

UBIQUITOUS COMPUTING

Summer 2004



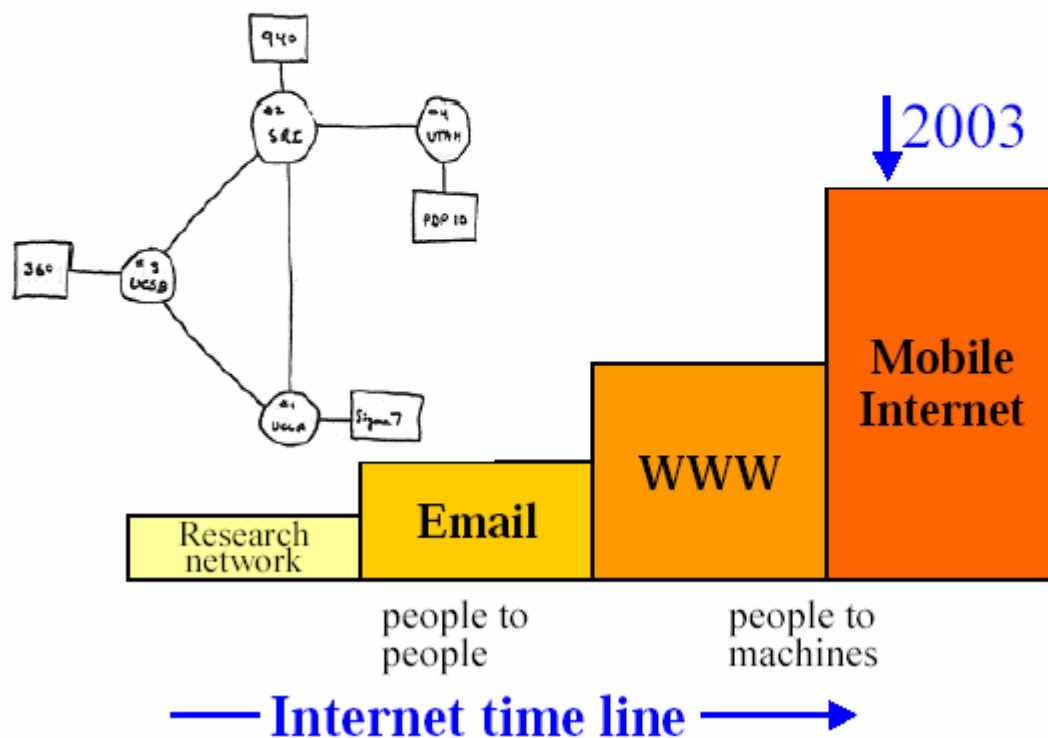
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THE TRENDS

The Qualitative Growth of the Internet

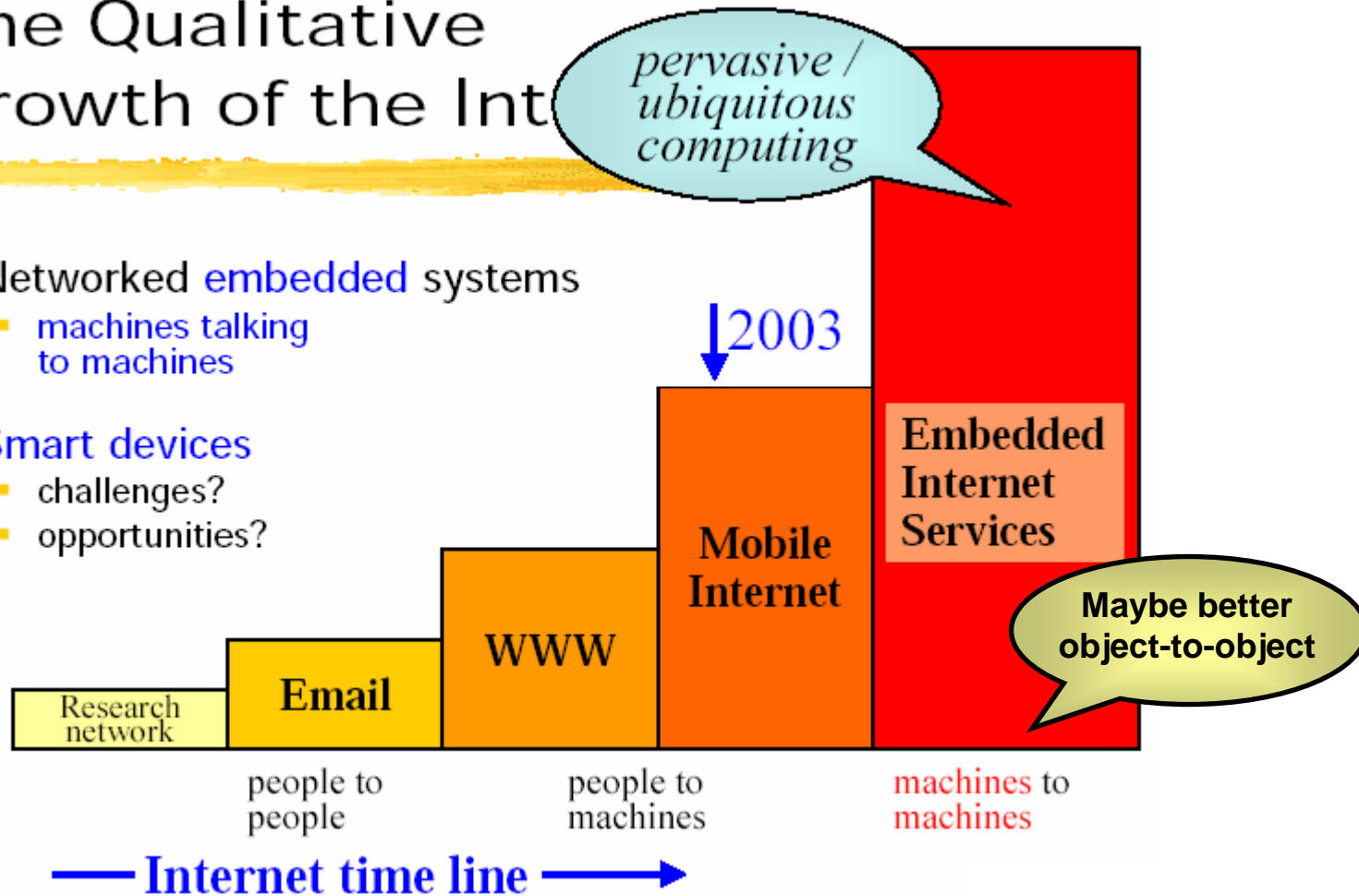


Source: Friedemann Mattern (ETH Zurich)

THE TRENDS

The Qualitative Growth of the Internet

- Networked **embedded** systems
 - machines talking to machines
- Smart devices
 - challenges?
 - opportunities?

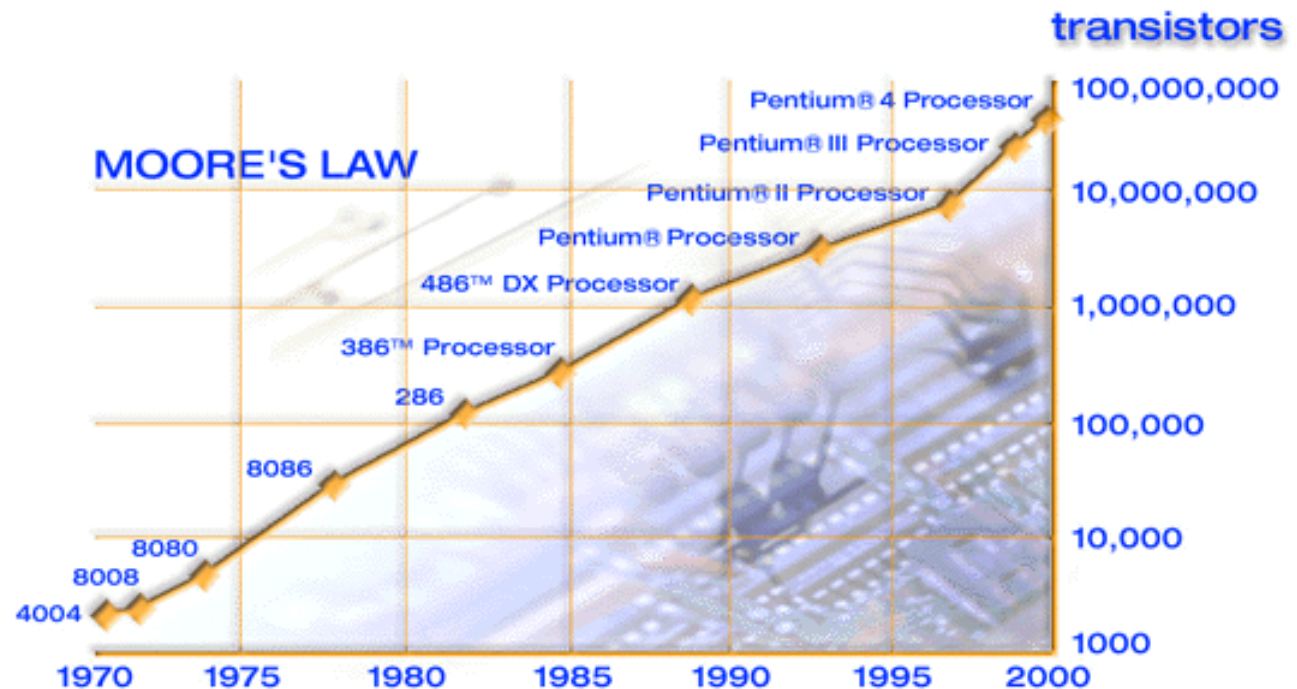


THE TRENDS

Microprocessor Development (Moore's Law)



Dr. Gordon E. Moore (co-founder of Intel 1968) made his famous observation in 1965, just four years after the first planar integrated circuit was discovered. The press called it "Moore's Law" and the name has stuck. In his original paper, Moore predicted that the number of transistors per integrated circuit would double every 18 months. He corrected this to 24 months in 1975.

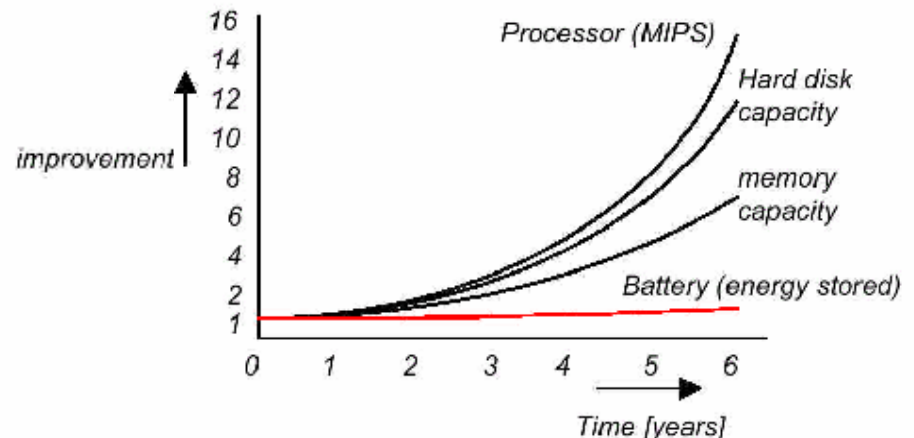
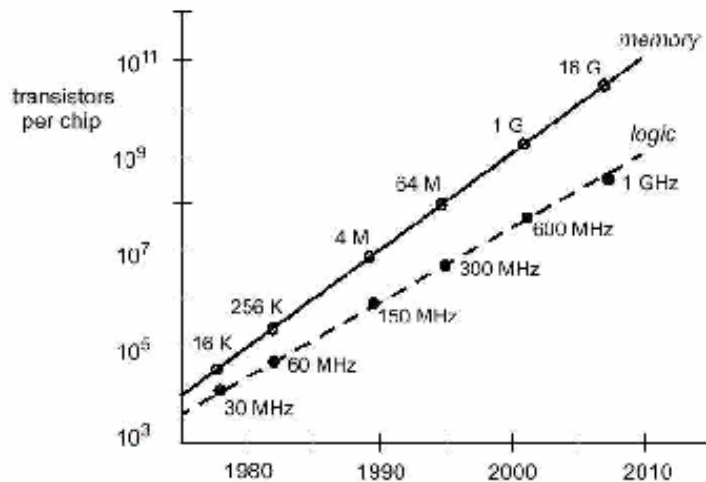


