

UBiQUITOUS cOMPUTiNG

Summer 2004



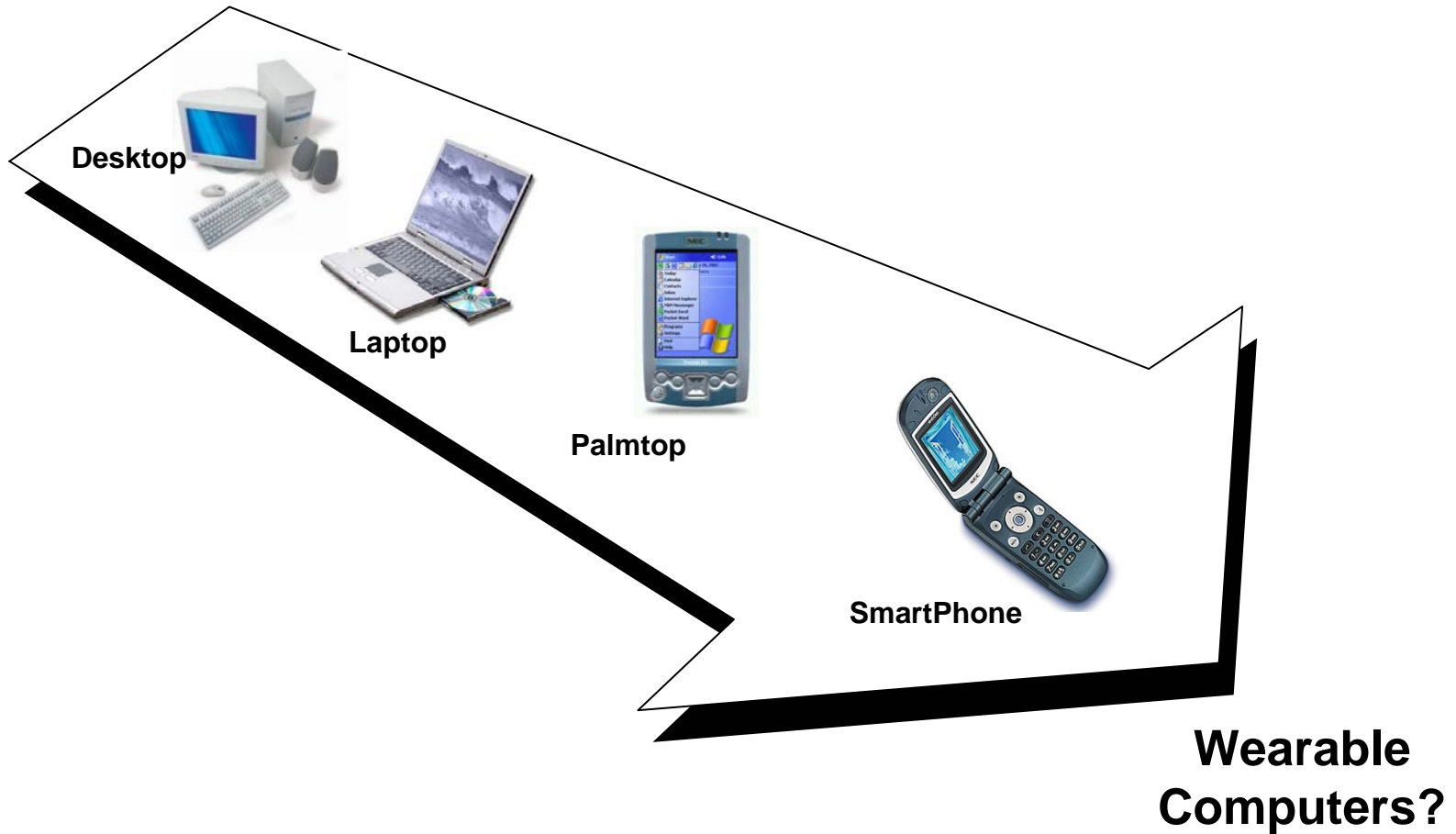
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WEARABLES

The Evolution of Computers?



WEARABLES

What are Wearables?

