

Ten lessons learned about Ubiquitous Computing

Roy Want

Intel Research

Dagstuhl, September 2001

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Ubiquitous Computing

■ Olivetti 1988-1991

- Andy Hopper
 - Pandora
 - Active Badge

■ Xerox PARC 1991-2000

- Mark Weiser (until, sadly, April 1999)
Seminal paper “The computer for the 21st Century” Sept 1991
 - Parctab project 1991-95
 - Tacit 1995-96
 - Bridging the Physical and the Virtual World 1997-1998
 - Hikari Project 1999-2000

■ Intel Research 2000-Present

- David Tennenhouse
 - Personal Server Project



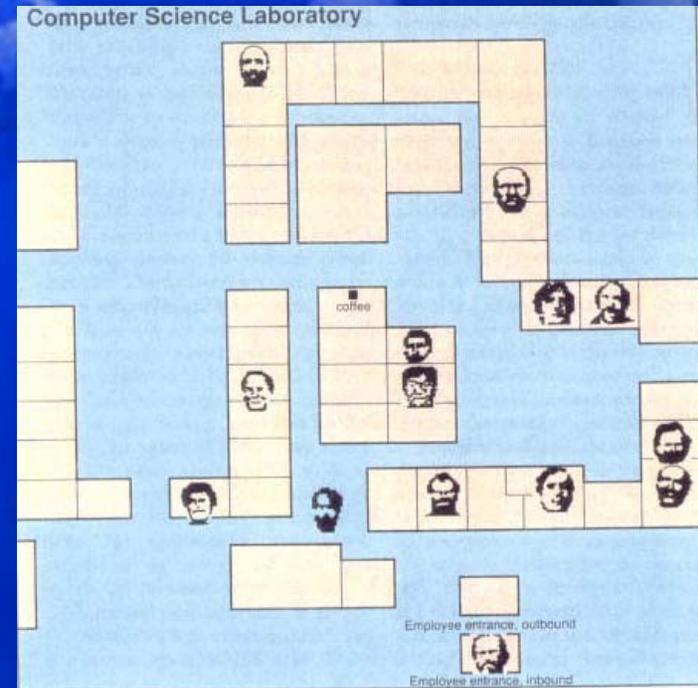
Some Early History

■ Active Badges 1988-

- Smart telephone networks
- Interested in the problem of automatically routing telephone calls to the correct place in a building
- Gave rise to the creation of the Active Badge project
- Project turned out to be not just a peripheral for Pandora but opened up a whole new area of research for me and helped me realize the new opportunity for context based computing.

In-Building Location Systems

Active Badge



Olivetti Research Hardware

Xerox PARC/EuroPARC *AIR project *Ubicomp



Lesson 1

- **People really care about personal and ubiquitous technologies, so be prepared to have many long debates about how these technologies are used**
 - Long discussions with colleagues
 - Many very emotional arguments about
 - Privacy
 - Security
 - Access control of the data
 - System architecture

Lesson 2

■ The press 'love' stories about ubiquitous computing

- Lots of interviews requested
- Adding the human factor to computing makes it compelling material for journalists to write about
- Began to be very time consuming
 - But also lots of fun

BIG BROTHER, PINNED TO YOUR CHEST

IDs that track employees offer efficiency—but what about privacy?

Alarms do not go off when Andy Hopper ducks out of his Olivetti Research Laboratory office in the middle of the afternoon, nor do red lights flash. Just the same, within 15 seconds of his departure, any colleague who checks the employee-tracking data base at the lab in Cambridge, England, will discover he's gone. Not only that: By tapping into the data base from afar, any of the 5 million users of the world-wide Internet computer network—utter strangers, even—can find out who that Hopper has hopped.

When he's in the office, inquisitors can usually find out when he has visitors—and exactly who they are.

Hopper, director of the Olivetti lab, willingly sheds his privacy each day when he puts on his "active badge," a computer in the shape of a clip-on ID card. The badge signals its wearer's location by sending off infrared signals, which are read by sensors sprinkled around a building. The sensors, in turn, are wired to a

and track people in their daily activities. Already, global positioning systems keep tabs on cross-country trucks. And cellular phone systems act as tracking systems, since they must pin down the approximate location of every customer to deliver incoming calls via the closest antenna.

But as the use of such systems spreads, government and business increasingly will be challenged to balance the individual's right to privacy with cor-



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Business Week '92

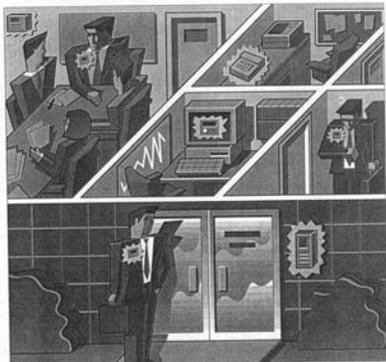
Track People with Active Badges

DICK POUNTAIN

You're in a meeting with a colleague, far from your desk, and you need to consult some figures from your PC. You approach your colleague's workstation, and as if by magic your own customized desktop appears. This is just one way that an electronic location system could enhance a computer network; you might also have phone messages or E-mail routed to the workstation nearest to you, or check a workstation display to find the whereabouts of another colleague. Electronic location, or Active Badge, systems like this are finally emerging as a commercial reality.

