog adds. "Some of them were generally curious. But most had knee-jerk reactions. Look, we did not say engineers have a terrorist mind-set—please write that. We said that engineers tend to be politically to the right and more conservative than other graduates. You can therefore infer that their radical fringe is closer to those of religious groups."

Hertog and Gambetta believe that a combination of social conditions and an engineering mind-set make engineers susceptible to radicalization.

The paper cites evidence that engineering graduates are much more religious and politically conservative than those pursuing other courses

FIELDS OF STUDY	
Engineering	78
Islamic studies	34
Medicine	14
Business/economics	12
Sciences	7
Education	5
Other	28
Subject unknown	18
Total	**196**

Source: "Engineers of Jihad," by Diego Gambetta and Steffen Hertog, *Sociology Working Papers*, paper number 2007-10, University of Oxford.

BRIAN STAUFFER

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WHO CHOOSES ENGINEERING?

I HAD HOPED to find more data in "Extremist Engineers" [Careers, September]. Without knowing how many college-educated people there are in the pool of people who become jihadis, how can one reach any conclusion? My suspicion is that many of the college-bound from the Middle East select engineering because it is a profession where a bachelor's degree can get you a decent job in a Western democracy based on your skill, knowledge, and intelligence. Those who major in religion, psychology, and similar fields where cultural differences, connections, and prejudices make it more difficult to find employment don't migrate or otherwise acquire the skills and knowledge to function in the West. And while contact with the West and advanced technology directly or through academia may allow one to acquire the skills to become an effective jihadi, I believe that only a very small percentage of engineers who migrate to Western countries become jihadis.

J.P. FITZSIMMONS
IEEE Member
Newburyport, Mass.

IS IT really so surprising to find engineering so well represented in extremist organizations? What other profession would we expect? If the researchers did a survey of the U.S. defense industry, my guess is that they would get similar results. Would that surprise anyone? I don't think so. Isn't the primary purpose of every militia to apply technology to defeat the perceived enemy? So why is it so surprising when a so-called extremist organization requires technology? And what is it that makes an organization extremist? *IEEE Spectrum* and the researchers may call them extremist, but I'd say they see themselves as freedom fighters or even liberators and see the cause as righteous. By the way, isn't liberation one of the many justifications we in the United States were given for our invasion of Iraq? The war has applied a massive amount of technology attempting to defeat our perceived enemy. It's not so surprising that groups who see us as the enemy would do the same. Extremists, terrorists, freedom fighters, defenders of democracy—whatever tag you hang on them—require applied technical skills, and who better to supply that than engineers?

MARK CARANGI
IEEE Senior Member
Livingston, N.J.

SCAT, CAT! BEGONE, BOMB!

HAVING READ "Countering IEDs" [September], I remember that in 1958 Varian Associates had a project to perfect a microwave device to find plastic land mines. They tested this system in a wooden shed containing a large sandbox and an apparatus that moved the microwave antenna at a constant height. The results showed that the system was able to find plastic land mines. However, stray cats had found a hole in the shed, gone in, and used the sandbox. The system could not tell land mines from cat scat!

A physicist at Varian told of being asked to evaluate an experiment in which trained dogs were to find land mines. The dogs were confined in a wooden pen while men buried the mines in an adjacent plowed field. The dogs would find the mines and be rewarded with a nice piece of meat. When the experiment was performed, other observers watched the men burying mines, but my friend watched the dogs. The dogs were watching the mines being buried through holes in the fence!

ROBERT J. RORDEN
Los Altos, Calif.

CORRECTIONS

In "Battery Czar" [August], we wrote that "the software algorithm that controlled the firing of the spark plugs had to 'know' the position of every cylinder to fire at the optimal time." The algorithm had to know the position of every *piston*.

In "Energy-Efficient Ethernet" [Update, May] we stated, "In 2005, all the network-interface controllers in the United States—computers, switches, and routers all have them—burned through 5.3 terawatt-hours of energy, enough to keep 6 billion 100-watt lightbulbs shining all year." The figure should have been 6 million.

more online at www.spectrum.ieee.org

update

High Speed Down Under

Australia invests in a multibillion-dollar national broadband network

An Australian national broadband network began as a 2007 election campaign promise. Liberal party Senator Helen Coonan, then communications minister, said it couldn't be done. The Labor party's telecom expert, Senator Stephen Conroy, thought otherwise. Now that Conroy's party is in the majority, he's taken over as communications minister, and Australia plans to invest AUS $4.7 billion (US $3.1 billion) in a national network. After numerous delays and worry that the government would not follow through, the project seems to be on track—telecommunication companies vying for the job are to submit their proposals by 26 November. The government plans to pick a winner in early 2009.

The Australian plan calls for a fiber-optic network. But because of costs and practicality, analysts say, it will likely include a mix of fiber, WiMax wireless systems, and satellite services. How much of each nonfiber technology the government will go for is the big question that bidders are struggling with.

Building a national broadband network is a daunting task for any country, but particularly for Australia. The combination of a large land mass (slightly smaller than the contiguous United States) and low population density—just 2.7 people per square kilometer—make broadband infrastructure both a technological and economic challenge. Serving Australia's scattered coastal cities—where 85 percent of the population lives—is one thing, but bringing broadband to the outback, where people often live kilometers from one another and hundreds of kilometers from the nearest city, is quite another.

The national network must deliver broadband to 98 percent of the population at a download speed of 12 megabits per second. Those targets might be hard to meet, given Australia's current average speed of 1.7 Mb/s and a

HIGH FIBER: Australia's broadband scheme must cover a sparsely populated continent.
PHOTO: TELSTRA

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100 BILLION Liters of gasoline that might have been conserved in 2007 if every U.S. car had been outfitted with a device—invented by Temple University researchers—that thins fuel with an electric field

update

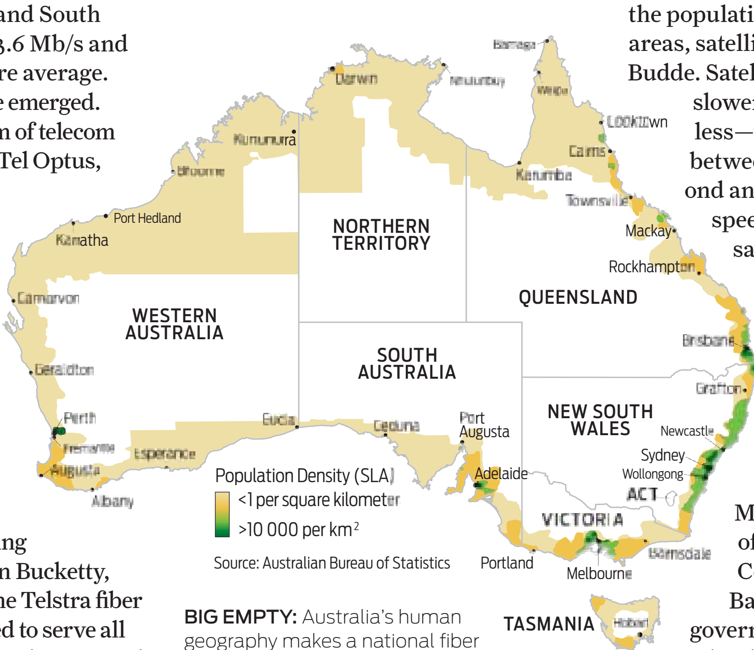
penetration rate of roughly 60 percent of households, according to a report by the Information Technology and Innovation Foundation, in Washington, D.C. While 12 Mb/s would be a huge improvement, it would still leave the country lagging behind others in its region, notably Japan and South Korea, where speeds of 63.6 Mb/s and 49.5 Mb/s, respectively, are average.

Two main bidders have emerged. One is Terria, a consortium of telecom companies including SingTel Optus, Australia's second-largest carrier. Terria will compete against Telstra, Australia's principal telecommunications company. Telstra, in which the Australian government held a controlling interest until 2006, already has much of the infrastructure for a broadband network in place. Paul Budde, managing director of BuddeComm, in Bucketty, Australia, estimates that the Telstra fiber network could be expanded to serve all of metropolitan Australia at the required speed in early 2009. The challenge, he says, will be providing service to the suburbs, small towns, and rural areas.

Telstra has a clear edge, but in the event Terria snags the bid, it will push for an open network so that it can access Telstra's infrastructure. "From a national economic point of view—just like electricity, water, and gas—it does not make sense for that infrastructure to be duplicated or tripled to serve the same function," says Ravi Bhatia, CEO of Primus, a company in the Terria consortium.

The bidders could not disclose the exact details of their proposals because of a government-issued gag order, but both bids most likely include a combination of fiber optics and wireless services such as WiMax, which, ideally, has download data rates of 10 Mb/s to 70 Mb/s, but in practice is more like 1 to 2 Mb/s.

The fiber part of the network, which is likely to be used only in the more densely populated areas, can come in two flavors, fiber to the node or fiber to the home. In fiber to the node, fiber-optic cables form most of the network. Then copper wires branch off from node stations—usually serving a few blocks' worth of buildings—to service the individual customer. The use of a neighborhood's existing copper greatly reduces the cost. But broadband speed over copper cables is limited by distance and the number of subscribers.



BIG EMPTY: Australia's human geography makes a national fiber network difficult. *ILLUSTRATION: ARMAND VENEZIANO*

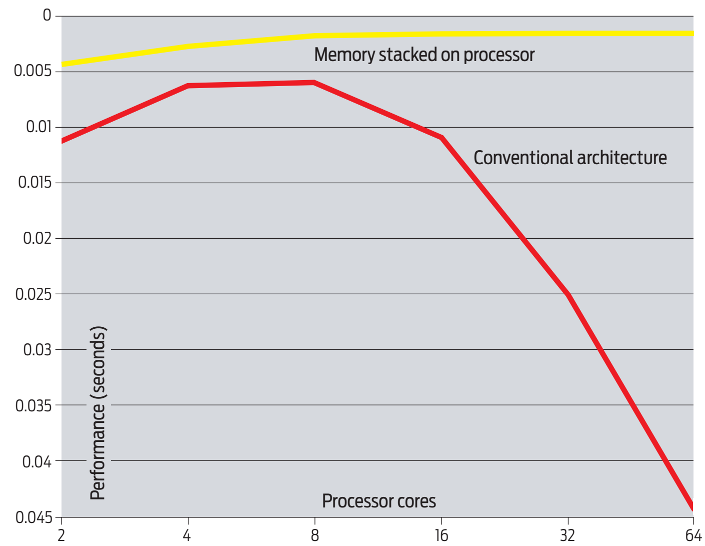
Fiber to the home eliminates the need for node stations but requires running new fiber lines to each building, something that makes economic sense mostly in greenfield developments, says Vince Pizzica, special advisor on technology strategy for Telstra. An entire network of fiber to the home would be extremely expensive. Mark Lutkowitz, a cofounder of Telecom Pragmatics, in Nashville, estimates that it could cost Australia as much as AUS $30 billion—well over the government's AUS $4.7 billion subsidy.

Instead, analysts say, a combination of technologies makes the most sense. Budde says the best mix would be fiber to the home in all major metropolitan areas and smaller cities, with WiMax linking the homes up to 50 km outside the cities. For the 3 percent of the population living in remote rural areas, satellite is the only option, says Budde. Satellite would be a great deal slower than fiber and wireless—with download speeds between 800 kilobits per second and 1.5 Mb/s, and upload speeds of around 500 kb/s, says analyst David Gross of Telecom Pragmatics.

The Australian plan demands a fiber network, so it is unclear whether the government would support proposals that include a large wireless component. Peter Moon, managing director of Horizon Broadband Communications in Ballarat, Australia, says the government's position seems to be shifting as it becomes evident that wireless is a more cost-effective solution. The government is thought to be expecting a proposal with 8 to 10 percent wireless, says Moon. But the general consensus in the industry is that wireless will compose 20 to 30 percent of the system. The government "should have been technology-agnostic from the beginning," Moon says. "That would have been the smart thing." Moon is hoping to have his antenna technology incorporated in the wireless component of whichever bid wins.

Once the bid is awarded, the winner will have to rush to roll out the network. Optimists still cling to an April 2009 time frame for most of the network to be up and running. But some analysts estimate that it will take as long as 15 years to deploy a full network.

—Monica Heger



TROUBLE AHEAD: More cores per chip will slow some programs [red] unless there's a big boost in memory bandwidth [yellow]. SOURCE: SANDIA

Multicore Is Bad News For Supercomputers

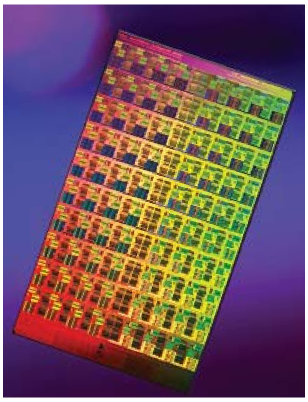
Adding cores slows data-intensive applications

WITH NO other way to improve the performance of processors further, chip makers have staked their future on putting more and more processor cores on the same chip. Engineers at Sandia National Laboratories, in New Mexico, have simulated future high-performance computers containing the 8-core, 16-core, and 32-core microprocessors that chip makers say are the future of the industry. The results are distressing. Because of limited memory bandwidth and memory-management schemes that are poorly suited to supercomputers, the performance of these machines would level off or even decline with more cores. The performance is especially bad for informatics applications—data-intensive programs that are increasingly crucial to the labs' national security function.

High-performance computing has historically focused on solving differential equations describing physical systems, such as Earth's atmosphere or a hydrogen bomb's fission trigger. These systems lend themselves to being divided up into grids, so the physical system can, to a degree, be mapped to the physical location of processors or processor cores, thus minimizing delays in moving data.

But an increasing number of important science and engineering problems—not to mention national security problems—are of a different sort. These fall under the general category of informatics and include calculating what happens to a transportation network during a natural disaster and searching for patterns that predict terrorist attacks or nuclear proliferation failures. These operations often require sifting through enormous databases of information.

For informatics, more cores doesn't mean better performance [see red line in "Trouble Ahead"], according to Sandia's simulation. "After about 8 cores, there's no improvement," says James Peery, director of computation, computers, information, and mathematics at Sandia. "At 16 cores, it looks like 2." Over the past year, the Sandia team has discussed the results widely with chip makers, supercomputer designers, and users of high-performance computers. Unless computer architects find a solution, Peery and others expect that supercomputer programmers will either turn off the extra cores or use them for something ancillary to the main problem.



THE FUTURE: Intel's experimental chip has 80 cores. PHOTO: INTEL

At the heart of the trouble is the so-called memory wall—the growing disparity between how fast a CPU can operate on data and how fast it can get the data it needs. Although the number of cores per processor is increasing, the number of connections from the chip to the rest of the computer is not. So keeping all the cores fed with data is a problem. In informatics applications, the problem is worse, explains Richard C. Murphy, a senior member of the technical staff at Sandia, because there is no physical relationship between what a processor may be working on and where the next set of data it needs may reside. Instead of being in the cache of the core next door, the data may be on a DRAM chip in a rack 20 meters away and need to leave the chip, pass through one or more routers and optical fibers, and find its way onto the processor.

In an effort to get things back on track, this year the U.S. Department of Energy formed the Institute for Advanced Architectures and Algorithms. Located at Sandia and at Oak Ridge National Laboratory, in Tennessee, the institute's work will be to figure out what high-performance computer architectures will be needed five to 10 years from now and help steer the industry in that direction.

"The key to solving this bottleneck is tighter, and maybe smarter, integration of memory and processors," says Peery. For its part, Sandia is exploring the impact of stacking memory chips atop processors to improve memory bandwidth.

The results, in simulation at least, are promising [see yellow line in "Trouble Ahead"]. —SAMUEL K. MOORE update

Self-Healing Hulls

Electric current could be the key to self-healing carbon-composite smart materials

TOUGH COMPETITION: Now carbon-fiber composites can take even more of a pounding.
PHOTO: JAVIER SORIANO/AFP/GETTY IMAGES

Among the claims to fame of Switzerland's Ecole Polytechnique Fédérale de Lausanne (EPFL) is *Alinghi*, the yacht, which won not one but two America's Cups. Part of that success can be attributed to the state-of-the-art carbon-fiber composites that make up *Alinghi*'s hull. In many cases, such composites can substantially heal themselves following a collision. Now a graduate student has invented a way to juice the self-healing with a little electric current.

EPFL doctoral student Eva Kirkby is developing a better way for carbon-composite materials to heal themselves. Carbon-fiber composites, made from many layers of lightweight carbon fibers and epoxy, offer a strength-to-weight ratio much higher than that of similar-weight materials. They're often found in Formula One race cars, and they make up 50 percent of the Boeing 787 airliner. But one weakness of these superstrong materials is a tendency to separate internally, or delaminate, when big impacts cause cracks parallel to the surface of the material. Delamination damage can decrease the composite's strength by an order of magnitude.

To counter this, a self-healing composite material is impregnated with hundreds of tiny, evenly dispersed bubbles filled with healing liquid-monomer molecules (about 10 bubbles per cubic centimeter) and smaller particles of catalyst that harden the monomer. When the material sustains a sufficient impact, the delamination cracks cause some bubbles to rupture and release their monomer and catalyst. The monomer fills the crack and hardens, and the damage is repaired. The problem with this approach is that for maximum material strength, you want to keep the concentration of bubbles and their size to a minimum. But when the bubbles are too small, their payload doesn't completely fill the cracks.

So Kirkby found a way to close the gap. She incorporated wires of what's known as a shape-memory alloy, or SMA, into the composite. When electricity flows through an SMA wire that has been bent, it snaps back into shape. That forces the delamination crack shut, constraining it to a size that can be effectively filled by fewer, tinier monomer bubbles. In initial tests, Kirkby's electrically activated material performed beautifully. The crack openings were reduced from 120 micrometers to about 17 µm.

Kirkby says that among the key issues is how to get this material to autonomously pulse the current to the SMA wires. To do that, the composite must first figure out where it has been damaged and then send current only to the SMA wires at the damage site.

Kirkby embedded optical fibers in the composite. When a shock pulse from an impact compressed or tensed the fibers, the light that passed through them dimmed or intensified in response. By tracking the pulse as it transected the fibers, Kirkby was able to pinpoint the impact site to within a few centimeters.

"What's interesting about this is that it merges the two different directions structural composite work has been going," says Iowa State University assistant professor Michael Kessler, who coauthored a seminal 2001 paper on self-healing composites. "I like the idea of combining a healing and a sensing function." But he cautions that a lot more work is required to create the damage-sensing logic devices that would make self-healing materials autonomous.

Kirkby says one obvious application for her new material is high-performance sports equipment like racing bikes and, of course, *Alinghi*. The aerospace sector would benefit from autonomously healing aircraft wings or meteor-proof satellites, and for injured soldiers returning to duty wearing prosthetics, self-repair could be essential.

—Sally Adee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update

Water Goes Off the Grid

A Canadian company rethinks atmospheric-water generators

The escalating cost of electricity has sent a growing number of consumers in search of ways to generate electricity at home. Element Four, based in Kelowna, B.C., Canada, is betting that with bottled-water consumption increasing and aging water distribution systems, water will be the next commodity consumers will want to produce at home. The company has done what it says is a top-to-bottom reinvention of the atmospheric-water generator—a device that pulls water from the air by cooling it to the point that condensation forms and then keeps it sterile for drinking.

Element Four's WaterMill is a 300-watt generator that makes up to 12 liters of drinking water per day—enough, it says, for your typical North American household. At Kelowna's rate of 6 U.S. cents per kilowatt-hour, the cost comes to about 3 to 4 cents per liter. The technical innovation is in two areas, according to Richard Weisbeck, chief technology officer. The first, a system of temperature, pressure, and humidity sensors that feeds into a microcontroller, makes the device automatically adapt to its environment. The microcontroller fine-tunes the flow of air and refrigerant in the machine to match its surroundings so that it continues to work in extremes of heat and cold, inside or outside. "From Toronto to Ecuador, you can pull it out of the box and the machine will search for its peak efficiency and then run that way," says Rick Howard, Element Four's CEO.

The control system's improved efficiency lets the machine use a bare condensation coil, unlike other such devices, which use cooling fins. Finned coils could harbor bacteria, says Weisbeck. But a bare coil can be kept sterile using the same ultraviolet lamp that kills bugs in the collected water.

Market trends appear to be in atmospheric water's favor. Consumers around the globe are turning away from the tap, Howard notes. Though he hopes they'll start turning toward atmospheric water, right now they're buying bottled water. According to the International Bottled Water Association, global consumption of bottled water has grown 7.6 percent per year on average since 2002, reaching 189 billion liters in 2007. The United States led consumption, with 33 billion L, but was followed closely by populous developing countries like China, Brazil, and Mexico. China's market grew 17.4 percent per year.

HAPPY NOW? Will the chance to generate drinking water from the air make consumers smile? PHOTO: ELEMENT FOUR

But bottled water is widely thought to be too energy intensive to produce and deliver. According to estimates by the Pacific Institute, a think tank in Oakland, Calif., just producing the bottles, caps, and packaging for the 31 billion L of water sold in the United States in 2006 ate up the equivalent of 17 million barrels of oil (about 106 billion megajoules), not to mention 62 billion L of water.

Even though they're buying more bottled water than ever, consumers in the industrial world are still trained to turn on the tap. But the drinking water infrastructure is in serious need of attention. According to a 2005 U.S. Environmental Protection Agency report, most drinking water systems in the United States contain pipes more than 80 years old. The agency estimates that the country's distribution pipe infrastructure needs an investment of US $183.6 billion over the next 20 years and a further $24.8 billion for drinking water storage. "We've gone 100 years without really giving [the system] much attention," says Vanessa Speight, an expert on water-distribution systems in Washington, D.C., who works for environmental engineering firm Malcolm Pirnie. Getting the funding to repair or replace the country's old pipes, especially with water utilities burdened by higher energy prices, is going to be a real challenge, she says.

Infrastructure funding is even more of a challenge in the developing world, and the need is even more acute. The United Nations estimates that 880 million people lack safe sources of drinking water. Atmospheric-water-generator companies are looking to make inroads there too. Element Four's other product, the WaterWall, is targeted at supplying a developing-world village or neighborhood. The device, which the company will start manufacturing in early 2009, is made up of a scalable number of generators, each of which is essentially a bare-bones form of the WaterMill. In places where the power grid is delicate, a kilowatt-scale water generator could easily draw so much power at start-up that it would cause a blackout—one reason atmospheric-water generators have failed in the developing world in the past. So Weisbeck designed the WaterWall to start up in stages, gradually increasing the load and, one hopes, sparing the local grid.

