INTEL REVAMPS R&D

A shift in strategy could help broaden the firm's horizons

Bring up the U.S. Defense Advanced Research Projects Agency (DARPA) in technology circles, and most people will think of the blue-sky research that the agency funds, like the work that spawned the Internet *(see "DARPA's Disruptive Technologies," p. 42)*. Bring up Intel, and a different image comes to mind: a not very imaginative research-and-development program that cranks out one Pentium processor after another. Great stuff, but hardly research capable of producing tomorrow's technological breakthroughs.

That could all change, as Intel's research director David Tennenhouse is engineering a sweeping overhaul of his organization, modeled largely on DARPA. Tennenhouse, who directed DARPA's Information Technology Office for three years before joining Intel in late 1999, says the problem is straightforward: although Intel will shell out more than $4 billion this year for R&D—ranking it among industry's top spenders—the company rarely ventures off the familiar semiconductor road map into emerging areas like ubiquitous computing, wireless networking and biological computing. But such "disruptive research," Tennenhouse says, is "the research that's going to lead to new business for Intel or open up areas that are going to jar the road map."

Tennenhouse bills Intel's new research structure as a DARPA-like "virtual laboratory." The company will follow the agency's lead by using a small cadre of program managers to identify and fund projects—inside the company and out—that fit Intel's long-term strategy but are beyond the scope of its existing business lines and research. At the same time, Tennenhouse plans to open six to eight small "lablets" near top universities; the first three will be running by this fall.

Intel's modeling of a significant portion of its research—which might eventually total more than $100 million per year—after a government agency appears unique in business, says Harvard Business School's Henry Chesbrough, an expert on industrial R&D. The changes, he notes, illustrate the need for companies to balance the pressure to improve existing products with the desire to hit a few home runs. "Every company has to learn how to access the wealth of ideas that are distributed outside its own four walls," as well as those inside, says Chesbrough.

Tennenhouse spent more than a year studying Intel's R&D structure before he began implementing the new plan last February. The company employs about 6,000 R&D people, almost all in business-division labs. Intel also sponsors some 360 university projects, including several disruptive studies. Tennenhouse didn't want to upset these efforts; he wanted to enhance them and, especially in the case of the disruptive projects, make them part of a more formal long-term strategy. What he didn't want to do was create a separate central research lab like those at IBM, say, or Microsoft.

The answer was to create a small group—fewer than 20 people—to evaluate, fund and oversee the additional disruptive studies he felt would be vital to long-term growth. These efforts can take place in Intel's existing labs or in universities and nonprofit research organizations, in close conjunction with Intel scientists. If and when they mature, the efforts will be brought into the main R&D pipeline.

Tennenhouse identified five "sectors" for Intel to explore: microelectromechanical systems (MEMS), distributed systems, biotechnology, statistics and machine vision. Sector directors were charged with developing strategic plans in their areas and working with researchers to develop projects that fit those plans. Projects that make it through an approval process led by Tennenhouse will receive $2 million to $3 million a year for two to four years. In contrast to the vast scale of Intel's conventional semiconductor research, which can involve hundreds of people on a single effort, the ideal disruptive-project size is probably five or six people, says Tennenhouse. "Most good research gets done at that size."

Another principle guiding Tennenhouse's vision is that some of the sponsored projects originate at Intel. Big firms

GENE GREIF

BRANCHING OUT

Intel's first three "lablets," opening this year

SITE/AFFILIATION	PROJECT
Berkeley, CA/ UC Berkeley	Extremely networked systems, like highway sensor networks
Seattle, WA/ University of Washington	Ubiquitous computing; wireless systems; high-frequency communication
Pittsburgh, PA/ Carnegie Mellon	Software for widely-distributed-storage systems

tend to expect disruptive ideas to come from outside the box—and outside their walls. Tennenhouse, though, thinks the opportunity to work on disruptive projects will be a creative spark for current employees—and could even become a great recruiting and retention tool.

Many of the initial efforts funded, in fact, are taking place in-house. One is Roy Want's "Ubiquity" project. The idea is that in the future people will carry "personal servers" through which they issue commands or make requests. But rather than harbor displays and do all the computing themselves, the devices will tap into local computing infrastructure. Say you want to review a PowerPoint presentation while on the road, Want says. Your device would relay the request wirelessly to the local network, and the page would be shown on the nearest display—a hotel-room television or office monitor. Before Intel, Want was at Xerox's Palo Alto Research Center, which supports many such disruptive projects. But he says the Intel program is unlike anything at PARC in that his work is now done in close association with a business unit. At PARC, he says, far-out efforts "ran free," with no connection to Xerox businesses.

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In parallel with in-house efforts, Intel will step up its funding of disruptive projects in universities. But Tennenhouse is worried that the focus of university computer science researchers has become too short term—so he hopes the new lablets will become a vehicle for encouraging longer-term efforts. "We really do want them [looking] farther ahead," he says.

