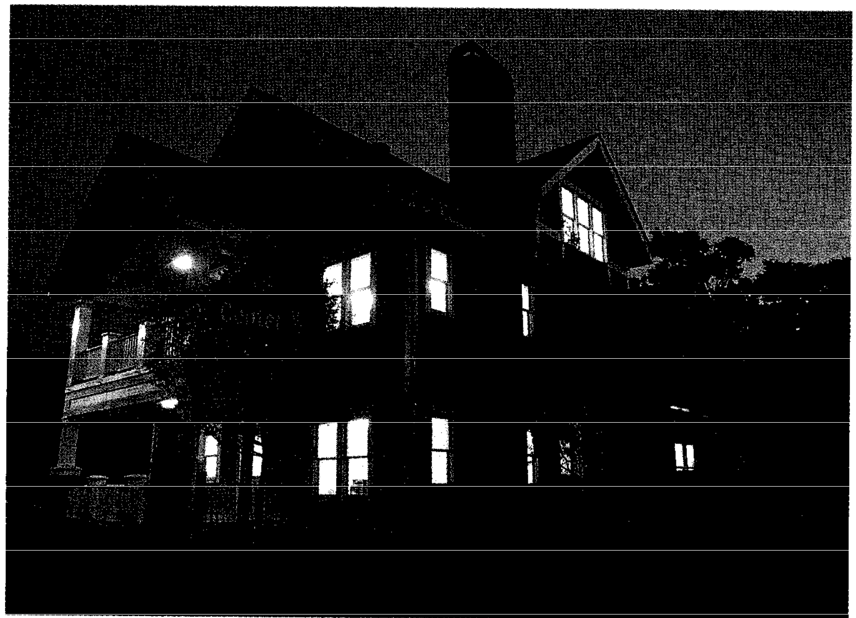
As We May Live

Computer scientists build a dream house to test their vision of our future

ATLANTA—To pedestrians walking past in the muggy summer heat, the green house at the corner of 10th and Center streets looks very much like any of the other two-story homes in this quiet neighborhood a block north of the **Georgia Institute of Technology.** Only the loud whir of two commercial-size heat pumps in the side yard hints at the fact that the house is infested with network cables threaded through the floorboards, video cameras staring from the ceiling, sensors tucked into kitchen cabinets, workstations stacked in the basement, and computer scientists bustling from room to room.

Inside the house, some passing student has arranged toy magnetic letters on the refrigerator door to spell out the purpose of this odd combination: "Aware Home of the Futur," a laboratory in the shape of a house where humans can try out living in more intimate contact with computers. There's a piece missing from the message, but the project itself has many gaps to fill. Construction wrapped up only a few months ago, and seven faculty members from Georgia Tech's computer science department are still working with a battalion of students to get the house's sensory systems online.

This house does all the light-switching, stereo-piping tricks of "smart" homes that provide technophiles with electronic convenience, but here that is just a starting point. The goal is to make this place the most ambitious incarnation yet of ideas that have been fermenting in computer research labs for a decade, ever since Mark Weiser launched the first "ubiquitous computing" project at the **Xerox Palo Alto Research Center** (PARC) in the late 1980s. In a seminal 1991 article in *Scientific American,* Weiser predicted that human use of computers would in the early 21st century go through a transition comparable to the shift from shared mainframe machines to personally owned workstations, laptops and handhelds. The third generation of "UCs," he argued, should look like everyday objects—name tags, books, jewelry, appliances, walls—but should be highly interconnected and able to adapt their behavior to different users, locations and situations. In this vision, we will share many kinds of UCs, and the devices will share us.



IT'S AWARE: a new computer science lab will monitor its live-in test subjects.

A decade's work on UbiComp, as it is known in the field, has produced a zoo of ideas and many demos but few real-world tests. **NCR** unveiled a microwave oven that could support e-mail and electronic banking in 1998 and last year demonstrated a trash bin that can use a bar-code scanner on its lid to track the contents of the pantry. Neither has made it beyond prototypes. On a quick stop at the **IBM Almaden Research Center,** Cameron Miner shows me a glass case full of digital jewelry: a tie-bar microphone, earring earphones, a ring with a multicolored LED. "It might flash when you get an incoming call," Miner suggests. But these are mock-ups; they do not actually connect to anything.