—Samuel K. Moore

BIG CHILL: The relationship between Europe and Russia is cooling. PHOTO: FYODOR SAVINTSEV/WPN

commentary

Gas Pains

Russia's dominance of Eurasian markets means long-term trouble

RUSSIA EXPERT Marshall Goldman has dubbed the country a "petrostate," but with all due respect, that's somewhat misleading; Russia is really a gigantic natural-gas company backed by a huge nuclear arsenal and an increasingly proficient, conventional military [see The Data, in this issue]. Though it's also a top oil producer, it uses almost all of its oil itself and has little influence on the world market. But with its seemingly boundless gas reserves, Russia is in a position to dominate the Eurasian market for at least a generation to come.

Why can't the European Union just adopt a strategy of energy independence and wean itself from Russia and the "stans"? After all, the EU has its ambitious 20/20/20 program, aiming to obtain 20 percent of its energy from renewables, increase energy efficiency by 20 percent, and cut carbon emissions by 20 percent, all by 2020. And the EU has also been trying hard to diversify gas supplies. In mid-September, for example, it informed Nigeria of its interest in cofunding a proposed 4300-kilometer pipeline to bring natural gas directly from Africa to European markets.

Here's the problem: from any viewpoint, natural gas is such an attractive fuel that no matter how much you try to reduce your consumption and diversify your supply, you're always going to want more. Since the 1990s, gas has been the fuel of choice for electricity generation, because of high turbine efficiency and its cleanliness and relatively low carbon content. Per unit of energy produced, gas emits no more than half as much carbon as coal, which means it makes good sense to replace coal with gas plants to meet emissions targets.

Gas is also a very attractive home-heating fuel and is increasingly being used for motor vehicles too. In compressed form, it's powering public transportation and fleet vehicles in cities from New Delhi to New York.

If fuel cells ultimately power most cars and the vision of a hydrogen economy is realized, a lot of that hydrogen will have to come from natural gas—or from water hydrolyzed using electricity generated by gas plants.

Under the circumstances, Europe will want to keep importing all the gas it can persuade Russia to sell at reasonable prices. But Russia will be in a position to manipulate the Eurasian markets, playing off fast-growing East Asian demand against Europe's needs.

Europe's dependence on Russian gas would not necessarily be a big problem if the Europeans trusted the regime running Russia. But, increasingly, they don't. Russia has repeatedly shown its willingness in recent years to cut off gas supplies for political reasons, basically to bring countries it considers its satellites to heel, notably Ukraine. Of course it wouldn't dare cut supplies to a country like Germany, which gets about half its gas from Russia. But where German and Russian interests and values collide, Russia could manipulate markets to get its way and use the threat of its market power to ward off diplomatic or military action.

For some years, as the Putin regime has consolidated its position and eliminated opposition, European unease about Russia has grown. But there has also been fierce determination to avoid a renewal of Cold War tensions and a tendency to focus on U.S. misdeeds. Important turning points in European elite opinion were the arrest in October 2003 of oil oligarch Mikhail Khodorkovsky, who had been pouring millions into oppositional groups and toying with the idea of challenging Putin for the presidency, and the murder a year later of the crusading journalist Anna Politkovskaya, Putin's sharpest and most persistent critic.

A recent survey by London's *Financial Times* found that European mistrust of Russia has increased sharply in the past six months: the proportion of respondents who consider Russia the greatest threat to world stability rose from just a few percent in July to nearly 20 percent in September, putting it well ahead of Iran and almost as high as China. It may come as a shock to many American readers, however, that the United States still ranks in European minds as the greatest threat to world stability, scoring over 25 percent in September.

—WILLIAM SWEET

the big picture

ARACHNOID AFFAIR

Early in September, a gigantic mechanical spider took to the streets of Liverpool, England, drawing a crowd of tens of thousands that paralyzed the city center. It was all part of an arts and culture celebration, and for two days the 15-meter-high arachnid paraded through town accompanied by musicians and other performers. Built by the French group La Machine, the robotic beast had a steel and wood frame powered by 50 hydraulic actuators. A dozen operators strapped to the spider controlled its articulated legs, and a wheeled crane supported its 37-metric-ton body. The arachnofest was pricey—it cost nearly £2 million—but it left Liverpudlians exhilarated. Some kids even cried when the spider vanished in a cloud of smoke. There are rumors that it will emerge in another city next year.

PHOTO: MATTHEW ANDREWS

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reflections

BY ROBERT W. LUCKY

The Blinking Light

I WAS CONSIDERING buying a new desktop computer, and I thought I had found the ideal model. That is, until I noticed that one little thing was missing—the activity light for the hard drive. The manufacturer probably saved a few cents by leaving it out, but that little light was of some psychological importance to me. How could I possibly buy a computer that was just going to sit there and not give me any indication that it was working?

A very long time ago, not long after the dinosaurs went extinct, I was working on modem design. At the Bell System, we had designed modems the way they were supposed to be—big, heavy clunkers with a telephone handset and an embedded rotary dial. They were just what the users needed to connect to their time-shared mainframes. But one day, a competitor came out with a small modem that had an array of LED lamps on the front panel, indicating control signals like clear-to-send as well as data activity. "What user could possibly care about such things?" we joked among ourselves.

Well, it seemed that people did care about such things. That little company sold a lot of modems, and pretty soon we had indicator lights on our modems too. As a consequence, I learned a key principle of design: *people want blinking lights.*

Too many electronic gadgets are inert steel boxes with stickers on the bottom that say something like "no user-serviceable parts inside." Often, you have no idea whether or not the gadget is working. When it doesn't do something you expect it to do, you stare helplessly at the box. "Are you alive in there?" you ask plaintively. But such entreaties are a waste of breath. You'd think that the box could at least hum or vibrate to communicate life.

A blinking light makes all the difference—even though you have no idea why it's blinking the way it is. Over the millennia, humans have evolved a subconscious ability to recognize and categorize moving visual patterns, like the flash of tiger fur seen through dense foliage. So it is with the activity light. I've had several cable modems go bad, as well as several routers, and in every case I've recognized the problem by the unfamiliar blinking patterns of the activity lights. "Aha," I say to myself. "That box is sick."

Quite often there is no visible activity on my computer screen, but I see the hard-drive light blinking furiously. What is it doing? I wonder. At least the little light tells me that it is alive, though I worry about why it is so busy. At such times I often wish that there were a special key labeled "What are you doing?" I've always found the task manager rather useless for this purpose, and no human being could possibly interpret the gibberish that fills your screen following the dreaded "blue screen of death."

Instead of an unintelligible binary dump, my imagined key would give a simple English explanation: "I'm busy at the moment reformatting your hard drive," it might say, "but I'll be through in a jiffy." Or perhaps, "I'm just finishing the installation of a new virus."

Back when dinosaurs ruled the planet, computers had lots of indicator lights, showing the activity on many of the backplane signals. When you walked past a computer center, a dynamic light show was taking place inside. Tapes spun and everything hummed. "Wow, look at those things think!" you said to yourself. But now it seems that the only indication of life is the roar of air-conditioning.

So the computer I picked out had joined the growing legion of gray boxes devoid of charisma, its only outward manifestation of personality having been sacrificed for a few cents. Maybe I'm the only one who cares about that light now, but I'm not buying that computer. Its designers are probably joking among themselves, "What user could possibly care about such things?" Well, I'm one who does. For want of a cheap little light, they lost a customer. Hopefully, they'll put it back in their next model. ❑

RANDI SILBERMAN

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FORREST ARAKAWA/ZERO MOTORCYCLES

WORLD'S CLEANEST DIRT BIKE

The Electric Zero X has zero emissions

DIRT BIKES aren't the cleanest vehicles. There's the noise, oil, and grease, and the noxious fumes from the combustion engine. And then there's all that, um, dirt. The Zero X electric motorcycle, from Zero Motorcycles, in Scotts Valley, Calif., can't do much about that last item, but it's got to be the quietest and least polluting off-road bike around—and the lightest. With an aircraft-quality aluminum chassis, the 64-kilogram Zero X is less than half the weight of a gas-powered motorcycle. That helps its 20-horsepower electric motor go from 0 to 48 kilometers per hour (30 miles per hour) in less than 2 seconds. Its lithium-ion battery pack runs for about 60 km on a 2-hour charge.

The Zero X is the brainchild of Neal Saiki, a former aerospace engineer who holds a master's in aeronautical engineering from California Polytechnic State University. While working at NASA's Dryden Flight Research Center, in Edwards, Calif., he participated in a state-funded panel looking at transportation alternatives. In terms of environmental impact and cost, the panel concluded, electric vehicles overwhelmingly made the most sense.

Saiki left NASA in 1991 and started designing mountain bikes. He never forgot the lesson about electric vehicles, though, and he kept tabs on developments in battery technologies. Finally, in 2005 he saw that lithium-ion packs had achieved sufficient power density to make a good electric motorcycle. He figured motorcycles offered a much easier entry into the electric-vehicle market than cars. Then, too, he'd always had a passion for riding.

Since coming on the market in April, the Zero X has won over quite a few veteran bikers. "Off-roaders value a lighter-weight bike because it's maneuverable and can handle higher jumps," Saiki says. When former motocross champion Jeff Emig first rode a Zero X, the bike's speed and acceleration surprised him, and he wiped out almost immediately, Saiki recalls. "He jumped up, all bloodied, and he said, 'I can't believe I just got thrown by an electric motorcycle! I love this thing!' "

But the Zero X is also good for complete novices. Just flip a switch and you can reduce its top speed by half; a second switch decreases the acceleration.

At US $7450, the Zero X runs about $1000 more than a conventional 250-cubic-centimeter bike—but you'll never spend a dime on gas or on filters for the oil and air. The battery pack should last five to six years with normal use, and it takes about 30 seconds to swap it out. "The battery industry is advancing all the time, with new chemistries and new technologies," Saiki says. "We wanted to make it really easy to upgrade the battery pack."

Currently, the Zero X can be ordered only from the company's Web site, and there's a three-month waiting list, which the company hopes to eliminate by tripling production. For those who must ride before they buy, Zero has models available for test drives at the company's headquarters and 15 other U.S. locations. Bikes for test drives will be available in Europe in 2009.

Kits are also available to convert the Zero X into a "streetable" bike, Saiki says. A more powerful street-legal model, the Zero Supermoto, will be introduced this January, and the company is already taking orders.

—JEAN KUMAGAI

ZERO X
US $7450 plus shipping ($300 in the U.S.; $1000 to Europe).
http://www.zeromotorcycles.com

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gifts

A LAPTOP ON STEROIDS

The Toshiba Qosmio is more powerful than some desktops—and heavier

TOSHIBA'S NEW Qosmio G55-802 notebook computer packs so much power, it can peel the paint off many of today's desktops. Of course, at a hefty 4.9 kilograms, it ought to.

The specs for the Qosmio (pronounced "KOS-mi-o") look like a desktop's—and then some. It uses a new chip developed by Toshiba, the Quad Core HD, which acts like a video supercharger for an Intel Core 2 Duo CPU with 4 gigabytes of RAM. And with its 18.4-inch screen and an Nvidia GeForce 9600M GT graphics card, it makes a darn good gaming computer—but, stresses Toshiba product manager Mark Lackey, "the G55-802 is designed for multimedia enthusiasts."

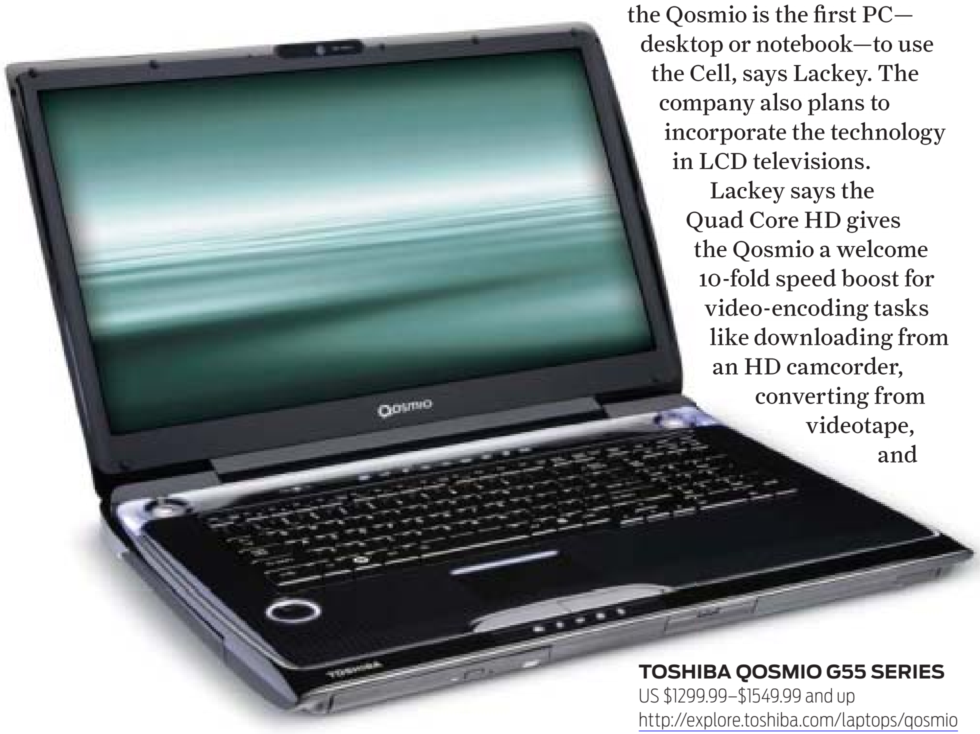
The Qosmio is indeed a media maven's dream, with its high-end graphics card, enormous screen, gigabit Ethernet, high-definition multimedia-interface port, 802.11b/g/n, and Wi-Fi. And did we mention its Harmon/Kardon stereo speakers (plus subwoofer) and Dolby Home Theater compatibility?

The Quad Core HD is based on the Cell Broadband Engine, jointly developed by IBM, Sony, and Toshiba. The Cell is famous as the backbone of Sony's PlayStation 3, but so far it hasn't been used much for general-purpose computing. The high end of Cell-based systems is the IBM-built US $120 million Roadrunner supercomputer at Los Alamos National Laboratory, and Cell technology can also be found in products like IBM's BladeCenter QS22. But the Qosmio is the first PC—desktop or notebook—to use the Cell, says Lackey. The company also plans to incorporate the technology in LCD televisions.

Lackey says the Quad Core HD gives the Qosmio a welcome 10-fold speed boost for video-encoding tasks like downloading from an HD camcorder, converting from videotape, and upscaling your DVDs from standard to high definition. In addition, Toshiba has written or tweaked some video software for the new processor. One program helps users find and select video frames that include a specified face. Another reads hand gestures made in front of the Qosmio's built-in webcam to let you play, pause, or fast-forward a DVD or CD without touching a keyboard or a remote controller.

The Quad Core HD processor doesn't work automatically with existing applications like Adobe Photoshop, although they will run just fine on the computer's Intel processor. So far only a few programs use it, including Toshiba's webcam gesture-control software and its Ulead video-editing software, which come with the computer, and Microsoft PowerPoint.

The Qosmio G55-802 lists for $1549.99, as if adding that extra penny might push potential buyers past their price limit. The Qosmio G55-801, omitting the Cell processor and some other features, is $250 cheaper. If you need to do serious video work, the G55-802 currently stands alone in its field. And if you don't mind lugging it around, either machine can act as a mobile media center for family trips. "It plays games great," Lackey confesses. "I've used it for *Gears of War*, *Call of Duty*, and *Dino Crisis*." —DANIEL P. DERN



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TOSHIBA (2)

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LITTLE FLYING WONDER

A $50 flying toy avoids obstacles on its own

"WHAT'S THIS THING?" my editor asked me the other day, pointing to the FlyTech Bladestar sitting on my desk. It took me a minute to explain.

The Bladestar, by Hong Kong–based WowWee, is a remote-controlled rotary-wing flying toy—nope, not a helicopter. It doesn't use a motor to turn its blades. Instead, two little propellers, facing opposite directions, cause the whole craft to spin; the angled blades generate lift.

The manual emphasizes that the Bladestar is for "indoor use only," recommending a gymnasium, shopping mall, or garage. I settled for our executive office. Good thing the CEO wasn't in.

The basics of flight are easy: slide the infrared controller's throttle to climb or descend, and press the direction buttons to maneuver forward or backward, left or right. Yes, the craft performs all these maneuvers by varying the speed of the two propellers. (Can anyone work out the control equations for that?)

One cool feature is the autopilot mode. The Bladestar uses two infrared sensors to hover away from ceilings and walls. Nonetheless, the Bladestar has the usual flying-toy fondness for obstacles, and controllability is a bit haphazard. Look out for the *vaaaase!* But that's part of the fun.

I set as a challenge taking off from the CEO's desk and landing on the conference table across the room. It took me a few tries to succeed. One thing I couldn't test was the mid-air battle, for which you need two units. The idea is to fire infrared shots at your opponent; the first to get hit three times goes down.

The toy is made of cheap Styrofoam and plastic, but it proved quite crash resistant and, despite warnings about the fast-moving propellers, it did no damage to walls, furniture, or my hands. You get only 5 minutes of flight time; recharging takes 20 minutes.

At US $50, it makes a good holiday gift. Is the Bladestar a "revolutionary indoor flying machine," as WowWee claims? It certainly revolves.

—ERICO GUIZZO

CANDID CAMERA

A video camera that fits into a purse is always there when you want it

THE FLIP MINO series camcorder, by Pure Digital Technologies, is a little gem, and I do mean little. The Mino is even smaller, lighter, and sleeker than last year's Flip Ultra.

In one short month, this 90-gram gadget, measuring 10 by 5 by 1.5 centimeters, has transformed me into a candid-camera mama. I now have images of a 3-year-old's first gasp at the towering bones of a *T. rex* and a 6-year-old's madcap rainy-day "I like mud!" dash through same.

The Mino's resolution is a grainy 640 by 480 pixels, but when played in a YouTube-size box, its movies look fine, even on a high-resolution monitor. More important, the camera self-adjusts to light. Also, the 2x digital zoom works well, and the sound is terrific, with great filtering of nearby noise. Sure, I could have gotten better images from a bulkier camcorder, but so what? I wouldn't have had it with me in the first place.

The Mino is always in my purse or pocket; I've even worn it on a lanyard. What makes such convenience possible is the confluence of inexpensive and virtually weightless 2-gigabyte Secure Digital flash memory cards—a single one can hold an hour of video at the Mino's modest resolution—and better battery technologies. I was still on the initial battery charge after taking 58 short videos, about 45 minutes' worth. Good software helps as well. Moving videos to a Mac or PC is effortless, and the Mino walks you through the installation of some additional video-editing software.

The Mino lists for about US $180, but it shows up regularly on Amazon for under $150.

—SHERRY SONTAG

FLIP MINO
US $179.99
http://www.theflip.com

TOP: WOWWEE; BOTTOM: PURE DIGITAL TECHNOLOGIES

"Our role is to broadly research the issues ranging across lifestyle, technology, business and policy; to identify trends and participate in formulating standards and supporting toolkits and infrastructure; to foster entrepreneurship and community; to offer leadership and to educate students and faculty, to actively participate and lead in this avalanche of change."
~ Martin Griss, Co-Director, CyLab Mobility Research Center

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http://mobilityresearchcenter.org/

GOING MOBILE?

Mobility is integral to the future of computing, and at Carnegie Mellon University's CyLab Mobility Research Center, the future has already arrived.

MOBILITY IS NOT A BUZZWORD. "Speed" and "ease of use" are buzzwords. Mobility is a transformational concept. There aren't all that many of them, "PC," "World Wide Web" and "Information Age" stand out. Mobility ranks with them. And like those other transformational concepts, Mobility has shattered one paradigm and is birthing a new one. "Anywhere, anytime"– that's the computing vision evolving all around us, right now.

Once upon a time there were telecommuters, road warriors and desktop users. But they have all been swallowed up in this great transformational concept. Now there is only you: you at home, you on the road, you at the office -- "Anywhere, anytime." Wherever you are, whatever you want to do, work or play, this transformational concept has brought you a new culture both in the physical and cyber dimensions -- "Anywhere, anytime."

Mobility is a technological imperative which is re-shaping human culture, and a cultural and economic imperative which is re-shaping technology. Mobility is integral to the future of computing; and in some places, the future has already arrived. One such place is Carnegie Mellon University's CyLab Mobility Research Center, based at the Carnegie Mellon Silicon Valley campus in the pulsating heart of the entrepreneurial ecosystem.

"Our role," says Center Co-Director, Dr. Martin Griss, "is to broadly research the issues ranging across lifestyle, technology business and policy, to identify trends, participate in formulating standards, supporting toolkits and infrastructure; to foster entrepreneurship and community; to offer leadership and to educate students and faculty to actively participate and lead in this avalanche of change."

Mobility is one of the most dynamic areas of technical research and education for the 21st Century, and the CyLab Mobility Research Center is positioned to lead the way. That's why a group of movers and shakers, C-level executives, representing Adobe, Bosch, Cisco, Google, HP, Intel, Microsoft, Motorola, NASA, SAP, Sun, and Yahoo gathered to brainstorm at the Center's Mobility Research Summit.

Which companies will have the resources to capitalize on this moment and establish the foundational underpinnings of the new mobile digital universe? Which technologists will have the vision, fortitude and opportunity to move at the forefront of the advancements that will come over the next few years?

"This is where we can make a difference," Dr. Priya Narasimhan, Center Co-Director explains. "While industry faces these time-to market pressures, we can act as a proofing ground for newer technologies, e.g., security, privacy, reliability. We can answer these more difficult questions that the market needs and that our industrial partners can leverage, even as they continue to develop and release new products. At the Center, we believe in solving real problems in the real world. We're exploring all of these systems concepts -- infrastructure, devices, user interfaces, data, networking, operating systems, file-systems -- through large-scale pilot and testbed deployments. This is a significantly different approach from building small one-off lab projects."

"We take a holistic perspective, integrating issues such as business, policy, ecosystem, security, usability and technology in choosing projects to work on, partners to work with and in how we educate and guide students to think about the problems," Dr. Griss adds, "while many other programs focus only on technology or a small number of items."

Technology companies searching for ways to compress the arc of time are looking to the CyLab Mobility Research Center as a collaborative partner in vital research.

Technologists searching for a competitive advantage in the marketplace of ideas are turning to the Center for Ph.D. degrees in Electrical and Computer Engineering and Master of Science degrees in Information Technology – Mobility (MSIT-MOB), offered in conjunction with Carnegie Mellon's Information Networking Institute (INI). The Center is also a beacon for those looking for promising faculty and post-doctorate opportunities.

Join them all and travel to the future.

gifts

A SOULFUL DINOSAUR AND A SOMEWHAT OBEDIENT DOG

Sensor technologies come of age in a pair of pricey holiday toys for tots

HASBRO KOTA
US $300
HASBRO BISCUIT
$180
http://www.hasbro.com

How about taking home a baby triceratops that growls, munches leaves, moves its horns, and plays such classic songs as "I'm Gonna Catch a Baby Dinosaur"?