© 2001 Intel Corporation

THE TRENDS

Microprocessor Development (Moore's Law)

- Similar rules are true for the memory and disk capacity as well as the processing speed (chip clock)

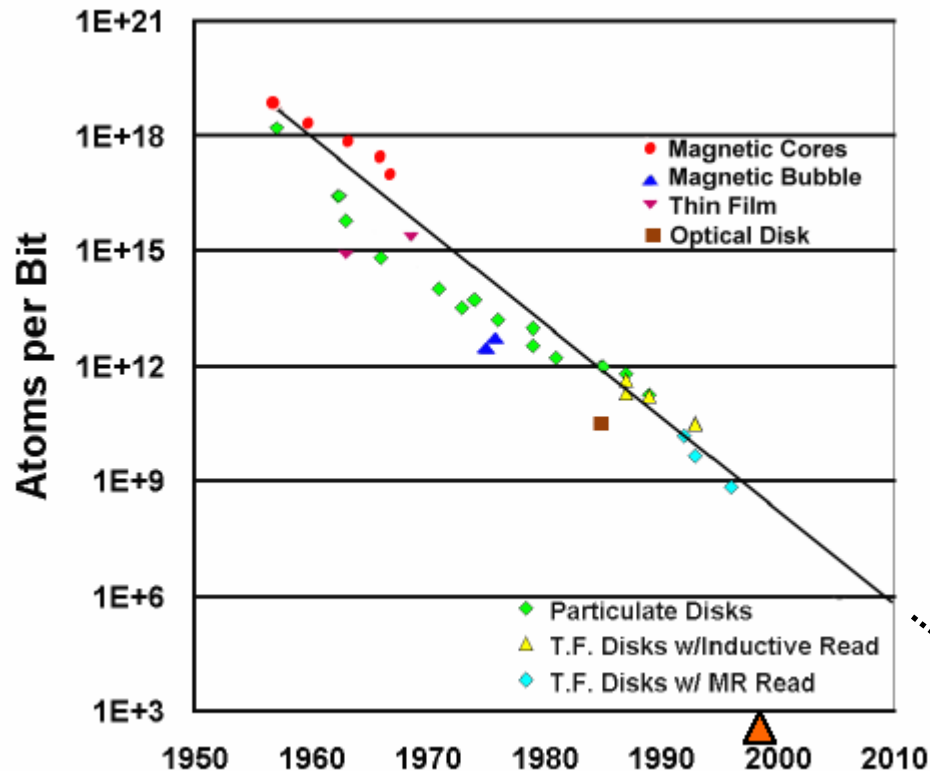


- This trend might continue for the next 10 years with conventional materials
- Afterwards we need new materials (nanotechnology?)
- **But:** Battery development only linear (20% in 10 years)
- Therefore power supply of mobile devices crucial problem today!
Especially in always-on scenarios

THE TRENDS

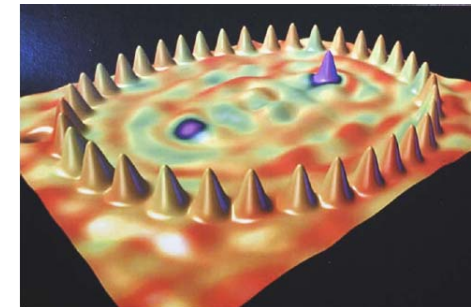
Storage Density

- Ever increasing number of bits per square inch



„There is plenty of room at the bottom.“
Richard Feynman 1959.

Nanoscale?



THE TRENDS

Storage Density

❑ Example: Harddisk

- ❑ 1980: IBM launches first 1GB drive
 - Size of a refrigerator, weighs 250kg, costs \$40,000
- ❑ 2000: IBM launches first 1 GB Microdrive™
 - Size of a coin, weighs 25g, costs <\$500
- ❑ 1GB is
 - ~ 2500 high resolution photos or
 - ~ 1000 200page books or
 - ~ 18 hours high quality music



Source: David Convey-Jones (IBM)

THE TRENDS



Storage Density

❑ Example: Harddisk

❑ 2004: Toshiba

❑ 0.85-inch HDD

❑ 1-4 Gbyte !

❑ Less than 10 grams



Source: <http://sdd.toshiba.com>

THE TRENDS

Size

Generalized Moore's Law

- Most important **technology parameters** double every 1 – 3 years:

- computation cycles
- memory, magnetic disks
- bandwidth

Problems:
- increasing cost
- energy

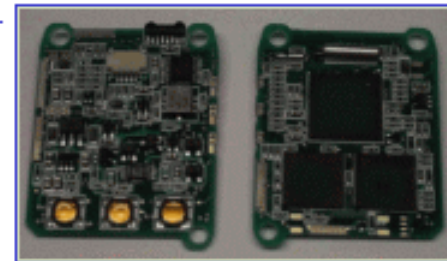
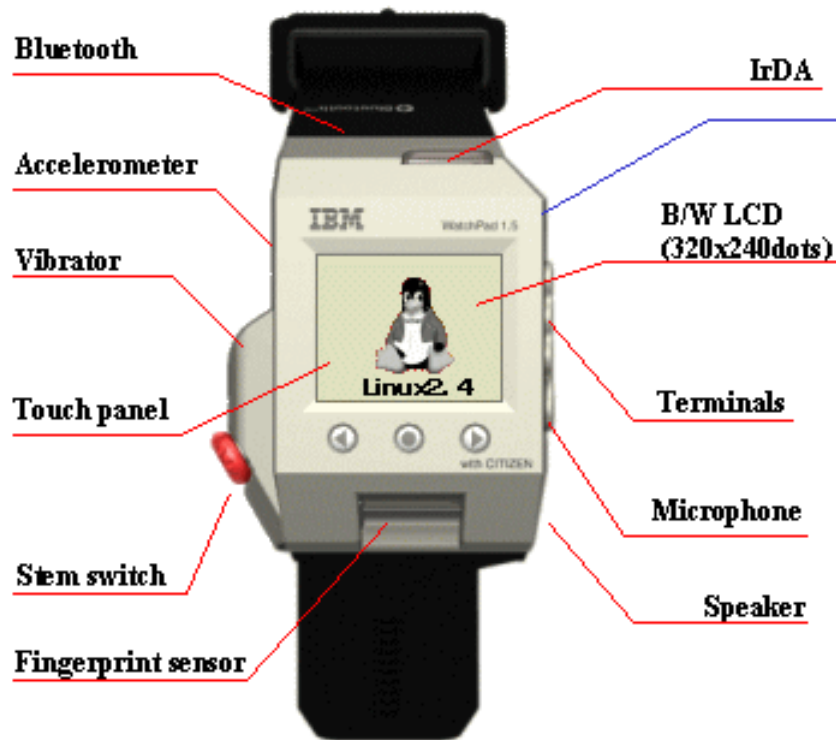
- Consequence:
scaling down



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Size

Example: IBM Linux Watch



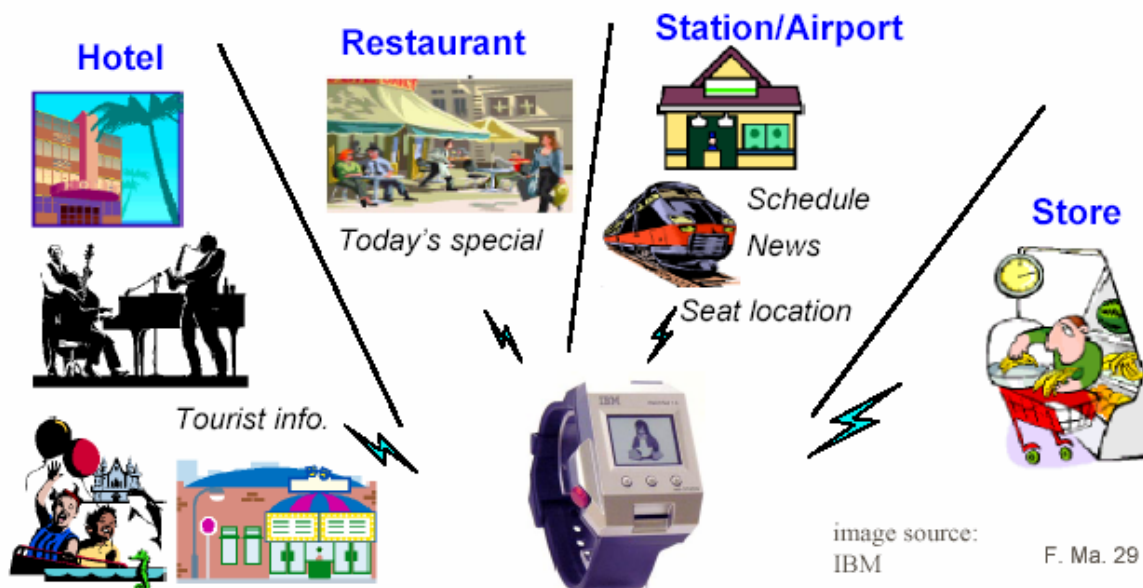
Source: <http://www.research.ibm.com/WearableComputing/>

THE TRENDS

Size

Use as a Display for Location Based Services

- Provide **personalized advertisement** and offering information
- **Timetable** and flight schedule at station and airport
- **Navigate** you at stations



THE TRENDS

Mobile Communication Technologies

One of the First Mobile Phones...



F. Ma. 34

Source: Friedemann Mattern (ETH Zurich)

THE TRENDS

Mobile Communication Technologies

Mobile Phones



1978



1982



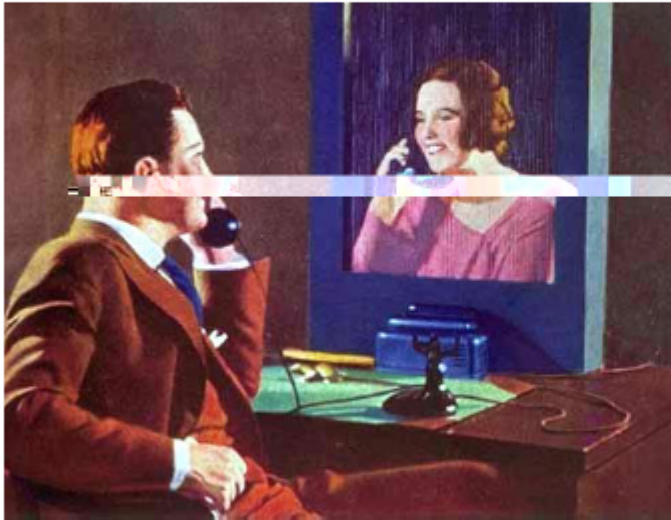
1987

shrinking volume (& increasing functionality)

THE TRENDS

Mobile Communication Technologies

Picture Phone – Vision and Reality



„Hello, Dorothy... You're looking well!!“

A vision in 1929 (from a journal ad)...