❑ Computer(s) carried at/on/in the (human) body

❑ Goals:

- **Supporting** mobile users
 - Tourist guides,
 - Language translators
 - Military services
 - Repair and Maintenance
- **Replacing** lost body functions
 - Prosthesis control,
 - Ear implants
 - Artificial eyes
- **Extending** the body functions
 - Persistent memory of recordings
 - New sensor functionalities



Deep Map Project
(EML Heidelberg)



Limb Prosthesis
(Robotics Laboratory
Politecnico di Milano)



Cyborgs?

Source: <http://robotica.mecc.polimi.it/>, <http://www.eml.villa-bosch.de/>

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Challenges in Wearable Computing

- ☐ A wearable computer is not just a mini-PC
- ☐ Old MIT definition:
 - always-on, always accessible, always with the user
 - also: comfortable, unobstrusive, easy-to-use
- ☐ Current MIT definition:
 - Mobile (where you go, it goes)
 - Persistent (always on and always working)
 - Secondary or tertiary tasks (Hands free, Eyes free, Brain free ...)
 - Proactive (Agents and interrupt)
 - Context aware
- ☐ Main Challenges:
 - ☐ Technology (Devices and Smart Clothing)
 - ☐ Energy efficiency
 - ☐ Ergonomics & Design
 - ☐ User interfaces

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History of Wearables

☐ Early examples of pure mechanical wearables:

- **1268** Earliest recorded mention of eyeglasses
- **1665** Robert Hooke calls for augmented senses
- **1762** John Harrison invents the pocket-watch



Harrison's H4

☐ Some early examples of electronic wearables:

- **1960** Ed Thorp and Claude Shannon: analog roulette computer in shoes
- **1960** Heilig patents a head-mounted stereophonic television display
- **1966** Sutherland: Head-mounted display (HMD)
- **1977** HP 01 algebraic calculator watch
- **1978** Eudaemonics: Digital roulette computer in shoes
- **1986** Steve Roberts: Winnebiko II, bicycle with on-board computer



HP 01



Head-Mounted Display



Winnebiko

Source: <http://www.media.mit.edu/wearables/lizzy/timeline.html>, <http://www.microship.com>,
<http://www.hpmuseum.org/>

The first Wearable Computer

- ❑ Developed by Ed Thorp and Claude Shannon to predict roulette numbers
- ❑ An **analog computer** the size of a cigarette pack, was linked to microswitches in the wearer's shoes.
- ❑ **Input was big toe pressure** at the moment when a wheel's spun ball passed a reference mark and when it passed it again, allowing to calculate speed.
- ❑ **Output was in the form of tones** through the bettor's hearing aid.
- ❑ Conceived by Thorp in 1955, built in 1960-1961 and tested by a nonchalant Thorp, a nervous Shannon, and their wives in a Las Vegas casino in 1961.
- ❑ „Predictions were consistent with the laboratory expected **gain of 44%** but a minor hardware problem deferred sustained serious betting.“

Thorp first went public with his story in 1966.

By 1985, Nevada would ban "use or possession of any device to predict outcomes, analyze possibilities of occurrence, analyze strategy for playing or betting, and keeping track of cards played."

Thorp observes: "The descendants of the first wearable computer were formidable enough to be outlawed."

THE ViSiON

Examples: The Eudaemonic Gambling Shoe

- ❑ The first digital wearable computer was developed 1978 by a group called „**Eudaemonic Enterprises**“ (Doayne Farmer, Norman Packard and others)
- ❑ Computer (6502 CPU) fitting in a shoe had toe-operated buttons for input (the left toe switched through eight data-gathering modes, while the right increased or decreased pre-programmed game parameters). Radio frequency output transmissions were felt by the bettor as tapping against the body through solenoids.



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Example: Active Badges (Olivetti Research Lab, Cambridge, 1988)

- ❑ Developed 1988-92 in Cambridge in the Olivetti & Oracle Research Laboratory
- ❑ Worn by users to locate them on the campus
- ❑ Mobile IR Sender for persons and equipment
- ❑ More than 1500 badges and 2000 senders have been produced

Third Version
48 bit code
bidirection
87C751
microprocessor



Second Version
10 bit code

First Version
5 bit code

WEARABLES

Xerox PARC – Parc Tab System (since 1992)

- ❑ Mark Weiser
- ❑ Main components are three classes of devices which are used in offices:



▪ Tabs

Tiny computer, analogous to tiny individual notes or Post-it notes, also similar to the tiny little displays of words found on book spines, light switches, and hallways.