True, it doesn't walk, and at first my kids—Sam, 3, and Coby, 6—were disappointed. Still, the 1-meter-long triceratops was long enough and strong enough for even the older boy to ride Kota's spring-loaded seat in place, making her (the kids quickly determined that Kota was a girl) hipper than any hobbyhorse. After some pretty soulful looks, far more than anyone would expect from a mechanical beast, my kids would say goodbye only after lots of dinosaur hugs.

Sam has not yet decided if Kota should be his holiday gift this season, and Coby is trying to talk me into an iPhone instead. They grow up so fast! Parents, too, have a decision to make. Hasbro, Kota's manufacturer, refused to discuss the dinosaur's projected life span, of some concern when getting ready to fork over US $300 for a prehistoric pet—especially in light of reports of durability problems with a Hasbro 2006 pet, the FurReal Friends Butterscotch Pony. Perhaps by Christmas one of Kota's many blogger-admirers will have hacked into her and documented her 11 embedded sensors.

Nearly as cool for the kids—and electronically much more interesting to Mom—was Biscuit ($180), a sort of golden retriever puppy who answers to six voice commands. While he only reacted correctly to "speak," "lie down," and "shake" about half the time, he responded to anything he didn't recognize with an endearing blink of his eyes, a quizzical tilt of the head, and a bark. What real dog obeys every command anyway? I was impressed that Biscuit did as well as he did without being trained to understand individual voices. Still, both boys would rather have Kota "cause dinosaurs are just cool." —Sherry Sontag

hands on

Free the AAAA Six!

Inside every 9V battery there are six AAAA batteries

You may not have seen many AAAA batteries yet, but you will. MP3 players, glucose meters, penlights, remote controllers, Bluetooth headsets, and even toothbrushes are increasingly using the smaller size, according to Jon Eager, an aptly named marketing director at Energizer Holdings, in St. Louis.

Weighing only 6.5 grams, AAAAs are as much as 43 percent lighter than AAAs. That makes a big difference when wearing a headset. AAAAs are the same voltage and almost the same length as AAAs but 20 percent thinner.

Naturally, AAAAs don't last nearly as long. Eager says that in a 25-megawatt test at a continuous drain with a noise-canceling headset, "the run time for a AAAA is approximately 24 hours, versus a AAA at approximately 55 hours." At about the same cost, that makes AAAAs relatively expensive to use.

So here's a little trick we picked up from the Web sites Xkcd and Makezine (Metacafe has a nice video report as well). Cut open a 9-volt battery and you'll find six AAAAs wired in series. Xkcd reports that you need to keep track of the polarity because the individual batteries aren't labeled, and you might want to use some silver or aluminum foil to ensure good contact, especially if you use them in place of AAAs. Naturally, Energizer advises against the practice, noting the difference in length and the risk of personal injury.

A twin pack of AAAAs costs US $4 or more. A single 9V battery costs about the same, so freeing the AAAAs within yields four free batteries. Because of the difference in run times, when AAAAs are used in place of AAAs, your "profit" is roughly two free batteries. —*Steven Cherry*

AAAA BATTERIES
US $6.95 (six-pack)
Metacafe video: http://tinyurl.com/2rbubo

TOP: HASBRO; BOTTOM: RANDI SILBERMAN

iPhone Accessories

iPhone Earbuds Suck

Pardon our bluntness, but they do. They're ill-fitting sound sieves, and people you phone ask if you're calling from inside a NASA wind tunnel. You can't use an ordinary music headset for phone calls because it lacks a microphone, or even for regular music listening, because the iPhone's audio port is too deeply recessed to provide a proper connection for most 2.5-millimeter audio jacks.

Griffin Technology solves these problems in two different ways. Its US $39.99 TuneBuds Mobile earbuds offer a better microphone for speaking and three sets of rubber ear tips for better listening. Its $19.99 SmartTalk audio-jack adapter has its own microphone, so you can use it with any earphones at all.

—*S.C.*

GRIFFIN SMARTTALK
US $19.99
GRIFFIN TUNEBUDS
$39.99
http://www.griffintechnology.com/devices/iphone

BELKIN TUNEBASE FM (LEFT)
US $99.99
http://catalog.belkin.com/ipod/iphone

GRIFFIN iTRIP AUTO WITH SMARTSCAN (BELOW)
US $69.99
http://www.griffintechnology.com/devices/iphone

Two FM Transmitters For Your Car

An iPhone or iPod would sure sound sweet through your car's stereo speakers, but how best to do it? Cassette adapters wear out, a tuner that broadcasts to an unused radio station has to be reset to new frequencies as you drive around, and tapping into the stereo's wiring is expensive or messy.

This summer, we tested two new auto-tuning transmitters, the Griffin iTrip Auto with SmartScan, and the Belkin TuneBase FM. The Griffin was considerably better than its predecessors. The Belkin was darn near perfect.

Both devices draw power from the cigarette lighter outlet, not from the iPod, so you can end your road trip with a fully charged iPod. Both come on thick, easily adjusted, flexible stalks.

Both units do their own searching for unused radio frequencies. The iTrip's SmartScan technology finds the quietest frequency and tells you exactly where to tune. It sets up two alternate locations in case you want to switch, and you can also store favorite locations. Unfortunately, the small OLED display is extremely reflective and nearly impossible to read in bright sunlight. And the three-button interface and menus are not intuitive.

The TuneBase doesn't choose a station for you. It has two buttons for seeking up and down the dial, just like your car's stereo, except that your stereo seeks frequencies with strong signals, while the Belkin seeks the reverse. When it finds one it likes, the frequency is displayed in large, easy-to-read digits. You can then manually change to that station on the car's radio, or—and this is the best part—you can use the radio's seek function, because the Belkin unit is now broadcasting a strong signal on that frequency.

—Steven Cherry & Tekla S. Perry

Recharging On the Go

Your iPhone battery is so low on power that a telephony coma is imminent, and you need to run some errands. It's no problem, though, if you have the Mophie Juice Pack.

The pricey "pack" is an 84-gram lithium polymer battery, measuring 10 by 11 by 2 centimeters, that looks like half a carrying case. My wife so enjoys the added heft and the hard-rubber texture that she wants to keep her phone in it all the time, a practical enough idea if she remembers to recharge the Juice Pack every few days. According to Mophie, the Juice Pack extends a first-generation iPhone's battery up to 250 standby hours, 8 hours of talk time, or 24 hours of audio playback. For the iPhone 3G, the stats are said to be even better.

—*S.C.*

MOPHIE JUICE PACK
US $99.95
http://www.mophie.com/products/juice-pack

CLOCKWISE FROM TOP: BELKIN; MOPHIE; GRIFFIN TECHNOLOGY (3)

WHAT'S WRONG WITH WEAPONS ACQUISITIONS?

ESCALATING COMPLEXITY, A SHORTAGE OF TRAINED WORKERS, AND CRASS POLITICIZATION MEAN THAT MOST PROGRAMS TO DEVELOP NEW MILITARY SYSTEMS FAIL TO MEET EXPECTATIONS

By Robert N. Charette

STEALTHY AND STEEP: The US $137 million F-22, officially fielded in 2005, has yet to fly a mission in Iraq or Afghanistan.

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IN THE VAST AND VARIED WORLD of advanced military technology, the U.S. Army's proposed Aerial Common Sensor aircraft was neither the biggest nor the sexiest. But it was very important to the U.S. Army. The Army desperately needed the ACS to replace its Guardrails, a fleet of small, piloted reconnaissance aircraft that first began flying in the mid-1970s.

The Army was so keen on the ACS, in fact, that it showcased the program to Congress and the American public as an example of cost-efficient and timely procurement. The service was still smarting from several high-profile failures, including the cancellations of the Crusader howitzer and the Comanche helicopter. And so, in August 2004, when the Army awarded a US $879 million five-year contract for the ACS to a team from Lockheed Martin and the Brazilian aircraft company Embraer, it had high hopes. Lockheed did too: it stood to earn an additional $7 billion once the plane entered production.

Almost immediately, things started to go wrong. Barely four months after signing the paperwork, the contractors revealed that their aircraft, based on an Embraer commercial jet, was rated for only 9 *g*s of force, not the 16 that the Army wanted. Fixing the problem drove up the plane's weight, putting it 1400 kilograms over its safety threshold.

A panel brought in to assess the ACS concluded that the program was "unexecutable" and estimated it would cost at least another $900 million and two more years to get it back on track. So the Army canceled the program 18 months after it formally began, paying Lockheed $200 million for its trouble. The Army is now faced with spending $462 million over the next eight years to keep those old Guardrails flying.

To summarize: a big, basic technological problem emerged long after such an obstacle should have been spotted and resolved, in a program that would have been hugely over budget and behind schedule had it been left to run its course. But those factors aren't what made the ACS unusual. The Government Accountability Office, the U.S. Congress's investigative arm, recently scrutinized 72 major defense programs and found that only 11 of them were on time, on budget, and meeting performance criteria. No, what set the ACS apart was that it was not allowed to linger for years, racking up more costs and delays—it was actually canceled. Less than 5 percent of major defense programs ever suffer that fate, the GAO says.

Problems in defense acquisitions have existed for decades. What's new is the economic scale. The Pentagon now spends about $21 million every hour to develop and procure new defense systems. As recently as the mid-1990s, the largest of these cost tens of billions of dollars. Today, some, like the Army's Future Combat Systems, now range in the hundreds of billions. Topping the charts is the F-35 jet fighter, which is expected to cost taxpayers an astounding $1 trillion to develop, purchase, and operate. That sum is close to what the United States spent to fight both the Korean and Vietnam wars.

The spiraling costs are linked to schedule delays that are equally troubling. In 2007, the GAO estimated that current programs in development were experiencing an average delay of 21 months, with a few programs nearly a decade behind schedule. A 2007 GAO report to Congress noted that because of such delays and cost overruns, "not only is the buying power of the government reduced and opportunities to make other investments lost, but the warfighter receives less than promised."

Behind the deterioration is a convergence of factors, say analysts both inside and outside the Defense Department. New military systems are more technologically complex than ever before, and they rely increasingly on unproven technologies. Defense programs are now "so mas-

PREVIOUS PAGES: WESLEY T. KITTEN/PHOTOSHELTER; THIS PAGE: LOCKHEED MARTIN

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sive and so fanciful we don't know how to get there," says Katherine Schinasi, the GAO's managing director of acquisitions and sourcing management. And engineers, scientists, and technicians skilled enough to design, build, and debug such complex systems are scarce. The ranks of DOD acquisitions managers have also been thinned, even as the number of major military programs has risen.

Too often, also, politics trumps technology and even common sense. DOD managers and service brass aren't the only people who have a stake in which military systems get developed and which don't: congressmen, defense contractors, lobbyists, and economic development officials are all aggressive players in the weapons-acquisition process, all pushing for their own pet projects. The result is a proliferation of development efforts that the Pentagon cannot fully fund and that are nearly impossible to cancel. Politics also leads contractors to overpromise on what they can deliver and leads DOD staffers to turn a blind eye when those promises aren't met.

The situation has become so dire that even former top defense officials are weighing in with uncharacteristic pessimism and alarm. "The [U.S.] military has been living in a rich man's world," says Jacques Gansler, a former undersecretary of defense for acquisition, technology, and logistics. "Very little attention has been paid to cost. We're coming up against a very serious fiscal crisis."

ISTOCKPHOTO (5)

This month, U.S. voters will elect a new president. Whoever takes office in January will need to make reforming the weapons-acquisition process a high priority. "The next president is going to need to set the tone very, very quickly," says David M. Walker, who was head of the GAO until March. "If we don't make some fairly dramatic and fundamental acquisition reforms soon, we could find ourselves in a situation in the not-too-distant future where we have a lot of things that people wanted but not enough of what we really need."

ARMY GEN. EDWARD HIRSCH was a blunt-talking man who spent many years after retirement trying to improve the acquisition process. Among other things, he was instrumental in establishing the School of Program Managers at the Defense Acquisition University. The DAU, at Fort Belvoir, Va., provides mandatory training for the Defense Department's 140 000 military and civilian acquisitions personnel.

Shortly before he passed away last year, at 85, Hirsch told me that he was deeply troubled by the present state of affairs. He felt that the process the Pentagon uses to develop and acquire new military systems actually works against those who try to follow it. "Put good people into a system that is designed for failure—it isn't going to work," Hirsch said.

On the surface, at least, it's hard to see why Hirsch felt the way he did: the defense-acquisition process looks perfectly logical. Acquiring a major defense system generally consists of nine steps, each step having multiple criteria that must be met before moving on to the next step. A "major" program in the DOD realm is any acquisitions effort whose research, development, testing, and evaluation costs exceed $365 million or whose procurement costs exceed $2.19 billion, in FY 2000 constant dollars. There are now roughly 95 such programs on the books. It's a traditional top-down approach that should be familiar to any engineer:

First, you determine and validate your national and military strategies and ensure that they align;

Second, identify the missing defense capabilities you will need to carry out your strategies;

Third, identify alternative approaches and their technical feasibility;

Fourth, select the best approach in terms of technology, cost, and schedule;

Fifth, get the budget and schedule for your approach approved;

Sixth, design and then implement the system;

Seventh, test the system in operational conditions;

Eighth, produce the vetted system in the quantities needed; and

Ninth, support and upgrade the system until its retirement from service.

Repeat each step as necessary.

The process is intentionally long and iterative, each step aimed at reducing the

F-22: Success, Failure, or Both?

WHEN THE first of the U.S. Air Force's F-22 Raptors was officially fielded in 2005, it was without question the world's most advanced fighter, far surpassing any of its competitors. It was also, in many ways, an acquisitions failure.

This fighter jet had been conceived in the 1980s as a counter to two hypothetical Soviet aircraft that military analysts believed likely to be fielded by 2010. To meet the projected threat, the F-22 was designed as a "fifth generation" aircraft having stealth technology, supercruise capability, high maneuverability, and a state-of-the-art avionics suite. In other words, it was a fighter pilot's dream machine. At a projected and highly optimistic cost of US $35 million per plane (or $74 million in today's dollars), 750 of them were to be fielded by 1995.

"The F-22 demanded a step ahead in technology across multiple fronts that had not been done before," says Ralph Heath, executive vice president of aeronautics for Lockheed Martin, the lead contractor on the F-22.

After the collapse of the Soviet Union in 1991, however, the biggest threat to the F-22 was no longer those two as-yet-unfielded Soviet fighters but the Air Force's own "fourth generation" F-15 fighter. Many analysts argued that the F-22 was no longer needed and that upgrading the F-15 was more than adequate. Others countered that the F-22 was "twice as good" as the F-15 and therefore worth pursuing.

To damp down the debate, then Deputy Secretary of Defense William Perry directed the Air Force in 1993 to ready a prototype F-22 for a "fly-off" against the F-15. If proven sufficiently better than its predecessor, the F-22 would go into production.

Throughout the F-22's development, Lockheed experienced a number of technological problems, particularly with the plane's avionics, its stealth capability, and its engine. "We had to refresh [technology] early in the production cycle, actually even before we concluded development, because of obsolescence of some of the electronic components," Heath says. By the time the first F-22 went into service in 2005, its avionics systems had undergone at least three such refresh cycles. As development costs rose, the number of F-22s was repeatedly cut, to 648 in 1990, 442 in 1994, 339 in 1997, and 276 in 2003.

The fly-off was never held, but the F-22 did perform well enough in its operational tests to go into production—10 years behind schedule. Even so, the Pentagon further reduced the order to 183 planes in 2006 to save money. The cost of each F-22 (the total cost of its development and production divided by the number of aircraft procured) is now over $300 million. To help pay for its F-22s, the Air Force has scaled back on upgrades to the F-15 and other aircraft and also cut personnel. And it continues to argue that it needs at least 381 F-22s to meet its mission requirements.

Others are less enamored of the fighter. The late Edward Hirsch, a leading proponent of reforming the acquisitions process, considered the aircraft a failure, because in not

risk of failure and increasing the likelihood of meeting cost, schedule, and technical promises. You might expect then that the normal outcome would be a successful defense system. In fact, though, the process has nearly the opposite effect.

It now takes years—more than 110 months on average—for a major military program, once funded, to wend its way through this process. Some programs last even longer: the Marines' EFV amphibious vehicle is projected to take more than 20 years before it gets fielded. While the weapons program makes its way slowly and methodically through the nine steps, the defense strategy that gave rise to it moves on, in response to new threats, shifting geopolitics, and changing imperatives.

So why does the Pentagon stick with such a slow and flawed system? Because many in the DOD believe that following "hundreds and hundreds and hundreds of regulations that say, 'do this and not that' and 'check this over five times'" means that acquisition risk is under control, says the GAO's Schinasi.

Moreover, the best way to protect yourself from accusations of failure is to simply follow the process, says Thomas Lassman, a historian with the Pentagon-sponsored Defense Acquisition History Project. "Then you can't be blamed," Lassman says, "because you followed procedures correctly."

THE COMPLEXITY of military systems stems increasingly from their interconnectedness to other systems. One of the Pentagon's biggest, most ambitious, and most controversial programs is the Future Combat Systems (FCS), a sprawling effort to digitally link battlefield vehicles, sensors, and communications gear and improve their interoperability. The FCS consists of 14 individual systems, including manned and robotic ground and air vehicles, software radios, and satellites, as well as an overarching network and operating system tying those components together. Developing such enormous "systems of systems" poses technical and management problems that are neither well defined nor well understood. The software alone—95 million lines of code for the FCS, at last count—poses a daunting challenge. Nobody has yet figured out a way to develop reliable, secure software for much smaller projects. Yet now the DOD is contemplating systems beyond the FCS that would require more than a billion lines of code.

$21 MILLION

AMOUNT THE PENTAGON SPENDS PER HOUR TO PROCURE NEW DEFENSE SYSTEMS

Another factor contributing to program failure is the shortage of technically trained people, especially systems engineers. A systems engineer translates technical needs into an overall system architecture that creates the best operational capability at the most affordable cost. As a project proceeds and goals or needs shift, systems engineers have to determine the difficult but necessary cost, schedule, and performance trade-offs to keep everything on track. As programs get bigger and more complex, the need for rigorous systems engineering increases.

But the ranks of DOD systems engineers have not increased. "One of the reasons we have such problems in systems engineering today is that we don't have people with the training and experience," says Paul Kaminski, a former U.S. undersecretary of defense for acquisition and technology who recently headed up a National Research Council study on the state of systems engineering in defense. "Gaining the needed expertise," he adds, "is not a 3-year proposition but a 10- to 15-year proposition." In canceling the contracts for the U.S. Navy's Littoral Combat ship program in 2007, Pentagon officials cited inadequate systems engineering as one of the main causes of the huge cost overruns that prompted the cancellations.

Systems engineers are not the only professionals in short supply. Over the past two decades, the DOD has outsourced much of its scientific and engineering expertise to industry. In many of its programs, the Pentagon now has one private contractor for every full-time meeting its cost and schedule objectives, it drained off funding from other worthwhile programs. "The warfighter expects to have a platform capable of supporting his mission and the mission of the Department of Defense," Hirsch said in an interview shortly before his death last year. "If that program is so costly as to jeopardize all other platforms, you can't consider it to be an outstanding success."

Even Defense Secretary Robert Gates has questioned the plane's necessity, pointing out that "the F-22 has not performed a single mission" in either Iraq or Afghanistan.

The F-22's troubled procurement hasn't stopped the Air Force from planning for a "sixth generation" aircraft to be built in the 2020s.

—*R.N.C.*

HIGH FLYER: The F-22 is without question the world's most advanced fighter. But multiple technical problems during development delayed its deployment, drove up costs, and forced the Pentagon to cut the number of planes it could field. The U.S. Air Force plans to field 183 F-22s, at US $137 million per plane, or more than $300 million apiece when research and testing are factored in.

1980s: F-22 conceived as a counter to two hypothetical Soviet fighters. Lockheed Martin wins contract for 750 F-22s, at $35 million per plane.

1990: Pentagon cuts order to 648 F-22s, citing rising development costs.

1991: Collapse of the Soviet Union.

1994: F-22 order cut again, to 442 planes.

1997: Order cut to 339.

2003: Order cut to 276 planes.

2004: Operational testing completed.

2005: First F-22 officially fielded, 10 years late.

2006: Pentagon announces it will purchase only 183 F-22s.

2008: U.S. Defense Secretary Robert Gates tells Congress "the F-22 has not performed a single mission" in Iraq or Afghanistan.

U.S. AIR FORCE

civilian employee. In some cases, the DOD has admitted, contractors are doing jobs that should be performed only by federal employees, such as weapons procurement and contract preparation. The DOD has also outsourced the systems integration and management of some of its most critical programs, including the FCS.

The Pentagon believes outsourcing saves money, but the practice has depleted the ranks of technical, managerial, and contractual personnel who can provide effective oversight of the department's defense acquisitions. As Norman Augustine, former chairman of Lockheed Martin, told me, "If you're not smarter than your suppliers, you can't manage them effectively."

The situation will only get worse. This year alone, nearly one-fourth of the United States' 637 000 aerospace workers are eligible to retire. Both Northrop Grumman and Lockheed Martin, two of the biggest U.S. defense contractors, report that well over half of their workers will reach retirement age within the next five to 10 years. The same is true of DOD federal employees. Younger workers are not rushing in to replace them. Many students who pursue scientific and technical disciplines don't want careers in defense-related work. The implications for the DOD are grim.

Definition

Next-war-itis *n*: The creation of complex and expensive machinery for possible future conflicts while ignoring the present need for affordable weapons.

THOUGH PERSONNEL skilled in the arts of managing acquisition programs are on the wane, the programs themselves are on the rise, along with the Pentagon's budget. The FY 2009 defense budget of $488 billion is the largest in real terms since World War II and 6 percent higher than this year's budget. Meanwhile, the total projected development costs for the 95 or so major weapons systems currently in the pipeline have more than doubled in the last seven years, from $790 billion in 2000 to $1.6 trillion in 2007.

There are no quick or easy solutions to labor shortages and escalating costs, but the standard response in the private sector is to lean more heavily on automation and information technologies. But the DOD seems not to have benefited from technological advances that would make development less expensive. "One might have thought that more efficient production methods, including computer-aided design and manufacturing, microminiaturization of components, and the employment of greater computing power, all would have reduced costs or at least held them level," former DOD comptroller Dov Zakheim told a Washington, D.C., audience in January 2005. The fact that they haven't, he said, is "not easy to fathom."