Source: Friedemann Mattern (ETH Zurich)



...and reality
some 70
years later



**NEC UMTS
VideoPhones
2003**



Bell Labs 1962



ATT 1965



NTT 1968

THE TRENDS

New Devices



Main Screen



Intercom System



Communicator



NEC Conceptual Study for W-CDMA



NEC UMTS Design Study



NEC VideoPhone

THE TRENDS

New Devices



THE TRENDS

New Devices



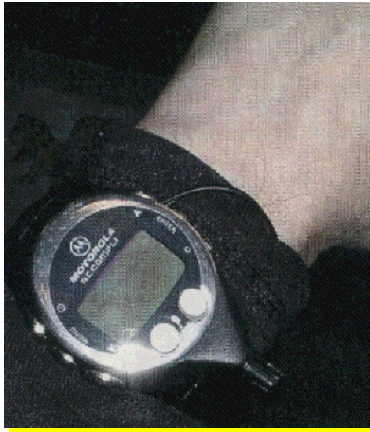
THE TRENDS

New Devices



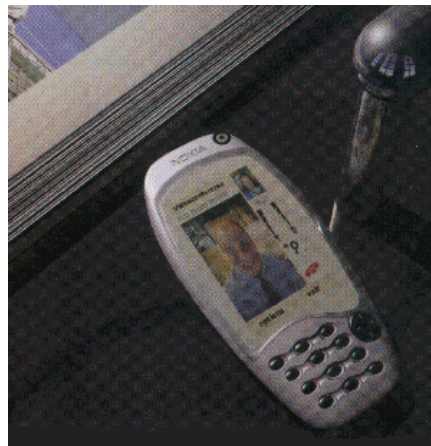
THE TRENDS

New Devices



THE TRENDS

New Devices



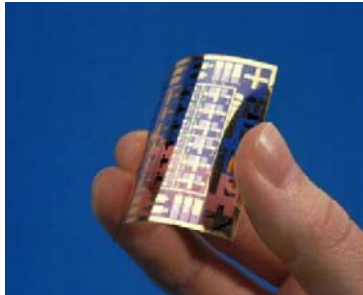
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New Materials

- Flexible materials allow for complete new kind of smart objects



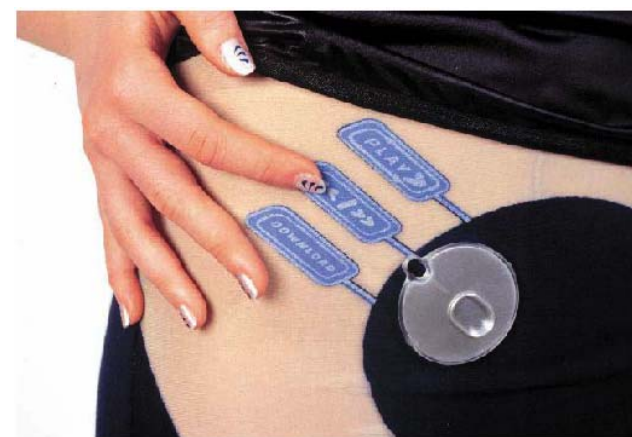
Fiber Optics



Flexible Substrates



Organic Displays



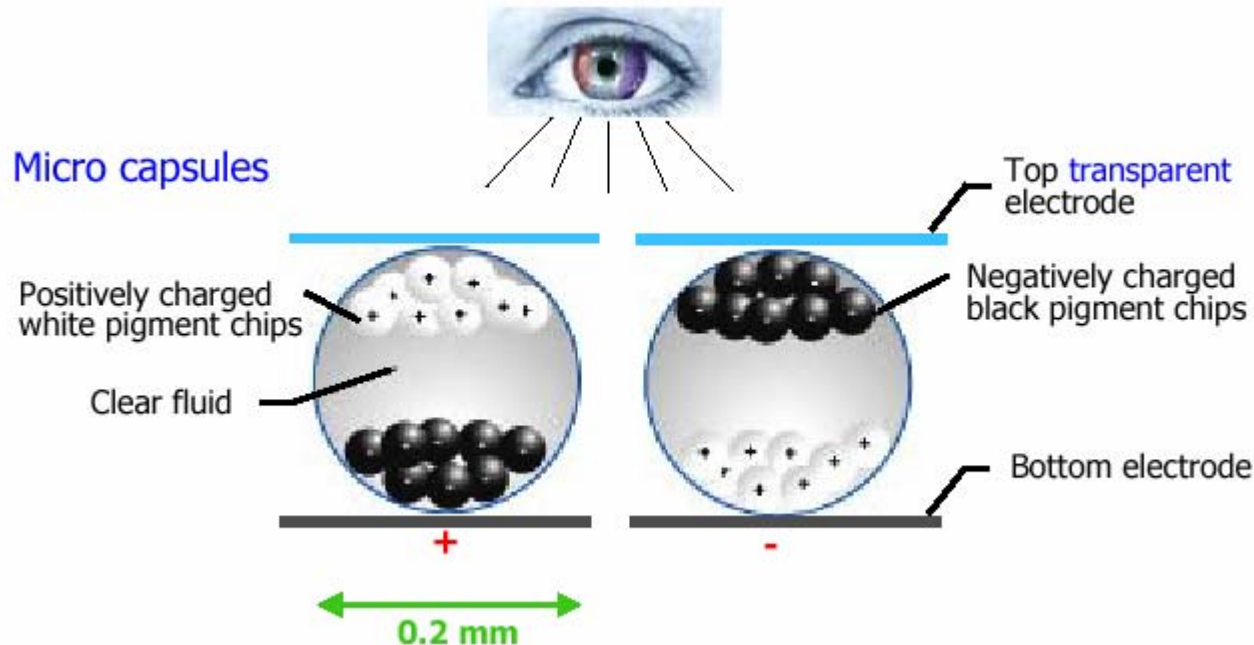
Conductive Electronic textiles

<http://www.wearable.ethz.ch/index.php?textiles>

THE TRENDS

📺 New Materials – Electronic Ink / Electronic Paper

- ❑ Gyricon developed by Xerox PARC.
- ❑ Thin layer of transparent plastic with millions of dispersed small beads.
- ❑ Beads, each contained in an oil-filled cavity, are free to rotate.
- ❑ The beads are "bichromal," with hemispheres of two contrasting colors (e.g. black and white, red and white), and charged so they exhibit an electrical dipole.



Source: <http://www2.parc.com/dhl/projects/gyricon/>

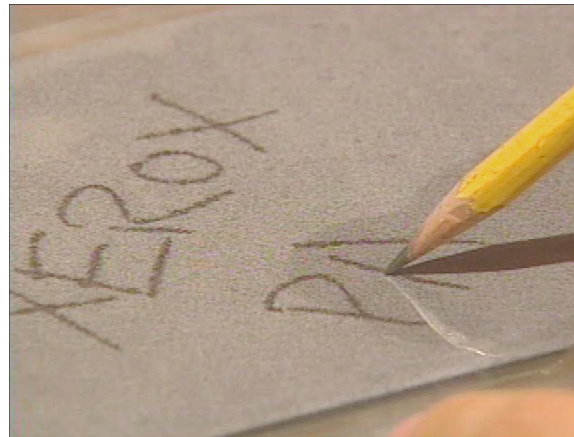
THE TRENDS

New Materials – Electronic Ink / Electronic Paper

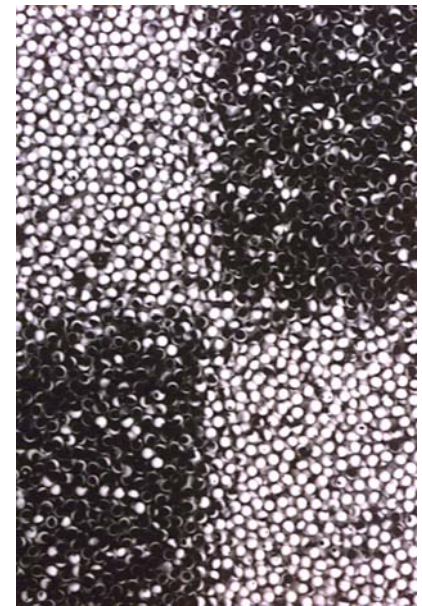
- ☐ Gyricon developed by Xerox PARC.
- ☐ When voltage is applied to the surface of the sheet the beads rotate to present one colored side to the viewer.
- ☐ The image will persist until new voltage patterns are applied.
- ☐ Advantages: high contrast, low energy consumption, flexible, ,re-chargeable‘



Not thicker than
a standard transparency.



Electronically charged pencil
rotates the bichromal beads



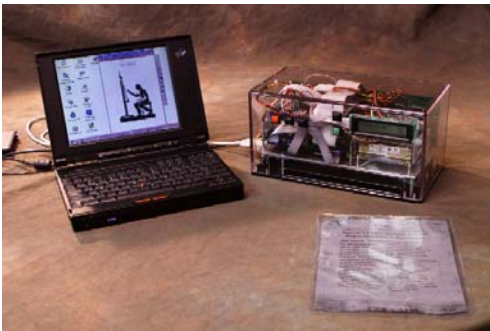
Enlarged view on the
bichromal beads

Source: <http://www2.parc.com/dhl/projects/gyricon/>

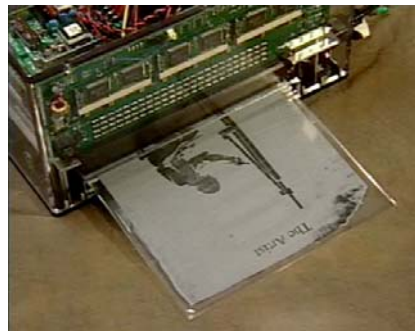
THE TRENDS

New Materials – Electronic Ink / Electronic Paper

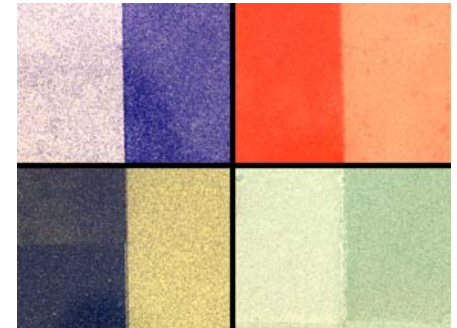
- ☐ Gyricon developed by Xerox PARC.
- ☐ State-of-the-art technology:



A Gyricon display, prototype printer and sheet of electronic reusable paper



This device may one day be small enough to fit into a purse.



First versions of color beads

- ☐ Some envisioned product ideas:

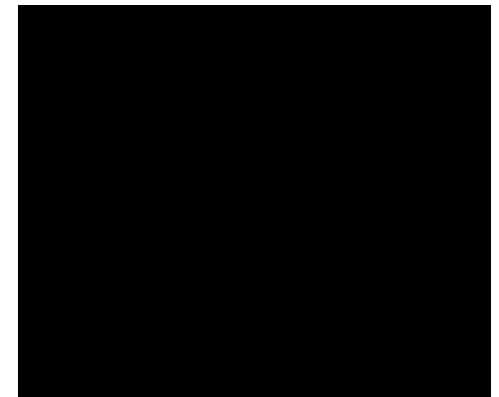
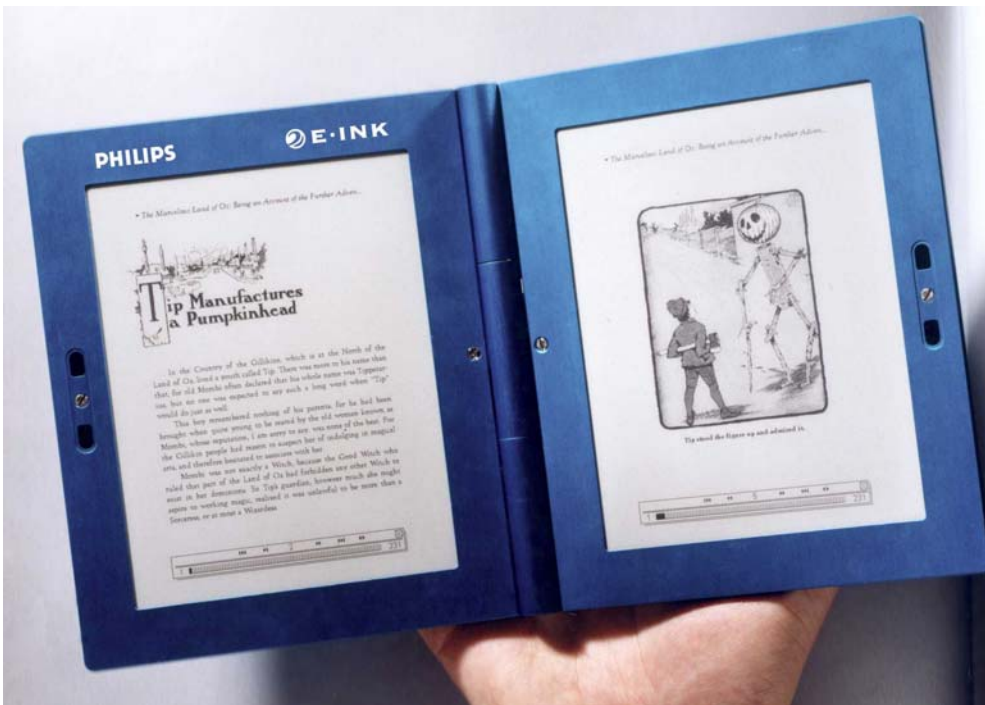


