Ten lessons learned about Ubiquitous Computing

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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

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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.

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In-Building Location Systems

Active Badge
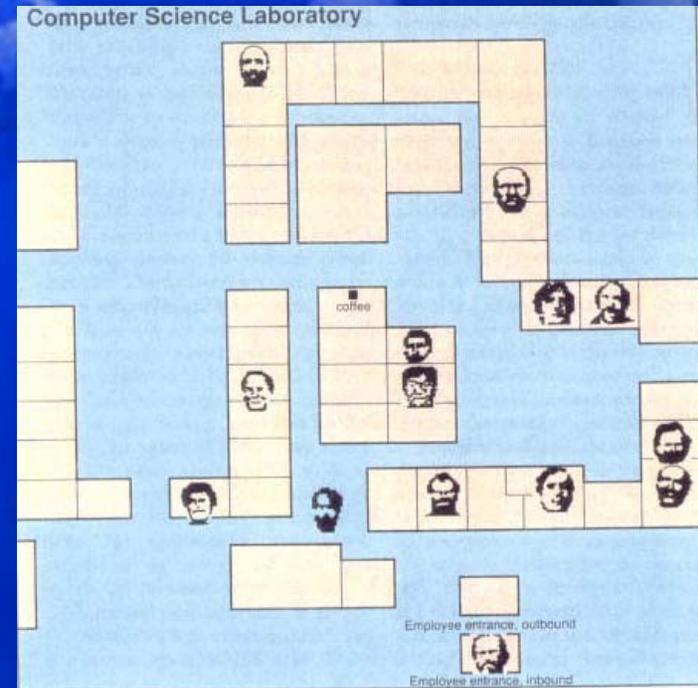
Olivetti Research Hardware

Xerox PARC/EuroPARC   *AIR project *Ubicomp

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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

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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

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Business Week `92

New York Times`92

Glamour Mag `93

PC World`90

Byte `93

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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.......**

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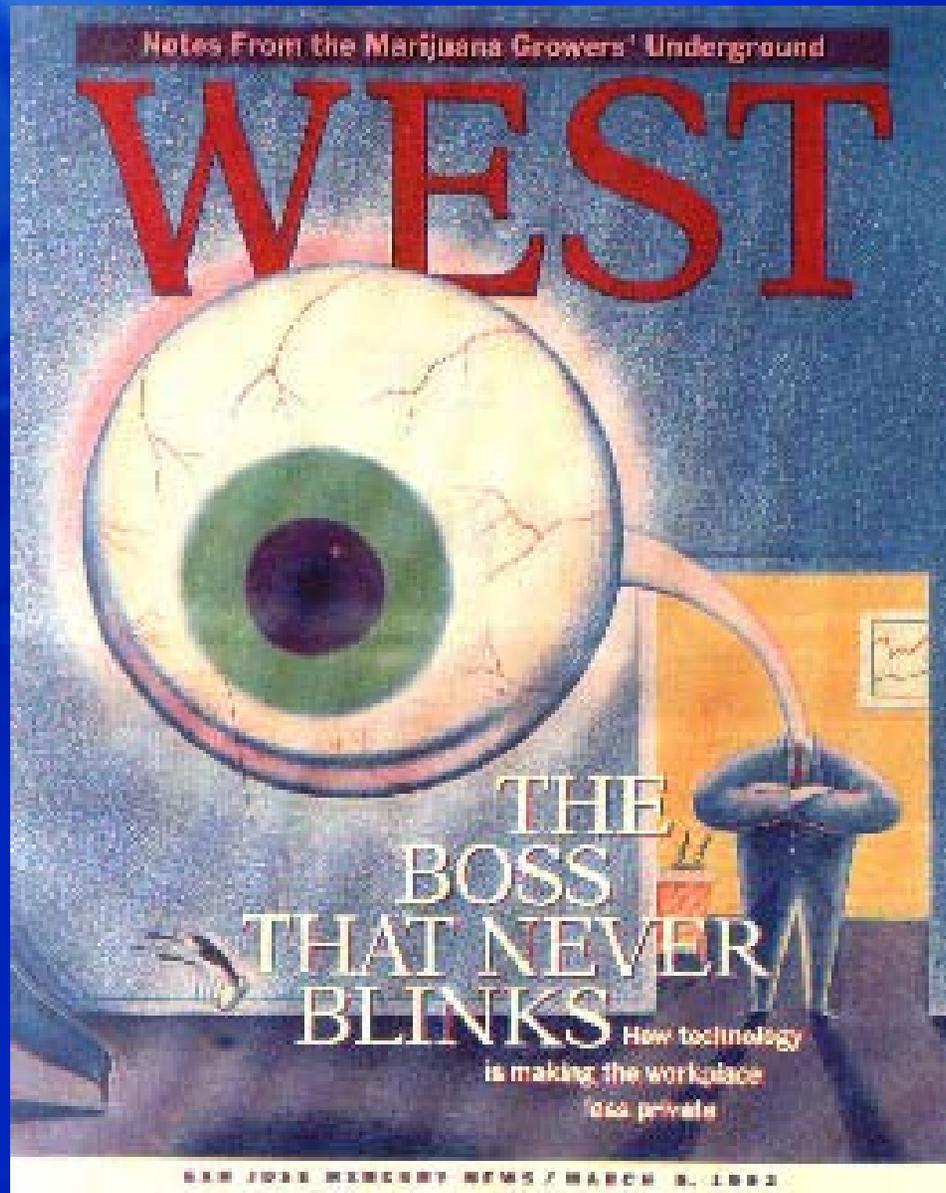
Lesson 4