Current location methods have their inconveniences. Broadcast techniques, like ringing around all extensions or hailing via a public-address system, cause disruption and annoyance to everyone. Beeper-based paging systems work well only if the sought person chooses to answer, as anyone who has worked on a hospital switchboard knows. An electronic location system, whether used by a human receptionist or connected to a call-forwarding PBX, can overcome all these problems.

Olivetti Research Ltd. of Cambridge, U.K., a research organization jointly funded by Olivetti—Europe's largest



Electronic location technology tracks your location within a network site and allows your system resources to follow you

Such location systems raise ethical concerns, as they have the potential to be abused by overzealous management to create almost Orwellian surveillance regimes. But this could be said of other network and telephone monitoring devices that are beneficial when used properly.

[JOB strategies]



Coming: Employee trackers

Roy Want, inventor of the Active Badge, says that in professional settings where employees often stray from their desks, his gadget is an efficient way to track someone down. The advantage to the employee: fewer missed phone calls and unnecessary interruptions. (If the badge, made by Olivetti, indicates that you're in an office meeting with three or four other people, your boss or coworker may choose not to disturb you.) Also, the pager could make a critical difference wherever employees need to be found fast—in hospitals, for instance, or potentially dangerous work environments like chemical plants.

But, warns Evan Hendricks, editor of *Privacy Times*, "Once the badge becomes easily available, there's nothing stopping lots of employers from using it to monitor their workers." In other words, the badge enables your boss to chart your whereabouts around the office and, possibly, use what she finds against you.

Employees, take heart. The Active Badge isn't foolproof: Placed in a dark drawer or face-down on your desk, it temporarily shuts off.

—Susan Vintella

Glamour Mag '93

PC World '90

9/27/2001

Orwellian Dream Come True: A Badge That Pinpoints You

By LEONARD SLOANE

Is Big Brother your boss? Another tool that lets "them" check up on "us"—where we are and with whom we are—is on the way. It is the active badge, a small clip-on microcomputer, about the size of an employee I.D. card, that transmits signals to a central system. As long as you wear the badge, the system can track your movements around an office building or even a larger area.

"When different people need to be found, I can ring directly to where they are," said Roy Want, who invented the active badge while at the Olivetti Research Laboratory in Cambridge, England, and who is now a member of the research staff at the Xerox Research Center in Palo Alto, Calif. "It's in your interest as a professional to stay in touch with your colleagues."

Andy Harter, a research engineer at Olivetti lab, added: "I get my communications so much faster when I carry the badge. And it's all completely hands-free."

For many people, however, privacy issues overwhelm any technological virtues of active badges. They see the badges as an intrusion into the lives of employees, eroding workplace privacy. And they compare the badges with the already widely used electronic monitoring devices that can quantify the number of keystrokes on a terminal, peek at voice and computer mail messages or listen to employees transact business on the phone.

"George Orwell would have been pleased," said Donald A. Norman, chairman of the cognitive science department at the University of California at San Diego. "This technology makes snooping easy. Especially intrusive technology should be under the control of the person using it, not of management."



Illustrations by Tom Elton

Evan Hendricks, editor of the *Privacy Times* newsletter, said: "There's a lot of surveillance in the workplace these days. They could say you were in the men's room or the cafeteria too long or that you were sitting in so-and-so's office too long. It has the potential of changing the modern office into an electronic sweatshop."

Visions of an electronic sweatshop.

Mr. Harter of Olivetti said that although active badges were still being tested, there were plans to make them available commercially starting next year.

The target market includes not only office workers, who are away from their desks, but also doctors and patients in hospitals or nursing homes, lawyers and laboratory scientists.

In addition to being worn by people, badges can be attached to objects, like luggage in airports or raw materials in factories, to track their progress.

Olivetti officials say active badges were initially developed about four years ago as a means of making



telephone communication more effective. Scientists at the laboratory found that with a badge emitting an identification code every 15 seconds—in the form of an infrared beam—to a network of wall-mounted sensors around a building, information about the location of the person wearing it could be constantly updated. The badge functions the same way that a remote control device does in transmitting a code to a television set.

The second generation of active badges is now being tested, with researchers in England and the United States wearing them for the purpose. This version, called the authenticated badge, is designed to assure that the signal is authentic, to prevent tampering with the system.

New York Times '92

Badges monitor staff

TWO OF THE STAFF AT THE LAB



Orwellian implications? — "Everyone trusts everyone else"

By Caroline Green
There are no secrets at Olivetti's research labs in Cambridge. Staff there are now wearing infrared "active badges" which monitor their every move.

But Liberty, previously known as the National Council for Civil Liberties (NCGL), has warned that such a system is open to abuse.

The badges, which measure about 5cm by 5cm by 0.5cm, clip on to the clothes, and are equipped with transceivers that send an infrared signal to sensors positioned around the building.

The signals are then transferred to PCs and workstations on a Lan, and staff can therefore be located at any time while in the building.

A research engineer at the lab, Mark Chopping, said the system has no Orwellian implications because the wearing of badges is optional. "And everyone trusts everyone else," he added.