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New Materials – Electronic Ink / Electronic Paper

- ❑ E-Ink/Philips high-resolution display (160 pixels per inch - ppi)
- ❑ Using E Ink's electronic ink display material and Philips' thin-film-transistor (TFT) backplane and driver electronics.
- ❑ Demo in May 2003, Product planned for 2004



Source: <http://www.eink.com>, <http://www.research.philips.com/InformationCenter>

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Concept Newspaper – IBM Research

- ❑ Flexible plastiv OLED display
- ❑ Wireless connection downloads news continuously



Source: PC Magazine

Andreas Schrader

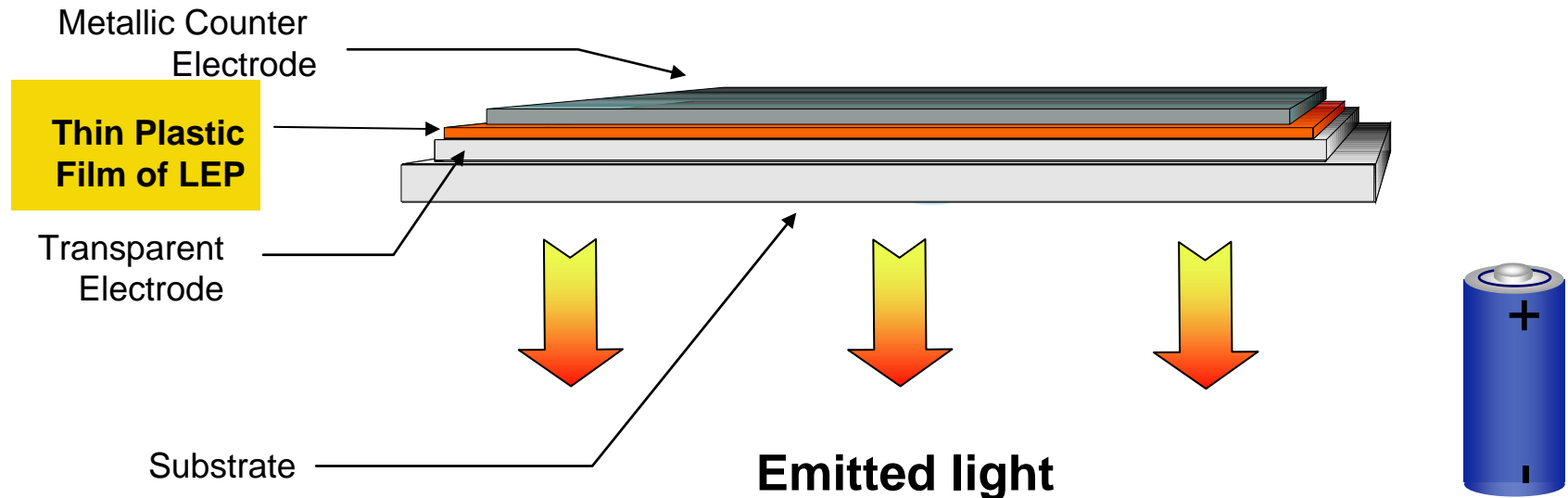
UBIQUITOUS COMPUTING



THE TRENDS

📖 New Materials – Light Emitting Polymer (LEP)

- ❑ Example: Ovion Organic Semiconductors GmbH, Frankfurt
- ❑ A thin film of Light Emitting Polymer put between two electrodes will glow

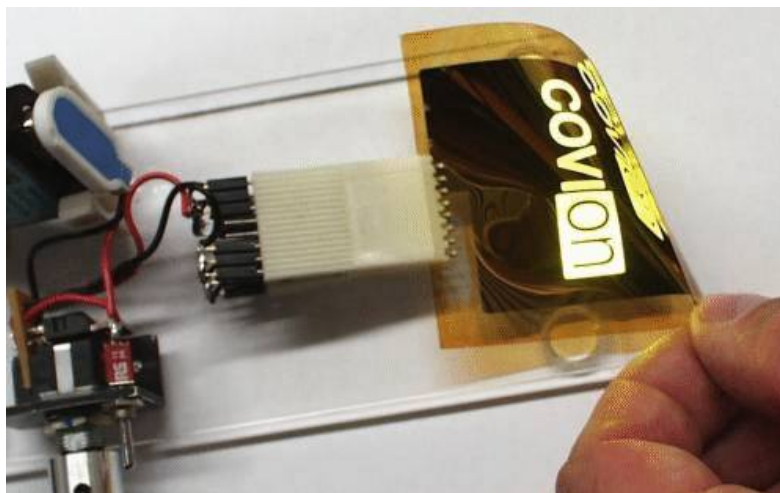


Source: <http://www.covion.com>

THE TRENDS

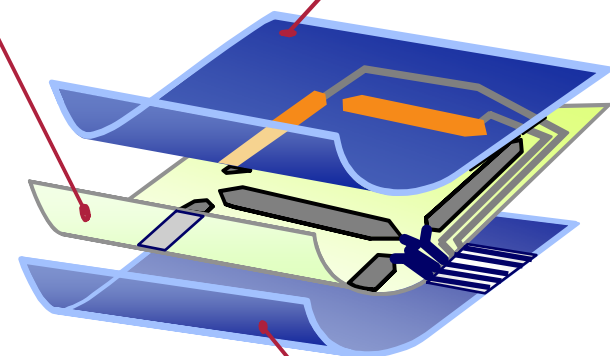
■ New Materials – Light Emitting Polymer (LEP)

- ❑ Easy to use technology
- ❑ Thin and light weight displays for portable electronics
- ❑ Very bright, all colors possible
- ❑ Low operating voltages (2-6 volts)
- ❑ Because plastic materials are flexible and robust even non-planar displays can be manufactured ...



Light Emitting Polymer Film

Transparent Protective Film



Protective Film

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New Displays



Retina Eyeglass Display

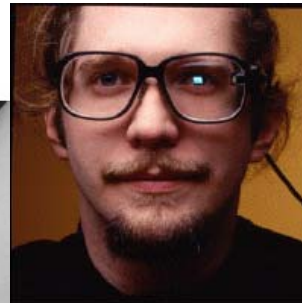


image source:
Microoptical
Corporation



300.000 pixels on 2x2mm



E Ink Corp. of Cambridge, Mass.



Dynawall GMD IPSI on 4.5x1.5m

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▣ New Displays – Reality and Vision



**Product: ChiMei Optoelectronics
20" OLED color display (1280x768)**



Product: Kodak EasyShare LS633



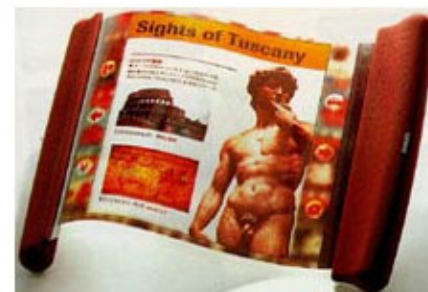
*a thin, lightweight, unbreakable display
of unlimited shape and form*



*a display that conforms to
the contours of your car*



*a display embedded into
your smartcard*



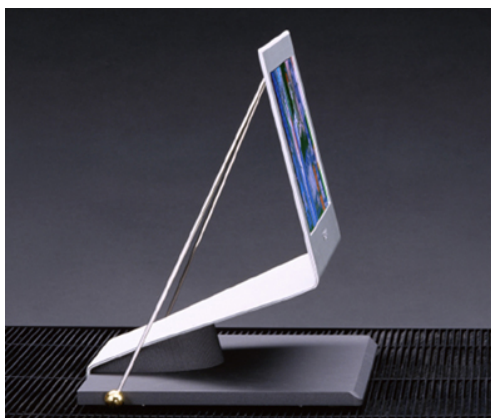
a display that pulls out from a roll

Future Visions from Philips

Source: <http://www.research.philips.com/InformationCenter/>

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■ New Displays – Reality and Vision



Sony prototype of OLED display



Universal Display Corp. Prototype of Pen with a built-in roll-up display (touch sensitive)



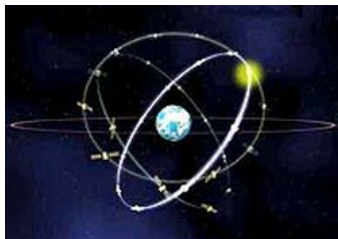
Toshiba:
LCD that can capture images.
Objects placed on the screen are scanned by light sensors in each pixel

THE TRENDS



Better Sensors

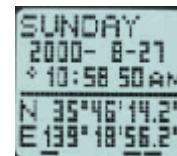
- ❑ Sensors get smaller, cheaper, and save energy
- ❑ Radio powered sensors don't need dedicated power supply
- ❑ **Location Sensors:** GPS (Global Positioning System), D-GPS, Galileo
- ❑ GPS is a system of 24 satellites in the orbit by the U.S. DoD
- ❑ Receivers are connected to at least 3 satellites and use triangulation to determine latitude, longitude, and sometimes also altitude within a few meters (~50cm) with D-GPS (Differential GPS)



Furuno U.S.A
<http://www.furuno.com/>



OEM Chipset u-blox ag
<http://www.u-blox.ch>



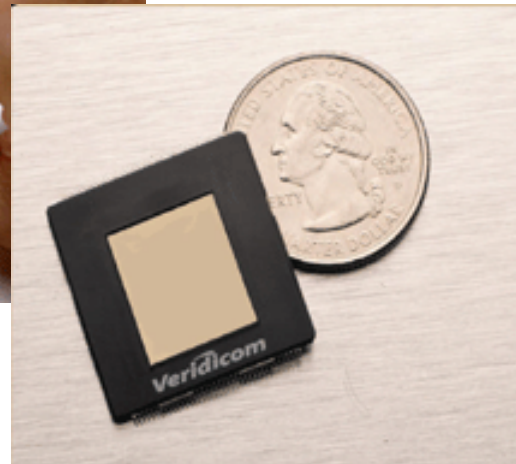
Casio Protrek GPS watch
~30 resolution, 140g, 400€

THE TRENDS



Better Sensors

- ❑ **Fingerprint Sensors:**
- ❑ Small enough to be placed on smart objects to
 - secure usage
 - identify users