No one knows yet what kind of infrastructure is needed to support a UbiComp world, so the designers of 479 10th Street took no chances. Every wall has at least six high-speed jacks to the internal Ethernet network. Cordless devices communicate through a house-wide wireless net. A radio-locating system can pinpoint any tagged object to within 10 feet. The two-gigabit-per-second connection to the university and the Internet is fast enough to transmit several channels of full-screen video and audio. And with some 25 cameras and almost as many microphones trained on the first floor alone, there is plenty of audio and video to go around.

Aaron Bobick, who specializes in computer vision, gives me the grand tour. "Everybody in our department thought building this must be a good thing to do," he says, "although we didn't really have a clear vision of why." The research team eventually decided that those who most need the home of the future are people of the past—not the rich gadget nuts who typically purchase smart homes but rather marginally infirm seniors. "If technology could help you be certain that your parent maintains social contact, takes her medicine, moves around okay, and that means she can stay another 18 months in her own home, then that's a slam-dunk motivator," Bobick says. "When we told that to the people from Intel, they just loved it." **Intel** is now one of the project's corporate sponsors, along with **Motorola Labs, Andersen Consulting** and **Mitsubishi Electric Research Lab.**

Two engineers from **Sprint**, which is interested in the project, arrive on a fact-finding mission and join us as we resume the tour. "On the surface, this could look like *Big Brother* or *The Truman Show*," Bobick concedes, gesturing to the video cameras aimed at us from several directions. Our images pour through wires onto the hard disks of computers in the basement. "But it is important to realize that we want to process video data at the spot where it is collected," he continues. "Then these won't really be video cameras but sensors that simply detect people's location or the direction of their gaze. I want to put cameras in the bathrooms, to make that distinction clear. Suppose your shower could detect melanoma? That's something people are working on." Behind Bobick, Elizabeth D. Mynatt grimaces.

Mynatt, the only woman on the team and the one who suggested the focus on the aged, spends half her time working with caregivers and anthropologists to figure out what problems tend to force seniors from their homes and what annoyances and invasions of privacy they might trade to postpone that. This approach sometimes conflicts with the more typical technocentric style of her colleagues. "I call it the 'boys with toys' phenomenon," she says. "Someone builds a hammer and then looks around for something to bang on."

Mynatt does not want cameras in the bathrooms. She used to work with Mark Weiser at Xerox PARC, and she remembers the lessons of his first experiments with ubiquitous computers. "Xerox tried to make everyone in the building wear these active name badges that we had developed," recalls Dan Russell, who worked in Weiser's group at PARC for several years before moving to IBM Almaden. The idea was to let anyone see where anyone else was at any time. "About half the people said, 'No way.' We also tried to put a Web cam in the coffee room, but again there was a huge backlash." This was at the lab where UbiComp was born.

"Still, I feel uncomfortable about focusing too much on the social implications," says Gregory D. Abowd, co-director of the Aware Home Research Initiative. Abowd is designing software that will automatically construct family albums from the video streams collected by the house—the same streams that Bobick claims he wants to distill at each source. Abowd is also trying to build an intercom system that will allow one person to speak with another simply by saying the person's name. And he enthusiastically describes his idea for a program that would automatically place a phone call to your mother when you talk to her picture—but only after checking with her house to make certain she is awake. "I'm under no illusion about the potential this creates for major privacy problems," he says. "But I'm one of 12 children. I'd rather push the boundary of privacy than cower from it."

Just over Abowd's head, a digital photograph of someone's grandmother sits on the mantle. The photo is bordered by pastel butterflies of various shapes and hues. It is a prototype of a device that one might place on an office desk to keep track of a distant relative living in an "aware" home. Every day the photo would contact the house for a status report from the system that tracks Grandmom's physical movement and social interaction; more activity would add a larger butterfly to the history. The idea, suggests Mynatt, who designed the device, is to find calming technology that helps family members feel close and in control without being invasive.