- **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

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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

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Ubiquitous Computing

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

Wearable

Carryable

Fixed

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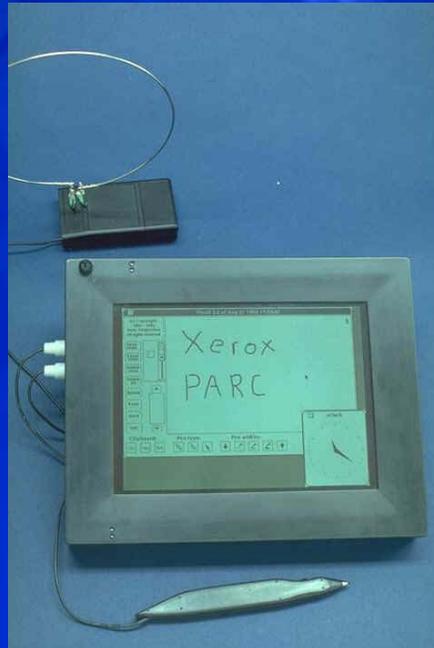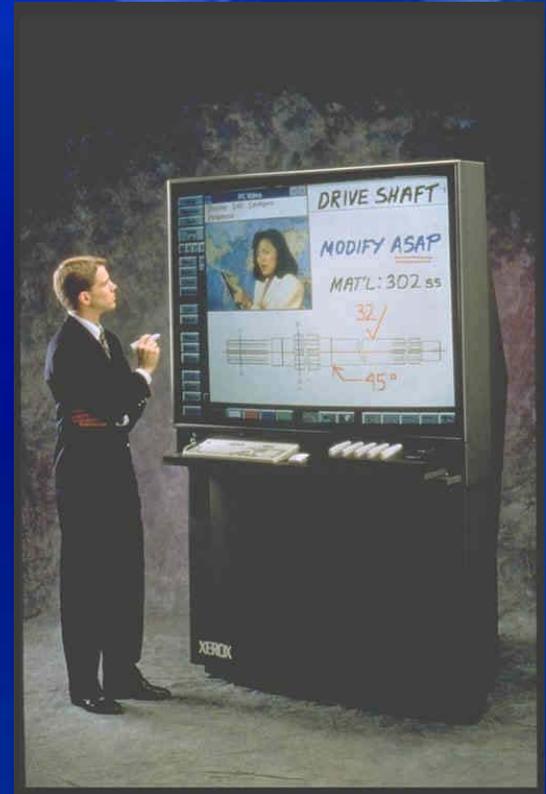
PARCTab Applications

- **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)