▪ Pads

Laptop size, analogous to scrap paper to be grapped and used easily, with many beeing used by a person at the same time



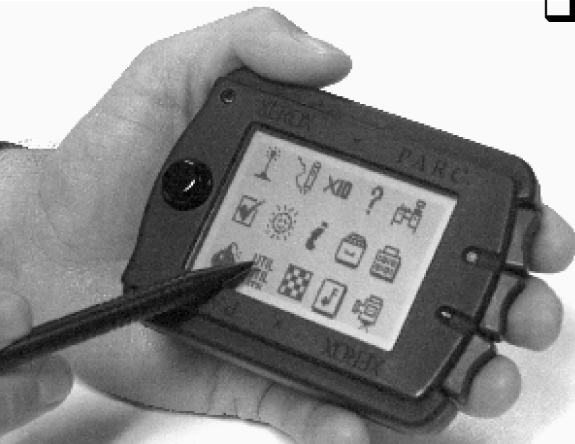
▪ Liveboards

Wall-sized interactive surface, analogous to the office whiteboard or the home magnet-covered reffridgerator or bulletin board.

WEARABLES

Xerox PARC - **PARCTAB**

- ☐ Post-it like device (many per user)
- ☐ Unistroke input using stylus
- ☐ Dimensions: 10.2 x 7.8 x 2.4 cm
- ☐ Weight: 215g (7oz)
- ☐ Screen: 6.2 x 4.2 cm, 128 x 64 monochrome pixels, 21 chars x 7 lines
- ☐ Touch input: passive pressure sensing, Button Input: three finger switches
- ☐ Sound: Piezo electronic tone generator
- ☐ Wireless Interface: IR at 850nm, DEC/Olivetti active badge compatible
 - 6 Emitters, 2 Detectors, Datarate: 19.2 baud
- ☐ Processor: Intel 8051-type (Signetics 87C524/528, 12 MHz)
 - ☐ Memory: 8K (v1) 128K (v2) RAM
 - ☐ Ports: I2C external bus, recharge port
 - ☐ Battery: 12 hours continuous or estimated 2 weeks normal use, rechargeable
- ☐ Case: Plastic with a removable belt clip
- ☐ Supports left and right handed use by flipping display automatically

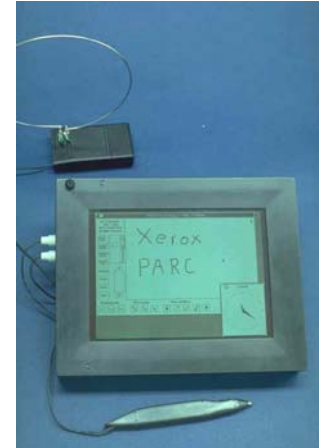


Source: <http://www.ubiq.com>

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Xerox PARC - PARCPAD

- ☐ Paper-Size device (some per user)
- ☐ Dimensions: 22.2 x 28 x 3.8 cm
- ☐ Weight: 51lbs 4oz
- ☐ Screen: 640 x 480 LCD Display (3 levels of grey)
- ☐ Pen: tethered electromagnetic sensing
 - ☐ Sound: Built-in microphone, speaker, piezo beeper
 - ☐ Wireless Interface: 250kbps radio, 19.2kbps IR
 - ☐ Processor: Motorola 68302, about 4 MB
 - ☐ External Ports: Stylus/micropone, PCMCIA, IMB Serial, RS232, I2C bus, keyboard
 - ☐ Internal Ports: second audio channel, ISDN, Expansion port
 - ☐ Battery: 3 hours (rechargeable)
- ☐ Used mainly as display and interaction means
- ☐ Computation is mainly performed at the server



WEARABLES

Example: Carnegie Mellon University

- ❑ **Wearable Computer Group** (<http://www.wearablegroup.org/>)
- ❑ Interdisciplinary project between computer scientists, electrical engineers, complex system designers and artists.
- ❑ Started in 1991 with 25 participants in a summer rapid prototyping course
Result: Vu-Man, since then more than a dozen wearable computers emerged
- ❑ Goal:
Investigating architectural and interface requirements of wearable systems