But a number of unnamed companies are looking at the technology, which was developed in-house by Olivetti, and Chopping admits it could be abused if used as a clocking-in device in offices and factories. "I can see there could be problems. To some extent it depends on the attitude

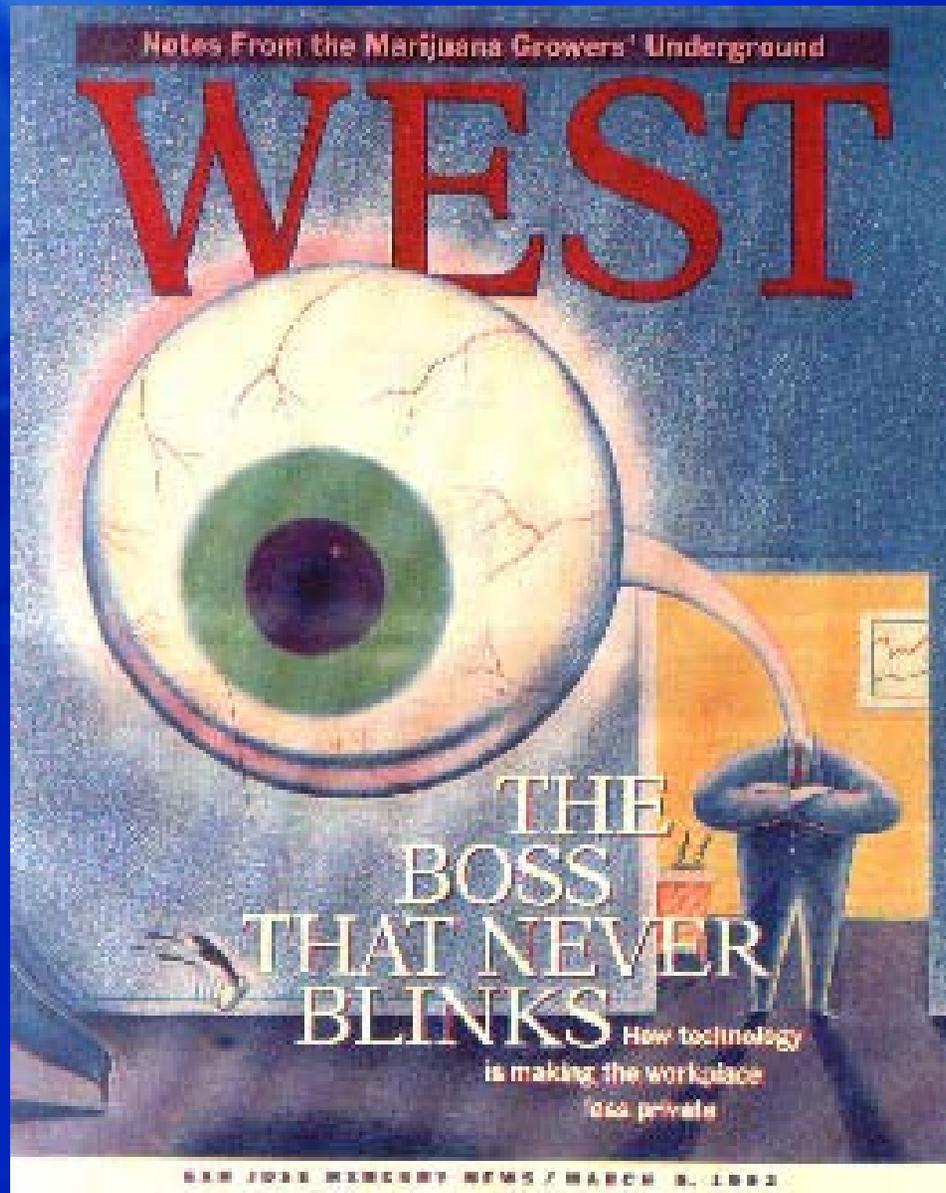
of the management," he said. A spokeswoman for Liberty said: "This system is wide open to abuse. We are very concerned that new technology such as this gets introduced with no safeguards to control its use. "This could potentially invade people's privacy."

Lesson 3

■ Beware of the Press

- Initially benign
- But you might be surprised how two-faced journalists can be

■ **Imagine you are sitting down to breakfast on a Sunday morning and have just opened your Sunday newspaper.....**



Lesson 4

- **Only building something actually allows you to explore its full design potential**
 - Badges had a one button interface for testing the system
 - Button became a command interface
 - One command
 - One command for every location
 - One command for every location with a difference combination of people at that location
 - One qualified bit, turned out to have N-way depth
 - Our first context-aware applications were built using this button

Lesson 5

■ Successful technology adoption is very dependent on the culture of the target users

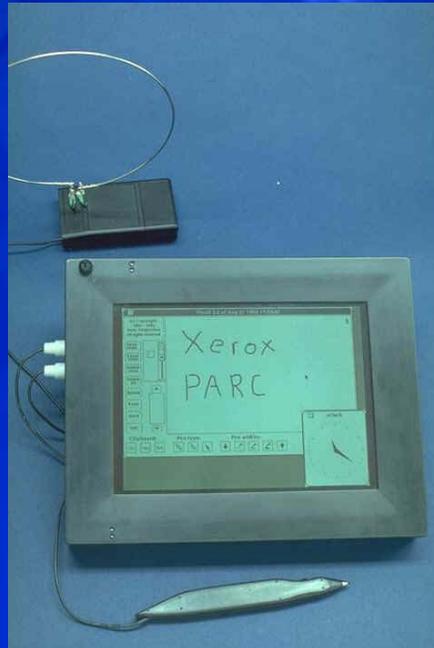
- Badges were adopted at Olivetti Research because there was a display for the receptionist to route telephone calls to the correct room – this was valuable
- Badges were adopted at Europarc initially just because they were cool to have and everybody wanted to be part of the club.
 - Later the trend reversed and equally quickly people did not want to wear badges anymore