Each lablet, which will house 20 to 30 researchers, will help Intel link up with a professor whose work fits with the firm's strategic plans. The researcher will take a leave of absence, maybe two years, to get the lab started. "It's not unusual for companies to establish research labs adjacent to major universities," says Ed Lazowska, chair of the department of computer science and engineering at the University of Washington, near where the first lablet started this July. "What's special, though, is that intimate collaboration with the neighboring university. We're going to have several dozen new researchers located adjacent to our campus, whose mission is to collaborate with us."

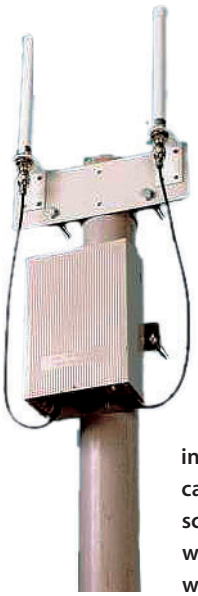
A lot of *if*s surround Intel's new structure. Can the lablets, for instance, build enough critical mass to stand on their own in a large organization? And at Intel, admits Tennenhouse, the idea of starting disruptive research in business-unit labs has met with resistance, because it means taking top researchers off vital road map work—or possibly diluting the company's focus on its core business. Tennenhouse figures it will take at least five years to determine if the new model is working—and probably more. And then, even if some great projects make it "downstream" into the main R&D fold, he'll have another worry: "The problem is, [if] the really good or great people take their projects downstream, that can leave you with people that are pretty good but not great." That, he says, would be a sure way for the new effort to wither. —*Robert Buderi*

CALLING ALL VILLAGES

TELECOM | For many people in rural areas of the developing world, just making a phone call from home is a distant dream. That's because building conventional phone infrastructure costs around $1,000 per home; to break even, companies would have to charge an amount out of reach for most would-be customers. But a new wireless telecommunications technology called corDECT could change that, potentially bringing millions of people not only phone access but the Internet as well.

Developed jointly by the Indian Institute of Technology in Madras and Midas Communication Technologies in Chennai, India, the new system is cheap and easy to install, as it replaces expensive cabling with wireless base stations *(below)*, each serving 30 to 100 subscribers in a neighborhood. An answering-machine-sized box in each user's home has ports for a phone and a computer. The system allows the phone and computer to share bandwidth: if a call comes in while somebody is surfing the Web, the Internet connection speed simply slows. The cost: $200 per home.

That price tag has prompted widespread interest in corDECT and pilot implementations of the technology in 11 countries, including Madagascar, Fiji, Kenya, Brazil and India. Harvard University's Center for International Development, together with the MIT Media Lab's Digital Nations consortium, chose corDECT for its project to connect communities in southeastern India. Says Colin Maclay, deputy director of the Harvard center, "We went with corDECT because it was cheap, robust and could scale up easily to a thousand villages." For the more than 95 percent of India's billion inhabitants who currently can't afford a phone, that scalability could mean a whole new connection to the world. —*Venkatesh Hariharan*



COURTESY OF MIDAS COMMUNICATION TECHNOLOGIES

JAMES YANG

GPS CLEARED FOR TAKEOFF

More accurate data could soon help guide planes

TRANSPORTATION | In a bid to modernize the U.S. air traffic control system and avert air travel gridlock, the Federal Aviation Administration has formulated a 10-year, $11.5 billion plan to replace today's radar-based system with one built around satellites. The project relies largely on Global Positioning System data, rather than radar, for navigation. The problem is that GPS still isn't accurate or reliable enough for such aviation applications. Now, a system that would allow GPS to provide nearly infallible signals for air traffic use is getting ready for rollout. If the technology passes testing over the next several years, it could help make the FAA's grand vision a reality.

In the new system, 25 ground stations constantly check the accuracy of the GPS signal. Software corrects glitches caused by things like atmospheric disturbances, and the stations beam corrected information to pilots via a pair of satellites. After seven years of trying, Raytheon of Lexington, MA, is expected to deliver the system as early as March 2003, the FAA says. "Everything is really coming to a head," says Timothy Katanik, a Raytheon manager working on the system. "We think we are there now."

Satellite-based air traffic control promises greater flexibility and capacity than radar-based systems *(see "The Digital Sky," TR March 2001)*. Pilots could freely optimize their routes and not herd themselves into clogged "highways" set by radar beacons. And when landing in bad weather, pilots could use satellite data to follow a variety of approach patterns, instead of the single rigid path required by runway landing signals. All this could mean shorter trips and fewer delays.

