COMPUTER SCIENCE

PARC Builds a World Saturated With Computation

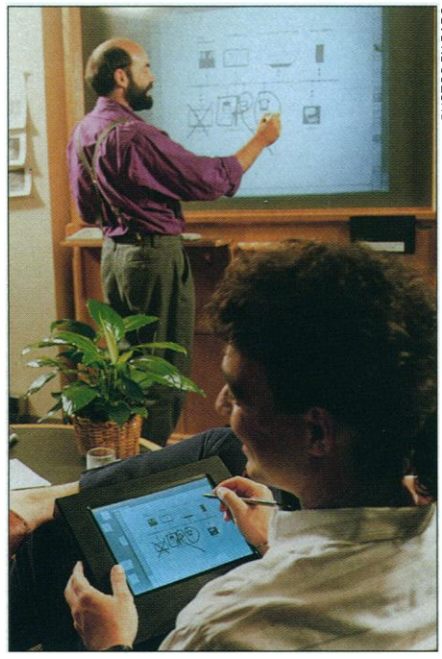
PALO ALTO—The ironies are obvious, but Mark Weiser has learned to savor them. Weiser is sitting in front of a very large personal computer that rests on his desk at the Xerox Palo Alto Research Center (PARC), the hillside laboratory that essentially invented the personal computer back in the early 1970s—not to mention the "windows" user interface, the ethernet local area network, the laser printer, and most of the other paraphernalia of the personal computer revolution. In fact, Weiser is head of PARC's computer science group. And yet here he is, calmly explaining why he wants to make computers disappear. "We're trying to *undo* what PARC did 20 years ago," he declares.

Of course, says Weiser, he doesn't mean that he wants to eliminate computers. He and his colleagues just want to get the things out of people's way. "Ubiquitous computing," as their approach has come to be known, is an attempt to turn the personal computer industry's current thinking inside out. Instead of putting more and more effort into increasingly powerful microprocessors and more dramatic user interfaces, they want to develop devices that are as unobtrusive as possible: "scratch computers" that would be so common and so easy to use that people would hardly be aware they were using them. After all, says Weiser, "why would you ever want a dramatic tool? Do you want an ornate hammer with flashing lights that you're afraid to use? No, you want the hammer to become an extension of your hand, so that you can focus on driving the nail."

Admittedly, he says, many of the prototype scratch computers that he and his team have developed look a lot like the new generation of pen computers and "Personal Digital Assistants" now being touted by companies such as Apple Computer. The difference, says Weiser, is that he's not talking about carrying around a gadget or two. He and his colleagues at PARC are trying to explore what it would mean to live in an environment that is saturated with computation, in the form of unobtrusive computers all linked by wireless networks. "Personal hardware is the wrong approach," says Weiser. "We don't have a personal telephone. In principle, you can go up to any phone in the world and just use it. And in the same way, you don't want a personal computer. You want many, many ways to access computational capabilities."

Perhaps not surprisingly, this kind of talk tends to get a cool reception from mainstream developers. "I just don't see how it could happen," says Forest Baskett, chief scientist at workstation manufacturer Silicon Graphics Inc. in Mountain View, California. "I'd be happy if we could get to a world with much, much greater use of computers. And there's no question that you get tremendous leverage from the coordination of computers. But when does all this wireless networking happen? What economic forces are going to drive it? No, I think it's much more likely that we'll have uncoordinated computers and workstations for a long time to come."

Others, however, are less pessimistic. "Mark is one of the visionaries," says Lance Glasser, who funds some of Weiser's work as head of the Electronic Systems Technology office at the Pentagon's Advanced Research Projects Agency. Lots of companies are working on mobile, lightweight computers and wireless communications, he points out. Moreover, the telephone companies and cable companies are already joining forces to bring digital and wireless communications into every home and office in the country. "We think there's going to be another computer revolution over the next 30 years," says Glasser, "one that gets the machines off the desks and out to the people in the field, in the streets." And PARC is unusual, he says, in exploring how this widely distributed and highly interactive system of humans and computers could work together as an integrated whole.