Ironically, the solution supported by the DOD and military service chiefs, as well as some members of Congress, is not to make acquisitions more efficient but to spend even more money. They advocate setting aside an amount equal to at least 4 percent of the annual U.S. gross domestic product for defense. At the current GDP of about $16 trillion, that would mean an annual defense budget of $640 billion.

Would even that much be enough? The wars in Iraq and Afghanistan have revealed that U.S. military strategy still focuses on winning conventional force-on-force wars and that it lacks the systems to fight asymmetrical or irregular wars against, for example, insurgents and militias. Secretary of Defense Robert Gates has criticized his own agency for what he calls "next-war-itis." The military services and defense contractors, he says, are too focused on creating complex and expensive machinery for possible conflicts far into the future and not sufficiently attentive to providing affordable weapons that the military can use right now.

So, given the fast-changing military imperatives of these times, what constitutes a successful acquisition program? There is no straightforward answer to that question, partly because in the realm of military acquisitions, there is no universally agreed upon definition of a "successful" program. Jacques Gansler, now a professor of public policy at the University of Maryland, has a definition that seems as good as any other: one that "satisfies

STICKER SHOCK: After major cost overruns on the Littoral Combat ship [left], the U.S. Navy suspended the entire program in 2007. The contractors, Lockheed Martin and General Dynamics, built only one prototype each. A prototype of the Non-Line-of-Sight Cannon [right], just one piece of the U.S. Army's vast Future Combat Systems program, fired its first artillery projectile in September, but the GAO says that a costly rework of the cannon may be needed.

LEFT: LOCKHEED MARTIN; RIGHT: U.S. ARMY

a military need for an intended cost and intended schedule."

By that definition, most major defense programs would be failures. The fact that only 5 percent ever do get canceled means that the defense community doesn't hold itself to a high standard.

"The definition of success in DOD is to start a program," the GAO's Schinasi says. "That turns on the program's funding. [Success] has nothing to do with the eventual fielding" of a system.

Ronald Fox, professor emeritus at Harvard Business School, adds that after a program gets funded, the definition of success changes again. "A successful program is one that hasn't been canceled," says Fox, who has studied defense acquisitions for over 40 years.

Defined that way, "success" can look an awful lot like what many people would call failure. Seven years ago, the U.S. Air Force awarded a $3.9 billion contract to Boeing to outfit its C-130 cargo aircraft with digital cockpits, which are equipped with monitor screens rather than analog gauges. But Boeing grossly underestimated how much engineering work it would require to modify the C-130's many different configurations. By last year, the program had gone so far over budget that it triggered a congressionally mandated review. The Air Force's response was not to cancel the program but rather to cut the number of planes getting the upgrade from 519 to 222, thereby "saving" a projected $560 million. Nevertheless, the total program still came in $1.4 billion over budget.

Why not just cancel such a program? For one thing, cancellation means lost jobs—and votes. Loren Thompson, a defense analyst at the Lexington Institute, puts it this way: "Most of the time what [the acquisition process] is trying to achieve is only partially 'equipping a soldier in the field.' It is also concerned with getting a congressperson reelected, advancing the career of a bureaucrat, and making certain that the defense-industrial base is sustained during periods of low demand." Politicians, urged on by lobbyists and defense contractors, routinely support programs that should have been killed or should never have been funded, he says.

THAT SORT OF COLLECTIVE conspiracy extends to the wildly optimistic promises that contractors make to win funding. Such optimism usually takes the form of "understating the cost [of a program] and overstating the technical requirements," says Fox. For example, company A claims it can produce its widgets for $1 apiece and that they will accomplish X, Y, and Z; it will win out over company B, which pitches its widgets at a more realistic $5 and says they will do only X.

The contractors are not solely to blame for this shell game. "Before you know whether the system will work, you have to define the price of all the units you expect to buy," notes Ron Kadish, former director of the DOD's Missile Defense Agency and now a vice president at consulting firm Booz Allen Hamilton. The cost estimate is always going to be wrong, he says, but everyone, including the DOD and military service procurement officials and Congress, pretends that it is correct. This intellectual dishonesty leads to expectations that can never be met.

"The bureaucratic incentives at work in the acquisition system militate fairly strongly against honesty," says the Lexington Institute's Thompson. "Until a weapon system is put into operational test and then must perform, there are lots of rewards for understating costs, for understating technical challenges, and for exaggerating the speed at which costs and technical problems can be overcome."

To be fair, part of that exaggeration stems from the real engineering problem of designing a system that has to meet some theoretical threat 5 or 10 or 15 years from now. If you had to design a car of the future, what technology would you put in it? Would it rely on just what's available today, or would it need to accommodate a power source or steering mechanism that doesn't yet exist? Even when you settle on a design, innovations will inevitably arise during the many years that your system is in development.

Dependence on unproven technology is anathema in the commercial world, but it's common in defense programs. The design for the Army's Crusader howitzer, for instance, relied on 16 "critical" technologies, including advanced armaments, ammunition handling, and mobility. But only six of those technologies had ever been demonstrated outside the laboratory when the Crusader entered development in 1994. Subsequent problems with those untested technologies contributed to the doubling of the program's development cost—and ultimately to its cancellation in 2002.

In their landmark 1962 book, *The Weapons Acquisition Process: An Economic Analysis*, Harvard professors Merton Peck and Frederic Scherer noted that the fundamental objective of acquiring any military system is that it either create a qualitative superiority over an enemy's weapon system or neutralize the enemy's superiority—not only today but into the future. Thus the eternal push for better fighting technology, from sharpened stones to GPS-guided bombs.

Each technological advance a country achieves should not only enhance its own military position but should also degrade the enemy's. For example, making a bomber stealthy enables it to be more destructive to the enemy's key installations. This situation is quite different from the commercial world. Buying an iPhone may rock your world, but it won't have any ill effects (except maybe envy) on your friend who owns a Motorola Razr.

This mind-set tacitly encourages the DOD to demand, and contractors to propose, ever more sophisticated technology. As one former senior military program manager put it, "to sell a program today, you need to claim that it is 'transformational' in some way."

But that quest for the "transformational" is now colliding with the hard reality that many of the fundamental technologies in today's weapons systems are already very advanced. The engines, avionics, and flight controls in military aircraft, for instance, are all close to the limits of what is possible. Even incremental advances come at enormous cost.

And so the infatuation with immature and exotic technologies, with their high costs and risks. James Finley, deputy undersecretary of defense for acquisition and technology, admits that in many programs "technology is being pushed too fast, too soon."

The widespread inability to meet promises creates a vicious circle: lowballed cost projections allow too many programs to be approved; as the projections for each program repeatedly get revised upward, the defense budget balloons; eventually, cuts have to be made, resulting in what military critic Chuck Spinney has termed the "defense death spiral." In congressional testimony in 2002, Spinney described the spiral as "shrinking combat forces, decreasing rates of modernization, aging weapons inventories, with the rising cost of operations creating continual pressure to reduce readiness."

OVER THE LAST six decades a dozen or so blue-ribbon panels and at least a hundred initiatives have called for detailed, concrete reforms in defense acquisitions. So there isn't much doubt that something is fundamentally wrong. What is most disheartening is that everyone knows it and nobody—not DOD management, not the military services, not Congress—has done much about it. "The problem in Washington isn't what we don't know but what we don't want to know," says defense analyst Thompson.

The most recent of these reform efforts was the 2005 Defense Acquisition Performance Assessment, led by Ron Kadish. The panel came up with 35 recommendations in all, some repeating earlier committees' findings, some new to that report. Among the people I interviewed who had read the Kadish report, nearly everyone said that three of the recommendations in particular would have an immediate impact on the acquisitions process, without having to change existing regulation or win congressional approval.

The first of these involves trying to break the defense death spiral by returning to a "block program" approach, in which systems would be built incrementally in capability, instead of trying to satisfy every mission requirement in the first increment. The second recommendation is that programs be "time certain," meaning that most programs would have to deliver some useful operational capability within five years. That requirement would force contractors to use only technologies that are essentially mature, rather than ones that would need to be invented on a schedule.

The third recommendation is to fund only those programs that have an 80:20 cost confidence level, meaning the program has an 80 percent chance of meeting its estimated cost target. Traditionally, the DOD has aimed for a 50:50 confidence level, and some programs don't even reach that cutoff. The Army's FCS program, for instance, was approved in 2003 with "somewhere down around [a] 28 percent chance of success," according to then Army chief of staff Peter J. Schoomaker.

If the DOD were to implement all three recommendations—funding only those programs that it deemed to have an 80 percent chance of succeeding, could deliver operational capability in five years, and could be developed incrementally—it would effectively cut the number of new programs by up to 25 percent. Unfortunately, the Pentagon and the military services have shown no great willingness to scale back, even though it would likely mean getting systems out into the field more quickly.

Still, the DOD's Finley insists that the department is at least attempting to implement all of the Kadish panel's recommendations. But will they in fact fix a broken system? Finley is quite optimistic, but even he admits, "I can't predict the will for change."

25 PERCENT

OF THE 637 000 U.S. AEROSPACE WORKERS ARE CURRENTLY ELIGIBLE TO RETIRE

Indeed, if there's one sentiment that has been repeated more often than any other in the past 60 years of failed attempts at acquisition reform, it is the need for "the will to change." That quality always seems to be in short supply.

In this election season, neither of the two presidential candidates has had much to say about reforming defense acquisitions. That's disappointing but not surprising. No politician wants to be accused of not supporting the troops. Any suggestion that defense spending be reined in has become, like Social Security, a political third rail. Most defense experts are skeptical that the Pentagon or Congress or the White House will fundamentally alter the current way of doing business. There is too much money and too many jobs at stake.

But reform will have to come. Each day that the acquisition process continues to operate ineffectively and inefficiently is another day that the troops are not getting what they need, the country is less secure, and much-needed programs, both civilian and military, don't get funded.

The next administration will need to choose wisely, and soon. ❏

TO PROBE FURTHER An extended discussion of this topic—including a look at successful procurement efforts, defense-acquisition problems in other countries, and some words of advice for the next U.S. president—is available online at http://spectrum.ieee.org/nov08/acquire.

IDIOT-PROOFING THE DEFIBRILLATOR

How a device that shocks a failing heart back to life became one of the greatest engineering success stories in medicine

By Mark W. Kroll, Karl Kroll & Byron Gilman

At its best, the human heart is a supple machine. When the hydraulics work as they should, an electric current rhythmically moves blood through the heart's four chambers. Electric impulses travel along specialized fibers and then dart from cell to cell, causing the muscle fibers to contract and relax as regularly as a second hand ticking around a clock face. When they contract, the muscle fibers create high-pressure regions that push open the heart's valves. Blood pours out of one chamber into another, and just ahead of the blood travels the current, methodically exciting the right fibers and cells in sequence.

But when things go wrong, that current can incite incredible chaos. If a heart is stricken by ventricular fibrillation—a common type of cardiac arrest—then its once-orderly conduction devolves into a scattering of impulses. These impulses travel through the heart as little wavelets, causing unsynchronized tightening and releasing of the muscle fibers in the ventricles, the two lower chambers of the heart. Without synchronization, blood flow ceases; starved of oxygen, other organs rapidly begin to fail. Within 10 minutes, the victim will almost certainly die.

About one-fourth of all deaths in the developed world can be attributed to cardiac arrest—an astounding figure, and one that now has a chance to drop, in no small part because of the automated external defibrillator. AEDs are designed to shock a heart that's in ventricular fibrillation back into a healthy rhythm. The device is now so easy to use that even an untrained bystander can administer this time-critical and highly effective medical procedure. AEDs, which fit into a case the size

JASON LEE

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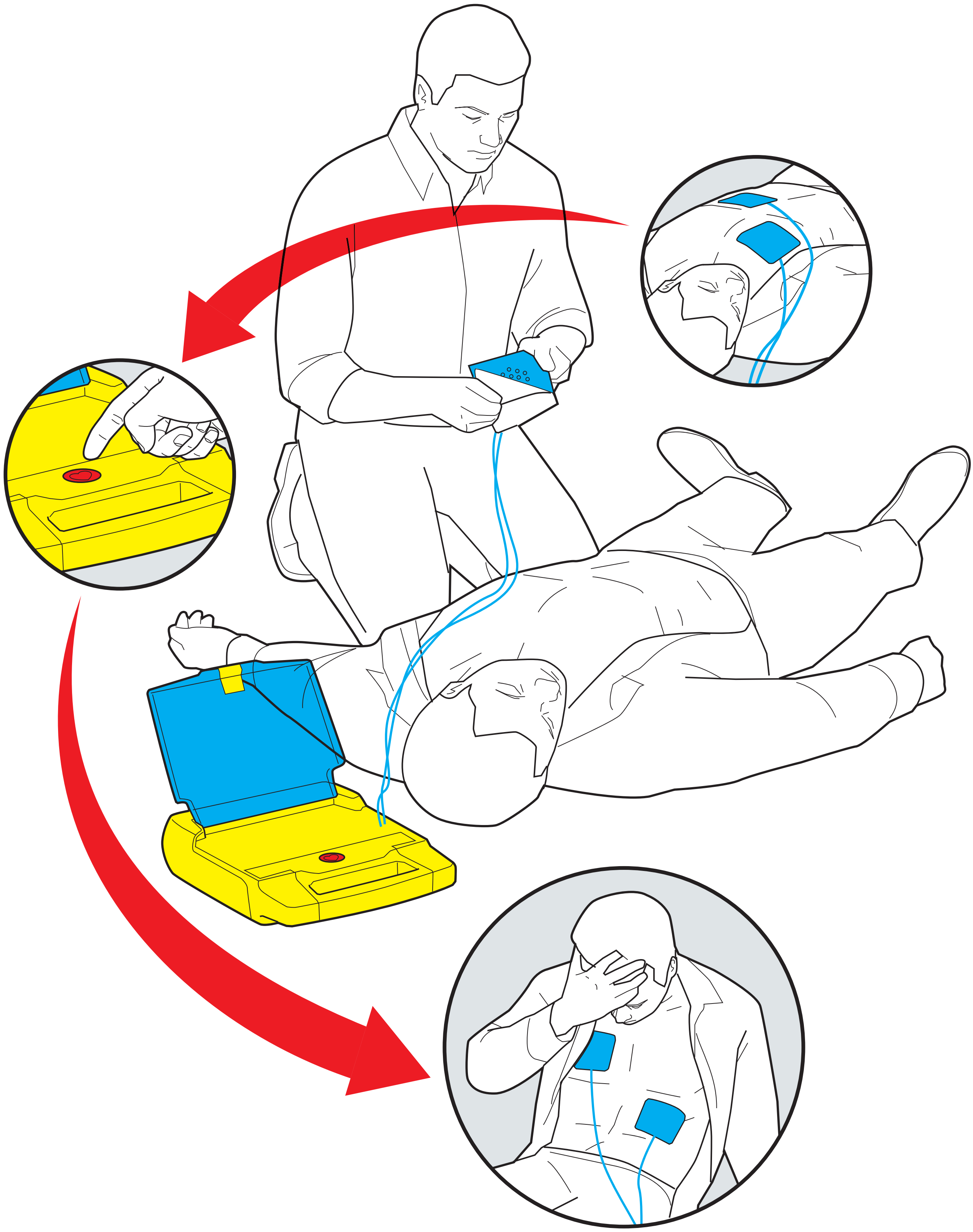

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SIMPLY SAVED: The automated external defibrillator, which shocks hearts out of cardiac arrest, hides its sophisticated engineering behind a simple and cheery exterior. *PHOTO: CARDIAC SCIENCE*

of a lunch box [see “Simply Saved”], can now be found in hundreds of thousands of public places, including office buildings, transportation hubs, and gyms; they’ve also been installed in police cars, in schools, and even on the International Space Station. As the price continues to drop—units can sell for as little as US $1000—some experts are urging people at high risk for cardiac arrest to keep an AED in their homes, just in case.

The AED’s widespread dissemination represents one of the greatest engineering success stories of the last few decades. In just 20 years, improvements in defibrillator design—in the efficacy of the waveform that delivers the electric shock, the way that the unit’s energy is stored and delivered, and the AED’s overall ease of use—have made it so that a layman can operate it with little more than a quick tutorial.

YOU’RE MEETING WITH a middle-aged coworker who suddenly slumps over. You have no idea what’s wrong with him, but cardiac arrest seems likely. Fortunately, you’ve had basic training in how to respond to an emergency, so you snap out of your initial state of shock and call for emergency medical assistance.

On average, the wait for an ambulance in populated areas of the United States is about 11 minutes. From your first-aid training you know that a cardiac-arrest victim’s chance of survival drops about 10 percent with every passing minute, which doesn’t bode well for your coworker. You remember seeing an AED hanging on a wall nearby, and you dash off to retrieve it. Defibrillator in hand, you struggle to keep cool as you try to recall how this strange device works. You’re under immense time pressure in an unfamiliar situation where every second counts.

Luckily for your colleague, the rest of your actions couldn’t be more straightforward. From the moment you open the AED’s brightly colored box, audio instructions prompt you with simple commands. First, they tell you to place two adhesive electrode pads on your coworker’s bare chest, following the diagrams on the pad wrappers. The defibrillator’s built-in electrocardiograph automatically detects and analyzes the state of the patient’s heartbeat, and its software judges whether to administer a shock. Your colleague’s heart is indeed in ventricular fibrillation, so the AED asks you to approve the delivery of a tailored burst of electric current. “Push the button,” announces a firm voice emanating from the box. There’s only one button, so you press it. Your coworker’s body jumps a little, and that may be all that’s needed to restore a normal rhythm to his heart. If not, the box prompts you to push the button again after some time. Thanks to your quick actions, your colleague is saved.

Meanwhile, what’s happening inside the AED is a technical marvel. The device performs two main functions. First, it needs to recognize the lethal haywire rhythm of ventricular fibrillation. Second, it needs to deliver a 100-kilowatt shock to the heart. This jolt allows the heart to restart its normal rhythm, sort of like a Ctrl-Alt-Del for the organ. If the shock is delivered in the first minute of ventricular fibrillation, in more than 90 percent of cases the heart will regain a normal sequence of electric signals, and the steady contractions will return. It took decades of careful engineering to develop a device that could perform those two functions reliably, have a long shelf life, and be both safe and easy to use.

SAVED BY A SPOON: The first defibrillator used spoons as electrodes. *PHOTO: DITTRICK MEDICAL HISTORY CENTER/CASE WESTERN RESERVE UNIVERSITY*

THE INHERENT VIOLENCE of an electric shock stands in stark contrast to its potential therapeutic effect. In fact, the origin of electrical defibrillation can be traced to both electrocution and efforts to electrify the United States in the early 1900s.

Engineers and medically inclined experimenters had long observed and tinkered with the potential of restoring life with electricity. Some of the first dedicated research into the mechanisms of electric shock, however, emerged from quite the opposite effect—electricity's ability to kill. When General Electric, the company cofounded by Thomas Edison, switched from direct-current to alternating-current transmission in the early 1900s, linemen began to die from accidental electrocution. In response, GE funded research at several universities to study what made electric current lethal. Two electrical engineering professors, William Kouwenhoven and Guy Knickerbocker, at Johns Hopkins University, in Baltimore, tested the phenomenon by shocking stray dogs to death. Serendipitously, they noticed that a second ac shock could sometimes bring an electrocuted dog back to life.

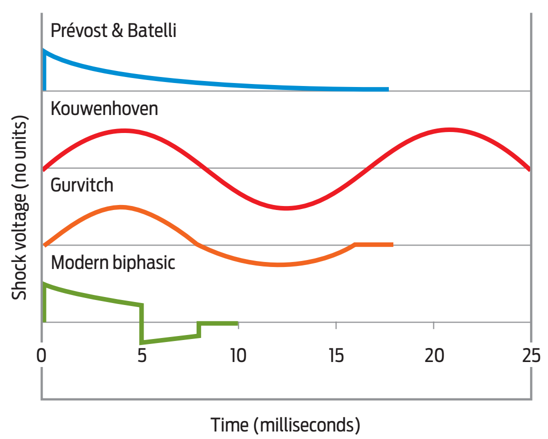
Kouwenhoven and Knickerbocker's observation was picked up by a pioneering cardiac surgeon, Claude Beck, at the University Hospitals of Cleveland. He began delivering ac directly to the exposed hearts of animals he had put into ventricular fibrillation. Beck might have continued methodically with his animal experiments, except that in 1947 a 14-year-old patient's heart stopped during surgery. Out of desperation, Beck ordered that his research unit be brought up from the hospital's basement. This simple defibrillator consisted of a transformer to isolate the patient from the 110-volt ac wall supply, a variable resistor to limit the current to a heart-safe value, and two metal tablespoons with wooden handles to deliver the jolt to the exposed heart [see "Saved by a Spoon"].

The first shock failed, so Beck administered a second. That brought the patient back to life, and the event made national news. But because so little was known about why the technique worked or how to improve it, these crude ac systems persisted for several years. Recipients of closed-chest ac defibrillation tended to suffer unpleasant side effects from the large steady currents, including broken ribs and damage to the heart muscle—if they were saved at all.

Unknown to Beck and his colleagues in America, investigators in Europe and Russia were far ahead of them in animal research and were beginning to use a single pulse, or dc, defibrillation. In the 1890s, Jean-Louis Prévost and Frederic Batelli, two physiologists at the University of Geneva, revived animals with a capacitor discharge delivered directly to the heart.

Decades later, one of their graduate students, Lina Schtern, moved to the Soviet Union and continued to refine the technique—that is, until she received a death sentence during a crackdown on intellectuals under Joseph Stalin. She was eventually pardoned by the dictator himself, who (according to accepted rumor) believed that she could bring people back from the dead.

In Moscow, at the peak of World War II, a young student of Schtern's named Naum Gurvitch made rapid advances in defibrillation. Gurvitch was the first to suggest using a biphasic waveform—a sizable positive jolt followed by a small negative pulse—to deliver the shock. That insight proved to be one of the most critical technical advances in the development of defibrillators. He published a short article on his use of biphasic shocks to resuscitate animals, but the idea didn't really take hold until a Lithuanian-born American cardiologist, Bernard Lown, built a dc defibrillator. Lown used his defibrillator to treat patients suffering from ventricular tachycardia, a less ominous arrhythmia that also responds to shocks. He later had defibrillators built using Gurvitch's schematics, but most U.S. researchers still refer to Gurvitch's breakthrough discovery as the Lown waveform.



WAVE SCULPTING: From the 1890s, experimenters defibrillated with some success. Naum Gurvitch's waveform, however, became the bridge to the modern AED. SOURCE: MARK W. KROLL

THE CORE COMPONENT of a defibrillator has always been the capacitor, which stores the energy needed for the shock. The first "portable" defibrillator, built in 1965, weighed 70 kilograms without batteries and was designed to be plugged into an ambulance's starter battery. The device consisted of a large Mylar-film capacitor capable of storing a 4000-V, 400-joule charge, a charging circuit (to convert the 12 V from the car battery to 4000 V), a gas discharge relay, and a large inductor. When the capacitor discharged, the current passed through the inductor to reduce its peak current, which, at up to 80 amperes, might damage the heart instead of defibrillating it.