Ubiquitous Computing

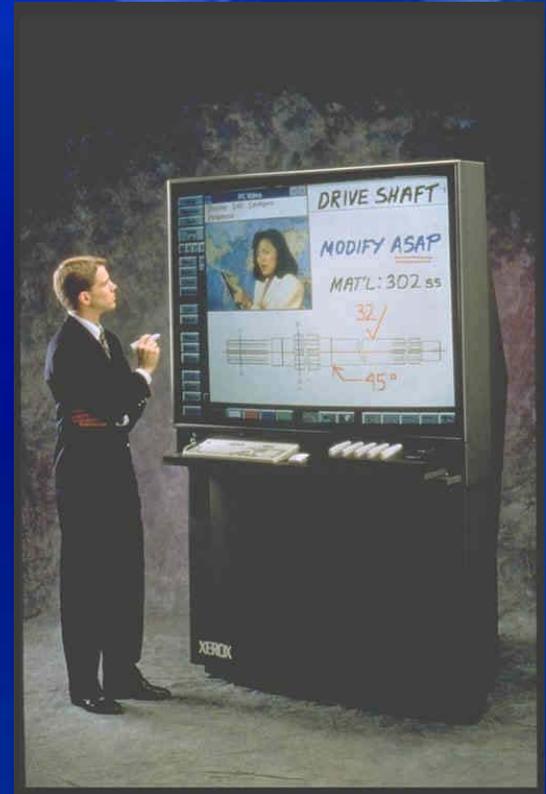
- Ubiquitous Computing Phase I 1988-1995
 - Parctab (inch) , ParcPad (foot), Liveboard (yard)



Wearable



Carryable



Fixed



PARCTab Applications

- **Palm Internet terminal**
Best PDA in the world

- **Communication**

- Email
- Video window

- **Collaboration**

- Group pointing
- Group voting

- **Remote Control**

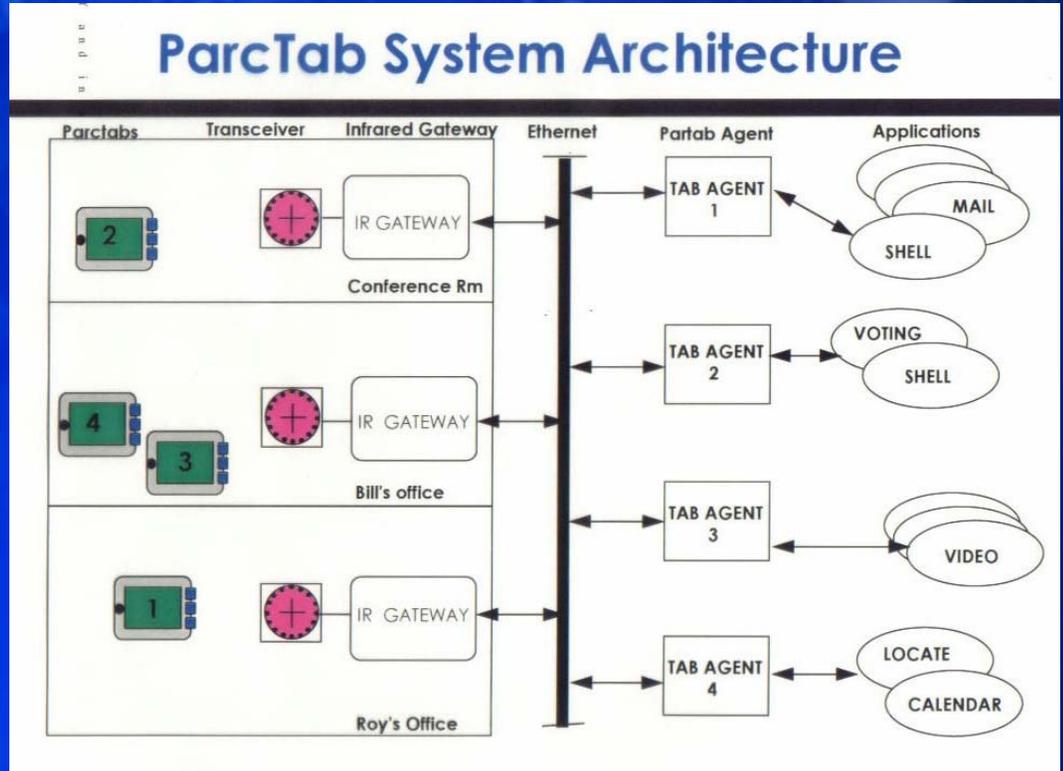
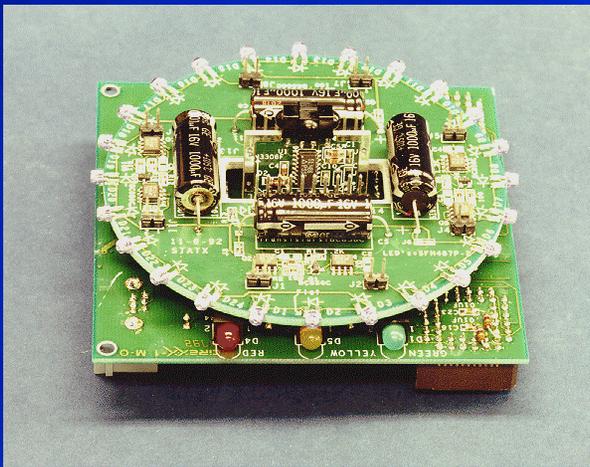
- Reactive Environment Project (temp, lights etc)