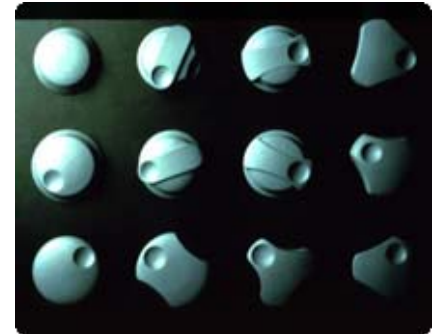


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Example: Carnegie Mellon University

- ❑ Hardware: **Vu-Man**
- ❑ VuMan 1 (1991), VuMan2 (1994), VuMan3 (1999)
- ❑ Wearable Computer with oversize controls for use with gloves or in cold weather.
- ❑ Rotating the dial moves the user through multiple-choice answers and pressing buttons makes the decision
- ❑ PCM flash cards hold up to 100.000 pages of manual documentation (e.g. airplane maintenance)

Vu-man received a 1995 International Design Award



Vu-Man 1



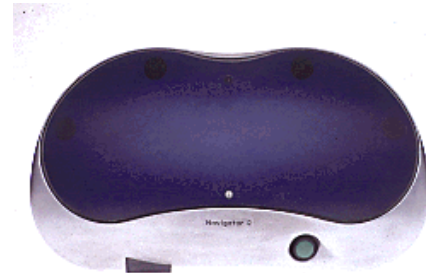
Vu-Man 2

Source: <http://www-2.cs.cmu.edu/~wearable/vuman.html>

WEARABLES

Example: Carnegie Mellon University

- ☐ Hardware: **Navigator 2**
- ☐ Multimedia wearable computer for a Boeing aircraft skin inspection application used by US Air Force to find cracks and corrosion (1995)
- ☐ Location and type of each defect is recorded on the Navigator 2
- ☐ Primary input is a joystick with 2-dimensional input for positioning on the aircraft model
- ☐ Used in conjunction with speech to mark discrepancies
- ☐ Field evaluations indicate 20 percent savings in inspection time and reduced inspection data entry time from hours to minutes



Navigator 2

Source: <http://www-2.cs.cmu.edu/~wearable/navigator.html>

WEARABLES

Example: Carnegie Mellon University

- ❑ Hardware: **TIA-P prototype**
- ❑ TIA-P incorporates a 100 MHz 486 processor in a ruggedized hand-held pen-based system designed to support speech translation and vehicle maintenance
 - Full duplex sound chip
 - 2 Mbps spread spectrum radio
 - 16 MB of main memory (upgradable to 32 MB)
 - 1.3 GB IDE disk drive



TIA Prototype

Source: <http://www-2.cs.cmu.edu/~wearable/tiap.html>

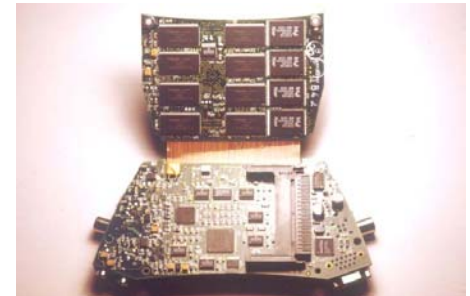
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Example: Carnegie Mellon University

- ❑ Hardware: **Spot**
- ❑ Developed as a platform for the exploration of interaction design, mobile ad-hoc wireless networking, and power-aware computing (2002)
 - Hardware accelerated 2D-graphics
 - Power management control functions
 - Customizable battery discharge function
 - Durable case
 - Flexible circuit board
 - Speech processing
 - Head-mounted displays
 - Wireless network included (2.4 GHz)
 - etc.