This early device had a button that controlled the gas discharge relay; when pressed, it completed a circuit and delivered a strong single pulse from the capacitor through the inductor to the patient. The current was transmitted through paddles the size of clothing irons placed on the chest so that the administrator could get a good grip. Because dry skin is an insulator, a rescuer had to apply sufficient pressure to overcome its impedance. (The Johns Hopkins engineers Kouwenhoven and Knickerbocker noticed that this heavy pressure also caused a patient's blood pressure to spike. That's how the chest-compression technique now used in cardiopulmonary resuscitation, or CPR, was invented. [See the online sidebar, "Rethinking CPR," at http://www.spectrum.ieee.org/nov08/cprsb.])

These defibrillators required two trained operators: someone to press the paddles against the chest and someone else to push the button. One of the operators had to first acquire and interpret the electrocardiogram, or EKG. Then someone had to remove the leads from the EKG because the shock would otherwise destroy its electronics.

The device wasn't truly portable—even after some design modifications, the cumbersome units weighed between 20 and 40 kg. There was also no safeguard to keep the device from being used in the wrong situation—say, erroneously shocking an unresponsive individual who might actually be experiencing a seizure or a fainting spell.

Two major advances cut the energy requirement for defibrillation in half, from 400 J to 200 J, while significantly reducing the failure rate. The first, which took hold in the 1980s, was to eliminate the bulky paddles.

Unlike the electrons that carry current through wires, current in the body is carried by ions, chiefly sodium, potassium, and chlorine. When the electric potential across a cardiac cell's membrane reaches a certain threshold, ion channels open, allowing ions to enter the cell and trigger muscle contraction. In place of the defibrillator's paddles, biomedical engineers developed flexible adhesive patches coated with a metal chloride gel (such as tin chloride) to transfer current from the wires to the body. Each patch has a different polarity: on the patch with a negative polarity, for example, an electron from the wire replaces a negative ion from the chloride in the gel, which frees the chloride ion to pass through the skin and carry current into the body.

The patches reduced the typical contact resistance from about 150 ohms to about 75 ohms, which allowed for smaller voltages. The lower voltages meant that defibrillators could be built with higher-density electrolytic capacitors and smaller semiconductor switches. Thanks to the adhesive patches, the defibrillation operation now required only one person.

However, these gelled patches sometimes dried out, so paramedics had to check their electrodes every day. Two of us (Karl Kroll and Byron Gilman) had the idea of packaging the two pads together with a partially conductive release liner between them. Now the AED was able to pass a small shock between the patches to prevent them from getting dried out.

The other big advance was to switch to the modern biphasic waveform, which, in addition to its higher efficacy, also reduces the power requirements for defibrillation [see "Wave Sculpting"]. One of us (Mark W. Kroll) was the first to publish a quantitative description of the biphasic waveform, in 1994. In essence, the first phase of the shock charges the cell membranes; the second phase, where the current reverses, returns the cell membranes to zero voltage. We still don't know entirely why the biphasic waveform is so effective, and we have yet to learn of any analogues in the rest of biology. One purpose of the second phase appears to be to discharge and heal the blasted-open membranes of cells closest to the electrodes (which receive the most extreme current) and to discharge cells that are only marginally charged. Mark coined the term "burping" (based on the idea of a mother burping excess gas from an infant after feeding it) to describe this strange phenomenon.

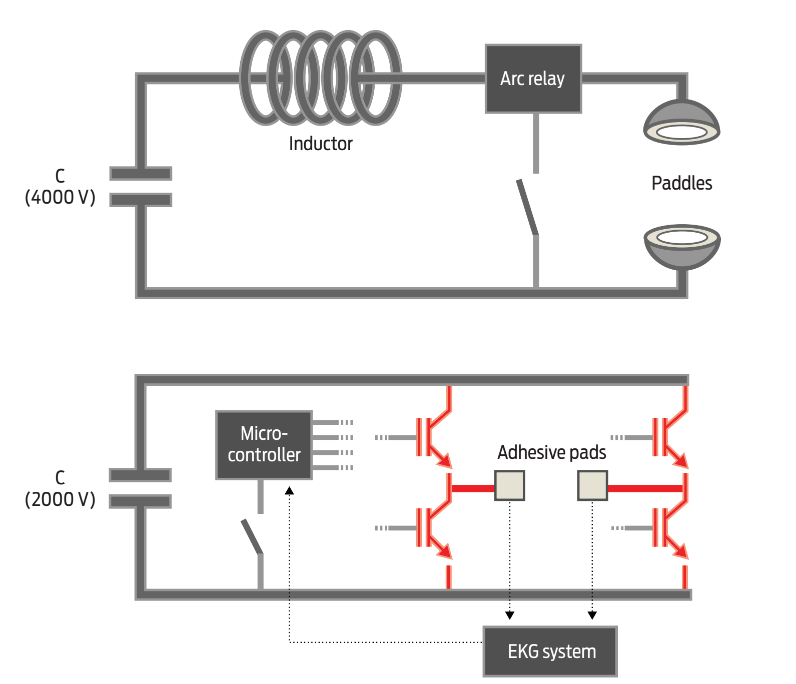
Because biphasic waveforms require less power than their precursors, the size of a defibrillator's components could also shrink. The heavy metal film capacitor was replaced by a lightweight bank of aluminum electrolytic capacitors connected in series, and the heavy iron inductor was eliminated altogether, as it was no longer needed to reduce the peak currents.

With the accompanying reduction in peak voltages from 4000 V to less than 2000 V, the gas arc relay was dropped; switching is now performed by modern compact insulated-gate bipolar transistors. These are configured in a classic H-bridge circuit, the component that allows motor controllers to run forward or backward [see "Tender Loving Shock"]. Depending on which two of its four switches are closed, the circuit can deliver a normal or reversed-polarity voltage. Two switches are turned on for 5 to 8 milliseconds to deliver the main shock. Immediately afterward, the two remaining switches are turned on to deliver the residual capacitor charge and perform the burping function of the second phase.

Taken together, these changes reduced the weight of the unit from 40 kg to 1.5 kg and made it safer to operate. Further advances in the capacitor, battery, and high-voltage semiconductors should eventually reduce the size of the AED to that of a deck of playing cards.

THE NEXT CHALLENGE was to design the brains of the machine. The defibrillator had to figure out, on its own, when to deliver a shock.

The heartbeat is most vulnerable during a period known as the T wave. The T wave occurs just as the heart is beginning to relax after contraction and lasts about 100 ms, or about one-tenth of a heartbeat. A shock administered to a nonfibrillating heart during the T wave could potentially induce fibrillation. If the AED's electrode patches are positioned far from the target, such as on the belly, the current that finally reaches the heart could be sufficient—if it arrives during that vulnerable period—to induce fibrillation, but it may not be strong



TENDER LOVING SHOCK: In the original defibrillator circuit [top], a manually tripped gas arc relay delivered the shock. In modern AED circuitry [bottom], the shock and the EKG signals pass through the same electrodes. An H-bridge circuit, shown in red, generates the biphasic waveform by flipping the voltage at the right time. ILLUSTRATION: EMILY COOPER enough to then defibrillate and undo its own damage. To provide a check on such situations, AED designs began incorporating an analysis system that checks for a pulse.

Recall that fallen colleague of yours. Once the AED is turned on and you've attached the electrode patches, the device's first task is to recognize the EKG signal to see if ventricular fibrillation has occurred. The system starts by delivering a low-voltage, almost imperceptible 30-kilohertz signal through the two electrodes. That action measures the impedance to verify a good contact on the body.

When you get an EKG at the hospital or in a clinic, your right leg is used as the ground, or common, electrode from which to measure the tiny voltage differences that make up the EKG. However, as the astute engineer will notice, an AED has only two electrodes—there is no ground electrode. So the average voltage at these two electrodes is used as the reference.

The two-electrode signal is then fed into a very high common-mode-rejection amplifier, which differentiates between the two signals by rejecting the voltages common to both. (Additional complicated circuitry protects this microvolt-sensitive amplifier from the 2000-V shock—20 million times the EKG voltage—delivered to those same electrodes used for the sensing.) A sophisticated peak detector then analyzes the signal in search of a heartbeat. A normal heartbeat is essentially a cycle of blood-pressure increases and decreases, which show up on the cardiogram as clear voltage peaks followed by comparatively flat regions. In ventricular fibrillation, those distinct peaks disappear, and instead a noisy, messy signal will appear on the cardiogram. The peak detector interprets this noisy signal as a series of rapid, randomly spaced heartbeats. The AED makes its initial diagnostic decision by measuring the heart rate. If this rate is more than 150 beats per minute (2.75 hertz), the defibrillation-detection algorithm presumes that ventricular fibrillation has occurred, and the device will announce that the rescuer should administer a shock.

However, dozens of subtle issues can undermine this process. For example, if a patient has an internal pacemaker, that device's higher-amplitude 60-beats-per-minute pulses could confuse the AED's peak detector into ignoring the 100-microvolt ventricular fibrillation signal, so no shock would be administered. The opposite problem can occur if the patient has atrial fibrillation, a fairly benign rhythm disturbance in which the heart still perceivably beats but at irregular intervals. This condition can generate high heart rates, potentially causing the AED to call for an inappropriate shock.

To deal with these confounding rhythms and other interferences, the defibrillation-detection algorithm performs a simple spectral analysis. What follows is one example of such an algorithm; many competing approaches exist. If too much of the signal occurs at a higher frequency (30 to 100 Hz), then noise contamination, perhaps from an ac power line or some skeletal muscle contractions, is suspected and the algorithm will move away from diagnosing ventricular fibrillation. To handle the possibility of atrial fibrillation, the algorithm calculates the average derivative of the EKG voltage. If the average exceeds a critical threshold, that tends to rule out atrial fibrillation. The EKG of a heart in atrial fibrillation has a higher proportion of flat regions of zero voltage, and therefore a zero derivative.

Those tests and more are performed during a three-second window, leading to a tentative diagnosis. The process is then repeated to produce three diagnoses. Only if two or all three analyses indicate ventricular fibrillation will the shock be authorized.

The single-button design was another key improvement over earlier AEDs. An untrained operator who's facing a panic-filled, life-or-death decision should not be confronted with multiple buttons and expected to quickly figure out which button turns the unit on and which one administers the shock. The breakthrough idea of one of us (Karl) was to have the device turn on automatically and start speaking when its lid is opened.

EVERY TIME an AED is used, whether or not a shock is delivered, it sows the seeds for its own improvement. Every EKG is stored in semiconductor memory for later downloading to a computer at the emergency-response headquarters, from which data can be sent back to the AED's manufacturers. Researchers use this large database of diagnoses to develop and refine future algorithms. Linear methods (such as fast Fourier transforms) and nonlinear techniques (such as neural networks) may soon improve the detection of ventricular fibrillation. These sophisticated signal-processing techniques are being tuned up to make the correct diagnosis, even in the presence of electromagnetic interference, muscle noise, and unusual arrhythmias that might be plaguing the heart. Today's algorithms may well be supplanted in a few years by more advanced ones that will barely resemble the method described here.

Thanks to the advances in the AED, the weak link in the chain is now CPR. The classic protocol is for a rescuer to administer manual chest compressions and mouth-to-mouth ventilations until someone brings an AED or an ambulance arrives. This keeps blood oxygenated and moving to forestall brain death. Surprisingly, recent studies have shown that the chest compressions also move some air through the lungs, at least for a few minutes after the onset of cardiac arrest. As a result, mouth-to-mouth breathing is now being dropped from those protocols.

However, even trained responders will tire after delivering chest compressions for more than a minute. Researchers at Minneapolis-based Galvani, a company founded by Mark W. Kroll and headed by Gilman, are now exploring an automated electrical form of CPR. Using the same defibrillation patches, this technique relies on complex, lower-voltage waveforms (100 to 200 V) that are delivered once or twice per second and cause strong chest constrictions. The constrictions appear to move blood as effectively as would chest compressions performed by a trained human rescuer.

If this research pans out, in the future a bystander need only attach the patches and the AED will do the rest, performing electrical CPR for a minute or two, followed by a calculated defibrillation shock if it's needed. Indeed, we may now be on the cusp of a wave of medical automation that allows ordinary individuals to intervene constructively when other people's lives are at stake. The AED, we think, serves as an important case study for how to fit sophisticated life-saving medical electronics into health care and rehabilitation outside of hospitals. Advances in portable and easy-to-use equipment, home-based therapy, remote health monitoring, and telemedicine may one day allow patients to avoid long, expensive, and emotionally draining hospital visits.

As their efficacy and ubiquity continue to grow, AEDs, we hope, will pave the way for a future where emergency health care is available to all. ❑

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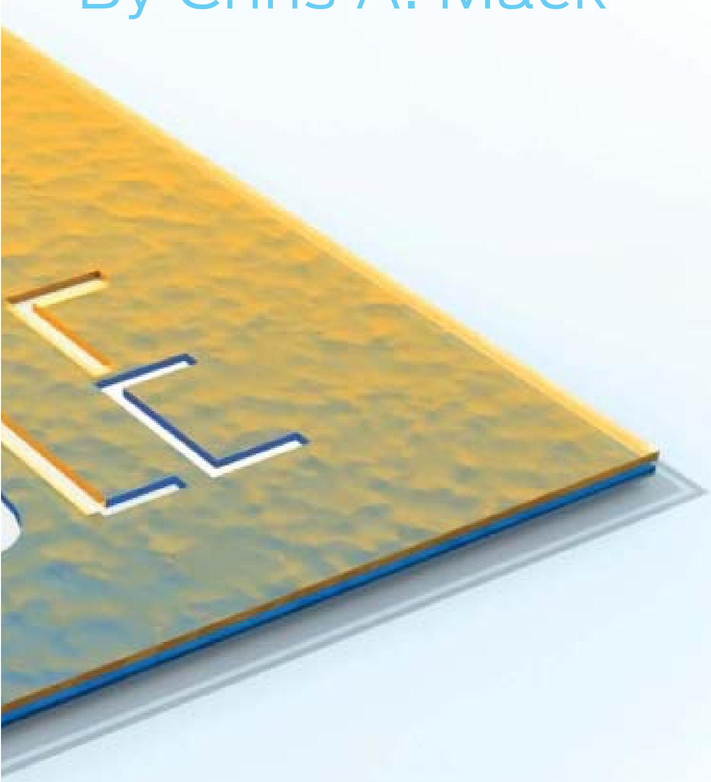
Someday, chips might be made with X-rays. Until then, double-patterning lithography will be the only game in town

By Chris A. Mack



IN 1971, Intel astounded the world with its 4004 microprocessor, whose 2300 transistors could execute 60 000 instructions per second. Today, the 820 million transistors of an Intel Core 2 Extreme chip can process nearly 72 billion instructions per second.

Such an improvement is the inevitable result of several decades of Moore's Law, which refers to the semiconductor industry's ability to double, every 18 to 24 months, the number of transistors on an integrated circuit. But the chips haven't seen a commensurate six-orders-of-magnitude cost increase, and that's because chip manufacturers have had to make those transistors not only smaller but cheaper. In 1963, a transistor cost US $10. That transistor corresponded to half a storage bit and cost as much as an automobile tire at the time. Today flash memory costs $25 for 8 gigabytes, or 64 x 2^{30} bits—enough storage to encode the text of all the books in a small-town library, or more than a 100-word-per-minute typist could type in his lifetime. And it will be cheaper still by the time you read this article.

If we can keep the pace for several decades more, we'll see remarkable things: trillion-transistor supercomputers that can track the twists and turns of the world economy; climate modeling that can reliably predict when you should unfurl your umbrella; robots that can mimic human behavior and emotions convincingly enough to make good companions. You'll be hard-pressed to find anything that can't use a microprocessor by 2030.

As it turns out, however, that's a rather big "if." For its entire history, semiconductor manufacturing has depended on optical lithography, which projects light through stencil-like masks to delineate, layer by layer, the infinitesimal structures that make up the transistors of an integrated circuit. But we're fast approaching the point where optical lithography cannot take us where we need to go next. Consider that the transistors in next year's state-of-the-art chips are so small that 4 million of them will fit into the period at the end of this sentence. The wavelengths of light we are using now are simply too large to print such fantastically dense patterns. We may not be at the end of the road for optical lithography, but it sure is getting tough to navigate.

For at least 25 years, lithographic researchers have anticipated the waning of optical lithography. They spent billions of dollars developing exotic lithographic systems that exploit radiation other than light: X-rays, electron beams, even ion beams. None became commercially viable, although there are always new contenders waiting in the wings. The most probable successor to optical lithography is extreme ultraviolet (EUV) lithography, which uses light of 13.5-nanometer wavelengths. But a little over a year ago, the experts realized that EUV would also fail to materialize before 2011 or 2012—the time frame during which chip makers will need a major lithographic advance to keep Moore's Law going.

Fortunately, another option has emerged. It's called double-patterning lithography, and it promises to extend optical lithography's useful life for about four more years, or through two more doublings of chip transistor density. It will be a timely and lucrative reprieve: the Moore's Law paradigm, which helped propel the integrated-circuit industry into the $255.6-billion-a-year juggernaut that it is today, will live to fight another day.

Double patterning is another of the many "cheats" that lithographers have had to invent over the past decade to keep pushing the size of transistors into ever more remarkably minute realms. The technique involves complicated methods of doubling up the layers of printing, which means it's about twice as expensive as conventional optical lithography, and it ties up the equipment for longer periods. But it's the only method that will be able to tide

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the industry over until the arrival of EUV lithography in four or five years. Double-patterning lithography, to borrow a phrase from Winston Churchill, is the worst method that's out there right now, except for all the others.

DOUBLING transistor density on a chip means shrinking its dimensions by about 30 percent. The industry is understandably desperate to see the pace of Moore's Law continue, and that pace is dependent on the technology that can create those ever-shrinking transistors: optical lithography, also known as photolithography.

Photolithography literally prints microchips layer by layer. The technique's most basic parameters are resolution and cost, and they are in more or less direct conflict. To print the billions of tiny individual features that make up a modern chip, you need extremely fine resolving power. And because that modern chip with nearly a billion transistors sells for only a few dollars, the printing method has to be stupendously cheap. Chip makers are constantly jockeying for advantage by trying to introduce new technologies ahead of their competitors, but for the most part they all move in lockstep between what are called technology nodes.

A "node" loosely refers to the width of the smallest features of an integrated circuit—for example, the length of a transistor's gate. In 1971, those 2300-transistor Intel 4004s were manufactured using technology that could create features measuring 10 000 nanometers (10 micrometers). Today's most advanced chips are at a 45-nm node, ostensibly because the smallest features in the pattern measure 45 nm. Intel expects to begin producing 32-nm node chips in 2009. Chips based on 22-nm node processes are already under development and slated for production from 2011 through 2012. Using smaller wavelengths and larger lenses, the semiconductor industry has done a stunning job of scaling down transistors. Consider that if the transistors in the Intel 4004 had been the size of Humvees and had been scaled down to the extent that they have, they would today be as small as sesame seeds.

Every chip starts its life as a tiny patch on a gleaming round wafer of silicon about the size of a dinner plate. This wafer moves in and out of a series of machines through a fabrication plant the size of a football stadium. The result is a wafer imprinted with patterns of hundreds of identical microchips, which are then sliced and diced and go out into the world to populate routers, coffeemakers, ATMs, laptops, and fighter jets.

Optical lithography, which imprints the patterns onto the wafer, is a lot like old-style film and chemistry photography. It actually works a lot like a slide projector, in which a light source shines through a pattern to beam an image onto a surface.

First, the wafer is covered with a light-sensitive material known as a photoresist, which is like a more sophisticated version of the emulsion used on photographic paper. Next, light is streamed through a photomask—an opaque "master pattern" plate with holes that let light through to form a pattern below; this mask is analogous to the negative in film photography. The pattern is projected onto the photoresist-coated wafer using extremely sophisticated optics. Where the photoresist is exposed, its chemical properties are changed by the light. The parts that are masked, and therefore unexposed, retain their integrity, but the photoresist under the illuminated areas becomes chemically "weak." That exposed photoresist is washed away by a developer solution, revealing the material underneath.

This optical system is called a stepper or a scanner because it projects postage stamp–size chip patterns onto the wafer one at a time, exposing the silicon patch and then rapidly moving on to the next one, until the entire wafer is covered with identical microchip patterns, hundreds to thousands of them per wafer. Last, a corrosive plasma easily eats away the exposed wafer material, transferring the photoresist pattern onto the semiconductor wafer below. A wafer will cycle through these photolithographic steps, each cycle producing what eventually will be a single layer of the finished microchip, up to 40 times.

This basic process has gotten more complicated with each successive generation of chip because, according to the fundamental laws of optics, in order to produce smaller and smaller features on chips, lithography tool manufacturers have had to repeatedly reduce the wavelengths of light used to project the chip patterns. And as the wavelength becomes shorter, the light source and optics become more complex and expensive, which is why lithography tools are subject to their own version of Moore's Law: tool prices reliably double every 4.4 years. That's partly a result of the journey down the wavelength ladder from the big, easy wavelengths of visible light in the 1960s, to shorter-wavelength mercury lamps in the 1970s, to the even shorter wavelengths of krypton-fluoride lasers in the late 1990s, and finally to the punishingly short-wavelength argon-fluoride laser light used today. The projected use of incredibly small 13.5-nm light has been hampered by the fact that you can barely design a lens for it—light of wavelengths that short is absorbed by everything in its path, including the lens and the air itself.

But even using today's wavelengths, we need to do more to achieve good resolution. When light shines through a photomask, it diffracts, spreading out as it travels away from the lens. That diffraction causes the features projected onto the silicon to blur, rendering the finished chip unusable. Because each diffracted light beam contains important information about the chip's pattern, as much diffracted light as possible must be collected if you want a satisfactory image. The lens between the light source and the photomask is there to make sure that this diffracted light is caught and used in the image.

Thus, how fine you can get your resolution—how small you can make your features—depends on the two most fundamental characteristics of an imaging system: the wavelength of the light and the size of the lens aperture—the opening—through which you're shining that light. Wavelength and aperture are related in a fundamental equation, called Rayleigh's resolution criterion, that governs all lithography: resolution is proportional to the wavelength divided by the size of the lens opening. So to print smaller features, you need shorter wavelengths, a bigger lens, or ideally, some combination of the two.

Making the aperture bigger means that more light can be captured. More captured light means that smaller features can still be "seen" by the lens. But in optics, as in life, there is no free lunch: while a larger-aperture lens yields better resolution, it also requires a more complicated and expensive stepper.