- **Local operation**

- Data cache
- Applications (note taking editor with automatic upload)



Parctab Project



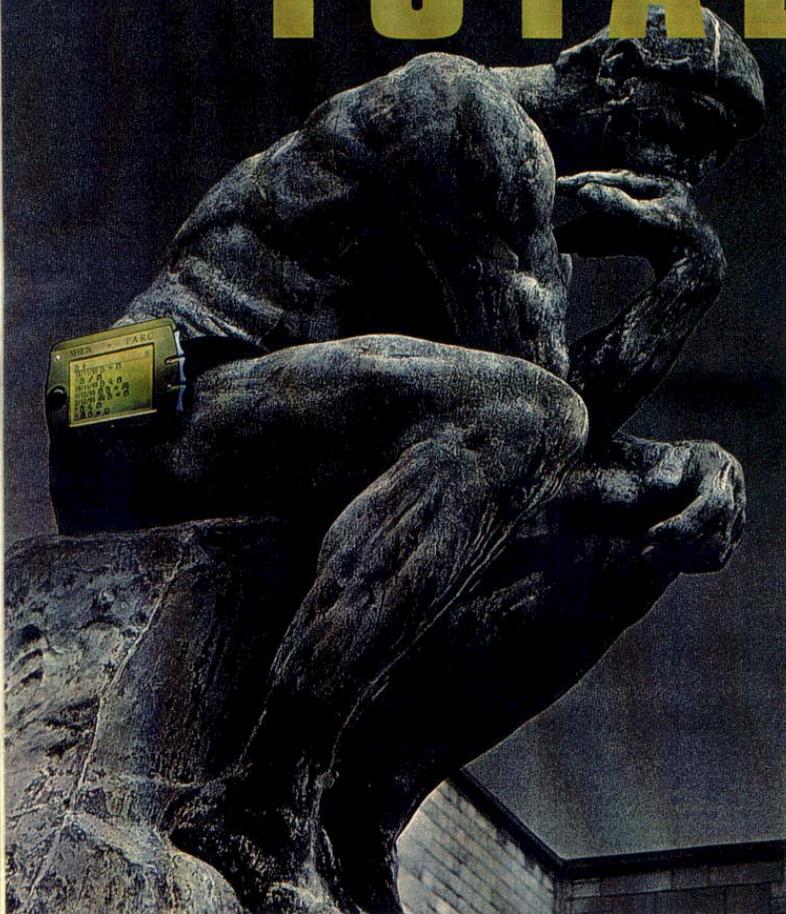
Diffuse-IR Wireless micro-cellular PDA



Lesson 6

- Its really hard to get people to adopt a new way of doing something unless it brings a new level of utility
 - Parctabs could be used to give great visitor demonstrations
 - They were initially very popular for reading email with
 - **PROBLEM:** Everywhere a Parctab Infrared micro-cell existed there was also a powerful workstation.
 - The workstation was a much better platform for reading email
 - The exceptions were conference rooms, but then 20 people would try to use Tabs simultaneously and the utilization of the network would approach 1 making it very slow to use.

TOTAL



RECALL

Today's computers remember only what you tell

Y

ou're at the office, and you must call back that important executive you met at the sales conference. But you misplaced his business card, and can't remember his phone number—let alone the name of his company. So you unclip a small, pager-size device from your belt or wristband and press a few buttons. A list of all the people you met last week appears on the LCD, grouped by date. You scroll through the list and then touch the screen above the name "Rod

them. In the future, computers may remember everything you do—and where you did it—automatically.

BY

ROBERT
LANGRETH

Smith." Bingo. His title, address, and phone number pop up.
Later the same day, you're at home getting ready to go to the Johnson's party. But where did you put the directions? No problem. You take out the palm-size gadget and review the log of where you went after getting the mail last Monday. The icons indicate that you opened the refrigerator at 18:53, then at 18:56 went to the bedroom. Sure enough, you find the invitation hiding on the nightstand under a book.

Xerox's prototype mini-computer/memory aid is worn by Rodin's "Thinker," who seems to need it.

Wouldn't it be amazing if you had a tiny computer on your belt that remembered everything you forgot? Not a glorified appointment book like today's PDAs (personal digital assistants), but something that tracked your past and then regurgitated it whenever you forgot something?

PHOTO: JEFF REYNOLDS FOR

POPULAR SCIENCE FEBRUARY 1995 • 47

Popular Science, 1995

intel®

Lesson 7

■ Build applications so that they are high quality, customizable and have appeal

- We always tried to make our prototype hardware have the physical appearance of a commercial product
 - This really helped in deploying our technology to an existing user community
- However, we initially tried to enforce the look and feel of our devices e.g. labels, the iconic look of applications etc
 - This cause more problems than it was worth
- User customization was key to integrating with an existing community.
- Invisible computing was much more appealing for the Press to understand.

