Ubiquitous Computing

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ETH Eidgenössische
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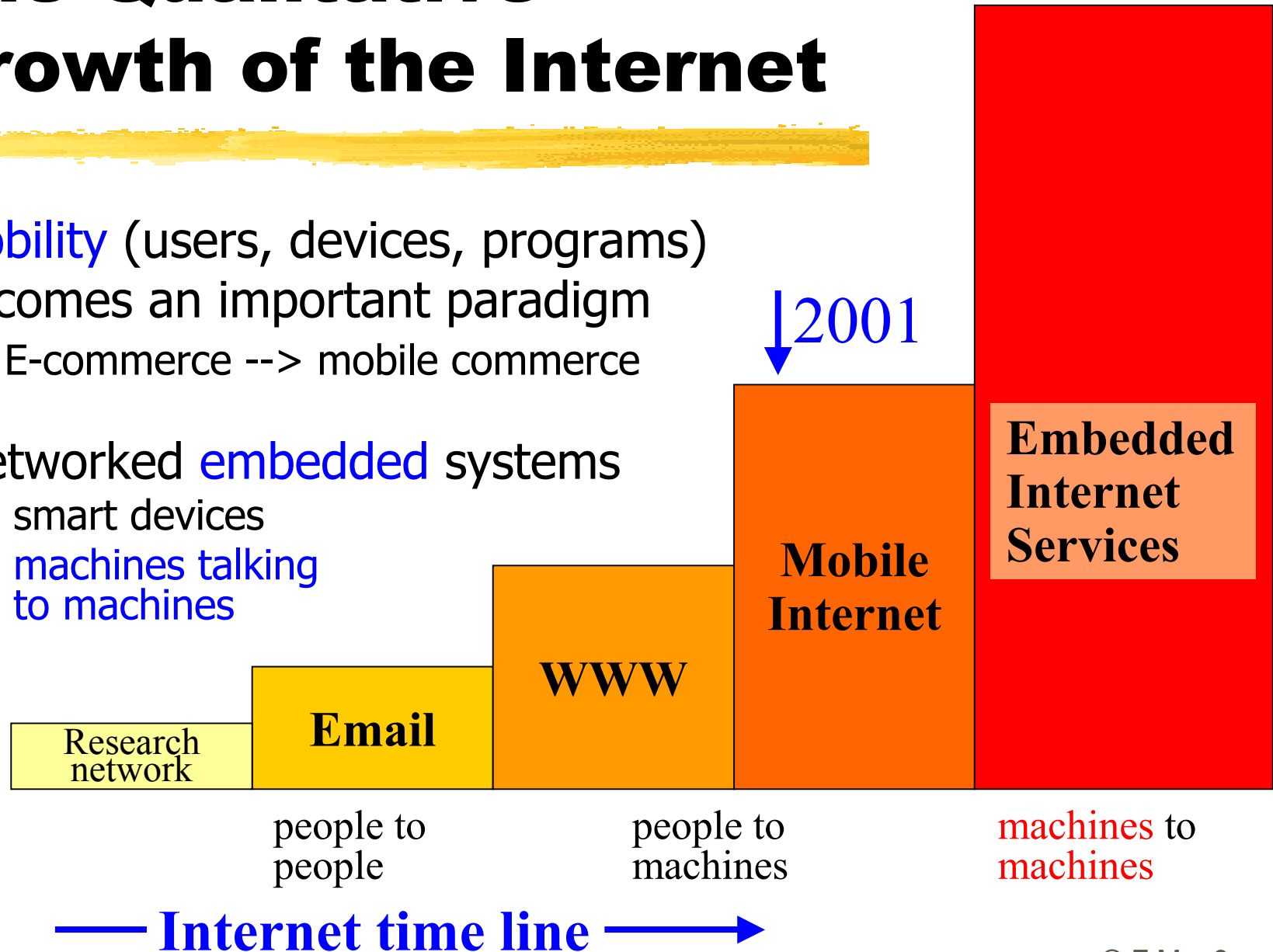Zürich

Networking Trends

- Networking in the past:

- Networking today:

- Networking tomorrow?