Numerical apertures have increased steadily over the years, from 0.167 in 1973 to 1.0, long considered a barrier because 1.0 is the refractive index of air. In 2005, Nikon and ASML broke that 1.0 barrier with a fantastic cheat called water-immersion lithography. The idea is simple: boost resolution by replacing the standard air gap between the lens and the wafer surface with water, a medium with a refractive index greater than 1.0. The mythical 1.0 barrier was vanquished, and three years

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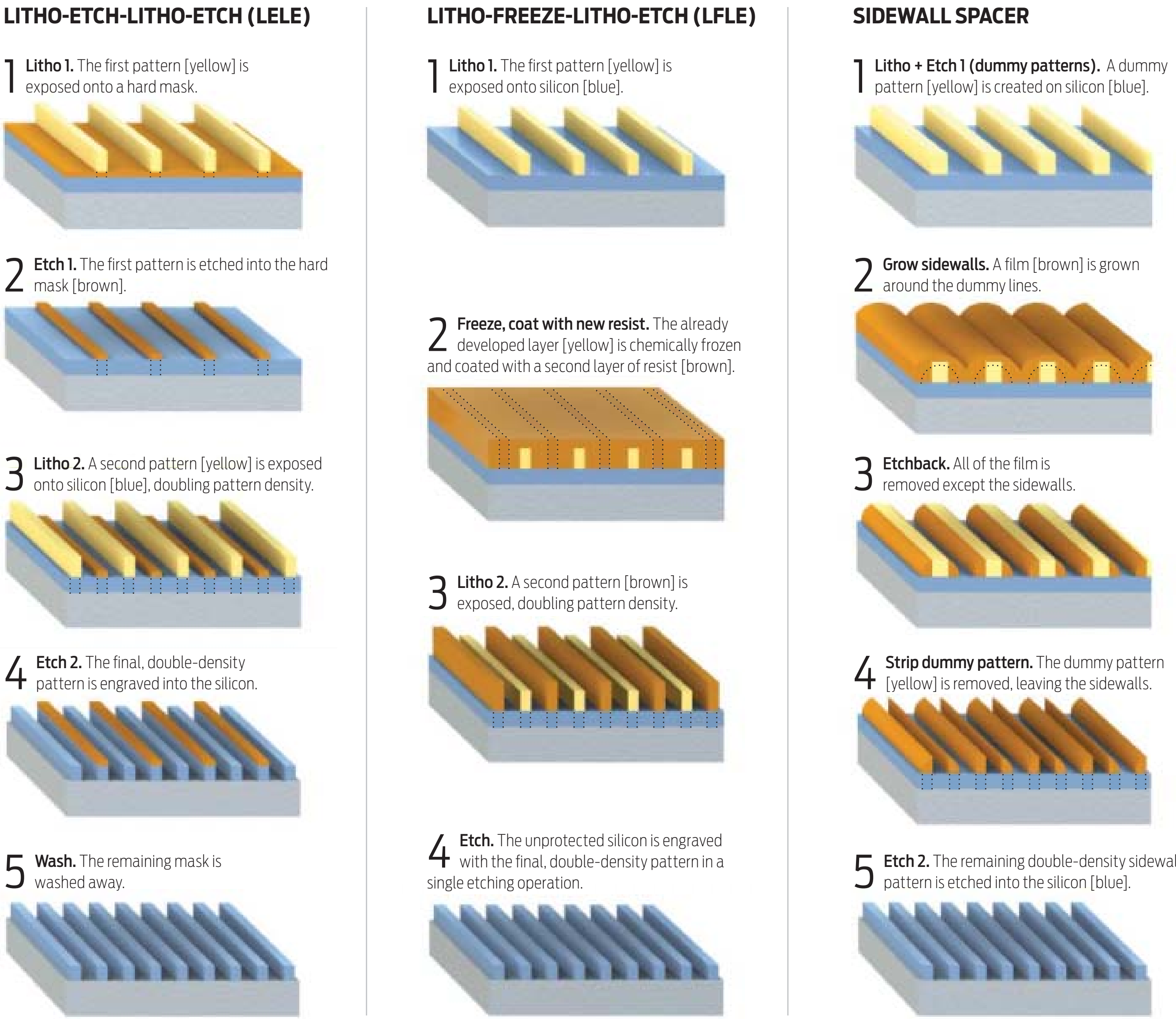
All Double-Patterning Variations Lead to Rome



ILLUSTRATIONS: EMILY COOPER

later we are at an incredible 1.35.

But even with such improvements, the challenges to lithography at the 32- and 22-nm feature sizes of the next two generations of chips are enormous. For these, even a wavelength of 193 nm is too big, and even an aperture of 1.35 is not big enough.

THE UPSHOT? The scaling of wavelength in optical lithography hit a dead end about five years ago, when Intel announced in 2003 that it would suspend development of 157-nm lithography indefinitely. Efforts to switch to 157 nm failed because researchers found it just too difficult to build lenses and photoresist materials that worked well at 157-nm wavelengths. Likewise, pushing numerical apertures higher than 1.35 will require the development of high-refractive-index glass and immersion fluids, something that will probably not happen in the next year, if at all.

Until about 18 months ago, researchers thought they'd be saved by the big wavelength reduction that EUV lithography promised. But EUV lithography has also hit serious roadblocks. For one thing, EUV light sources simply aren't bright enough. With wavelengths down to 13.5 nm, EUV is near the edge of the ultraviolet/X-ray boundary. It's far beyond not only what human eyes can perceive but also what currently available lithography tools can use. EUV is absorbed by everything: glass, oxygen molecules, water—you name it. Not only do you need optical assemblies made out of something far more exotic (read: expensive) than glass, you also need to carry out the entire process in a vacuum. The ultrasmall wavelength of EUV makes extremely small defects on optical surfaces and the photomask critical—and both hard to detect and eliminate. EUV sources are also too weak to produce chips at the rates needed for commercial success. You can make up for weak sources to some extent with a more sensitive photoresist, but that degrades the resolving capability of the resist.

EUV light sources are getting stronger, but they still have a long way to go. EUV lithography is still the preferred option for many companies for the 32-nm node, due to its extendability to 22 nm and beyond. But the 13.5-nm wavelength goal has been as elusive as an ever-receding mirage.

SO OUR BEST HOPE is double-patterning lithography. Belgium's Interuniversity Microelectronics Centre (IMEC) was the first to demonstrate the technique for the 32-nm node two years ago, using a combination of double-patterning and immersion lithography. Conceptually, it's simple: instead of exposing the photoresist layer once under one photomask, as in conventional optical lithography, expose it twice.

Let's say you've bought a prefabricated picket fence. It has a certain number of posts that are evenly spaced, but your dog can still get into the neighbor's yard. What you need is a higher density—the technical term is "lower pitch"—of fence posts. That situation is analogous to what's going on now with lithography: we want a higher density of transistors on chips. Returning to our fence analogy, to get the exact density of fence posts needed to keep your dog in the yard, you want to double the density of the prefab posts. You could build a whole new fence with twice as many posts, but here's an easier solution: buy a second picket fence and install it so that the posts are shifted over by half the pitch. That is, put the fence right behind the first one, but shift the whole thing over just enough so that the density of the fence posts has doubled. Now you have twice as many fence posts.

That's the basic idea behind double-patterning lithography. To understand how it works, consider the specific factors that limit the resolution of conventional optical lithography. First, think of the features being printed: they often consist of patterns that are repeated—for example, many transistors a set distance apart. For a given aperture and wavelength, there is a limit to how small these projected repeating patterns can be. Make the pattern too small and the optical system will fail to resolve it. In lithography, any photomask with patterns packed more tightly than the spatial period required by the imaging lens will fail to print. In other words, if you squeeze too many fence posts too close together, your dog will no longer be able to see out of the yard—he'll just see a wall.

For today's limit of a 193-nm wavelength and a numerical aperture of 1.35, the smallest pattern period possible is about 72 nm (or a "half-pitch" of 36 nm), meaning that the distance from the middle of one fence post is 72 nm to the middle of the next fence post.

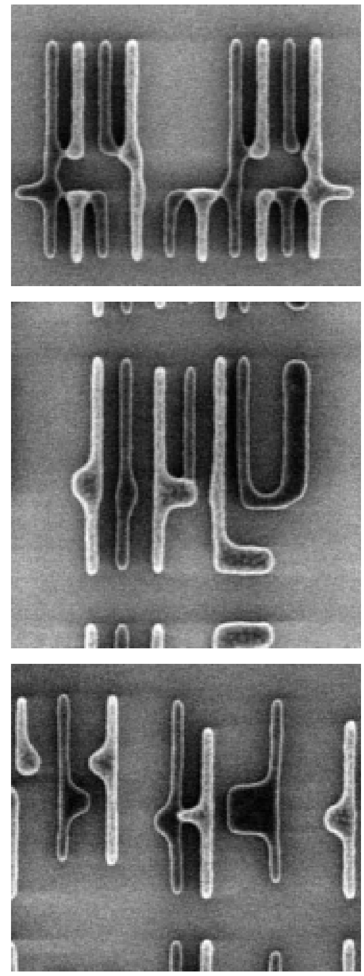
Note that this limit is for the spatial period (the pitch), not for the size of a single feature (the fence post, in other words). For a pattern of lines and spaces of a fixed pitch, it is possible to make the fence post thinner by increasing the space between posts, or to decrease the space between posts by making them wider. The resolution limit of a single line or space is more flexible, and a variety of techniques allow fairly good control of individual features down to a quarter of the minimum pitch, which at current cutting-edge resolutions would be 18 nm.

This ability to control a very small feature at the limit of pitch resolution opens up the possibility of double patterning: printing two interlocking, complementary patterns to produce a final pitch much smaller than the limit for one patterning step.

But double patterning is very difficult to implement practically. There are several impediments, which is why the technique comes in three major flavors, each of which offers its own benefits and drawbacks: litho-etch-litho-etch (LELE); its close cousin, litho-freeze-litho-etch (LFLE); and the sidewall-spacer technique [see "All Double-Patterning Variations Lead to Rome"].

LELE is the most straightforward. As the name suggests, two complete lithography-and-etch operations are carried out, one atop another, to transfer the mask pattern to the wafer [see "The Two-Step"]. Think back to the dog and the fence: LELE is the closest analogue to simply buying two fences and stacking them one in front of the other. One big drawback of this approach is cost: two complete pattern-transfer operations will essentially double your lithographic cost, just as buying two fences would double your fence cost.

Another problem is an extreme sensitivity to overlay accuracy. When the mask pattern is projected onto the wafer the second time, any variations in overlay—that is, misalignments between the placement of the second printed pattern with respect to the first—will translate into variations in the width of the spaces between the lines. In fence terms, it means you need to line your fences up so that every post is spaced exactly the same distance apart. If you make a mistake, for example shifting it by a third instead of half the pitch, your dog will be able to squeeze through every other gap.



THE TWO-STEP: Three scanning electron microscope photos of different examples of LELE double patterning, each one showing the final result. The dark-colored features were printed in one lithography/etch step, and the light-colored features in the second lithography/etch step.
PHOTOS: IMEC

Early results for LELE have been promising, but we need to improve the overlay capabilities of current exposure tools. To put it in some perspective, LELE for a 64-nm pitch will require a pattern placement accuracy of 2 to 3 nm over an exposed area bigger than 2 by 2 centimeters. That's not a lot of room for error, especially because lithographers are accustomed to a much more generous error allowance for single patterning. The industry still needs to come up with major improvements in pattern-placement accuracy if it wants to make LELE produce a good yield of working chips. Otherwise the promising results will stay in academic papers and never make it to commercial production.

Double-patterning flavor number two, LFLE, was developed to address LELE's cost issue. LFLE is a variation on LELE: after the first lithography step forms the patterns on the wafer's photoresist, a chemical treatment of the resist "freezes" the pattern. Then, without etching or otherwise transferring the resist pattern into the substrate, technicians apply a second film of resist over the first pattern. Because of the freeze operation, that second coating of resist does not intermingle with the existing pattern. A second lithography exposure and development creates the second pattern while leaving the first pattern intact. Then a single etching operation transfers the compound pattern into the underlying substrate.

To use the fence analogy again, this is the equivalent of hammering the two fences together before you put them in the ground—saving time and money by putting only one fence into the ground instead of two. The fact that all these exposure and processing steps can be carried out within a single machine significantly reduces cost and processing when compared with LELE. Recent progress in various freeze processes is making this approach look very attractive, but results are still preliminary. It's not yet clear whether the new freeze materials can be manufactured, and the overlay difficulties of LELE are just as severe for LFLE.

The third variation of double patterning, the sidewall-spacer technique, is attractive because it elegantly addresses the problem of tighter overlay requirements. This technique creates small lines around the outer edge of the original pattern, doubling the frequency of lines for a repeating pattern, but not in the same blunt-force way as LELE and LFLE.

Consider the picket fence again. In the sidewall-spacer approach, a fence is built with spaces that are twice as big as what you actually need. Then smaller posts are attached to both sides of each original post. Then you remove the original posts. Now you have twice as many of the new, smaller posts as you had originally, and they are all perfectly spaced. In both the LELE and LFLE processes, the errors in overlay translate into irregular and uneven patterns that will cause the chip to fail. By contrast, the sidewall-spacer process does the opposite, turning dimensional errors (irregular patterns) into overlay errors. But because it's easier to control a pattern's dimensions than its placement, the sidewall-spacer process significantly relaxes the requirements of the lithographic optical system.

The main problem with the sidewall-spacer approach is that it restricts every final feature (the final, skinny "fence post") to the smallest possible dimensions rather than whatever size the chip designer happens to want. Further, these sidewall-formed lines necessitate a second and sometimes even third patterning step: that's because they add extra material not only onto the sides of the original patterns but on the fronts and backs as well, creating patterns that look more like closed loops than straight lines. Obviously, that is not what the final chip design is supposed to look like, so the extra patterns must be removed separately, and once again, that creates added cost. The sidewall-spacer technique is much better suited to creating memory cells than logic cells, because the patterns for memory cells are much more regular than those for logic cells, which are essentially random.

ASML, Canon, and Nikon, which supply the tools for all flavors of double patterning, tend to like LELE and LFLE best, mainly because mainstreaming these techniques will probably mean that IC companies will have to buy a new generation of scanners to get tighter overlay performance. For the sidewall-spacer technique, IC companies may be able to use their existing tools. Applied Materials is pushing the sidewall-spacer technique because it involves processing steps that will be done on Applied Materials tools, thus giving the company more tool sales.

Because essentially no IC companies are major players in both memory and logic, the big logic companies (the IBM partnership companies, Intel, Sony, TI, Toshiba, and TSMC) will stick with LELE and LFLE, while the big memory companies (Hynix, Micron, Renesas, and Samsung) will likely use the sidewall-spacer technique.

In the end, all double-patterning techniques will require new chip-design tools capable of splitting an existing chip mask layout pattern into two separate sets of mask patterns. An error in just one feature could kill an entire device, so we need automated and nearly foolproof pattern splitting. The common practice of scaling down a design from the previous node will no longer work.

SUPPOSEDLY, the first production tools for EUV will arrive in 2011. These tools will be able to achieve resolutions of about 25 nm, which means they'll be able to usher in the 22-nm node (but see sidebar, "Why There Will Never Be an 8-nm Semiconductor Node"). That's according to the current schedule, anyway. Many people, myself included, are skeptical. Sure, the tools will be capable of 25-nm resolution, and sure, they'll arrive by 2011. But they won't be production worthy: they won't have enough throughput and yield to make them worth buying—especially because by then, double-patterning lithography will be in full swing, and using it to create 22-nm chips will be a lower risk at a lower cost.

In the end, double patterning is nobody's idea of an ideal solution. The extra steps and complexities could double the cost of lithography layers, pushing chip-making costs up even while consumers continue to expect more for less. Again, double patterning is probably the worst alternative—except for all the others. ❑

Why There Will Never Be an 8-nm Semiconductor Node

There will never be an 8-nanometer node. We might have something we call an 8-nm node, but it will be a lie, in the sense that this node will have nothing to do with 8-nm features or a 16-nm pitch, or much of anything that can be related to the number 8. We probably won't even get to the 11-nm node, due to arrive in 2018. Cost-effective lithography just won't be available at those dimensions.

To understand why, first recall that a node is the smallest component of the elements of an integrated circuit. From a 1971 size of 10 000 nm, today's most advanced chips have shrunk to the 45-nm node, so named because the smallest features in the pattern are nominally 45 nm, though the relationship between the name of the technology node and the actual component dimensions is only approximate. In addition to diminishing feature sizes, density and chip-performance improvements are now coming from innovations that have nothing to do with lithography—improved dielectric materials, for example. The traditional way of looking at Moore's Law as ever-shrinking node dimensions is becoming outdated.

Twenty years ago, technology nodes were named for the highest DRAM size available (does anyone remember the 64-MB node?). But when DRAM sizes stalled at 512 megabytes to 1 gigabyte and lithography scaling was recognized as the No. 1 technology driver for Moore's Law, the nodes were renamed to reflect the shrinking feature sizes.

In all likelihood, lithography won't remain the heart and soul of chip making much longer. It's time we developed a better descriptor for IC improvements and stop pretending that the 22-nm node will be scaled by a factor of two from the 45-nm node—or that this scaling will never end. —C.A.M.

POWER TO THE PEOPLE: From her desk in Casablanca, Fatima Mansouri oversees network projects for Office National de l'Electricité, Morocco's electric-power utility, which is already connected to Europe through undersea cables. *PHOTO: ANA NANCE*

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CLOSING THE CIRCUIT

ENGINEERS WORKING IN THE TEEMING CITIES AND LONELY DESERTS OF NORTH AFRICA ARE CREATING THE LAST LINKS IN A POWER GRID THAT WILL RING THE MEDITERRANEAN SEA BY PETER FAIRLEY

WITH BANDANNAS protecting their faces from the blistering sun and blowing sand, day laborers smooth the ground over freshly buried cables at Libya's newest electrical substation. Until a few years ago, this same patch of ochre earth in the sparsely populated Bir Osta Milad district, located on the outskirts of Tripoli, was the site of a Scud missile plant. Today, thanks to Libya's oil revenues and its recent rapprochement with the West, the rocket parts are gone, replaced by gas-insulated switchgear, transformers, and state-of-the-art controls. This and more than a dozen other 400-kilovolt substations located throughout Libya will bolster that country's beleaguered power grid. But these improvements are also part of a much larger drama. That's because they will form a key bridge for an electrical superhighway that could soon bind the fractious nations on the south side of the Mediterranean Sea.

The coming electrical unification of North Africa will advance a grand scheme known as the Mediterranean Electricity Ring, which has been the stuff of speeches and studies for decades. Engineers have recently made much progress on the ground, and perhaps as soon as mid-2009 they will cinch together all the power systems from Morocco to Syria with those of Europe. The same momentum could see the entire MedRing finally completed by the end of the present decade, connecting more than half a billion people in Europe, Africa, and Asia.

The MedRing took its first big lurch toward reality in 1997, when Spain and Morocco energized a set of undersea power cables bridging the Strait of Gibraltar. That event brought the integrated grids of Morocco, Algeria, and Tunisia—a legacy of French colonial rule—into synchronous operation with the Union for the Co-ordination of Transmission of Electricity (UCTE), whose 240 000 kilometers of high-voltage transmission lines connect 26 European countries.

BEAUTIFUL FRIENDSHIPS: Casablanca enjoys a juxtaposition of cultures, histories, and values, making it an appropriate hub for the integration of European and North African electrical grids. Although parts of the city might easily be mistaken for a modern European capital [left], Casablanca's ancient roots are apparent in its walled Old Medina [right], built centuries before Morocco's days as a French protectorate. *PHOTOS: ANA NANCE*

Since that first Gibraltar link, 400-kV transmission lines and substations such as the one in Bir Osta Milad have been popping up along the Mediterranean's sun-scorched southern flank. With this reinforcement of the region's older 220-kV transmission grids, power generated in Europe could soon flow all the way to the Syrian-Turkish border, which lies more than 3000 km from Gibraltar. Energizing existing power lines that connect Turkey to Syria and to Bulgaria, a UCTE member, is all that remains to close the ring and realize the dream.

There are strong, if divergent, interests on both sides of the Mediterranean backing this project. To the south, the secure and efficient provision of electricity is seen as a key ingredient for economic growth, which is sorely needed. Unemployment, particularly among younger workers, is endemic throughout the region, and the resulting unrest plays to Islamist groups seeking to topple the area's authoritarian and in many cases U.S.-supported governments. Ensuring stable electrical supplies, the local thinking goes, will help ensure stable societies.

European governments, for their part, see stability and harmony in North Africa as a safeguard against Islamist violence on their own streets. North Africa is also emerging as a critical source of diversification for Europe's energy needs. Algeria and Libya provide Europeans with natural gas today and want to sell them gas-fired electricity tomorrow. A few decades from now, exports of North African wind and solar power may well be supplying a large fraction of Europe's demand.

There is an additional, if intangible, benefit as well. Electrical integration helps tie together two worlds that seem at times to be racing apart—those of Muslim North Africa and an increasingly xenophobic Europe. The Mediterranean countries have tried, and to date failed, to create a free-trade zone integrating their economies. Electrical interconnection—with power plants in Libya keeping the lights on in Italy, for example—offers another way to link these divergent cultures.

Bruno Cova, a grid expert with Milan-based Centro Elettrotecnico Sperimentale Italiano, expresses that sentiment aptly: "This is a positive consequence beyond mere energy interchange. You become, in some sense, part of the same family when you are this tight with your neighbor."

No one believes more keenly in the interconnection's potential for good than Fatima Mansouri, who directs network projects for the Casablanca-based Office National de l'Electricité (ONE), the state-owned utility that runs Morocco's grid. She says there are times when they couldn't cope without the power flowing across Gibraltar. "Just two days ago we had a problem with two steam groups at Jorf—each one producing about 300 megawatts. Thanks to the interconnection, we covered the energy gap," she says.

It's no mean feat to keep power flowing in the face of consumption that rose between 7 and 9 percent for each of the past five years and shows no signs of abating. The country's monarch, King Mohammed VI, has made it clear that he is counting on ONE to sustain Morocco's economic growth.

The stakes are clear on the streets of Casablanca, a city of more than 3 million that fairly crackles with contrasts. At the Place des Nations Unies, the Hyatt Regency looks over the rundown Old Medina, and Paris fashions rub shoulders with the occasional burka. Although part of an overwhelmingly Sunni Muslim country, this cosmopolitan hub is home to several thousand Jews, five of whom ran for parliament last year. Real power resides with the king, yet Islamist violence remains an ever-present danger.