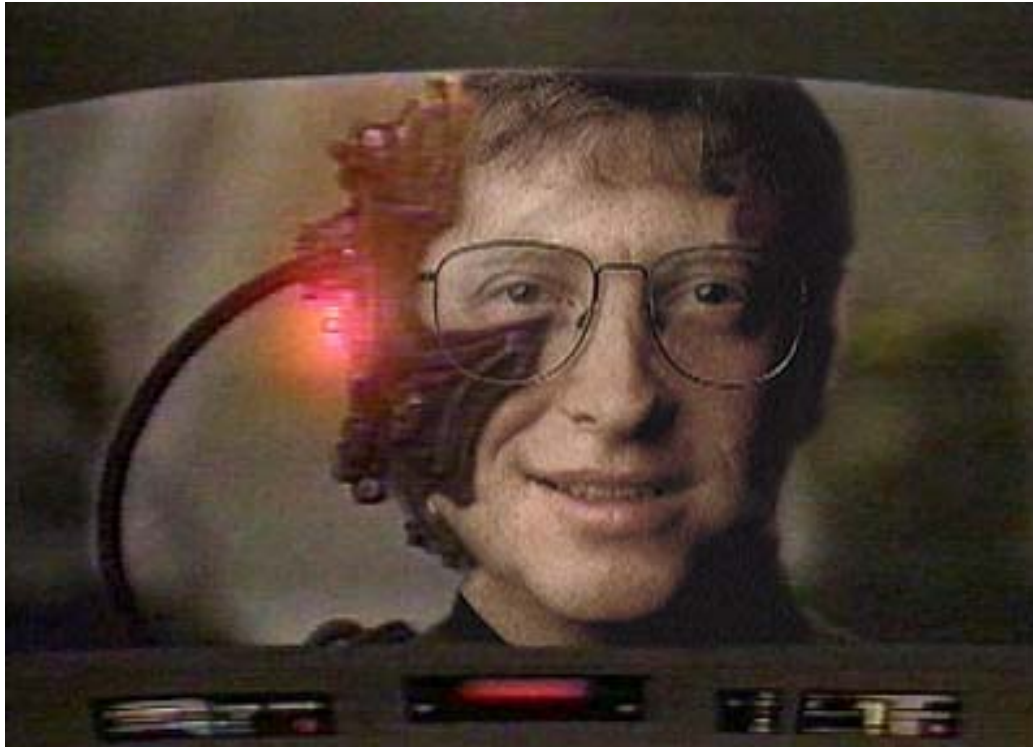


Example:
Veridicom Scanners
<http://www.veridicom.com>

Source: <http://www.kinetic.bc.ca/Biometrics/sensor-comparison.html>

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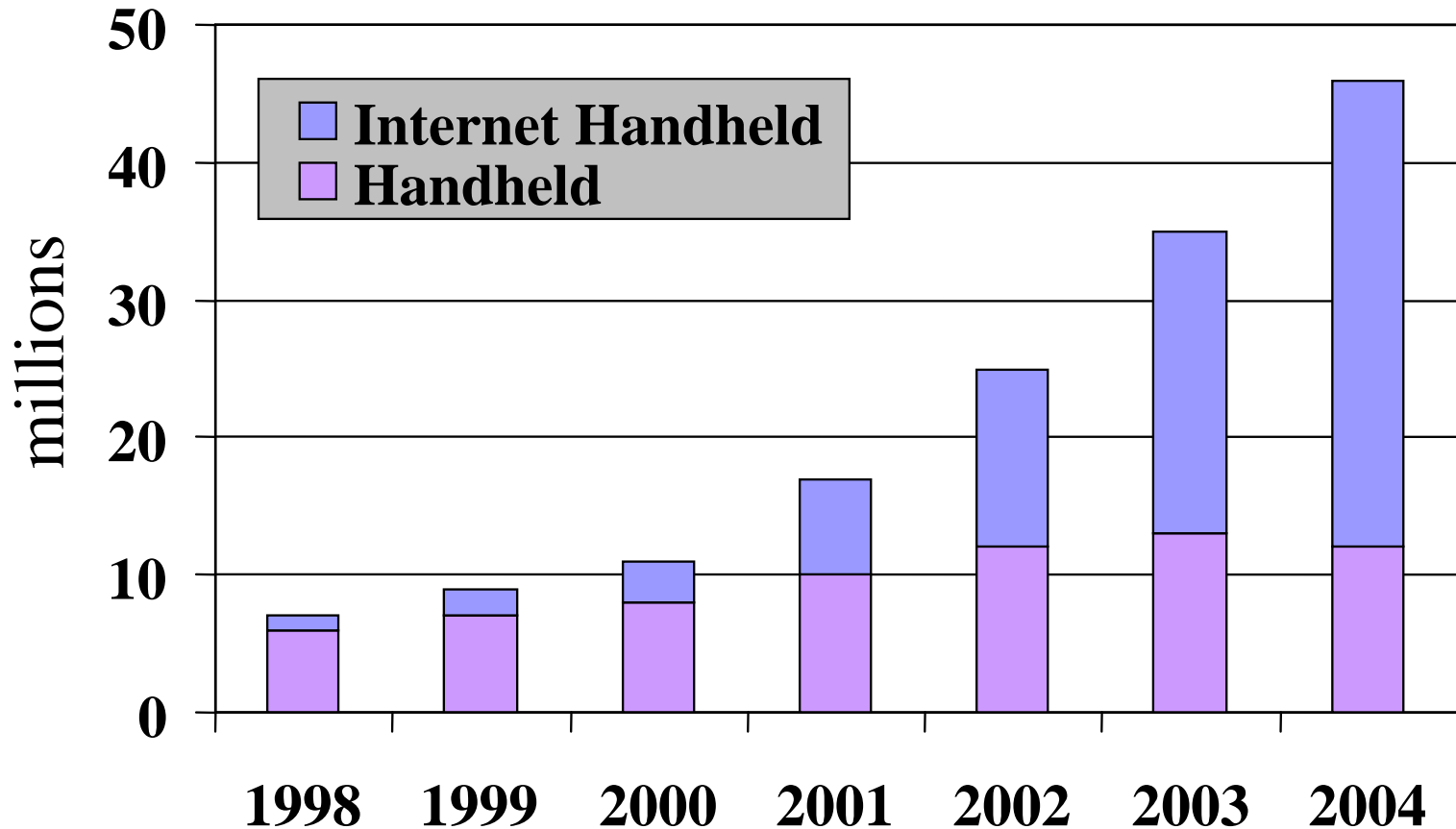
🌀 New Users (Cyborgs) ?



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Internet handheld devices

□ World

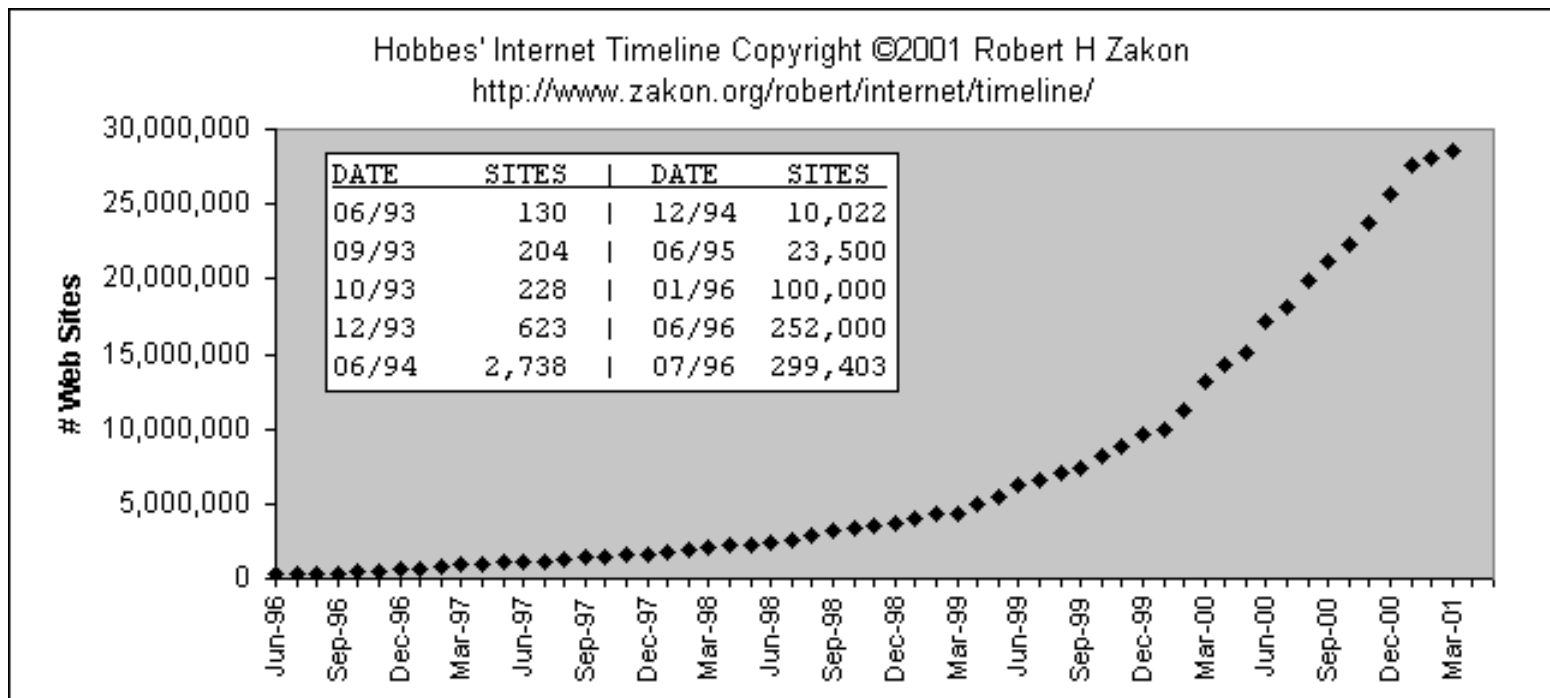


Source: IDC 2000

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Problems with Forecasts

- ❑ Sometimes, prediction of the future is a very hard job
- ❑ Example: Development of the number of web sites world-wide
- ❑ Looks like an **exponential growth**