The Qualitative Growth of the Internet

- **Mobility** (users, devices, programs) becomes an important paradigm
  - E-commerce --> mobile commerce

- Networked **embedded** systems
  - smart devices
  - **machines talking to machines**

↓2001

Embedded Internet Services

Mobile Internet

WWW

Email

Research network

people to people

people to machines

machines to machines

— Internet time line ⟶
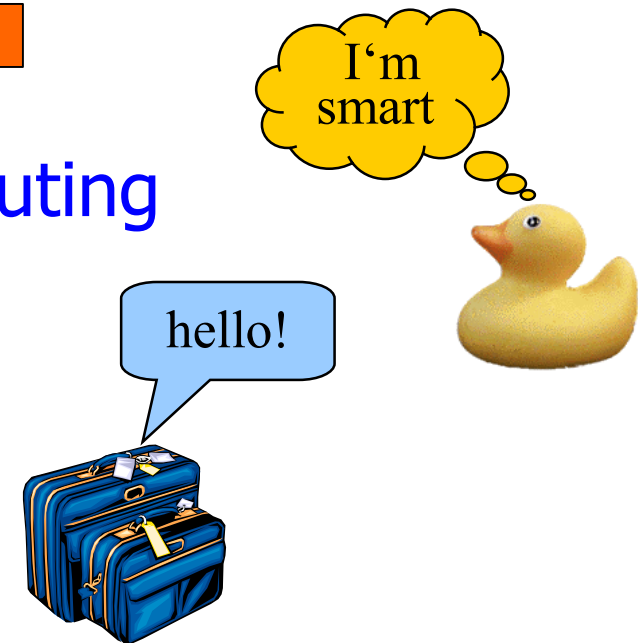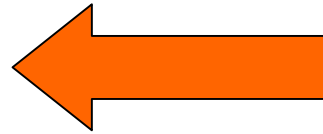
Ubiquitous Networking

- Today, the Internet connects all *computers*

- Tomorrow everyday *objects* will become smart and they will all be interconnected
  - Ubiquitous Computing

image source: "Die Zeit"

© F.Ma. 4

Outline

- Smart Objects

- 5 Reasons for Ubiquitous Computing

- Information Appliances

- Connecting Atoms and Bits

- Consequences

I'm smart

hello!