Mass demonstrations at the other end of the continent show the least of the troubles that can occur when demand outraces supply. South Africa began suffering a shortage of power in January, requiring operators to ration electricity and up the price—a move that sparked a nationwide strike in August. The electricity shortfall seems likely to clip the growth of South Africa's gross domestic product, from the 5 percent level delivered for the past five years to about 3.4 percent predicted for this year. Mansouri says that only the interconnection with Spain has kept Morocco a step ahead of similar shortages.

Indeed, last year ONE bought 3479 gigawatt-hours of electricity—15.4 percent of its total supply—on the European market. The value of that power is especially high in Africa, where difficulty raising capital, dependence on pricey foreign contractors, and widespread corruption all take a toll and in some cases add years to the process of power-plant construction. What's more, Morocco has no natural-gas fields, so it depends on imported coal for domestic power generation.

The connection with Spain is important for power quality as well: the UCTE, with its vast reserves, acts as a bulwark against instability in the 50-hertz ac signal in Algeria, Morocco, and Tunisia. The UCTE has 630 gigawatts of installed capacity, more than enough to smooth over any glitches in the comparatively tiny amount of North African generation; Morocco, by contrast, can produce just 5.3 GW. Disruptions that would throw off the frequency of an isolated North African grid, whether from short-term mismatches between generation and demand or from a downed power line, are instead absorbed by the UCTE's heft.

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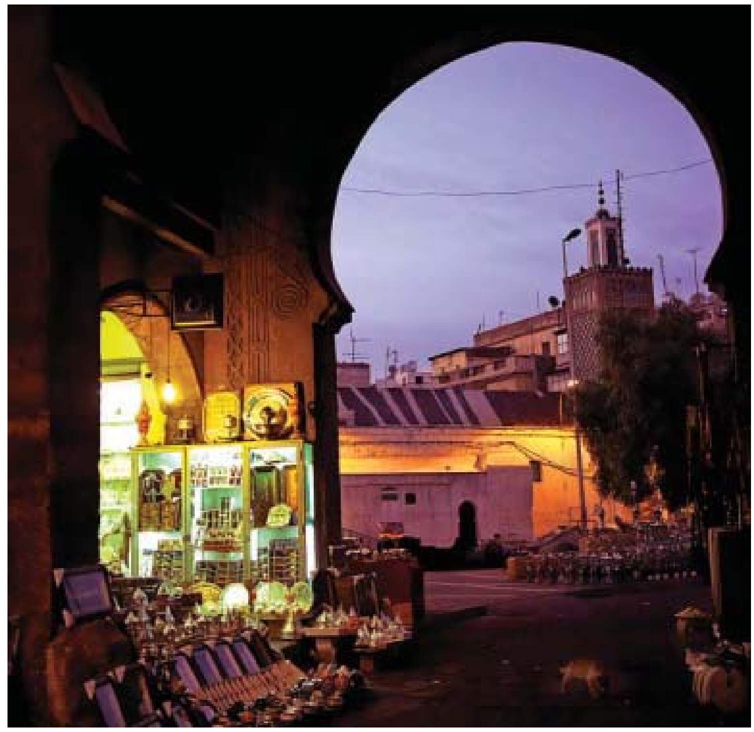


MANSOURI'S OFFICE, on the north side of Casablanca, is the nerve center for expanding the flow across Gibraltar and for accommodating new power generation within Morocco using 400-kV transmission lines.

It's a hectic job. Mansouri's explanations are interrupted by frequent calls from engineers in the field. One reports rats—the usual suspects in many power outages—pouring out of one of Casablanca's new substations. Another gives the latest news on a rural landowner who has been demanding several hundred thousand euros to let a 400-kV transmission line cross his property.

"He has a little house in the country. Our line is well to the side," says a slightly exasperated Mansouri. "That line is going to kill me. Truly."

But she perseveres, knowing what the benefits will be. Completion of the first phase of the 400-kV transmission network—1250 kilometers' worth, snaking through northern Morocco—has already enabled ONE to get more power from Spain. A second cross-Gibraltar tie-line went in last year. Although these links are rated to carry a combined 1400 MW, the nation's wobbly 220-kV grid could handle only 200 MW when the first set of undersea cables came into commercial use. But with the new 400-kV improvements, Mansouri expects soon to be importing 700 MW.

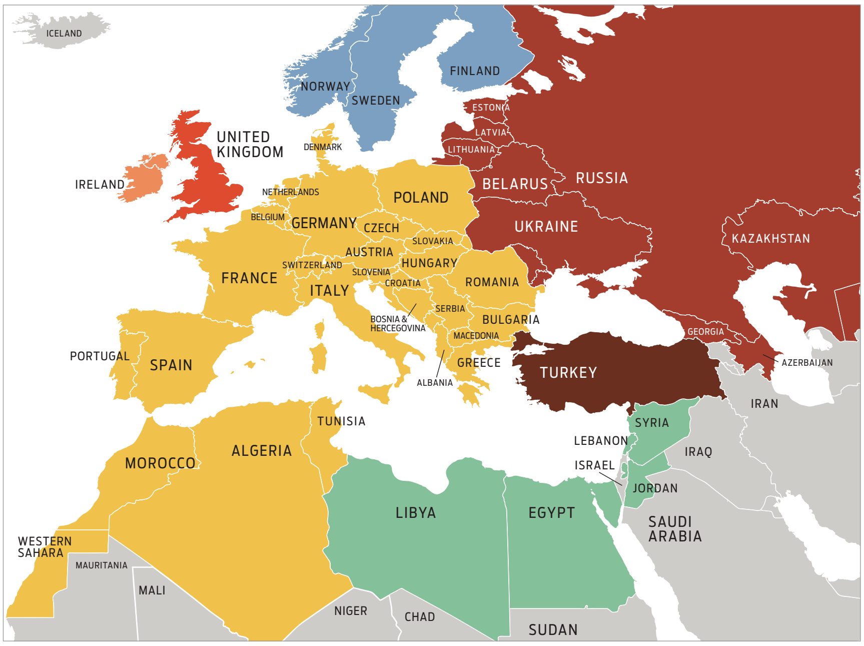
ONE has other big plans for the next five years, starting with the addition of 4800 MW in new power generation south of Casablanca. The utility calculates that tying that power into the national grid will require 1045 km of new 400-kV lines. Those and other upgrades will in turn further boost Morocco's capacity to import power from Europe to 1200 MW—close to maxing out the existing undersea cables. It's no surprise then that ONE's director general is hoping to interest Spanish grid operator Red Eléctrica de España, of Madrid, in a third cross-strait link.

The 400-kV grid might even help relieve another major heartache for Morocco: its dysfunctional relationship with neighboring Algeria. Their 1559-km-long frontier slammed shut to people and goods in 1994 when disputes over the border and an independence movement in the Western Sahara boiled over. But all through the estrangement, electricity has continued to flow between Morocco and Algeria, preserving a channel of technical exchange and demonstrating the benefits of cooperation. Morocco's 400-kV lines and similar infrastructure nearing completion in Algeria should multiply the value of their interconnection by increasing the amount of power they can exchange as much as sevenfold.

These and other grid upgrades in the region mean even more to the nations east of Tunisia that represent the next frontier for the MedRing: Libya, Egypt, Jordan, Syria, and Lebanon, which are already electrically interconnected—a bloc that, not surprisingly, bypasses Israel and the Palestinian territories. Three years ago, the power-transfer limits of the weak 220-kV lines then prevailing in the region torpedoed a first bid to hook this eastern bloc up to the emerging MedRing, heightening anxiety among the UCTE energy planners overseeing the project and raising the stakes for a soon-to-be-mounted second try.

THE PROSPECT OF linking Libya to Europe electrically is a testament to the ongoing changes in the Great Socialist People's Libyan Arab Jamahiriya, as Colonel Muammar al-Qaddafi renamed it upon seizing power in 1969. To end decades of isolation under his rule, in 2003 Libya renounced its nuclear-weapons program and offered a measure of financial compensation to the families of those killed in the terrorist bombings of Pan Am 103 and UTA 772. Now the government is working to secure its electrical supplies and to take on a growing role in regional energy markets—a response to years of pent-up demand in Libya, and indeed throughout North Africa, for a better quality of life.

Why is Libya expending such efforts to connect with its African and European neighbors? After all, this oil- and gas-rich nation has the cash to finance new power plants and the fuel to run them. It should have no trouble doubling its gen-



BUILDING BLOCS: The electrical grids of Europe, North Africa, and the Middle East form different synchronous blocs. Western North Africa is already tied to Europe's Union for the Co-ordination of Transmission of Electricity [yellow]. In 2009, Libya, Egypt, Jordan, Syria, and Lebanon [green] may join that bloc. Energizing existing linkages to Turkey [brown] would then close the Mediterranean Electricity Ring.

SCUDS TO PLOWSHARES: A new 400-kilovolt substation, located in the sparsely populated Bir Osta Milad district on the outskirts of Tripoli, Libya, was built on the site of a former Scud missile factory. *PHOTO: PETER FAIRLEY*

eration capacity within a decade to meet projected demand. But generating capacity isn't enough, as Libyan leaders were reminded last April when a blackout knocked out power in the eastern half of the country, including its second-largest city, Benghazi, for more than four hours. Subsequent analysis zeroed in on the aging 220-kV lines connecting Libya's population centers, which are dispersed along the Mediterranean coast.

Libya clearly needs a more robust and stable grid. It also wants to move up the value chain, by exporting electricity instead of gas. And above all, it yearns to end decades of isolation from the international community.

The impact of that history lingers. Libya's social infrastructure, including hospitals, educational institutions, and transit systems, remains outdated and inadequate. The problems are obvious even to the casual traveler. The roads between Tripoli and its 1970s-era airport, for example, are run-down and lined with unfinished housing blocks—along with larger-than-life portraits of Qaddafi, the "Great Leader."

Although he as much as anyone is responsible for the country's sorry state, Qaddafi now perceives Libyans' powerful yearning to make up for lost time. In March, he criticized his government for moving too slowly to translate Libya's recent oil and gas windfalls into improvements in the average person's quality of life, saying that the nation was "paralyzed by bureaucracy and corruption." Unfortunately, his proposed solution—to privatize the ministries by the end of this year and redistribute oil wealth directly to the citizenry—threw government planning into disarray.

The ferment is evident in Faraj al-Ammari's office at the electric-power ministry, the General Electric Company of Libya, where the phone seems to ring constantly. "For the past two years, I've been working from, maybe, 8:30 until 12 at night," laments the mild-mannered engineer. Ammari is preparing his ministry for privatization while simultaneously overseeing a massive expansion of the Libyan power system. Peak demand has been increasing by about 7 percent a year, but that rate could soon double because of the electricity needed to run the massive pumps of Libya's ambitious Great Man-Made River, a megaproject of wells and aqueducts designed to transport water from deep aquifers in the Sahara Desert to coastal population centers.

To meet this challenge, Ammari's ministry commissioned a national center to control the country's transmission grid; the ministry claims to have more than 5000 km of 400-kV lines, 25 new 400-kV substations, and 6000 MW of natural gas–fired generation under contract or construction. When that work is finished, power transfer across the grid's weakest link—a key east-west connector that failed during the April blackout—will jump from a few hundred to 2000 MW. "We will be the strongest network south of the Mediterranean," boasts Ammari.

A KEY TEST of North Africa's upgraded power infrastructure will come in early 2009, when Libya is scheduled to try once again to connect with Tunisia. A first attempt in 2005 was cut short after just 7 minutes, when slight mismatches in North Africa's ac frequency, compensated for by the might of the UCTE, caused larger-than-expected power flows in and out of the UCTE that overtaxed the North African lines. This time around

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those lines are beefier, and they are now regulated by smarter control systems.

If everything works as planned, the trial will run for four days, at which point engineers will shut down the linkage to study how well it functioned. Barring any surprises, they will reconnect and go on. And if they fail again? Then they will have to turn to high-voltage direct current (HVDC) interconnections, which is how the eastern, western, and Texas grids are linked together in the United States, for example. HVDC transmission systems move power by converting ac into dc at one end of the line and then converting this dc back to ac on the other side. Two ac grids tied together in this way do not need to be synchronized and can even run at different frequencies.

The downside of HVDC is that it requires solid-state converters, which cost hundreds of millions of dollars. The upside, besides immunity to instabilities, is increased power transfer. Electricity travels over ac networks following the path of least resistance, so managers of ac grids must leave a large margin of safety on their lines to accommodate unexpected shifts. In contrast, HVDC's power electronics precisely control the electricity flow, so HVDC connections can operate closer to the physical limit that their cables can bear.

For the time being, North Africa's power-grid engineers are more focused on the relatively economical frequency stabilization that ac offers. There is also an important additional benefit to ac that technical studies don't capture: the symbolism of synchronization. "The operation of this large power network is a symbol of unity, of cooperation," says Brahim Oumounah, ONE's director of network engineering. "I believe that the engineers involved, be they from North Africa or the UCTE, will exhaust all the technical means for ac."

THOUGH THE EMPHASIS REMAINS on ac today, dc interfaces may be the only way to close the MedRing. That's because transmission rings on the edge of large power grids are susceptible to loop flows that are hard to manage. Just as system operators in the United States and Canada sometimes struggle with unscheduled power flows looping around the Great Lakes of North America, North African system operators could find their lines overwhelmed when large power exchanges between European countries unexpectedly take a southern route.

Juan Manuel Rodriguez Garcia, international liaison for Spanish grid operator Red Eléctrica de España, is coordinating the UCTE's preparations for the next test connection between the eastern and western sides of North Africa. He believes that one or more dc interfaces will be needed along the southern loop to block such rogue currents. "The operation of a ring like that is a challenge," says Rodriguez Garcia. "I'm convinced that we'll have to introduce some dc interfaces."

Major dc connections are also the only way to accommodate the multigigawatt ambitions of North Africa's power producers, who can tap the kind of energy Europe most desires: clean-burning natural gas and world-class wind and solar resources. Astonishing as it may seem, some entrepreneurs, engineers, and system planners are confident that the development of such clean energy will reverse today's net north-to-south flow of power in as little as five years.

The most solid plans are for undersea HVDC lines to deliver power across the Mediterranean to Europe from natural gas–rich Algeria and Libya.

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Feasibility studies have already been completed for three proposed subsea lines to Italy, which depends on oil-fired power generation and as a result pays Europe's highest electricity prices.

How much power could be sent north through one of these proposed links? Ammari expects Libya to have no less than 2000 MW of spare capacity available by 2012, when the natural-gas power plants now in the works are due to be fired up.

North Africa's blistering sunlight and incessant winds will ultimately provide an even brighter export opportunity: renewable energy. Consider Morocco's wind resources, conservatively estimated at 6000 MW. The wind blows faster and more frequently at many Moroccan sites than it does in Europe, offering operators more megawatt-hours from every megawatt of installed turbine capacity. And this energy would not be subject to the price volatility that afflicts natural gas—a major challenge for would-be exporters of natural gas–fired power.

Mohamed Habbal, the politically savvy Casablanca native who directs developing markets for French wind-power developer Theolia, bets that Morocco could generate enough wind power to fulfill all its needs for the foreseeable future. But Habbal says exporting that energy over the Gibraltar interconnect is a much better idea. He reasons that European utilities facing mounting requirements to use renewable energy—especially those in Italy, which has little indigenous renewable generation—will pay dearly for Moroccan wind power. "They will surely pay a higher price than for conventional energy," says Habbal. They might also accept a swap: "We could receive 2 MWh of conventional energy for every megawatt-hour of green energy supplied."

The sunlight that bakes North Africa may seem like a more distant opportunity, given the higher cost of solar power today. But it, too, is attracting attention. The Union for the Mediterranean, French president Nicolas Sarkozy's recently launched effort to spur cooperation between Europe and North Africa, identified the creation of a "Mediterranean solar plan" as one of its first priorities. And some work of this kind is being done right now. European renewable-energy developers are building large power plants in Algeria, Egypt, and Morocco with solar-thermal technology that uses sunlight to produce steam. Algeria's renewable-energy authority is proposing a 3000-km-long HVDC line intended to deliver solar power from the Algerian Sahara to Germany.

The potential scale of these exports is awesome. According to analyses by the German government, HVDC lines from North Africa could carry 700 000 GWh per year of solar electricity by 2050—considerably more than Germany should need at that point. In the process, they would help boost renewably sourced power to 80 percent of Europe's electricity consumption. And get this: in this scenario the price Europeans pay for each kilowatt-hour actually drops as improvements in technology drive down the cost of solar power.

Europe's needs would be met using clean electricity generated by—and for the development of—their Muslim neighbors to the south. Klaus Töpfer, former executive director of the United Nations Environment Program, has called it a "new development paradigm" for both Africa and Europe.

That may sound optimistic, but you've got to admit it's a beautiful vision. ❑

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Holst Centre

Open Innovation by IMEC and TNO

Holst Centre is a new research centre, founded by **IMEC** and **TNO**, and is located on the **High Tech Campus** in Eindhoven. We are looking for people who want to be part of **creating the future**. Join us to work on tomorrow's challenges today. You are a **creative**, **energetic person** that wants to develop new ways to use technology in our everyday lives. But technology is not enough. Become part of the team that looks at trends and shapes them in to **business opportunities**. Holst Centre performs R&D in the field of **wireless autonomous microsystems** and **systems-in-foil**. Within our creative atmosphere, you will be part of a team of people who love **research** and the potential it has to enable the products that will be marketed 3 to 10 years from today.

Principal Researcher Ultra-Low-Power Analog Circuit Design

PhD degree in Electronics or equivalent through experience; 7+ years of experience analog circuit design and 3 years management experience; experience in device physics and/or transducers is a plus.

Researcher Sensors & Intregrated Optics

PhD degree in Physics or Materials Engineering or equivalent through experience; experience in design & fabrication of integrated optics based devices, characterization of nano-optical systems and experience in clean-room operations; experience in optical sensor concepts is a plus.

Principal Researcher RF Circuit Design

PhD degree in Electronics or equivalent through experience; 7+ years of experience in RF circuit design and 3 years management experience; solid understanding of wireless communication systems and architecture; experience in the field of low power IC design is a plus.

Principal Researcher Ultra-Low-Power Wireless Systems

PhD degree in Electronics or equivalent through experience; 5+ years of experience in wireless system design and 2 years management experience; solid understanding of communication theory and baseband signal processing, analog RF design knowledge is a plus; experience in the field of IEEE 802.15 standards and low power IC design is a plus.

Researcher Digital Circuit Design

MSc or PhD degree in Electronics or equivalent through experience; solid understanding of signal processing in wireless systems; proven experience in digital IC implementation at block- & top level; solid understanding of wireless communication systems and architecture.

Researcher Ultra-Low-Power Digital Circuit Design

MSc or PhD degree in Electronics; 3+ years of work experience; solid understanding of digital circuit design and tools; experience in the field of low power IC design is a plus.

For the complete **job descriptions** and other **job openings** please check our website

www.holstcentre.com

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IMEC Nederland | Margot Nijkamp / HR Director | **Phone** +31.40.2774006 | **talent@imec-nl.nl**

UWM
UNIVERSITY of WISCONSIN
MILWAUKEE

New Faculty Positions in the College of Engineering & Applied Science

The University of Wisconsin-Milwaukee invites applications for multiple new faculty positions at all tenure-track and tenure levels in the College of Engineering & Applied Science (CEAS). A significant increase in state support for UWM for the next three years has provided CEAS with new cluster hire positions in biomedical engineering and science, energy and environment, and green manufacturing, with continued growth expected over the next two years. A master planning process at UWM will include a new science and engineering building. The college seeks exceptional individuals at all faculty levels to expand its research portfolio and curricular offerings.

Biomedical areas of interest include biomedical imaging, analysis and processing, biomedical electronics and instrumentation, biosensing, biomaterials, bioprosthetics, biomechanics, biomedical informatics, databases, information and data security, supercomputing and computational modeling for medical applications.

The energy and environmental engineering cluster welcomes applicants with computational, analytical or experimental expertise in all areas of energy and environmental engineering. Specific areas of interest include clean energy, integrated approach to sustainable energy, environment and materials, nuclear energy, renewable energy (wind, solar, hydropower, tidal, geothermal, wave energies), hydrogen, methanol and ethanol as fuels, biomass and wastes, carbon management, energy conversion, transport and storage, environmental impact of energy consumption, energy efficiency, transport energy, energy systems (solar cells, fuel cells, batteries, capacitors, piezoelectronics, thermoelectronics), power electronics and power systems, supercomputing and advanced simulation for energy applications, and computational modeling.

Green manufacturing applicants with expertise in the following areas are welcome: operations and supply chain management; processing and manufacturing of metals and materials; environmentally benign manufacturing; instrumentation, including sensors, actuators and information systems. Other areas related to manufacturing are also of interest.

UWM is a doctoral/research extensive university and Wisconsin's premier public urban institution, offering a comprehensive liberal arts, sciences and professional education at the undergraduate and graduate level to its 28,000 students. The College of Engineering & Applied Science consists of five departments–Civil Engineering and Mechanics, Electrical Engineering and Computer Science, Industrial Engineering, Materials, and Mechanical Engineering, with ABET accredited programs. The College has more than 1,500 undergraduate students and over 300 graduate students, both Master's and Doctoral. External grants and contracts for the College increased by 300% over the previous year, a trend that is expected to continue. Greater Milwaukee, the third-ranked manufacturing center in the United States, is home to 400+ engineering firms and 1300+ manufacturing firms with annual receipts of 24 billion dollars. The College has a long history of industrial collaboration and research support.

More details about the College can be found at
http://www.uwm.edu/CEAS/

Candidates must have completed a doctoral degree in an appropriate field of computer science, engineering or a related science field, and will be expected to establish an independent, extramurally funded research program. Senior candidates must demonstrate a strong track record of scientific publication and extramural funding. Successful candidates will join appropriate science and engineering departments; joint appointments are feasible. Opportunities for biomedical collaboration include the Medical College of Wisconsin and local industries such as GE Medical Systems, Phillips, Aurora Health Care and many others.

On-Line Application Procedure:

Application materials should include: a letter describing your interest in and qualifications for the position; a curriculum vitae; a brief research plan; a teaching statement, requested departmental affiliation, and a minimum of three references that includes names, addresses (including e-mail), and telephone numbers. The complete application package must be submitted electronically to the following address: **https://www.jobs.uwm.edu**. Select "Faculty positions." Screening begins on November 1, 2008 and will continue until the positions are filled. Questions should be directed to Dr. Marjorie Piechowski, at 414-229-3721 or to **piechow4@uwm.edu**. Under Wisconsin's open records law, requests for confidentiality will be honored, except that names and titles of all finalists must be disclosed upon request.