SPOT 3



Internal design



IBM Head mounted display

Source: <http://www.wearablegroup.org/hardware/spot/index.html>

WEARABLES

Example: Carnegie Mellon University



Vũ-Man 2R



Navigator 2



Spot

Feature	Vũ-Man 2R	Navigator 2	Spot
Year	1994	1995	2002
Type	embedded, fully custom	general-purpose, semi-custom	general-purpose, fully custom
Processor	13MHz 80C188EB	33MHz 80486SX (Epson Cardio)	206MHz SA-1110
Main Memory	1MB SRAM	12MB DRAM (Cardio)	256MB SDRAM
Nonvolatile Memory	256KB EPROM	–	64MB flash
Card Slots	1 PCMCIA	1 PCMCIA, 1 PCMCIA ATA	1 PCMCIA, 1 CompactFlash
Mass Storage	1MB PCMCIA flash	420MB PCMCIA hard disk	1GB CF+ hard disk
Serial I/O	RS232, RTC 2-wire interface	PS/2 (Cardio)	RS232, USB host controller, FireWire, I ² C/DDC bus, battery SMBus, RTC 2-wire interface
User Input	integrated rotary dial and buttons	audio, PS/2 devices	audio, serial I/O devices
Video	Private Eye direct interface	VGA controller (Cardio)	DVI with 2D acceleration
HMD	Private Eye 720 × 280	Virtual Vision VGA 640 × 480	IBM DVI prototype 640 × 480
Audio	–	TERI speech recognizer w/codec and 13MHz DSP (PCMCIA)	44.1kHz 16-bit 2-channel in/out
Wireless	–	915MHz WaveLAN (PCMCIA)	2.4GHz 802.11 (PCMCIA), custom internal dual antenna
Energy Monitoring	–	–	16 subsystem monitor channels
Battery	1200mAh NiMH @ 9.6V	1800mAh NiCd @ 12V	dual 1000mAh Li+ @ 11.1V
Power	2W	7.5W	1.4W
Size	160 × 130 × 50 mm	270 × 150 × 80 mm	155 × 75 × 35 mm
Mass	790 grams	1800 grams	270 grams
Operating System	–	MS-DOS	ARM Linux

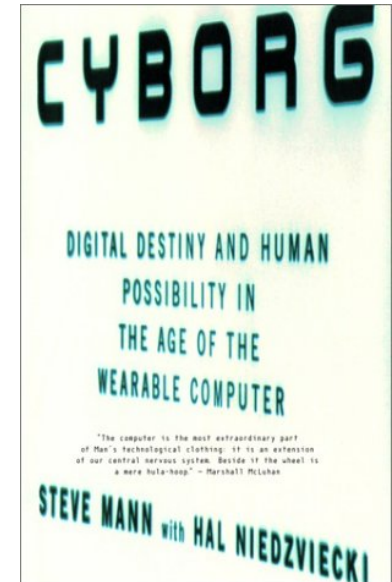
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Steve Mann (MIT, now Toronto University)

- ☐ Started to develop ,Cyborg‘ equipment in school
- ☐ Since the 1980s he is constantly warrying his ,WearComp‘
- ☐ He noticed two main trends:
 - The technology disminished (everything moved into sunglasses)
 - His ,Cyborg‘-feeling is growing over the years
- ☐ His main research is for privacy and social impacts



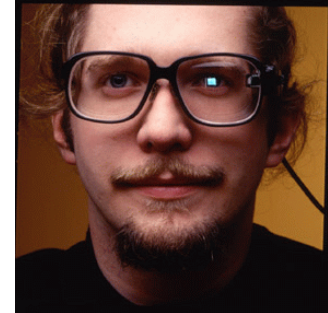
Steve Mann's "wearable computer" and "reality mediator" inventions of the 1970s have evolved into what looks like ordinary eyeglasses.



WEARABLES

History of Wearables

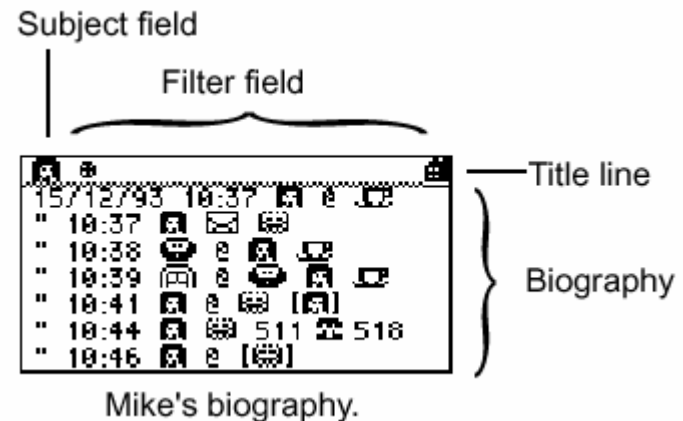
- **1993** Thad Starner (MIT) starts constantly wearing his computer which is later developed to the MITHril system
- **1993** Thad Starner (MIT) writes first version of the **Remembrance Agent** augmented memory software
- **1994** M. Lamming and M. Flynn: **Forget-me-not** a continuous personal recording system