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Parctab Project
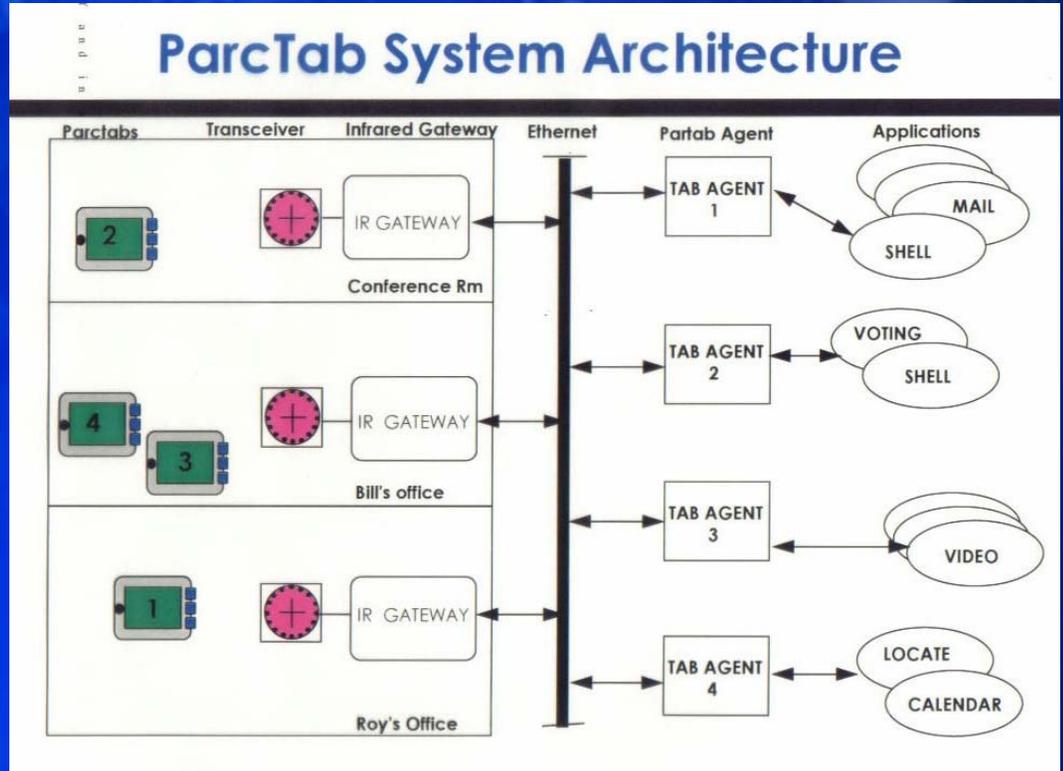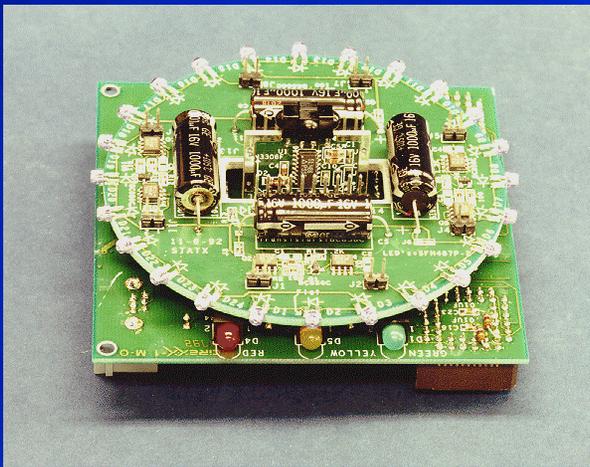
Diffuse-IR Wireless micro-cellular PDA

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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.

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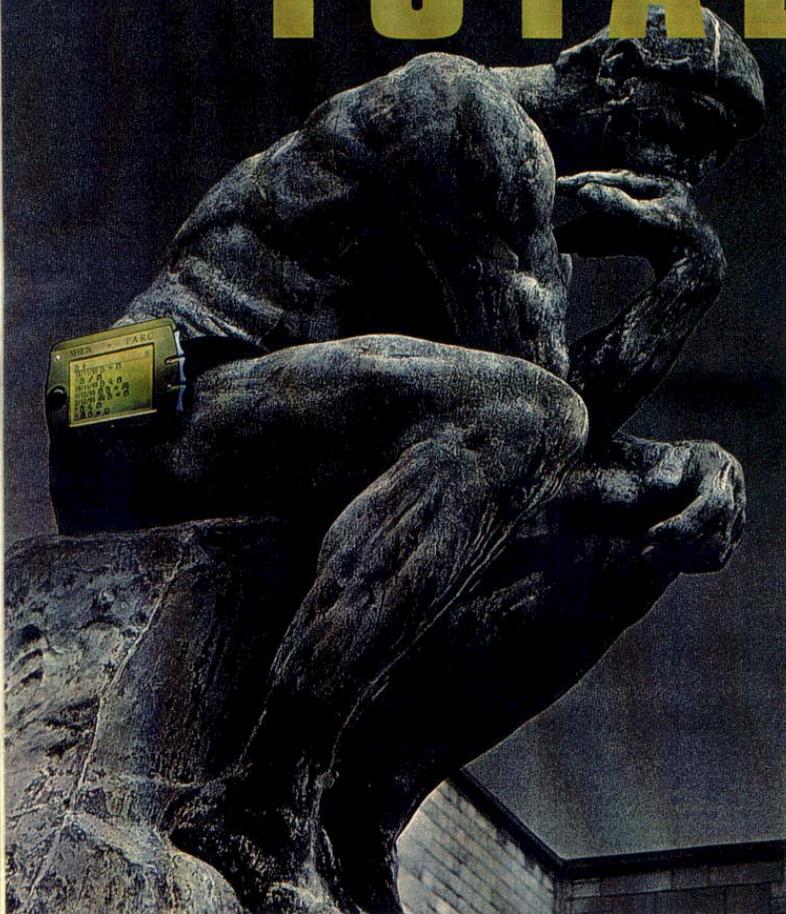
TOTAL RECALL