She describes another active project over lunch: "We know that kitchens are hot spots of activity and that older people suffer some cognitive declines that make it difficult for them to deal with interruptions." So she is designing a reminder program that will use the kitchen cameras and sensors to assemble a running montage of snapshots that can remind people what they were doing just before they were interrupted. She is similarly trying to come up with subtle sounds or images that the house can emit to help inhabitants remember important times of day, such as for appointments or medication. Other researchers want to stick small radio-tracking tags on easily misplaced objects such as keys and remote controls. The list of ideas seems to change weekly, reflecting the enormous uncertainties in the UbiComp field about what society needs and what people will accept.

In a year or so, test subjects will help answer that question as they move into the second story of the house and judge whether all this complex infrastructure and software does in fact simplify and enrich daily life. The project has its skeptics. There is no way to know what Weiser would think, unfortunately, because he died suddenly last year from liver cancer at the age of 46. But his colleague Rich Gold worries that the occupants of a UbiComp house may feel it controls them rather than the other way around. In an essay on "intelligent" houses several years ago, Gold wondered: "How smart does the bed in your house have to be before you are afraid to go to sleep at night?" —*W. Wayt Gibbs*

A Machine for Living In

The four-bedroom, four-bath Broadband Institute Residential Laboratory built by Georgia Tech has more cameras than windows. Amenities include:

- Computers: at least 60
- Video cameras: 25 (first floor only)
- Microphones: at least 1 per room
- Cabinet sensors: 40 (first floor only)
- Televisions (for fun, not research): 60-inch upstairs, 8-by-12-foot projection system in basement
- Network outlets: 48 (at least one per wall)
- Connections per outlet: 2 Ethernet; 2 coaxial; 2 optical fiber
- Internet bandwidth: 2 gigabits per second (via 4 DSL lines and an optical-fiber link)
- Internal wireless network bandwidth: 11 megabits per second
- Construction cost: at least $750,000, not including computer equipment

NETWORK CABLE: about 10 miles' worth in total.

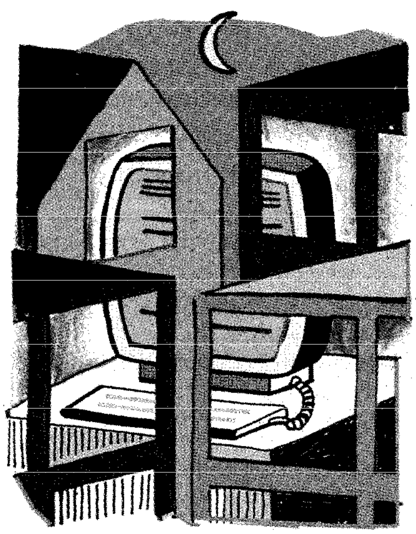
Wholesale Computation

Companies want to sell your computer's spare processing time. Are there buyers?

The fastest supercomputers in the known universe are virtually free. All you need to beat the performance of a $50-million, massively parallel research machine is a little software and some way to convince 1 percent of the people on the Internet to run it. Unlike a dedicated supercomputer, which generally requires special housing and a staff of attendants to keep it going while it falls rapidly behind the state of the art, the network equivalent increases in power regularly as people upgrade their PCs. And when you're done using the virtual supercomputer, you can stop paying for it. Little wonder, then, that more than a dozen startups should have appeared in the past year, all trying to scoop up spare computing cycles and sell them to the highest bidder.

The best-known example of virtual supercomputing is the volunteer SETI@ Home project, a search for radio signals from an extraterrestrial intelligence; it has attracted more than two million participants. Following in the footsteps of code-breaking ventures such as distributed.net, SETI@Home can run as a screensaver; then it is active only when a machine is not doing anything else. Each chunk of radio-telescope data can be processed independently, so machines don't need to communicate with one another, only with a central server. Other embarrassingly parallel problems include DNA pattern matching, Monte Carlo financial modeling, computer-graphics rendering and, appropriately enough, Web site–performance testing. Genome applications alone, says United Devices CEO Ed Hubbard, could soak up all the Net's spare computing power for the next 50 years.