Thad Starner



Forget-me-not on a ParcTab



WEARABLES

Example: MIThril

□ Goal:

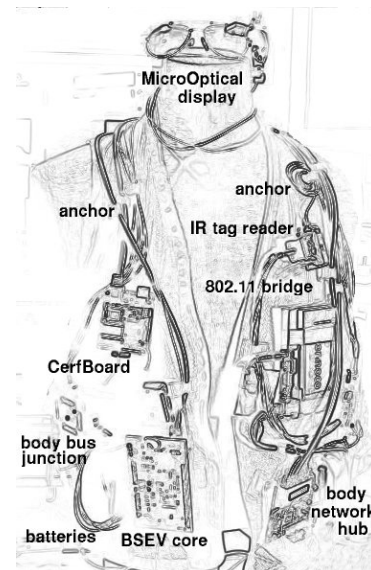
- Development and prototyping of new techniques of human-computer interaction for body-worn applications.
- Considering human factors, machine learning, hardware and software engineering
- Developing prototype applications for health, communications, and just-in-time information delivery.

□ Hardware platform:

Ergonomic distribution of sensors and networking elements in a clothing-integrated design.

□ Software platform:

combination of user interface elements and machine learning tools built in Linux



Source: <http://www.media.mit.edu/wearables/mithril/>

WEARABLES

Microsoft Research – The SPOT Project

- ❑ Microsoft's Smart Personal Objects Technology (SPOT) initiative turns keychains, pendants, and other objects into information-receiving devices that can bring subscribers news, weather, sports, stock quotes, and other bulletins via FM radio transmissions.
- ❑ SPOT devices will be sold with low-cost subscriptions for customized information retrieval.
- ❑ The first products will be Citizen and Fossil watches.



Source: <http://www.microsoft.com/resources/spot/>

EXAMPLES

Microsoft Research – The SPOT Project

- ❑ Magnetic alarm clock shows your schedule and let's you check traffic conditions while grabbing your keys from the kitchen counter



Source: PC Magazine

EXAMPLES

Intelli-Pen – Frog Design & Motorola

- ☐ Handwritten notes are recognized and stored in internal memory
- ☐ LCD panel can be used to review your notes later
- ☐ Data can be transferred with Bluetooth



Source: PC Magazine

EXAMPLES

Display Sunglass – Frog Design

- ❑ Integrated 800x600 pixel display
- ❑ Digital camera, ear bud and microphone



Source: PC Magazine

EXAMPLES

Smart Key Chain – IBM

- ☐ Bluetooth connection to cell phone
- ☐ Speech recognition and text-to-speech technologies for delivery of eMail or SMS messages



Source: PC Magazine

EXAMPLES

Cell Phone – Sony Ericsson

- ☐ Ordinary cell phone
- ☐ Plus: integrated beamer for contacts, calendars, etc. onto flat surfaces.



Source: PC Magazine

WEARABLES

Design of Wearables

- ❑ Example: **The Breakfast Tray** (Philips)
- ❑ Wooden tray with secure surface for breakfast in bed
- ❑ Soft base forms a stable, comfortable interface with the body
- ❑ Magnetic metal contacts integrated into the tray, cups and plates prevent from sliding about
- ❑ Contacts provide heating for coffee and croissants or cooling for orange juice
- ❑ Removable touchscreen allows reading of news and email



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Design of Wearables

- ❑ Example: **The foldable Display** (Carnegie Mellon University)
- ❑ Developed to address the problem of interacting with both simple and complex data in the same device
- ❑ Unfolded completely, the display screen is 8.5 x 14 inches

PDA size



Normal Size

Book size



Unfolded once

Web Browser size



Unfolded twice

Full Screen Size



Unfolded completely

WEARABLES

Design of Wearables

- ❑ Example: **Digital Ink** (Carnegie Mellon University)
- ❑ Can be used as normal pen but also offers new 'services':
 - Optical Character Recognition (OCR)
 - Send to fax, email, printer
 - Draw your own user interface on paper and use it (e.g. Calculator) !!!
- ❑ Prototype is under development



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Design of Wearables

Example: Digital Ink

wireless
link

LCD
display

battery charger
& PC connection



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Design of Wearables

- ❑ Example: **Promera** (Carnegie Mellon University)
- ❑ Handheld computer and projector
- ❑ Camera lens allows to take pictures or movies
- ❑ Inbuilt display and wireless communication means to the Internet
- ❑ Useful for medical diagnosis, navigation, maintenance etc.