UWM offers competitive salary and startup packages, commensurate with experience. Further information about UWM may be found at **www.uwm.edu**. UWM is an equal opportunity/affirmative action employer. Employment will require a criminal background check. For the UWM Campus Security Report see **http://www.cleryact.uwm.edu** or call the Office of Student Life at (414) 229-4632 for a paper copy.

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UNIVERSITÄT DES SAARLANDES

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

M²CI CLUSTER OF EXCELLENCE

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

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

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

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

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

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

Institute of Microelectronics

A*STAR

The Institute of Microelectronics (IME) is a member of the Agency for Science, Technology and Research (A*STAR). IME's mission is to add value to Singapore's semiconductor industry by developing strategic competencies, innovative technologies and intellectual property; enabling enterprises to be technologically competitive; and cultivating a technology talent pool to inject new knowledge to the industry.

Laboratory Director
Integrated Circuits & Systems

- ★ To lead a team of research staffs in the area of ICS design/modeling and testing in topics in Low-Power, Ultra-wide Band, Power Management
- ★ To build up a strong intellectual property portfolios in patent and publication
- ★ To set the strategic technology directions and develop the technology roadmap
- ★ To establish and support cross-disciplinary projects with other Laboratories and programmes (e.g., Bioelectronics, Photonics, MEMS)
- ★ To co-ordinate and foster collaborative research and development projects with industry and academic partners
- ★ To train postgraduate students with high quality research projects

Laboratory Director
Microsystems, Modules & Components

The laboratory has diverse research programs in multi-functional System-in-Package technologies; including 3-D (e.g., TSV), wafer level, bio- and physical-MEMS and photonic device packaging. You are expected:

- ★ To lead and direct a large team in setting its technology directions, developing its technology roadmap
- ★ To manage the resources needed for the effective running of the laboratory to spearhead the group to be one of the top few in the world
- ★ To build up a strong intellectual property portfolios in patent and publication
- ★ To establish high visibility and reputation for the organization
- ★ To establish and support cross-disciplinary projects with other Laboratories and programmes (e.g., BioE, Photonics, Electronics, MEMS)
- ★ To co-ordinate and foster collaborative research with industry & academia
- ★ To closely work with industry in developing commercial applications of IME's research outcomes. To be responsible for the recruitment and development of the R & D talent
- ★ To train postgraduate students with high quality research projects

Requirements for Both Positions

- ★ A PhD in microelectronics or equivalent discipline with an outstanding record of high quality research and its industrial applications
- ★ A proven capacity to provide leadership; a demonstrated ability to develop and manage research programs in relevant areas
- ★ Interpersonal skills in communication with industry and academics
- ★ Strong planning and execution capabilities
- ★ Industrial experience would be added advantage

Interested applicants, please email your detailed resume to *personnel@ime.a-star.edu.sg*
Institute of Microelectronics
11 Science Park Road, Singapore Science Park II, Singapore 117685

www.ime.a-star.edu.sg

The Faculty of Electrical Engineering and Information Technology of Graz University of Technology invites applications for the position of a

TU Graz
Graz University of Technology

University Professor for High Frequency Engineering.

The permanent employment contract under private law is due to start as soon as possible (at the earliest at the beginning of 2009).

We expect excellent scientific qualifications in the fields of design, simulation and measuring of RF systems and circuits, with emphasis on

- chip level (particularly RF-CMOS)
- system level (building units and circuit boards)
- antennas and antenna systems (especially smart antennas)
- interface to optical data transmission

Graz University of Technology is determined to increase the number of female faculty members and strongly encourages the application of qualified women.

Interested persons are kindly requested to submit their application (usual documents enclosed) to the Dean of the Faculty of Electrical Engineering and Information Technology of the Graz University of Technology (Prof. H. Stigler), Kopernikusgasse 24, A-8010 Graz, Austria.

Application deadline: **November 30, 2008** (postmark)

For further information please visit us at
http://www.e-i.tugraz.at/dekanat

Dean of the Faculty of Electrical Engineering and Information Technology

The Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, seeks applications to fill at least two tenure-track positions at the assistant, associate or full professor level for an interdisciplinary research cluster in ***Micro and Nanosystem Integration and Packaging***.

We are particularly interested in candidates with background in electronic micro/nano-system integration and packaging, biocompatible materials and packaging, solid state devices, reliability, testing, and micro/nano system modeling and simulation. Information on department research activities and curricula may be found on the web at **www.ece.utah.edu**. The web site also has information on five more positions available in the department, including a Chair search. Information on the College of Engineering can be found at **www.coe.utah.edu**. Successful candidates will conduct research with tenure track appointments in the Department of Electrical and Computer Engineering, but may also be appointed in other departments such as Materials Science, Bioengineering or Mechanical Engineering. Suitable candidates may be considered for joint appointments with the College of Science or the Medical School at the University of Utah.

These positions are part of the Utah Science, Technology and Research Initiative (USTAR), which was funded by the Utah State Legislature to attract focused teams of outstanding researchers who have the potential to help build major research programs and create new technology that can ultimately lead to commercial products and/or new industries for Utah. The USTAR initiative is also supporting a new interdisciplinary building which will house a new nanofabrication laboratory and characterization facilities that will cater to solid state devices, MEMS, sensor and packaging research and development, as well as the handling of biomedical samples. The building will facilitate communication for researchers such as the ones hired under this solicitation, from engineering, sciences and the medical school, as well as offering lab access for selected industrial stake holders. Information on the USTAR initiative can be found under **www.ustar.utah.gov**. Candidates for this initiative should have a demonstrated track record of successful, funded projects and an interest or track record in technology commercialization, entrepreneurial or industrial experience.

The positions are also associated with and partially supported by the **Fraunhofer Institute for Reliability and Microintegration IZM**, and leverage a strong collaborative and international research program with a Fraunhofer IZM branch laboratory in Utah. Fraunhofer support includes in-house access to Fraunhofer infrastructure, know-how, and resources. Selected positions may be associated with joint Fraunhofer appointments, possibly at a center director's or co-director's level.

Résumés with names, contact information for at least three references, and statements for research and teaching goals should be sent to Ms. Debbie Sparks, USTAR Faculty Search Committee, University of Utah, Electrical and Computer Engineering Department, 50 South Central Campus Drive, Room 3280, Salt Lake City, UT 84112-9206. Email applications are accepted at **dsparks@ece.utah.edu**. Applications will be reviewed starting September 1, 2008, and will be accepted until the positions are filled.

Faculty responsibilities include developing and maintaining an internationally recognized research program, effective classroom teaching at the undergraduate and graduate levels, and professional service. Applicants must hold a Ph.D. by the time of appointment. The University of Utah values candidates who have experience working in settings with students from diverse backgrounds and possess a strong commitment to improving access to higher education for historically underrepresented students. The University is an AA/EO employer, encourages applications from women and minorities, and provides reasonable accommodations for known disabilities of applicants and employees.

Texas A&M University at Qatar

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

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

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

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

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

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

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

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

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

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

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

ROGERS DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of TORONTO

The Edward S. Rogers Sr. Department of Electrical and Computer Engineering at the University of Toronto invites applications for a tenure-stream Assistant or Associate Professor position in the area of **electronics**, beginning July 1, 2009. Research areas of interest include, but are not limited to: **analog or mixed-signal circuit design, high-performance ADCs and/or DACs, or RF circuits.** Candidates must have (or are about to receive) a Ph.D. in the relevant area.

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

The successful candidate is expected to pursue excellence in research and teaching at both the graduate and undergraduate levels. The successful candidate will join a highly active research group in electronics.

Applicants must submit their application by electronic mail to Professor Glenn Gulak, Electronics Search Committee Chair, The Edward S. Rogers Sr. Department of Electrical and Computer Engineering, University of Toronto using the following address:

ElectronicsSearch@ece.utoronto.ca

Please submit only Adobe Acrobat PDF documents. Applicants will receive an email acknowledgement.

All applications should include: a curriculum vitae, a summary of previous research and proposed new directions, and a statement of teaching philosophy and interests.

In addition, applicants must arrange to have three confidential letters of recommendation sent directly (by the referee) by email to:

ElectronicsSearch@ece.utoronto.ca

Applications and referee-sent references should be received by January 15, 2009.

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

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

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

The Department of Electronic & Computer Engineering at The Hong Kong University of Science & Technology invites applications for several faculty positions for all ranks: Professor, Associate Professor and Assistant Professor. Applicants should have a PhD with demonstrated strength in research and commitment to teaching. We are particularly interested in qualified applicants with relevant experience in RFIC design; nanotechnology as applied to solar cells and solid state lighting; along with bioengineering, in addition to other traditional areas of electrical engineering. Applications are also encouraged from candidates whose research programs are nontraditional and interdisciplinary including areas in technology management, and whose instructional programs will bring innovation to the curriculum.

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

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

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

More information about the Department is available on our web-site
http://www.ece.ust.hk

Washington University in St. Louis
School of Engineering & Applied Science

Washington University in St. Louis, Department of Electrical and Systems Engineering. The Department of Electrical and Systems Engineering (ESE) invites applications for faculty positions at the levels of assistant, associate, or endowed full professor. The ESE department is the result of a recent merger between the Department of Electrical Engineering and the Department of Systems Science and Mathematics, and is under new leadership. New faculty members will have the opportunity to participate in building the department and in moving it forward in exciting new directions. Candidates should have a doctorate in Electrical Engineering, Systems Engineering, or related fields. The department is interested in candidates with a strong commitment to pursuing externally-funded research, and to teaching at both the undergraduate and graduate levels. Exceptionally strong applicants in all areas of electrical and systems engineering will be considered. Technical areas of interest include, but are not limited to, telecommunications, applied physics, energy, nanoelectronics and integrated circuits, systems and control theory, robotics, mechatronics, systems biology, mathematical and physical modeling, imaging, sensor networks, and security technologies.

Washington University in St. Louis is a medium-sized private university of approximately 7000 undergraduate and 6000 graduate and professional students, which enjoys high academic standing and a strong and growing national reputation. The ESE department presently has 17 full-time tenured and tenure-track and 4 senior faculty. There are approximately 80 undergraduate students, 80 full-time graduate students and 30 part-time graduate students. The department offers separate undergraduate and graduate degrees in Electrical Engineering and in Systems Science and Engineering. The University is located in a semi-urban area, adjacent to Forest Park, with many cultural and recreational activities.

More information on the department is available at
www.ese.wustl.edu.

Applications will be accepted immediately, and interviews will begin after January 1, 2009. Applicants should send a letter of interest, curriculum vitae, a list of at least 5 academic or professional references, and a statement of vision for research and teaching in electronic form (PDF) to ***facsearch@ese.wustl.edu***.

Washington University in St. Louis is an Equal Opportunity and Affirmative Action employer, and invites applications from all qualified candidates.

TOKYO INSTITUTE OF TECHNOLOGY
Global Edge Institute

TOKYO TECH
Pursuing Excellence

ASSISTANT PROFESSORS AT TENURE TRACK POSITION

Global Edge Institute invites applications for 2 to 5 tenure-track positions at the assistant professor level in the following fields of science and technology:

- Mechanical Sciences and Engineering
- Mechanical and Control Engineering
- Mechanical and Aerospace Engineering
- Communications and Integrated Systems

(Keywords: mechanical engineering, control engineering, communication theory, information theory, coding theory, signal processing, integrated circuits)

Tokyo Institute of Technology is interested in candidates who are committed to high standards and professionalism in their areas of expertise. Candidates should be independent, and will be supplied with a start-up fund (up to ¥6,000,000 per year for the first two years) and training under a mentor. Appointees will also be requested to take up joint research with academic staff and graduate students, and to participate in seminars to cultivate the spirit of challenge, a creative mind, and international leadership. The assignment term starts on April 1, 2009, or later, and lasts until March 31, 2014. The assessment for tenure will be held at the end of the term, and, if successful, a tenure position either as associate professor or full professor will be offered.

Applicants must have English language proficiency and a doctorate obtained no more than five years previous to applying. Salaries start at between ¥6,400,000 and ¥7,500,000 per annum.

To apply, make an entry on the website to receive an application number by November 17, 2008, and then send application documents required (application form, CV, general outline of research achievements, description of research plan and copies of about 5 representative papers) by November 20, 2008 to: ge-apply@jim.titech.ac.jp.

For further information, please visit our website: http://www.global-edge.titech.ac.jp/.

www.global-edge.titech.ac.jp 2-12-1 S6-20 Ookayama, Meguro, Tokyo 152-8550, JAPAN

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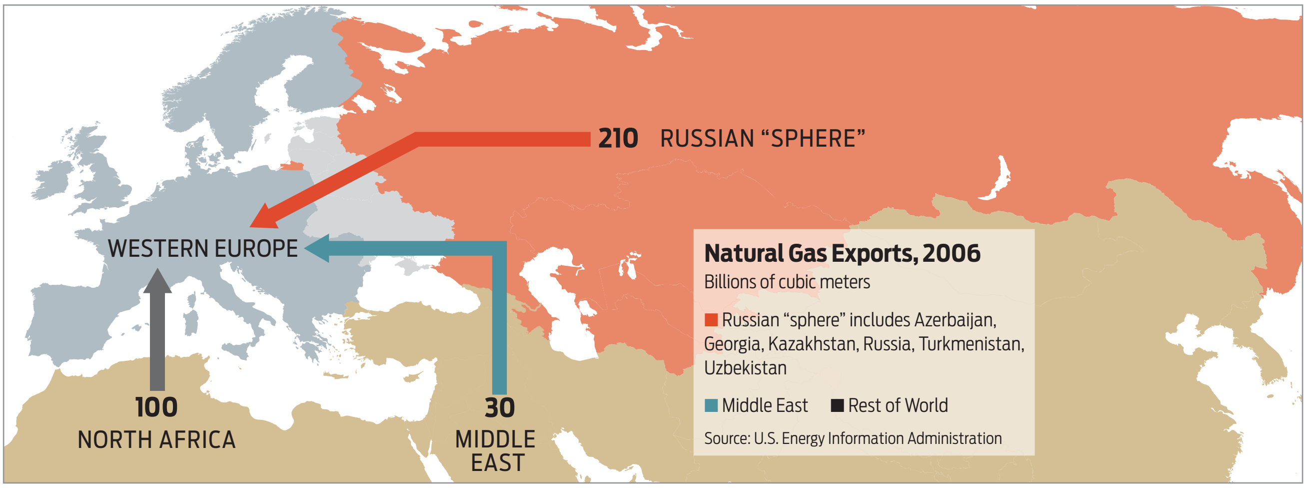


Russia Rules Eurasian Gas Roost

RUSSIA HAS THE WORLD'S largest natural gas reserves and is the world's top gas producer and exporter, supplying a quarter of the European Union's consumption. The Russian bloc—Russia and the "stans"—accounts for nearly two-thirds of Europe's imports, including those of the Baltic states (Estonia, Latvia, and Lithuania), Belarus, and Ukraine.

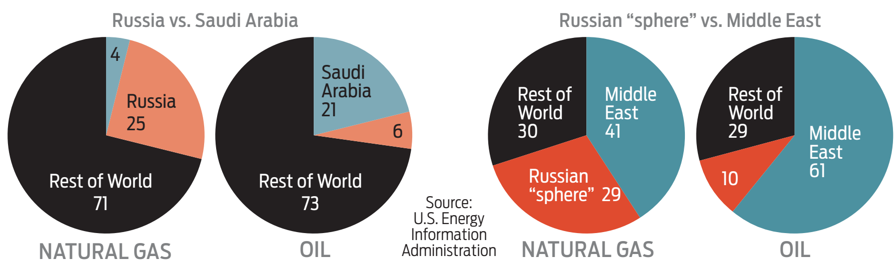
Russia's dominance in natural gas is even greater than Saudi Arabia's in oil. What is more, because it supplies a growing share of the gas going to Asia's fast-industrializing northeast, Russia is in a position to dominate the Eurasian gas markets for a generation to come, deciding who gets how much, when, and at what price.

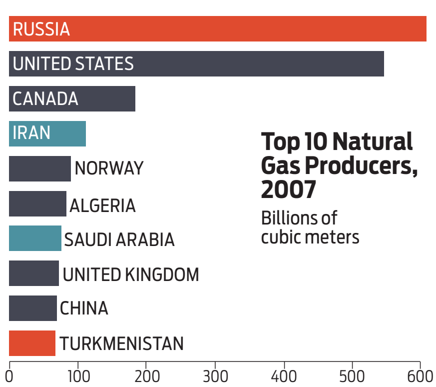
Russia is also a major oil producer, jockeying for position with Saudi Arabia for the distinction of being the world's largest, but it has little influence on the world oil price because its oil exports are relatively small. It is running down its reserves, much as the United States has been depleting its oil stocks.

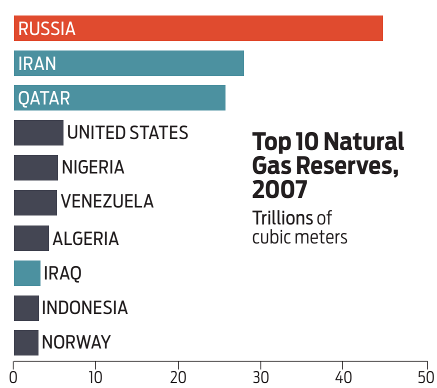
The United States depends on Canada for natural gas almost as much as Europe relies on Russia—but with an obvious and critical difference. Because of deeply shared political and social values, the United States basically trusts Canada. That sense of a shared ethos no longer prevails in relations between the major European countries and Russia [see the commentary "Gas Pains" in Update, this issue].

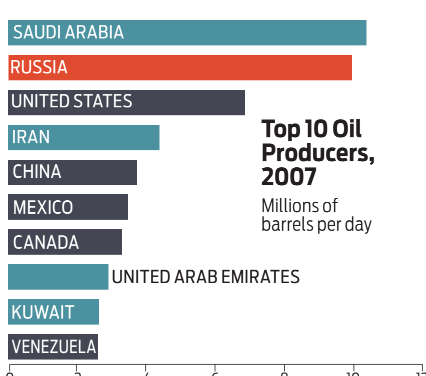
—WILLIAM SWEET

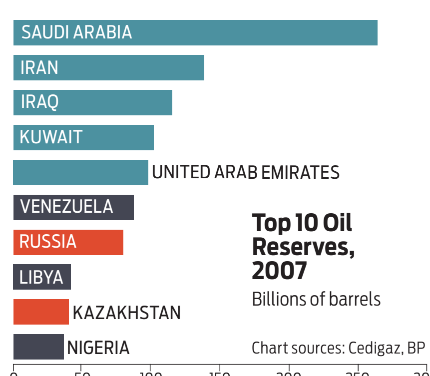
Market Power: Percentages of World Reserves, 2006

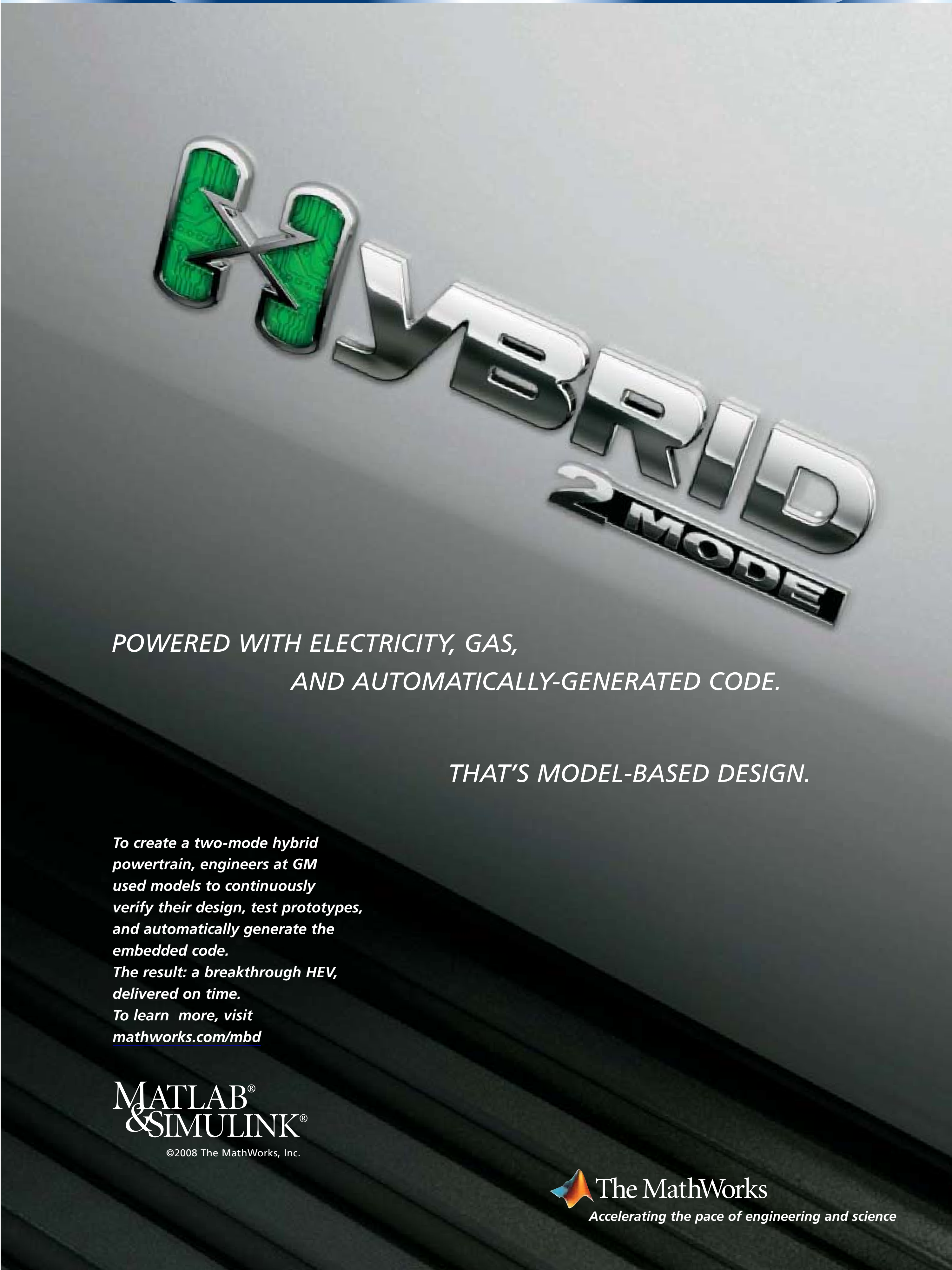











HYBRID
2 MODE
POWERED WITH ELECTRICITY, GAS,
AND AUTOMATICALLY-GENERATED CODE.
THAT'S MODEL-BASED DESIGN.
To create a two-mode hybrid powertrain, engineers at GM used models to continuously verify their design, test prototypes, and automatically generate the embedded code.
The result: a breakthrough HEV, delivered on time.
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