Invisible
computing is
received very
well

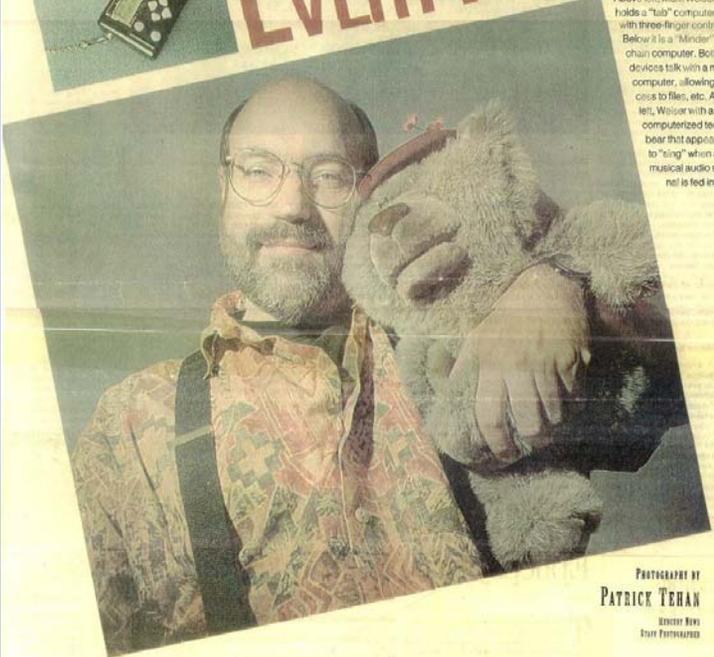
SECTION F ■ TUESDAY ■ JANUARY 6, 1998 ■ SAN JOSE MERCURY NEWS

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SCIENCE & TECHNOLOGY



Here, there and EVERYWHERE



Above left, Mark Weiser holds a "tab" computer with three-finger controls. Below it is a "Minder" key chain computer. Both devices talk with a main computer, allowing access to files, etc. At left, Weiser with a computerized teddy bear that appears to "sing" when a musical audio signal is fed into it.

PHOTOGRAPH BY
PATRICK TEHAN
SANTA FE
STAFF PHOTOGRAPHER

Xerox PARC scientist envisions a future of computers that all but think for us

BY ELIZABETH WASSERMAN
Mercury News Staff Writer

SITTING in his cluttered corner office at Xerox's Palo Alto Research Center, Mark Weiser is describing a future in which computers embedded into everyday objects—your wallet, your kitchen appliances, your chair, your car—commu-

nicate with each other as you go about your daily routine.

For one thing, you won't have to wonder whether you need to buy milk while standing clueless in the grocery store aisle.

"If your refrigerator

watches you take the milk carton in and out every day and your refrigerator could talk to your wallet," Weiser said, "then when you went to the store, the wallet could tell the milk cartons that you need milk. And the milk cartons

then say to you, 'Hey, buy me. You're out of milk.'"

Weiser, PARC's chief technologist, is credited in research circles with coming up with the concept now known as ubiquitous computing, what some see as the next revolution in computer science.

See WEISER, Page 2F

THE CUTTING EDGE

San Jose Mercury News, 1998

Invisible Computers

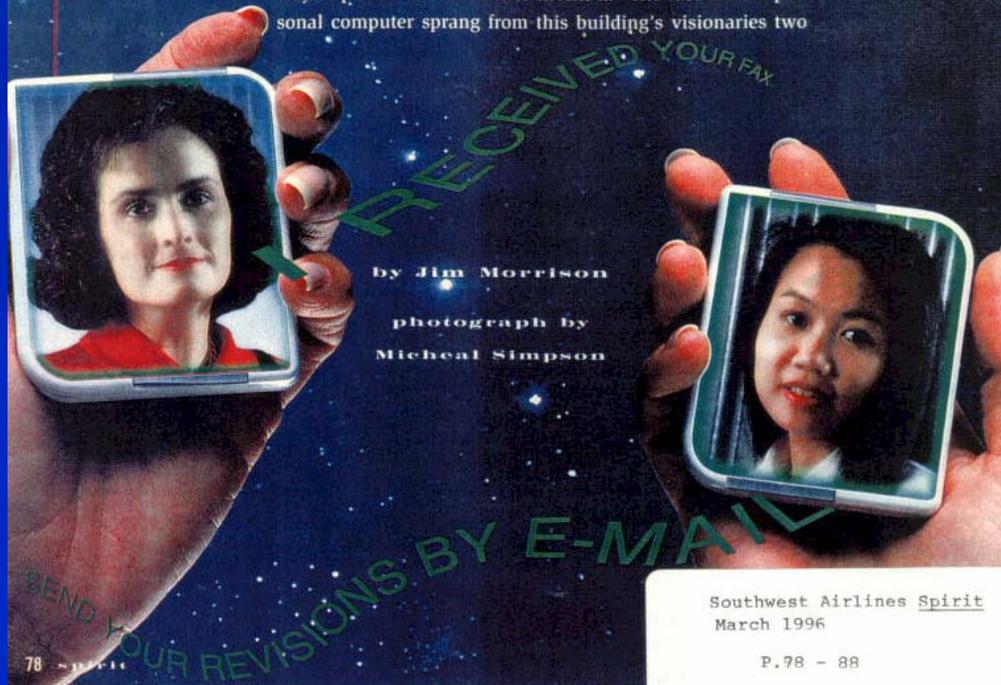
Program yourself for a technological revolution that promises remarkable global benefits while raising serious questions about the future of personal privacy.