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Design of Wearables

- Example: **Digital Jewelry** (IBM)
- Speakers, microphones, mobile phones, etc. included in jewelry



Mobile phone with
voice control



Wireless display
on wristlet



Ring flashes when
mobile phone calls

WEARABLES

Design of Wearables

- ❑ Example: **Java Ring**
(Dallas Semiconductor)
1million transistor chip
in finger ring allows for
remote computing using Java



- ❑ Example: **Communicator Eyepiece**
(Charmed Technology, Thad Starner)
Wireless, broadband-Internet
device that can be controlled by
voice, pen or handheld keypad



WEARABLES

Examples: Wearable Jacket (Pioneer)

- ❑ Wearable computer jacket with a display on the sleeve.
Organic film electro-luminescent (EL) display.
Expected to help medical, firefighting, and farming workers.
Project started in Tokyo 2001



2001



2003

Source: <http://www.i4u.com/article407.html>

WEARABLES

Examples: New Nomads (Philips)

Electronic Kidsware

Mobile phone and cameras to help parents pin point their kids' position and enabling new games



Electronic clubwear

Outfits for DJs to step out from behind turntables and move around the audience while continuing to shape the groove.



Electronic Kimono

Conductive embroidered spine disperse an electrostatic charge via the fibres inside, creating a tingling sensation to relax the wearer. Remote control inside the pocket. Biometric sensors monitor degree of relaxation.

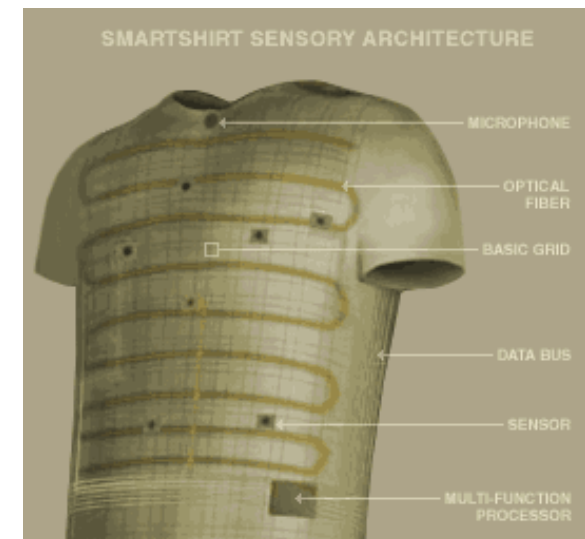
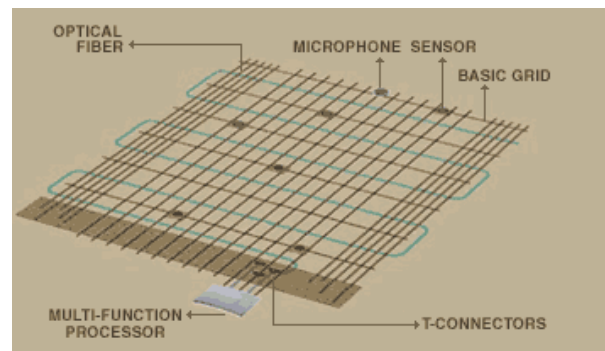


Source: <http://www.design.philips.com/smartconnections/newnomads/>

WEARABLES

Example: Smart T-Shirt

- ❑ Sensatex Inc. & Georgia Institute of Technology
- ❑ Sensatex Interconnection technology (optical and conductive fibers) can be incorporated into any fabric (cotton, lycra, wool, silk, etc.) or blend of fabrics without effecting the look, feel or integrity.
- ❑ Sensors are mounted at any location at the garment
- ❑ The Sensatex SmartShirt™ monitors biometric information and other data (firefighters, soldiers, athletes, etc.)