Refinement of GPS signals won't come cheap, though. And additional ground stations based near each airport will be needed for, say, landings in zero visibility. The total cost could run as high as $4.6 billion, says Hal Bell, the FAA's product leader on the system. And don't expect fewer delays at LaGuardia anytime soon. GPS will initially just help pilots land at remote airports that currently lack radar; FAA approvals for large, busy airports, and for zero-visibility landings and other tough situations, could take up to 20 years, Bell says. Which means passengers could be waiting for improved on-time rates for quite a while. —*David Talbot*

ELECTRONIC MEDICAL RECORDS

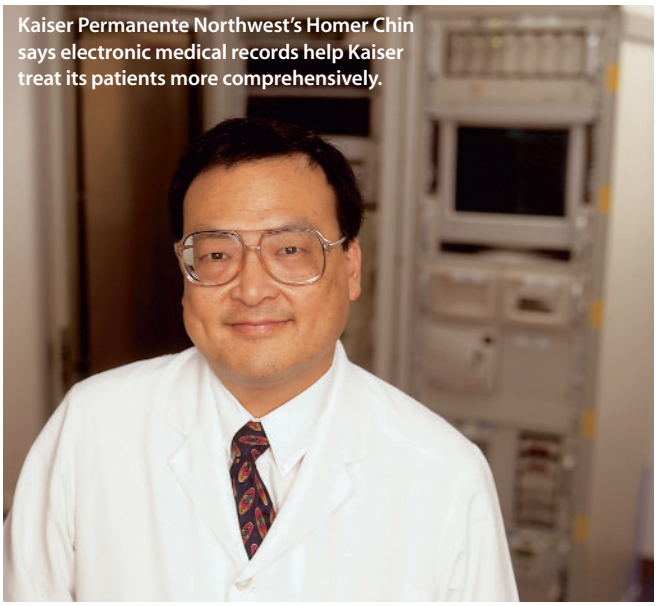
New rules mean doctors must go digital

MEDICINE | Doctors hear it all the time: if they kept patients' files on computers instead of on paper, it would save time and money—and patients would get better care. Still, less than five percent of U.S. physicians use electronic record systems. But new regulations from the U.S. Department of Health and Human Services could finally force doctors to enter the digital age.

None of the regulations, the first set of which is due to take effect in October 2002, prohibits the use of paper records, but they require health-care organizations to document and manage so much information that paper-based offices will likely find themselves unable to comply. "The whole field of medicine is going to change dramatically," says David Kibbe, CEO of Canopy Systems, a clinical software firm in Chapel Hill, NC.

The regulations, combined with rising concerns about medical errors, have prompted nearly two-thirds of doctors to make plans to implement electronic record systems, according to a recent survey by the research firm Gartner. And some 300 software companies nationwide are waiting in the wings, offering everything from speech recognition software to replace note-taking to programs that help doctors make treatment decisions.

The medical offices of Oregon managed-care giant Kaiser Permanente Northwest went electronic in 1994, converting all their lab tests, notes and treatment guidelines to digital files. According to Kaiser physician Homer Chin, the company has saved $5 million a year in labor costs alone. Still, about 70 percent of doctors work in small practices that probably won't be able to invest millions of dollars in their own computer systems and may instead turn to outside vendors to store and manage their records over the Internet. "The market for these vendors is huge," says Thomas Handler, a health-care analyst at Gartner. And the potential for more effective, and safer, health care could be even greater. —*Alexandra Stikeman*



Kaiser Permanente Northwest's Homer Chin says electronic medical records help Kaiser treat its patients more comprehensively.

TODD ECKELMAN

DIGITAL PRESERVATION

SOFTWARE | Increasingly, the record of our civilization is becoming digital, from census data to family photos. The Library of Congress alone has 35 terabytes of files. Yet rapid changes in computers and software could render this data unreadable.

Congress recently allocated the library $100 million to look for a way to preserve its files—one of the most ambitious efforts yet to tackle digital obsolescence. "With that money we'll be able to gather the technical people and the archivists and start to develop a prototype," says Abby Smith, preservation program officer with the Council on Library and Information Resources, which is working on the project.

Part of the challenge is that computers and software gallop ahead, while digital files remain static. The library's current solution is to convert files to work with the updated systems every few years, but "every time you convert something, you change it," says Jeff Rothenberg, researcher at the Rand Corporation in Santa Monica, CA. Rothenberg instead sees a solution in emulation software that can mimic a given hardware platform, allowing one computer to act like an earlier one. To demonstrate the approach's feasibility, he created a chain of emulators linking a present-day PC to the 1949 EDSAC, one of the first computers. "I was able to run any of the original EDSAC programs that were saved on paper tape," he says.

Ray Lorie, research fellow at IBM's Almaden Research Center in San Jose, CA, is working on an approach that creates a digital road map of a document at the time of its creation. Write a document, say, in Adobe Premier, and the software generates a second file that describes the content and formatting of the original document using a simple code. That code would be readable by a "universal virtual computer"—an emulator that mimics, not an earlier machine, but a hypothetical, extremely simple computer. "In the future we'd only need some way of interpreting this single virtual computer," says Lorie.