Today's computers remember only what you tell them. In the future, computers may remember everything you do—and where you did it—automatically.

BY ROBERT LANGRETH

You'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 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.

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?

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

Popular Science, 1995

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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.

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Invisible computing is received very well

San Jose Mercury News, 1998

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

Classified Ads
■ Buy it, sell it, find it fast with a Mercury News Classified Ad./3F

SCIENCE&TECHNOLOGY

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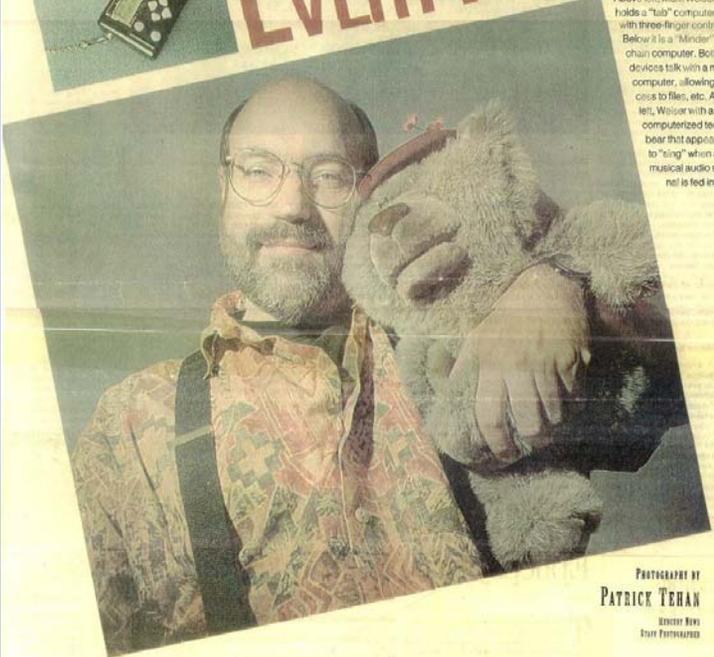
Above left, Mark Weiser holds a "tab" computer with three-finger controls. Below it is a "Minder" key chain computer. Both devices talk with a main computer, allowing access to files, etc. At left, Weiser with a computerized teddy bear that appears to "sing" when a musical audio signal is fed into it.

PHOTOGRAPHY BY
PATRICK TEHAN
MERCURY NEWS
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 — communicate 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 can 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

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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 Micheal Simpson