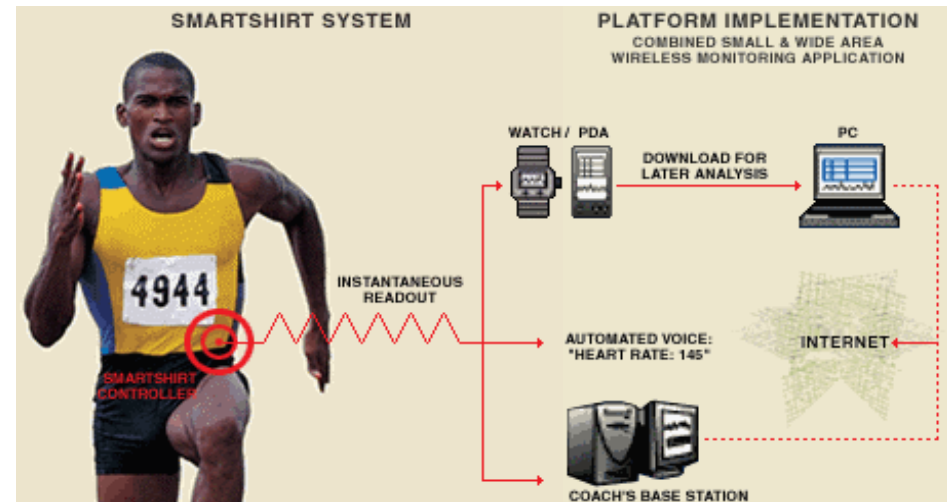
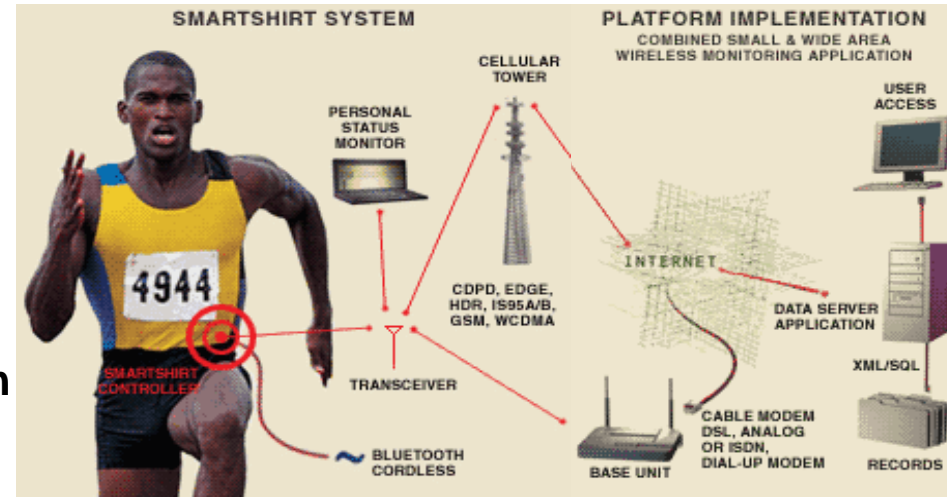


Source: <http://www.sensatex.com/>

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Example: Smart T-Shirt

- ❑ Athletes' vital signs can be monitored continuously by trainers using handhelds
- ❑ The first commercial generation of the Smart Shirt system will monitor EKG, heart rate, respiration, temperature, and puls data
- ❑ Microphones and speakers on the Shirt permit two-way voice communication



WEARABLES

Challenges for the Wearable Computer

Connectivity

- ☐ Seamless connection
 - across different kinds of network
- ☐ Occasional connection
 - in and out of range
- ☐ Local communication
 - ad-hoc peripherals

Usability

- ☐ Modes of interaction
 - visual and vocal
- ☐ Health and safety
 - strain on the senses
- ☐ Unobtrusive
 - socially acceptable

Situatedness

- ☐ Awareness
 - capturing context
- ☐ Interpretation
 - use of context data
- ☐ Augmentation
 - personal assistant
- ☐ Status symbol?

Technical

Social



WEARABLES

Example: Quite Cooling

- ❑ Cooling is usually quite annoying due to loud fans
- ❑ Heat sinks and quieter fans is a first step
- ❑ Other water-cooling concepts are under development
- ❑ Flexible tubes and plastic panels isolate liquid from electronics

Toshiba

