



Innovation: The Outer Limits

The hottest, most mind-boggling high-tech products are coming not only from corporate behemoths but also from start-ups you've never heard of.

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Quantum Computers: Always On Always Off The Right Answer Every Time

The Big Idea

In conventional computing, bits are either on or off, representing a *0* or a *1*. Quantum computers exploit a weird property of quantum mechanics that allows a bit to temporarily enjoy a dual reality where it is both on and off at the same time, thus embodying two numbers at once. Get these netherworldish *qubits* to interact with one another in the right way, and you've got a computer that can juggle trillions of numbers at the same instant instead of having to pore over them one by one. In theory, quantum computers will be able in the blink of an eye to crunch through problems that would bog down a conventional computer for hours. The speed will come in handy for things such as analyzing financial markets or recognizing would-be terrorists from vast national security databases. Quantum weirdness can also be applied to data networks to thwart hacking and network eavesdropping.

Time to Market

Two years to never.

Companies to Watch

A number of computing giants, including IBM (NYSE:IBM), HP (NYSE:HPQ), and Microsoft (NASDAQ:MSFT), are researching quantum computing, as are dozens of university labs. But a handful of start-ups are making headway as well. D-Wave Systems in Burnaby, British Columbia, is producing what might be considered a semi-quantum computer -- it won't be as fast as a fully quantum computer but may well prove much faster than a conventional one. And MagiQ Technologies, in New York, is developing products that target the quantum data-security business.

A Word from the Naysayers

Some physicists believe fully quantum computers will never be able to tame enough qubits to be useful. Most physicists seem to feel quantum data security, at least, is achievable within the next few years. Nonphysicists aren't sure what any of this means.

Company Close-Up

In November, D-Wave Systems demonstrated a 28-qubit computer able to solve Sudoku-like puzzles, and CEO Herbert J. Martin promises a 1,000-qubit version capable of limited commercial applications by the end of the year, with actual product shipments to begin in 2009. D-Wave, Martin adds, is talking to some 60 potential customers and partners, including financial service companies that are hunting for a faster way to evaluate complex portfolios. He thinks the application could also help the U.S. Air Force shave tens of millions of dollars a year from its fuel budget by computing more efficient schedules for in-air refueling. Skeptical physicists note a conspicuous lack of scientific papers from D-Wave, but Martin says the company is just protecting patents. "We have 25 Ph.D. scientists working on the project, more than some entire physics departments at major universities," he says. "But we've been putting more emphasis on producing products."

The Future of Gaming: Masters of Reality

The Big Idea

You and your pal have almost made it the two blocks from the parking lot to your office when two zombies pop out of a doorway. No time to draw a gun, but that's all right -- just thinking really nasty thoughts is enough to vaporize the ghouls. You trade grins with your friend, who's actually 1,700 miles away, unplug your mind-reading headset and virtual reality glasses from your cell phone, and make your way up to your office. Gaming is about to break down the barriers between the real world and fantasy, thanks to devices that will read your thoughts, gestures, and expressions; project gaming action onto the streets around you; and populate these quasi-real worlds not only with your distant gaming buddies but with characters that seem as real and wily as Ben from *Lost*.

Time to Market

Brain-wave-reading headsets are about to hit the market. Devices that project virtual worlds onto the real world around you are less than five years out.

Start-ups to Watch

3DV Systems, a start-up in Yokneam, Israel, has developed a camera that observes a player's motions and translates them into commands in a video game so that the game responds to gestures and body language. Several start-ups, including EmSense in San Francisco and NeuroSky in San Jose, California, are working on head-mounted devices that detect brain waves. Conduit Labs, a start-up in Cambridge, Massachusetts, is working on a hybrid social-networking and gaming environment -- think Facebook meets World of Warcraft.

A Word from the Naysayers

It's no sure thing that artificial intelligence has progressed far enough to endow characters with the smarts needed to make them appear truly real and interesting. And some insist accurate brain-wave measurement is an iffy prospect in an affordable device, so the technique could be glitch ridden for all but the most basic interactions.

Company Close-up

Emotiv Systems, a start-up in San Francisco, plans to introduce its brain-wave-reading headset at the end of this year. The \$299 device measures brain electrical activity via 16 scalp sensors, which the company claims allow recognition of basic emotions and up to 30 specific thoughts, such as "lift this object," "fire death ray," or "fly forward." The idea, says Tan Le, the company's president and co-founder, is to create games that adapt the action to the changing moods and thoughts of the players. "Games have never had a feedback loop for understanding how the user experiences content," she says. "When you have that feedback, you can vary the music, the lighting, and the story to help take the player

through an emotional journey." The company has raised \$13.4 million and has a team of 40 researchers, half of whom have Ph.D.s.

Manufactured Body Parts: We Can Rebuild Him

The Big Idea

The Six Million Dollar Man is finally here. Artificial limbs are becoming more useful and lifelike. And new technology allows people to control them with thought, much as we control our real limbs. Computers installed in the prostheses intercept signals from the wearer's nerves and translate them into commands for motors. Meanwhile, a number of efforts are under way to augment or replace eyes with artificial devices that capture images and relay them to the brain. Researchers also are developing techniques for assembling living cells into working biodevices -- which could mean a solution for damaged internal organs, such as livers, bladders, and kidneys.

Time to market

Eyes that can recognize objects will be available in about five years. In 10 years, we will begin to see prosthetic arms equal to human arms in most tasks, including sensing touch and playing the piano. Artificial organs are also at least a decade away.