Southwest Airlines *Spirit*
March 1996

P.78 – 88
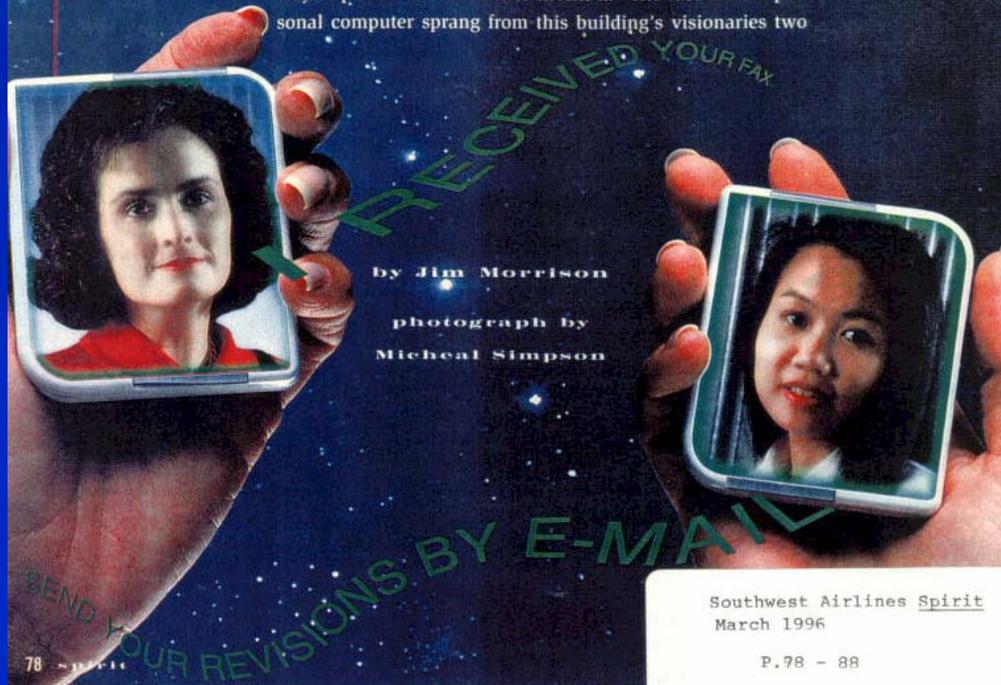
Southwest Airlines Mag. Spirit, 1996

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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

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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

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E-tag project

- **Label the world with passive electronic tags for identification and localization**

- **User a mobile device as a reader but connect it to a wireless LAN**

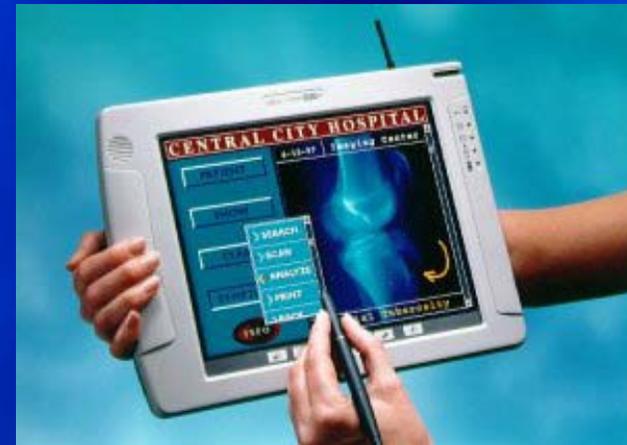- **Use the wireless LAN to provide a data channel back to the mobile**

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Key components

Wireless PC-Cards

Wireless Access Points

Electronic Tags

Portable low-power computers

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Augmenting the World

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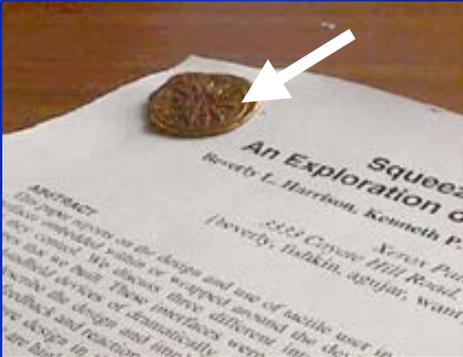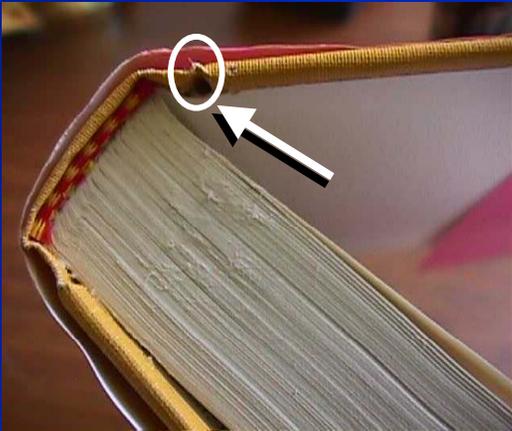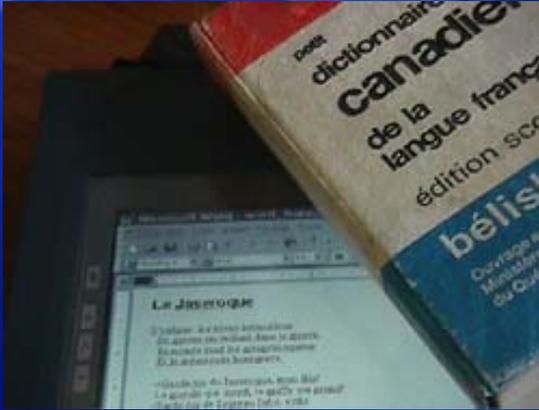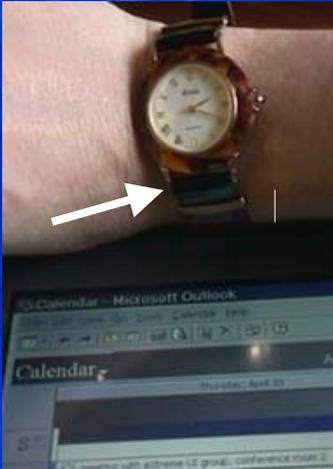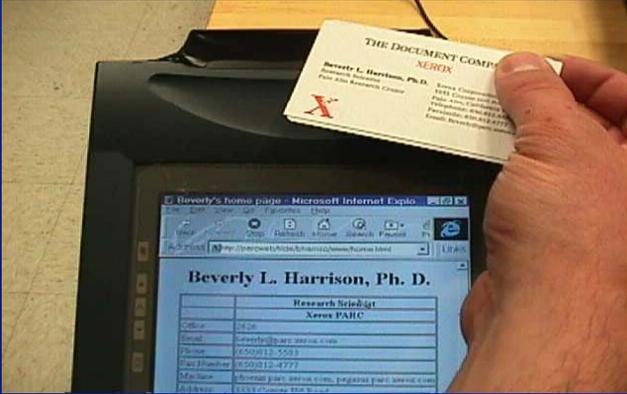
Other Examples of Scaleable Ubiquitous Computing Projects