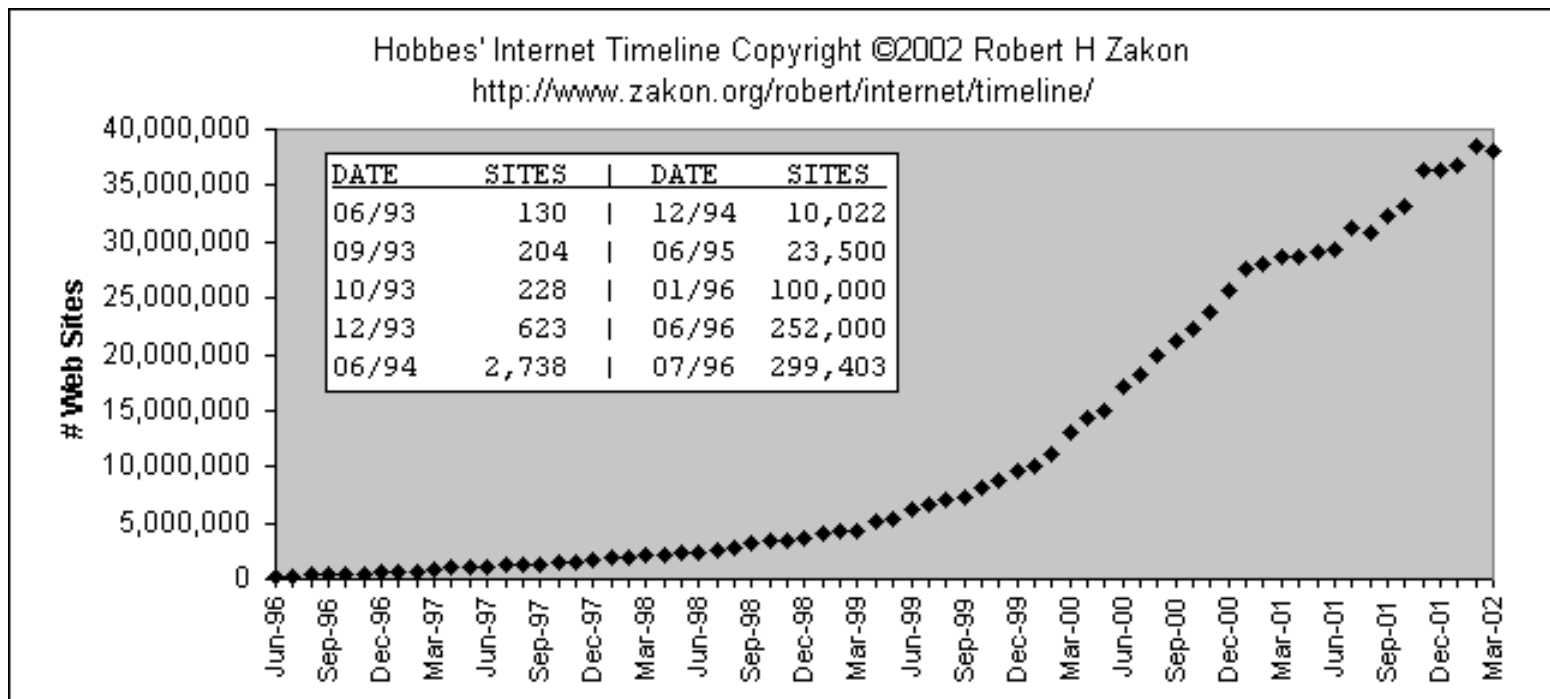


THE TRENDS



Problems with Forecasts

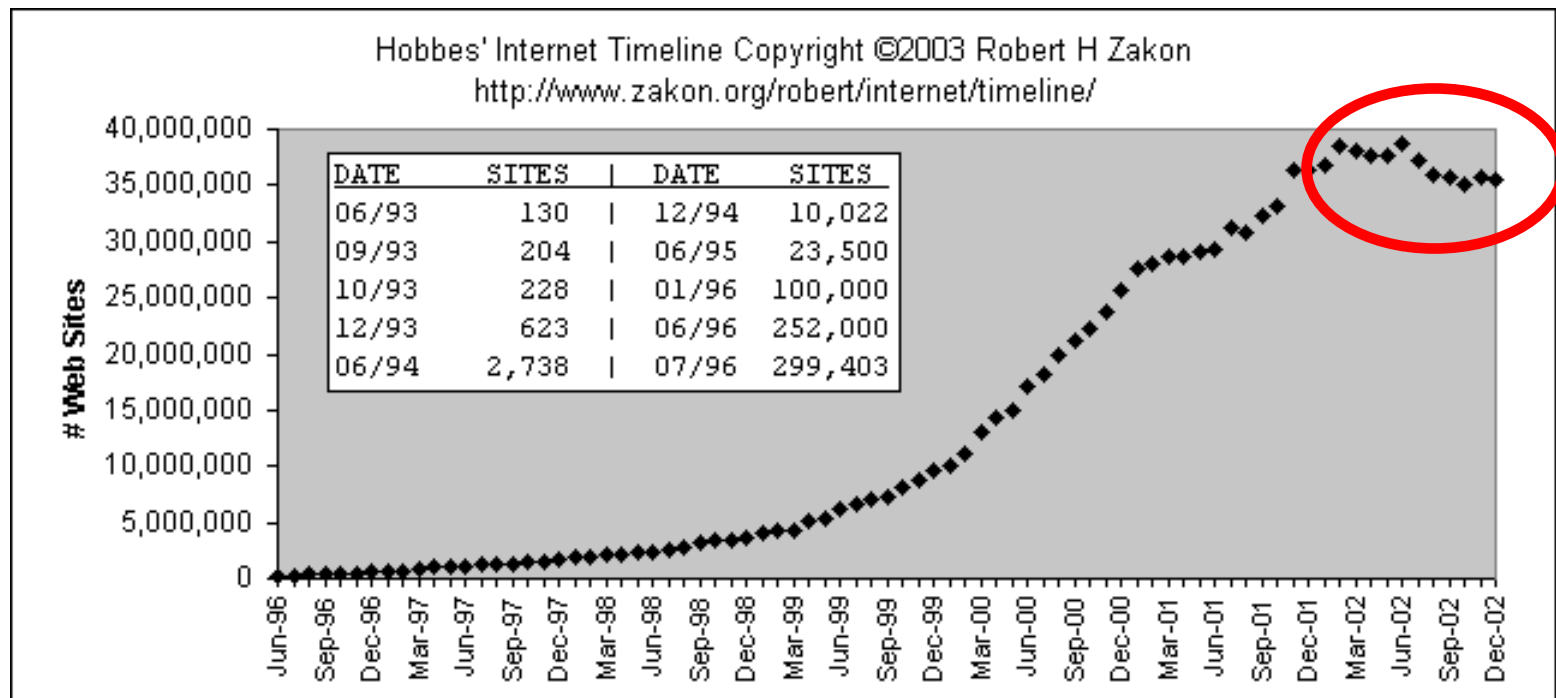
- ❑ One year later, it was **not that exponential any more!**



THE TRENDS

Problems with Forecasts

- ❑ In 2002, the number of web sites was actually **decreasing**!
- ❑ Reasons: the hype is gone!
People are bothered by the administration effort and the small effect.



▣ Problems with Forecasts

❑ Other nice examples



Prediction 1955:

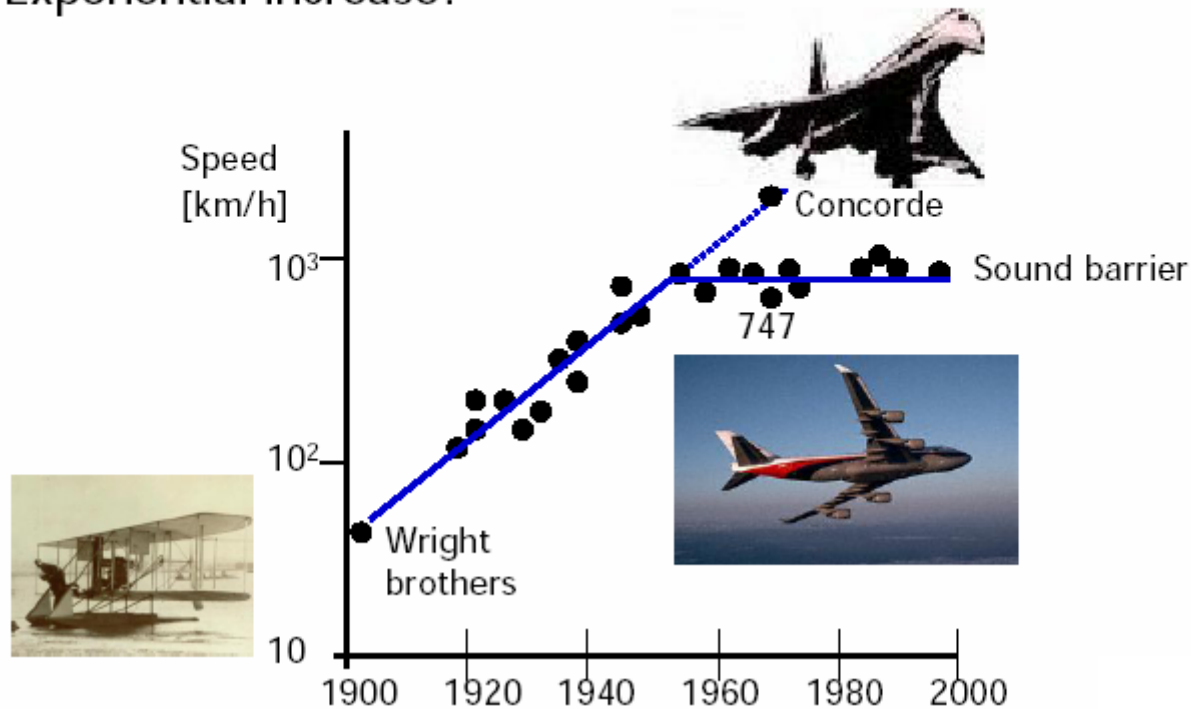
"Bei diesem besonders schnittigen Modell aus dem Jahr 1975 handelt es sich um einen eleganten Zweisitzer mit Heck-Atom Antrieb; die Sitze befinden sich dicht hinter den Vorderrädern..."

THE TRENDS

Problems with Forecasts

Predicting Aircraft Speed

Exponential increase?



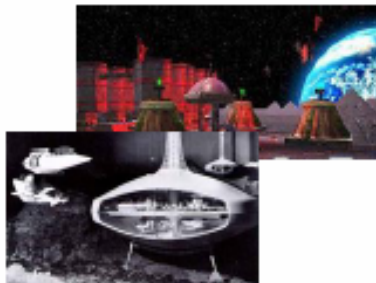
Source: Friedemann Mattern (ETH Zurich)

THE TRENDS

▣ Problems with Forecasts

How Accurate Were Previous Predictions?

- Moon colonies
 - → too expensive?
- Submarine towns
 - → ... + inconvenient?
- Flying cars
 - → ... + too dangerous?
- Paperless office
 - → too early?



THE TRENDS

▣ Problems with Forecasts

Predictions

- 1927: By 2000, atomic-powered zeppelins will zip along at 300 miles per hour.
Rudyard Kipling, "With the Night Mail"
- 1950: The housewife of 2000 can do her daily cleaning with a garden hose. Why not? Thanks to plastics, everything is waterproof.
Popular Mechanics
- 1966: By 2000, the machines will be producing so much that everyone in the U.S. will, in effect, be independently wealthy.
The Futurists: Looking Toward A.D. 2000, Time magazin

Source: Friedemann Mattern (ETH Zurich)

Problems with Forecasts

- In 1938 Arthur Train made some predictions about housing conditions 50 years later, in 1988 (in an article for the „Harper“ magazine):
 - air condition, color TV via coax cable and with remote control, radio clock, frozen food, mobile phone („pocket radio“), PC / PDA („photoelectric tabulating machine“), synthetic textiles,...
 - But also: synthetic air, roll of films instead of books and „the roof of the house is used as the landing field for the family's collection of airplanes of assorted sizes“,...

„I think there is a world market for maybe 5 computers.“
Thomas Watson, chairman of IBM, 1943

„We have always been very bad at predicting how a given technology will be used and for what reasons.“
Bran Ferren, Chief Disney Imagineer

▣ Problems with Visions

Carl Stauber: „Die Zukunft des Telefons“ (1882)



O, du göttliches Telephon,
was bist du eine praktische Er-
findung! Da kann man in der
Kneipe die Vorlesung hören und
braucht das Trinken nicht zu ver-
säumen.

F. Ma. 32

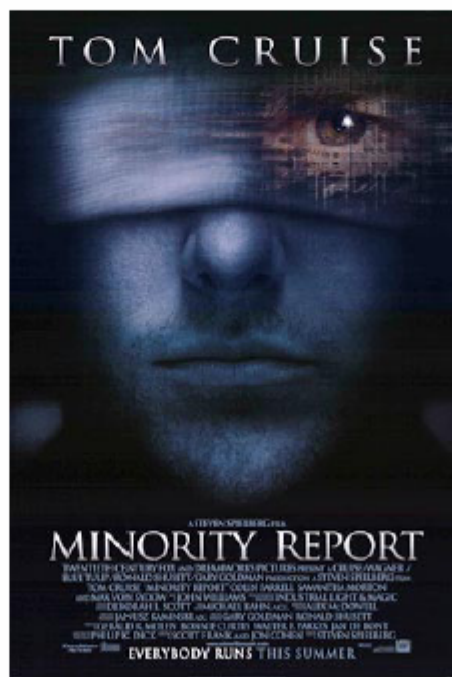
Source: Friedemann Mattern (ETH Zurich)

THE TRENDS

Utopia



- **Minority Report**
(Steven Spielberg)



Source: Friedemann Mattern (ETH Zurich)

Minority Report (Steven Spielberg, 2002)

- Anderton (Tom Cruise) lives in a futuristic world (year 2054) that seems to **respond to his every move**.
- A key plot element is that **iris scanners** are completely ubiquitous in the world.
- „The futurists that I assembled around that table didn't agree with each other on every point, but one of the several things they did unanimously agree on was that the entire **advertising industry** is going to **recognize us as individuals**, and they're going to **spot-sell to us**". (Spielberg)



THE TRENDS

Minority Report

□ Contains many elements of Ubiquitous Computing:

- Glove-controlled smart holo displays (min 2)
- Transparent memory disks (min 5)
- Virtual touch-wheels on displays (min 8)
- (Mobile) iris-scanner (min 12, 45, 74)
- Walls, street tunnels, and stores as commercial displays (min 14, 92)
- Products (cereal box) with video commercials (min 17)
- Variable screens and 3D-holo displays for home usage (min 17)
- Finger-controlled display content (min 36)
- Personalized commercials (min 45, 85)
- Electronic newspapers with video support (min 46)
- Thermoscanner, sensor networks (robot-spiders) (min 74)
- Brain scanner (min 89)
- Electronic magazines (min 92)
- Info-terminals with touchscreen (min 96)
- Wireless phones integrated in headphones (min 123)



Visions become reality

☐ Visions

- „Anything, Anytime, Anywhere“
- Each object has its own data shadow
- All objects are interconnected

☐ become reality through

- cheap hardware (-> „a lot, everywhere“)
- small hardware (-> „mobile, everywhere“)
- wireless communication (sometimes for free)

THE TOPICS

All Trends Together Lead to the Ubicomp Era

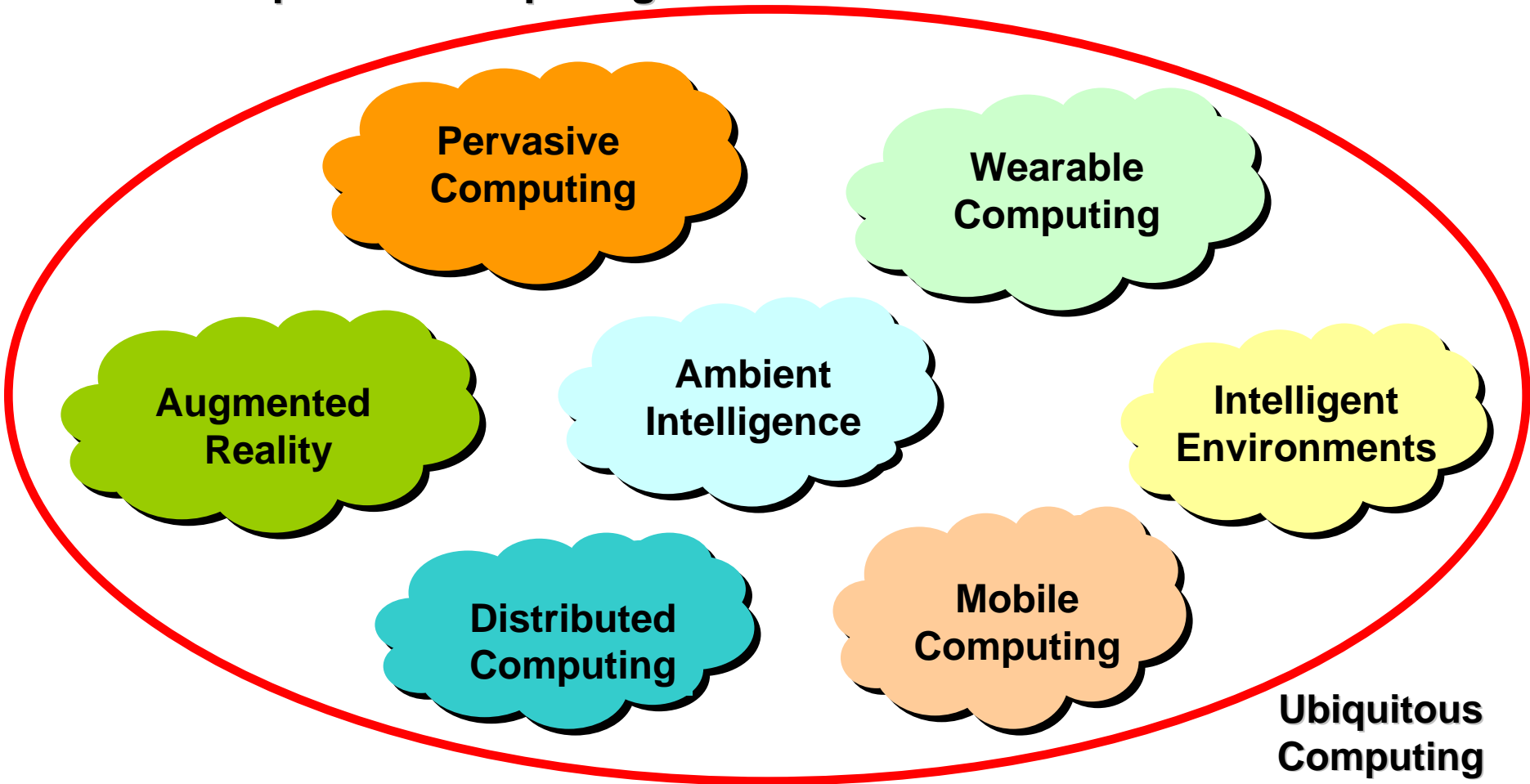
- Progress in

- computing speed
- communication bandwidth
- material sciences
- sensor techniques
- computer science concepts
- miniaturization
- energy usage
- battery technique
- display technologies
- price
- ...

→ Pervasive Computing
→ Ubiquitous Computing
→ Ambient Intelligence
→ Disappearing Computer
→ Invisible Computing

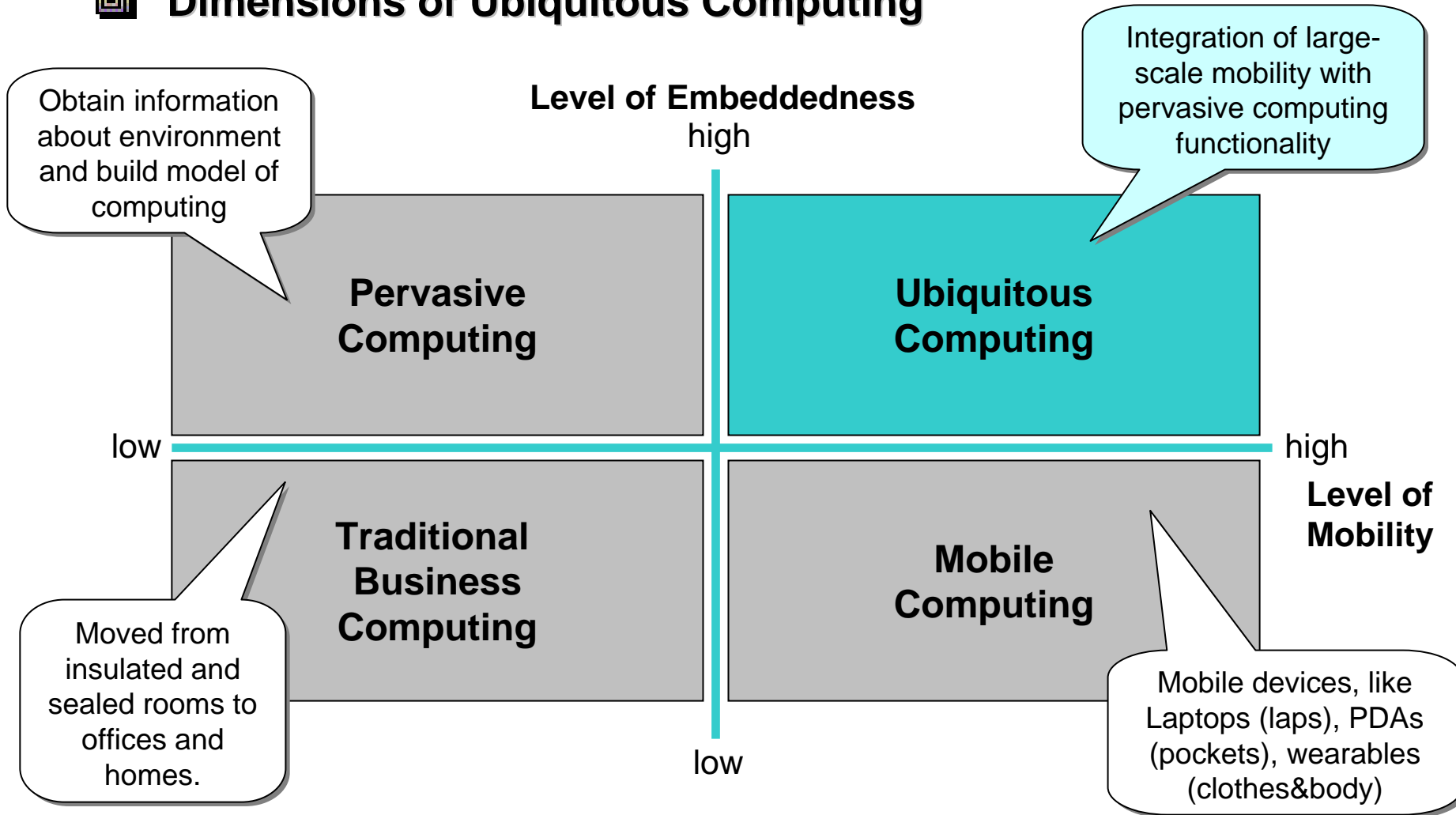
THE TOPICS

- Many different aspects are covered under the umbrella of Ubiquitous Computing



THE TOPICS

▣ Dimensions of Ubiquitous Computing



Ubiquitous Computing is a multi-disciplinary approach

☐ **Technical Issues:**

- Designing and implementing new ubiquitous architectures
- Dynamic configuration of ubiquitous services on a large scale
- etc.

☐ **Social Issues:**

- Policies for the usage of ubiquitous technology
- Solving the tradeoff between privacy and global information availability
- Security
- etc.

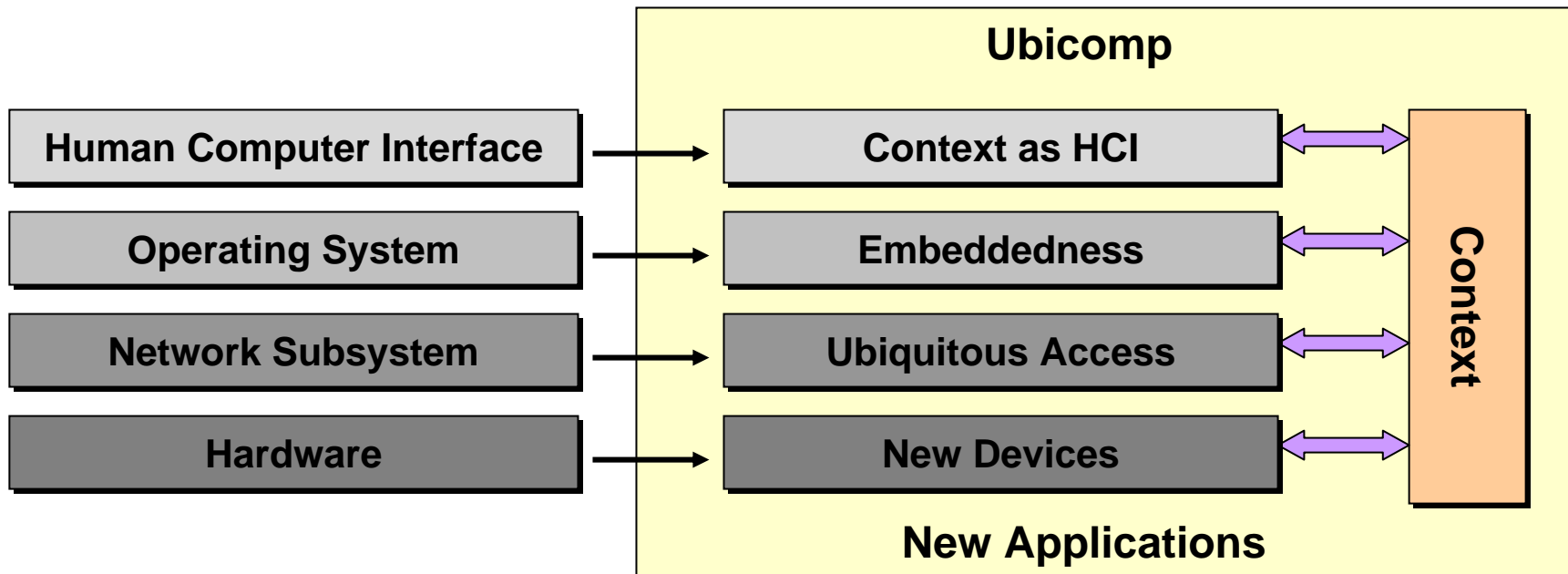
☐ **Organizational Issues:**

- Organization of work environments, organizations and institutions
- etc.