Marvin Theimer beckons me into his office and a glimpse of the near future. We are deep inside Xerox's Palo Alto Research Center, a concrete-and-glass creation topped by hanging vines and partially buried in a hillside overlooking Silicon Valley. Across the water, the Golden Gate Bridge lies within an afternoon haze. Along the road leading up to the center, horses, reminders of a time before modern technology, graze on rolling hills.

Since PARC, as it is called, opened in 1970, the researchers there have measured up to a challenging credo: "The easiest way to predict the future is to invent it." The idea for the personal computer sprang from this building's visionaries two

by Jim Morrison

photograph by
Michael Simpson



Southwest Airlines
Mag. Spirit, 1996

Lesson 8

- **You only really get one chance to impress a user with a technology. A second chance is rare.**
 - Deployment of the PARC Ubiquitous computing infrastructure had the early prototype problem
 - Both Parctabs and Mpads had failure modes that were only discovered after deployment
 - Corrections were successfully made!
 - But some users were already tainted by their first experience
 - It is hard to change a belief

Lesson 9

■ It's a lot of work to deploy a Ubiquitous Infrastructure and ...

- We are going to wire the building!
- We are going to give everybody in the lab a true palm computer!
- We are going to create a new suite of context-aware applications

These systems represented a major deployment effort. Being an advocate means signing up yourself

■it's even more work to maintain it

- This taught me something about the type of systems I thought would be practical (perhaps products) in the future

E-tag project

- Label the world with passive electronic tags for identification and localization
- Use a mobile device as a reader but connect it to a wireless LAN
- Use the wireless LAN to provide a data channel back to the mobile

Key components



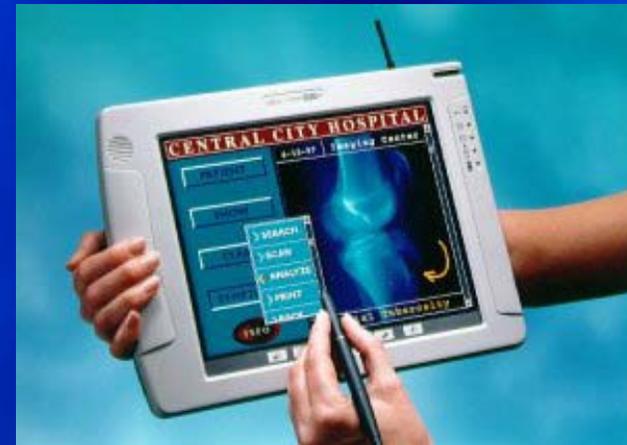
Wireless PC-Cards



Wireless Access Points



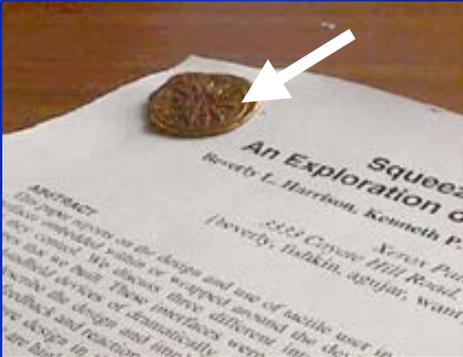
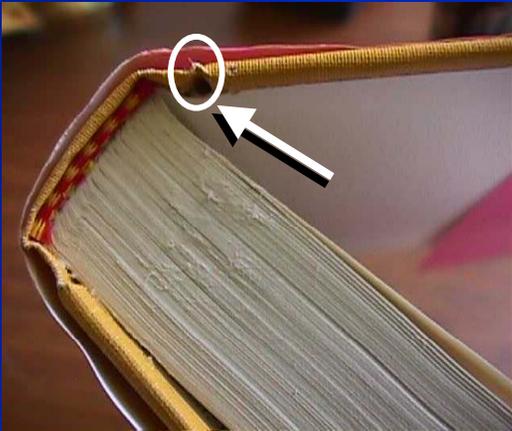
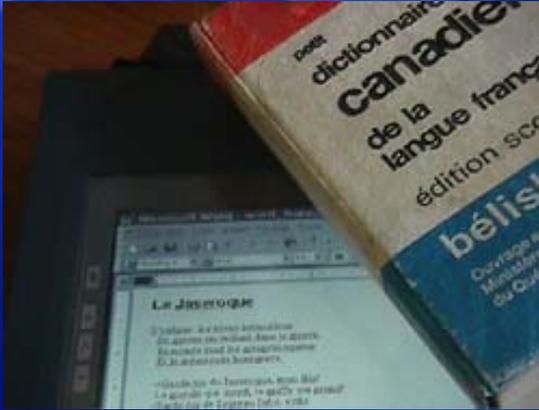
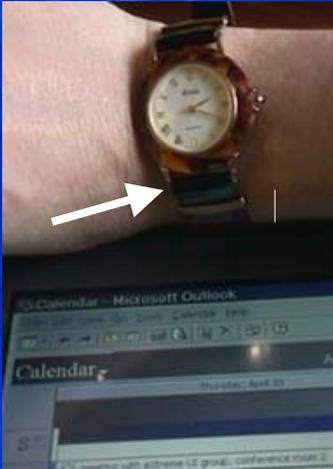
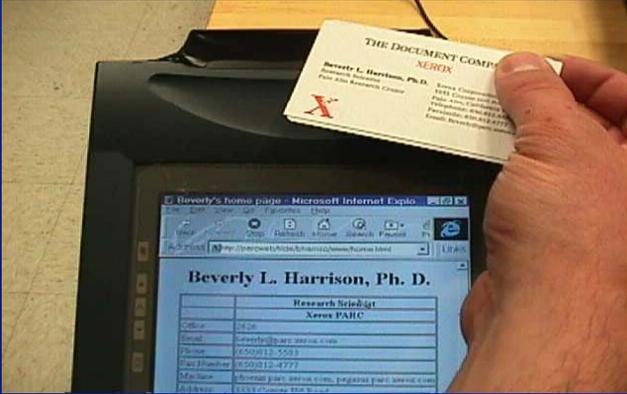
Electronic Tags