Start-Ups to Watch

Much of the work on high-tech prostheses is funded by the U.S. military. At the leading edge is Liberating Technologies in Holliston, Massachusetts, which has developed an artificial arm capable of reading as many as 10 different signals from the wearer's nerves to control five motors simultaneously at variable speeds. Second Sight, a start-up in Sylmar, California, is working on a retinal implant that takes the image from a tiny camera and relays it to the back of the eye. ReInnervate, a start-up in Durham, England, is developing a tiny, three-dimensional plastic scaffolding on which human cells can be grown into artificial tissue, and perhaps eventually into replacements for organs.

A Word from the Naysayers

There aren't many of them. Experts seem to agree this all will happen in the coming decade, though fully functioning artificial organs could be further off.

Company Close-Up

Organovo, a start-up in Los Angeles, is working on a process in which a bioprinter will squirt multiple layers of human tissue cells onto special paper. When the cells are arranged in the right way, the resulting artificial tissue can serve as a stand-in for human subjects in drug testing. "We may never be able to completely replicate a kidney," says co-founder Gabor Forgacs, a University of Missouri researcher who developed the technology. "But at some point we'll be able fabricate a biodevice from a patient's own cells that will duplicate the most important functions of a kidney and that won't be rejected by the patient's immune system."

Smart Materials: Shape-shifting Color-changing Self-repairing And That's Just the Wallpaper.

The Big Idea

Scientists are learning to custom-design matter by assembling molecules into microscopic structures such as spheres, tubes, and lattices. These nanoshapes can change a substance's properties, resulting in

materials that are stronger, lighter, shinier, electrically conductive, heat resistant, flexible, slippery, or sticky. The structures of some nanomaterials bend and change shape when given an electrical jolt, so that a material's properties can be altered at the flip of a switch -- it can change color, for example, or become transparent. Nanoengineers can even carve out molecular gears and levers that act as microscopic machines; in theory, some materials could be self-repairing, and others could carry out tasks inside our bodies, like scraping plaque from artery walls. Eventually, there may be few products sold that don't incorporate some nanomaterials.

Time to Market

Some nanotech-enhanced materials are available. A flood of higher-tech ones are expected in three to seven years. Practical nanomachines are at least 10 years away.

Start-Ups to Watch

Currently, nanomaterials are being mixed with, or applied as a coating on, conventional materials to alter their properties. Much of the progress has been driven by large companies such as Dow Chemical and DuPont (NYSE:DD). But a number of start-ups have staked out impressive claims. New York-based ApNano Materials makes lubricating nanocoatings for engine parts; Oxonica, in the United Kingdom, produces nanoadditives that improve sunscreens and diesel fuel; Oakland, California-based Nano-Tex manufactures products that make clothing stain-resistant, softer, and more breathable. "Nanotechnology has been in the research stage for about 20 years, and we're just now seeing it come to fruition," says Jurrón Bradley, a senior analyst at high-tech market intelligence firm Lux Research in New York.

A Word from the Naysayers

The emergence of nanomaterials is considered inevitable by most experts -- though there is skepticism about nanorobots.

Company Close-Up

SDC Materials in Tempe, Arizona, makes nanomaterials that can fend off bullets that punch through ordinary bulletproof vests. The nanomaterials are to be used in body armor for the U.S. military. Other substances help medical equipment kill bacteria on contact and create special inks that can be printed out as electronic circuits on paper. "If you design the right additive, you can dramatically improve the properties of a material for only a slight increase in cost," says CEO Max Biberger. The company has raised \$11 million and posted its first revenue last year.

Brain Enhancement: The End of Stupid

The Big Idea

Intelligence is all about chemicals made and passed around by your brain cells. So why not add more of the right chemicals and boost smarts and memory? Scientists know how to make fruit flies and mice smarter, and efforts to come up with a treatment for Alzheimer's and other neurological disorders are leading to drugs that enhance memory and cognition in humans. Recent insights into learning-oriented brain cells called mirror neurons even hold out the possibility that someday we will have pills that will impart particular types of skills, such as computer programming or business decision making.

Time to Market

Drugs and treatments that improve memory and slow brain decline in patients with Alzheimer's and other neurodegenerative diseases are expected within five years. Drugs that make ordinary people smarter could be commonplace within 10 years.

Start-Ups to Watch

At least 40 brain-enhancing drugs are under development, most of them designed to target Alzheimer's. CoMentis, based in South San Francisco, is working on separating the brain-boosting powers of nicotine from its addictive and other unhealthy side effects. Helicon Therapeutics, in San Diego, is working on a drug that can help convert short-term memories into long-term ones. Also in San Diego, Ceregene is developing a treatment for decaying brain cells that works via an injection of a harmless virus infused with a protein that keeps such cells functional.

A Word from the Naysayers

Brain wonder drugs have a long and discouraging history, as far back as Freud's touting of cocaine. The drugs under study today may turn out to have unacceptable side effects -- or they may just not do all that much for most people, which has been the case with several promising Alzheimer's treatments so far, including the much ballyhooed Aricept. What's more, the FDA will probably approve neurodrugs only for people with serious disorders, not for those of us who merely feel a bit off our game. On the other hand, that didn't limit the availability of Prozac, notes Casey Lynch, managing director of the market strategy firm NeuroInsights. "Markets tend to be expandable in psychiatry," she says. "Once there's a good drug for the condition, a lot of people suddenly seem to have the disorder."

Company Close-Up

Researchers at Accera, in Broomfield, Colorado, believe that in some forms of impairment, brain cells are actually starving for glucose, the basic food of cells. The answer could be as simple as finding an alternative food source for brain cells. Accera's drug, Ketasyn, aims to fill the bill. The treatment has made it through initial clinical trials; now, the company hopes to speed the drug's time to market by labeling Ketasyn a medical food. Physicians prescribe medical foods, but they are less tightly regulated than drugs and normally don't require large trials, which means the stuff could be on the market as soon as this year. The company has raised \$12 million and is said to be looking for another \$30 million to build a sales and marketing organization.

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