Only two questions stand between the venture capitalists and enormous profits: Can they get millions of users to surrender CPU time to profit-making organizations, and can they sell the resulting power to enough paying customers? Steve Porter of ProcessTree Network has little doubt that his company can retain the 100,000 people currently donating time to nonprofit computations by offering payments of between $100 to $1,000 a year (depending on processor speed and Internet bandwidth). That, he says, will enable him to sell a standard CPU-year (a 400-megahertz Pentium II operating full-time for 365 days) for about $1,500, or less than a fifth the cost of equivalent time on a supercomputer. Nelson Minar of PopularPower expects that even lesser incentives, say between $60 and $200, would still cut individuals' Internet access bills in half—or add up to a tidy sum for schools and libraries. And at Centrata, business development vice president Boris Pevzner says his company intends to bypass individual recruiting entirely



and use its high-powered venture-capital contacts to get computer manufacturers and Internet access providers to build the company's software into their products, where it will operate automatically.

Meanwhile Adam L. Beberg, one of the founders of distributed.net and now an independent software developer, predicts that no one will make money reselling computer power—too many sellers, not enough buyers. Completely open distributed computing has intractable security problems that will prevent firms from putting sensitive code and data out on the Internet for everyone to see. "The only market is behind firewalls," he says.

Andrew Grimshaw of Applied Meta agrees: "Most businesses won't buy consumer-grade [computing] resources from some Linux hacker's dorm room." Beberg and Grimshaw both argue that the real money is to be made with corporate networks, where tens of thousands of well-administered machines sit idle every night. (Applied Meta currently operates for the National Science Foundation a seamless, secure network of more than 4,000 CPUs.)

Proponents downplay such worries, pointing out that encryption, along with the very decentralized nature of the computing, make it unlikely that an adversary will be able to piece together more than a tiny bit of the big picture. Porter says that his company is mostly bidding on projects based on publicly available data and algorithms—it's only the computing power that his clients need. Minar points out that there's just as much need to protect PCs from potentially malicious distributed code. His company places programs in a Java-language "sandbox" that isolates them to prevent unauthorized access to a user's own information.

Moreover, it isn't just cycles that will be for sale. Centrata and Applied Meta, for example, both tout their ability to store information on what looks like one enormous disk. (Redundancy and encryption are just the beginning of the techniques required to make sure that the data are consistently available to the owners and inaccessible to anyone else.) Porter and others are also looking forward to trading in bandwidth: a PC with a megabit-per-second Internet connection, typical of cable modems and DSL connections, could cache data from distant Web sites and serve them to neighboring users, reducing the load on Internet backbones. (Companies such as Akamai are already doing a rapidly growing business in such "edge" caches, but their approach requires dedicated hardware.)

So in a few years, your computer could be surfing the Net looking for the best bids for its spare resources. But will the ready availability of computing power to handle peak processing loads end up curtailing the rapid increases in CPU speed that make distributed computing attractive, or will the ability to solve problems that were utterly unapproachable only a few years ago whet appetites for yet more power? That issue might not even concern the startups. It's possible that widely disseminated distributed-processing software—such as that recently released by Beberg and his friends—will allow buyers and sellers to work directly, leaving the intermediaries hoping to sell your computer power out in the cold. *—Paul Wallich*

Dams&Economics

Internet Data Gain is a Major Power Drain on Local Utilities

by John Cook
Seattle Post-Intelligencer - September 5, 2000

Server farms' voracious appetite for electricity sparks several concerns

In 1997, a little-known Silicon Valley company called Exodus Communications opened a 15,000-square-foot data center in Tukwila.

The mission was to handle the Internet traffic and computer servers for the region's growing number of dot-coms.