THE TOPICS

Technical Issues

- ❑ Karlsruhe (TeCo) view
- ❑ Classical approach: horizontal layered aspects of computing
- ❑ Ubiquitous Computing: vertical integrative approach



THE TOPICS

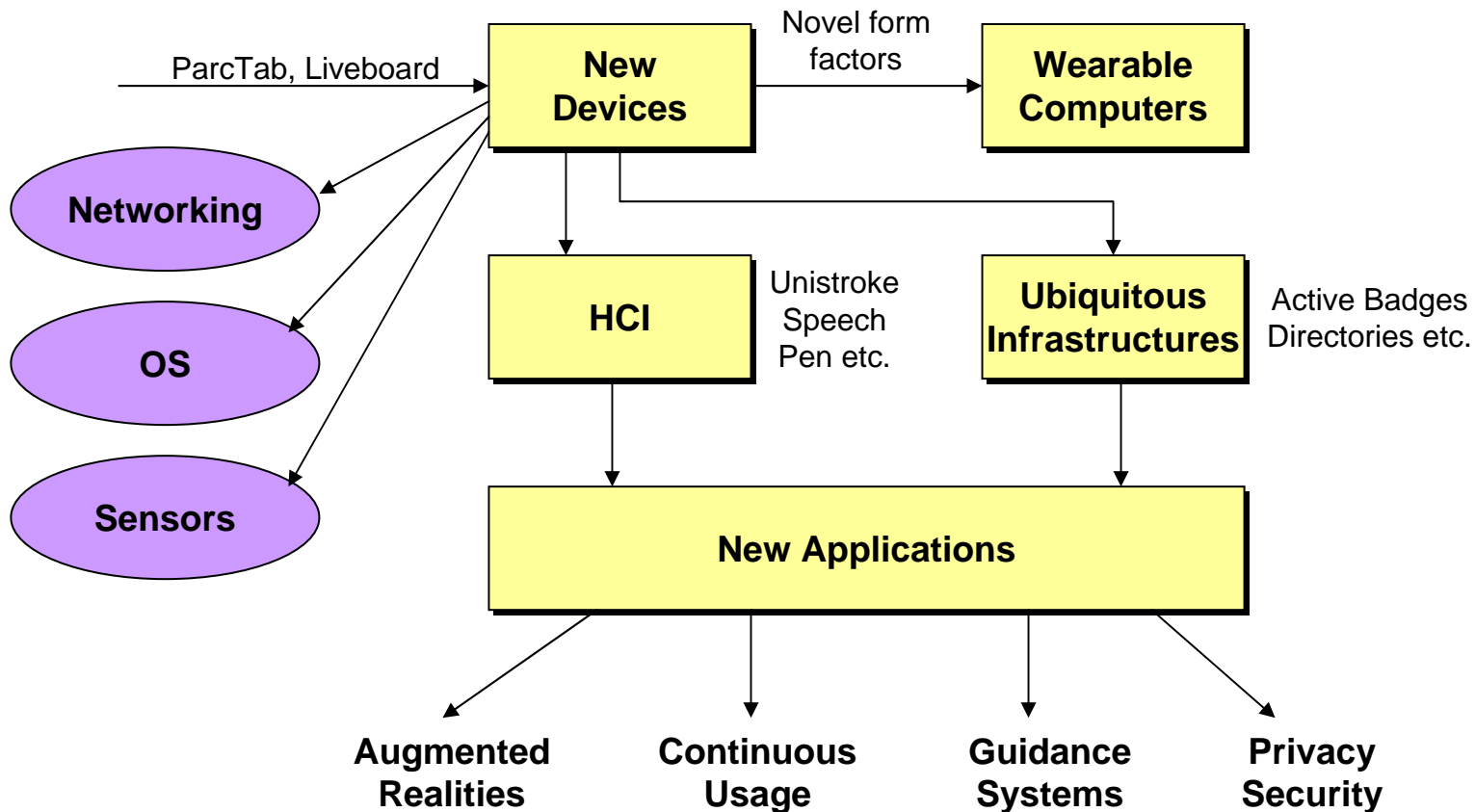
Technical Issues (Selection)

- ☐ Human Computer Interfaces (HCI)
- ☐ Artificial Intelligence (AI)
- ☐ Security / Privacy
- ☐ Operating Systems
- ☐ Networking
- ☐ Hardware
- ☐ Applications
- ☐ Middleware and Protocols
(RPC, CORBA, Jini, Web Services, RMI, UpnP, Salutation, etc.)
- ☐ Sensors and Sensor Networks
- ☐ Devices (Information Appliances, Gadgets, Multimodality)
- ☐ Wearable Computers, Smart Clothes
- ☐ Ambient Media (MIT)
- ☐ Location Based Services
- ☐ Quality-of-Service, Context Awareness
- ☐ Capability Analysis, Exchange, and Negotiation
- ☐ Mobile Networks, Adhoc Networks
- ☐ Wireless Networks

THE TOPICS

Future Challenges

- Abowd, Mynatt: Charting Past, Present and Future Research in Ubiquitous Computing, ACM Transactions on HCI, vol. 7, No. 1, March 2000



THE TOPICS



Challenges

❑ Computing with natural interfaces

- Human computer interaction (HCI) should model human-human interaction (speech, gestures, writing, altering physical artifacts)
- Perceptual User Interfaces (PUI) (-> see PUI workshops)
- Tangible / graspable media interfaces
- Sensor input
- Multimodal interfaces

❑ Future Issues

- Platforms for automatic handling and processing of „first-class“ natural data types (e.g. audio, video, pen input („ink“), physical object manipulation, etc.)
- Timestamping for synchronization
- Error-handling
(error reduction, error detection, re-usable infrastructures for error correction)

Challenges

☐ Context aware computing

- Location (Active Badges, GPS, etc.)
- Object identification (RFID, Barcodes, vision-based recognition)
For humans: Iris / fingerprint scanner, speech recognition

☐ Future Issues:

- Other context means (e.g. time, history, etc.)
The „five 5’s“: Who? What? Where? When? Why?
- Context representation frameworks
- Context fusion
Using competing context services with varying characteristics in terms of cost, range, granularity, etc. to deal with un-covered areas and un-reliable or un-deterministic data sets
- Coupling of context-aware and natural interactions -> Augmented Reality

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Challenges

☐ Automated capturing of live experiences

- Augment inefficiency in human record-taking
(e.g. fading memory and inability to capture multiple parallel activities)
- Timestamping, indexing, annotating
(e.g. Classroom 2000 [Georgia Tech] etc.)
- Usually capturing is separated from accessing and interpreting

☐ Future Issues in recording:

- Extend focus from meetings and lectures to
Brainstorming sessions
Building maintenance systems, etc.
Personal recording systems (Microsoft MyLifeBits project)
- Capturing of physical artifacts
- Deriving additional information (e.g. speech pause recognition, etc.)
- Recording of parallel streams
Multiple cameras, following focus points in sessions, etc.

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Challenges

- ☐ Automated capturing of live experiences
- ☐ Future Issues in accessing:
 - Other than realtime viewing
 - Automatic summaries
 - Stream foreshadowing (look-ahead)
 - Intuitive Interface design
 - Time-based interaction techniques
 - Privacy

Challenges

☐ Everyday computing

- Continuous interactions have 24-7 character
- Action density is like ebb and flow in tides
- Examples: Orchestration tasks, communications with families and friends, information management
- No clear beginning and end times defined

☐ Future Issues:

- Expected interruptions
- Presentation of past interactions (history visualization)
- Reminder for uncompleted tasks
- Allow for context shifting between multiple concurrent activities
- Associative instead of hierarchical models of information (e.g. for Email)
- Adaptation to the user context
- Design a continuously present interface (Agents, PDAs, Avatars, Wearables are not the final story)
- Tangible media and peripheral awareness support
- Better combination of real and virtual world

Source: Abowd and Mynatt

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Cross Challenges

☐ Evaluation of systems

- Balance between prediction and observation
- Moving from prototype demonstrations to stable and reliable systems
- User-centric perspective (story) more important than system itself

☐ Social Issues:

- Easy to build spy systems - „Who can read my bits?“
- Invisibility of devices is clear diametral to information requirements
„Whats going on behind my back?“
- „Our visibility in the virtual space should be as clear as our visibility in the real world“
- Should those being sensed or recorded be able to control the process?
- Establishing acceptable policies for „erasing“ or „forgetting“ shared memory (fading contexts?)

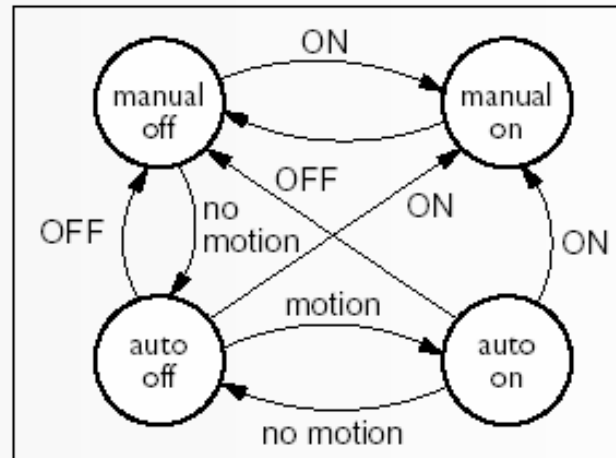
The main goal of Ubiquitous Computing is not a search for the „killer application“ but for **creating the „killer existence“**

Source: Abowd and Mynatt

THE TOPICS

Context Awareness

- ❑ Interaction patterns with smart objects should be as easy as possible
- ❑ Users should not be required to learn complex GUIs or browse handbooks
- ❑ Example: automatic light switches usually do not support manual light switch functions at the same time.
- ❑ Buxton et.al. presented a smart light switch, which is changing its behavior according to context information:

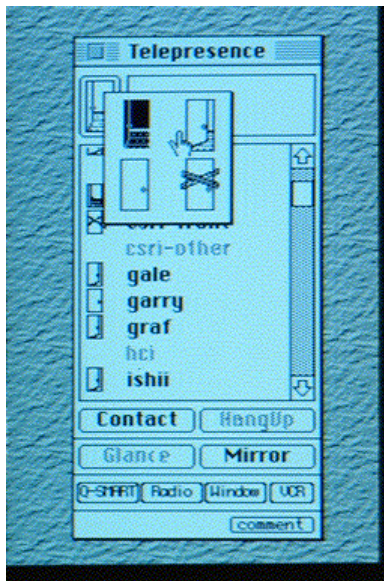


Smart lights diagram. The transition labels ON and OFF denote the pressing of the ON and OFF buttons respectively.

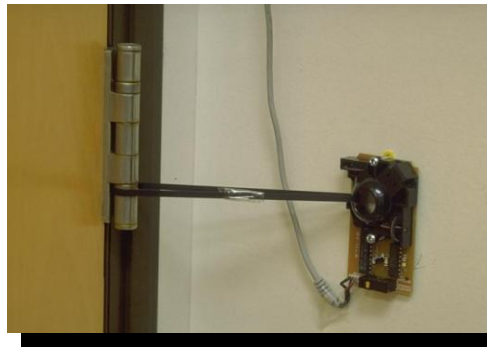
THE TOPICS

Reactive Environments (William „Bill“ Buxton, 1995)

- ❑ Example: **Door State as additional input**
- ❑ The door state (open, semi-open, closed, boarded shut) is used to indicate the accessibility of potential communication partners like in the real world
- ❑ Allows for using established social-patterns, like knocking, before disturbing, if door is closed, or interpreting the shut door as „do-not-disturb“ sign
- ❑ Context is part of the input/output means



Door-State
Visualization



Modified computer
mouse as door
state sensor