PHOTOS BY PARC

Computers, computers everywhere. A liveboard and pad in use at Xerox PARC.

Integration, in fact, is the key to Weiser's whole concept. As he realized in late 1988, when he first came up with the ubiquitous computing idea, computers don't have to be just occasional visitors to a network. They can subsist on it 24 hours a day, drawing their processing power and data from other machines. Even then, it was clear that the groundwork was falling into place. The PCs or workstations in most offices were already being networked locally. A small but increasing number of these local networks were also starting to provide access to the transnational Internet network, albeit at relatively modest transmission rates. Now efforts are getting under way in Congress to expand the Internet into a national "Information Highway" capable of transmitting data across the United States—and the world—at a billion bits per second.

Serious networking. Given that groundwork, Weiser found, it wasn't hard to imagine a future in which wireless infrared or radio links to this integrated global network would be as common as electrical outlets are now. A device that you could hold in your hand could conceivably tap into data archives and supercomputers anywhere in an organization or elsewhere in the world, at any time. In principle, that device could give you access to as much computational power and sophistication as you needed—regardless of how much processing power was actually contained in the particular box. The box wouldn't have to be anything more than a simple "window" into the network.

The upshot, says Weiser, is that instead of trying to turn every machine into a desktop supercomputer—the trend that dominates today—you could start to shrink some of them down until they looked like thin notepads with a flat screen on top that you could scribble on. These devices could be as easy to use as paper. In fact, they could be so cheap that you could own dozens or even hundreds of the things. Instead of constantly opening and closing applications in the on-screen windows of a single desktop machine, you could stack these scratch computers around your office like paper and have all of them in use for various tasks at the same time.

But Weiser found that vision wasn't easy to articulate, even to his colleagues at PARC. Software specialist Alan Demers, for one, was distinctly underwhelmed. "So what?" he remembers thinking. Portable computers and networks weren't exactly new ideas. And why would anyone need lots of computers?

It took a while for the notion to sink in, says Demers: Weiser wasn't really talking about the gadgets at all. He was talking about anthropology and sociology—the small details that can make a huge difference in what a given technology feels like and how it is used. Take ubiquitous access to the network, for example. "Apple's new Newton computer has infrared wireless communications," says Demers. "But the communications are intermittent. You have to point it at a receiver and say, 'Communicate now!' Then it sucks up all your electronic mail or whatever, and you log off." What Weiser was describing, however, was a system in which all the devices would automatically stay in contact with the network all the time. Moreover, each device would know where it was, and—through some kind of electronic identification badge—where you were. So the system could automatically make your files available on any machine you happened to pick up, or display your urgent messages on the nearest available screen.

With ubiquitous computing "your whole physical environment would *become* the computer."

—Alan Demers

Individually, says Demers, such examples may seem trivial. But overall, he says, "you would end up with the feeling that your environment is cooperating with you and aware of your presence. Your whole physical environment would *become* the computer—all of it able to react to you with a certain amount of intelligence."

To Demers, that seemed an idea worth working on. Nor was he alone in that feeling: Nearly a dozen PARC researchers have pitched in on the project. On the hardware front, for example, they have now developed prototype computers in a variety of sizes. Weiser's original concept was for notebook-sized devices, which his group took to calling "pads," and the prototypes are indeed about the size of notepads. The devices have two microprocessors, a high-speed radio link that connects them to the network via receivers in the ceilings, and a high-resolution black-and-white screen that displays the marks made by a stylus, enabling them to act as scratch pads or word processors. The pads also serve as windows into central data archives and let people join in a discussion group without even being in the same room: All the networked pads can be made to display the same thing, so each participant's notations are displayed on everybody else's pads.