AP PHOTO ARCHIVE

Will the data on these tapes soon be illegible?

While the Library of Congress appropriation won't solve the problem of digital preservation, it will allow for the first large-scale testing of possible solutions like Lorie's and Rothenberg's. "The Library of Congress project has a high enough profile that we might be able to get the attention of technology industry, and to finally get some answers," says Smith. —*Claire Tristram*

PERSONAL GENOMES

Individual sequencing could be around the corner

BIOTECH | The Human Genome Project's working draft sequence, which was completed to much fanfare in June 2000, took about a dozen years and more than $300 million to complete. The result was a composite map of the DNA from several people—a sort of averaged genetic picture of a human. But a growing number of companies are working on advanced technologies that could make it possible to have your own individual genome sequenced in a day, perhaps for as little as a few thousand dollars.

No one's genetic makeup matches "the human genome" exactly; the differences are what give one person brown eyes and another blue or make some people more susceptible to heart disease. The new technologies could give anyone access to the unique, letter-by-letter sequence of his or her entire genome and help doctors detect the variations that signal health problems down the road.

Today's sequencing methods are costly and slow in part because for each DNA letter read—of the roughly three billion in a human genome—researchers need to synthesize a separate copy of the DNA strand. Making the copies requires several chemical reactions; then you have to separate and identify the newly made strands. In contrast, two new techniques being developed could read the sequence directly from one DNA molecule. The first method, called "nanopore sequencing," involves pushing a strand of DNA through a tiny hole surrounded by sensors that detect the electrical changes caused by each DNA letter. The second takes advantage of an enzyme called DNA polymerase, which copies DNA inside our cells. Researchers use specialized optics to detect each letter added as the enzyme copies the original DNA strand.

In May, Palo Alto, CA-based Agilent Technologies signed an agreement with Harvard researchers Daniel Branton and Jene Golovchenko to further develop nanopore sequencing, which Branton coinvented *(see "Hole in the Wall Offers Cheaper Sequencing," TR May/June 1998)*. Also this year, Woburn, MA-based U.S. Genomics received its first patents on technologies that combine the two direct techniques. Thanks to these and several other efforts *(see table)*, the dream of sequencing a human genome in just a day could be a reality in two to five years, says George Weinstock, co-director of the Baylor College of Medicine Human Genome Sequencing Center in Houston. "They're all very clever techniques," he says. "We're getting very close to having them in hand."

Though the new sequencing tools will initially be used for biomedical research, they could eventually find their way into doctors' offices, not only providing for quick gene-based diagnosis of a host of diseases, but also helping doctors choose medicines tailored to individual patients. The expected price tag to sequence your genome—perhaps $5,000 to $30,000—might seem steep, but "it's kind of a life investment," says Harvard Medical School biophysicist George Church. "I would pay $10,000 to get my genome sequenced…rather than buying a second car." —*Erika Jonietz*

SEQUENCE SEEKERS

Others pursuing single-genome techniques

NANOPORE	POLYMERASE
Amersham Pharmacia Biotech (Piscataway, NJ)	LI-COR Biosciences (Lincoln, NE)
Eagle Research (Broomfield, CO)	Solexa (Little Chesterford, England)
EIC Laboratories (Norwood, MA)	

BUILDING A GREEN FUTURE

ENERGY | **Picture that monthly envelope from the electric company and imagine that it contains not a bill but a statement of credit—every month. That's the future of homes and other buildings, as seen by the U.S. Department of Energy. The agency hopes that its new road map for building-technology research and development will help make this green vision a reality by 2020.**

Developed in conjunction with the building industry, the road map sets goals for improving building "envelopes"—walls, windows, foundations and roofs. According to Mark Ginsberg, the agency's deputy assistant secretary in the Office of Building Technology, shortcomings or defects in a building's envelope can be responsible for as much as half of its energy consumption: poor insulation wastes heat, for example, and air leaks make air conditioners work overtime. The department's funding of research for the next two decades, Ginsberg says, is meant to produce "the next generation of insulation, roofing materials and building products that will perform significantly better than what we have today."

Instead of replacing a roof, for example, you might someday be able to simply spray a plastic foam over the existing shingles that provides not only waterproofing but also an additional layer of insulation. Intelligent lighting and climate control systems could learn your preferences and adjust each room to suit your needs as you move through your home—making the most efficient use of heating, cooling and electricity. And solar cells integrated into not only roofs, but exterior walls as well, could help a building generate its own power.

"My own personal goal," Ginsberg says, "is 120 percent energy efficiency—buildings that use so little energy, and produce their own, that they give back to the grid." And, come bill time, they'd give back to their owners as well. —*Lauren Gravitz*

JAMES YANG