Portable low-power computers



Augmenting the World

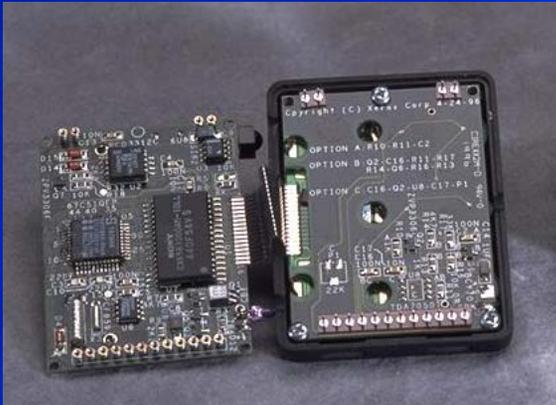


Other Examples of Scalable Ubiquitous Computing Projects

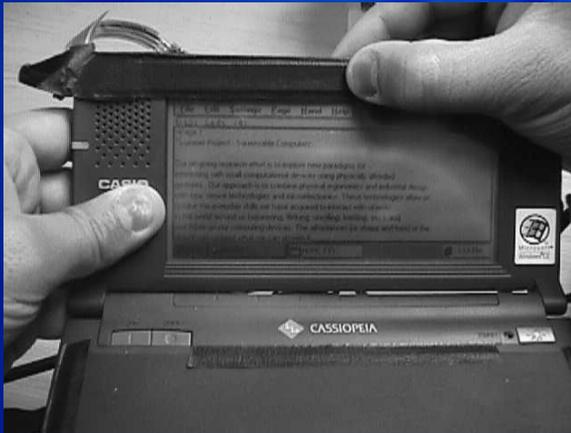
- **Key-chain Computing**
- **Manipulative User Interface project**

Keychain Computing

Uses existing IrDA port infrastructure – the right general approach



Augmenting the Computer



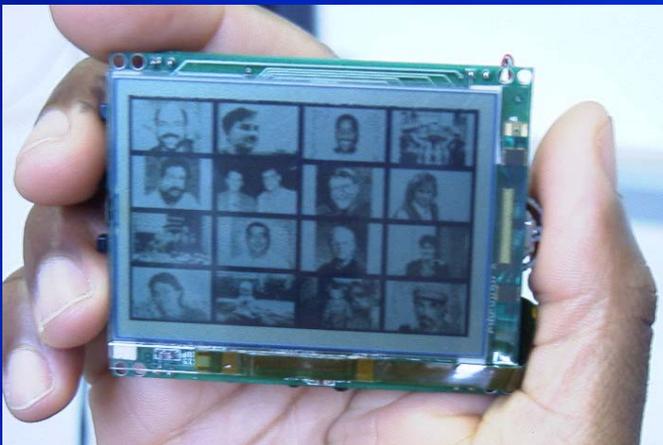
Cassiopeia with pressure strip



Pilot pressure interface



Pilot with 1D tilt interface



Xerox PARC/FX Hikari PDA
with 2D tilt (accelerometer) interface

Lesson 10

■ Listen to user experiences,but carefully filter their desires

- The problem is to figure out what they really want
- Very hard to ask people what they want before they have used it
- Quality really matters to users
 - Example Xerox Liveboard Project
 - Pen resolution was not good enough to provide an improved user experience over a whiteboard
 - Example Parctab
 - slow handset interactions are compared to a stand alone PDA with fast response

Summary of Lessons

1. People really care about personal and ubiquitous technologies, so be prepared to have many long debates about how these technologies are used
2. The press 'love' stories about ubiquitous computing
3. Beware of the Press!!
4. Only building something actually allows you to explore its full design potential
5. Successful technology adoption is very dependent on the culture of the target users
6. Its really hard to get people to adopt a new way of doing something unless it brings a new level of utility
7. Build applications so that they are high quality , customizable and have appeal
8. You only really get one chance to impress a user with a technology. A second chance is rare.
9. It's a lot of work to deploy a Ubiquitous Infrastructure and its even more work to maintain it.
10. Listen to user experiences, but carefully filter their desires

To find references to the projects described, please visit my web page
<http://www.ubicomp.com/want>



Roy Want