All shapes and sizes. Reasoning by analogy to the way writing and paper are used now, Weiser and his colleagues could see that a typical office might have 10 to 20 pads. But that same analogy to writing suggested that a typical office or conference room might have one or two scratch computers ("boards") roughly the size of a wall, just as offices are now routinely furnished with whiteboards. Such wall-sized devices, also known as liveboards, would obviously not be small and unobtrusive, Weiser admits. But nonetheless, they would share the most essential property of ubiquitous computing: They would just be *there*, ready at hand whenever you wanted to use them.

Sometimes known as "liveboards," the devices have also proved to be far and away the most successful spin-offs of ubiquitous computing to date. After several years of experimentation with prototype boards in the common rooms of PARC and a number of other Xerox laboratories, the company this year began offering liveboards as a commercial product. Standing about 6 feet tall, the devices look a good deal like big-screen projection televisions—except that you can scribble on them with a special stylus, just as you do on the pads, organizing information, storing it, and calling it up from the network.

The liveboards can also serve as settings for long-distance meetings, says PARC's Frank Halasz, who is in charge of liveboard software. The boards are linked so that everyone can see what people at different sites are writing. And there is usually an audio link as well to capture what they are saying. "It has a slightly unnatural feel when you start," says Halasz, who has participated in many such long-distance conferences himself. "You're missing any communication through hand gestures and body movements, so there's a much greater emphasis on what's actually being written on the board. But it's like a phone call: It very quickly starts to feel like a natural mode of communication."

Meanwhile, a final component of ubiquitous computing, "tabs," would be the digital analog of printed labels and handwritten Post-it notes. They wouldn't necessarily have much processing power, says Weiser, although one of PARC's prototypes does have enough smarts to function as a kind of datebook and personal communicator. Once a tab was attached to something (or someone), however, it would provide the network with a continuous stream of location and identification information. This, in turn, is what would allow people to function as integral parts of the ubiquitous computing system.

For example, at least some people around PARC (including Weiser) have started wearing tab computers in the form of identification badges supplied by the Olivetti company. The tabs allow them to grab any scratch pad they run across, or walk up to any liveboard in the hallway, and have the computer instantly know from communicating with their badge just who they are, where their files are stored, and which files they have been working on lately and might like to access again. The badges also allow the liveboards to function as personalized bulletin boards: By knowing who is standing there, the boards can display only the items that he or she is likely to be interested in.

Even as the PARC group continues to work on the hardware, however, they are facing up to a far more difficult challenge: the software and networking protocols that make ubiquitous computing work as a system. "Where now you have one computer in your office, if you're lucky," Weiser explains, "ubiquitous computing says that tomorrow you're going to have hundreds. They're all going to be wireless networked, and they're going to be moving around. Someone may walk into your office with a passle of tabs and leave them on your table. So you can never be sure what's in your room from one minute to the next. And the fact is that a lot of the assumptions that we've made in our systems for the last 20 years turn out to be fundamentally broken from the point of view of lots of mobile devices."

For example, says Weiser, "network protocols all have built into them the idea that a computer pretty much stays in one place. So if you know how to get information to that machine at time zero, you know how to get information to it at all future times." As a result, he and his team have had to create new operating system software, so that each device keeps the system informed about its identity and location at all times—and so that the assumption of mobility is built in from the start.

Further from solution is the problem of network integrity. A system that's this thoroughly intertwined with peoples' lives and livelihoods, after all, can't be allowed to crash. "A primary part of our software efforts has been to build very robust and self-maintaining systems," says Weiser. "Our approach is not to have any one point of failure. If our network operating system notices one piece of equipment going down, it tries to bring something else up to compensate. It's almost like homeostasis in biology: The system will have vital organs—but no vital cells. There's no one computer in charge. We're at the very beginning of understanding a technology like that."

Obviously, adds Weiser, it's going to be quite a while before much of his vision is realized outside PARC. But as far as he's concerned, that's okay. "This isn't a project," he says. "It's a 10- to 20-year quest."

–M. Mitchell Waldrop