- **Key-chain Computing**

- **Manipulative User Interface project**

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Keychain Computing

Uses existing IrDA port infrastructure – the right general approach

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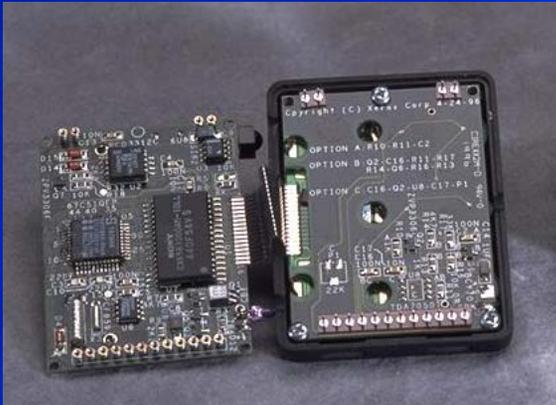
Augmenting the Computer
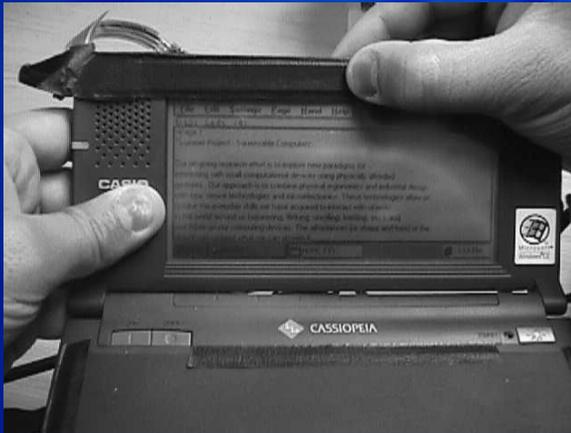
Cassiopeia with pressure strip

Pilot pressure interface

Pilot with 1D tilt interface
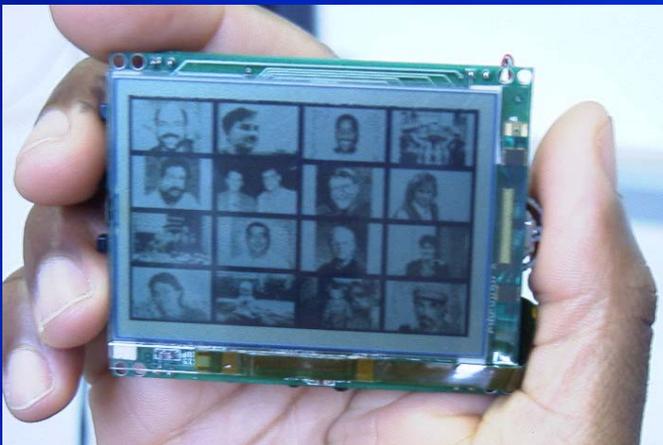
Xerox PARC/FX Hikari PDA
with 2D tilt (accelerometer) interface

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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

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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

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

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