Fast-forward to summer 2000. Exodus is now wrapping up construction on a new 13-acre, 576,000-square-foot data center less than a mile from its original facility. Sitting at the confluence of several fiber optic backbones, the Exodus plant will consume enough power for a small town and eventually house Internet servers for firms such as Avenue A, Microsoft and Onvia.com.

Exodus is not the only company building massive data centers near Seattle. More than a dozen companies -- with names like AboveNet, Globix and HostPro -- are looking for facilities here that will house the networking equipment of the Internet economy.

It is a big business that could have an effect on everything from your monthly electric bill to the ease with which you access your favorite Web sites.

Data centers, also known as co-location facilities and server farms, are sprouting at such a furious pace in Tukwila and the Kent Valley that some have expressed concern over whether Seattle City Light and Puget Sound Energy can handle the power necessary to run these 24-hour, high-security facilities.

"We are talking to about half a dozen customers that are requesting 445 megawatts of power in a little area near Southcenter Mall," said Karl Karzmar, manager of revenue requirements for Puget Sound Energy. "That is the equivalent of six oil refineries."

A relatively new phenomenon in the utility business, the rise of the Internet data center has some utility veterans scratching their heads.

Puget Sound Energy last week asked the Washington Utilities and Transportation Commission to accept a tariff on the new data centers. The tariff is designed to protect the company's existing residential and business customers from footing the bill for the new base stations necessary to support the projects. Those base stations could cost as much as $20 million each, Karzmar said.

Not to be left behind, Seattle City Light plans to bring up the data center issue on Thursday at the Seattle City Council meeting.

For the utilities that provide power to homes, businesses and schools in the region, this is a new and complex issue.

On one hand, the data centers -- with their amazing appetite for power -- represent potentially lucrative business customers. The facilities run 24 hours a day, seven days a week, and therefore could become a constant revenue stream. On the other hand, they require so much energy that they could potentially flood the utilities with exorbitant capital expenditures.

Who will pay for those expenditures and what it will mean for power rates in the area is still open to debate.

"These facilities are what we call extremely dense loads," said Bob Royer, director of communications and public affairs at Seattle City Light.

"The entire University of Washington, from stadium lights at the football game to the Medical School, averages 31 megawatts per day. We have data center projects in front of us that are asking for 30, 40 and 50 megawatts."

With more than 1.5 million square feet, the Intergate complex in Tukwila is one of the biggest data centers. Sabey Corp. re-purchased the 1.35 million square-foot Intergate East facility last September from Boeing Space & Defense. In less than 12 months, the developer has leased 92 percent of the six-building complex to seven different co-location companies.

"It is probably the largest data center park in the country," boasts Laurent Poole, chief operating officer at Sabey. Exodus, ICG Communications, NetStream Communications, Pac West Telecomm and Zama Networks all lease space in the office park.

After building Exodus' first Tukwila facility in 1997, Sabey has become an expert in the arena and now has facilities either under management or development in Los Angeles, Spokane and Denver. Poole claims his firm is one of the top four builders of Internet data centers in the country.

As more people access the Internet and conduct bandwidth-heavy tasks such as listening to online music, Poole said the need for co-location space in Seattle continues to escalate.

But it is not just Seattle. The need for data center space is growing at a rapid clip at many technology hubs throughout the country, causing similar concerns among utilities in places such as Texas and California.

Exodus, one of the largest providers of co-location space, plans to nearly double the amount of space it has by the end of the year. While companies such as Amazon.com run their own server farms, many high-tech companies have decided to outsource the operations to companies such as Exodus that may be better prepared for dealing with Internet traffic management.

"We have 2 million square feet of space under construction and we plan to double our size in the next nine months, yet there is more demand right now than data center space," said Steve Porter, an account executive at Exodus in Seattle.

The booming market for co-location space has left some in the local utility industry perplexed.

"It accelerates in a quantum way what you have to do to serve the growth," said Seattle City Light's Royer. "The utility industry is almost stunned by this, in a way."

John Cook
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