Smart Objects
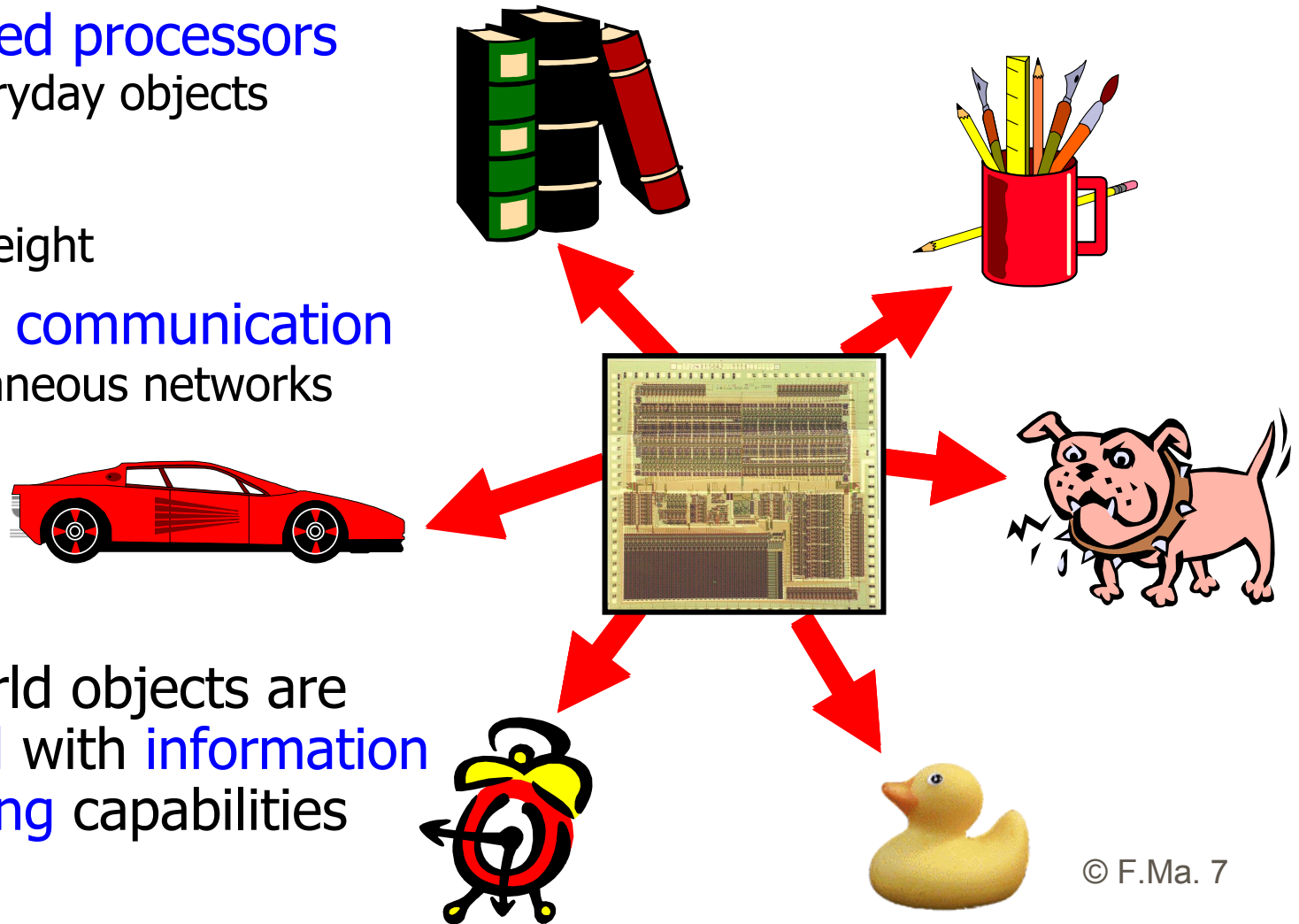
- **Embedded processors**
  - in everyday objects
  - small
  - cheap
  - lightweight

- **Wireless communication**
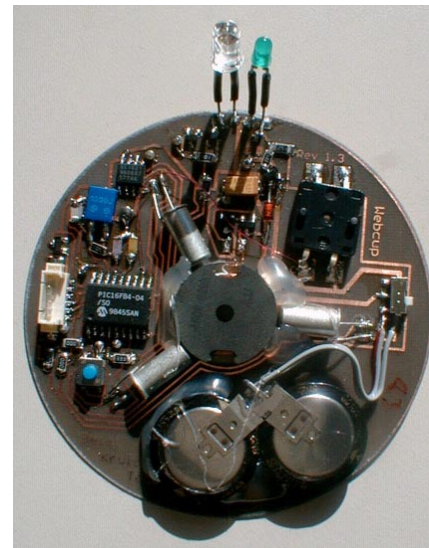 - spontaneous networks

- **Sensors**

- Real world objects are enriched with information processing capabilities
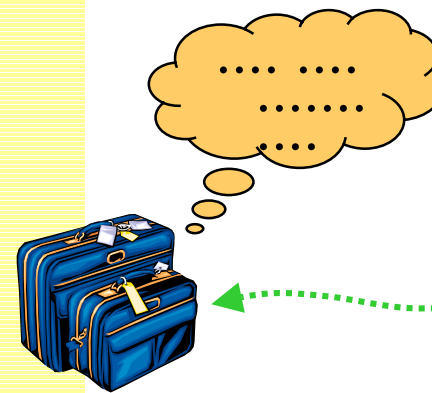
© F.Ma. 7

An Example of a Smart Object

- MediaCup from TeCo, University of Karlsruhe

Smart Objects

- May find their place everywhere
    - work, home, entertainment ,...

- Can remember pertinent events
    - they have a memory

- Show context-sensitive behavior
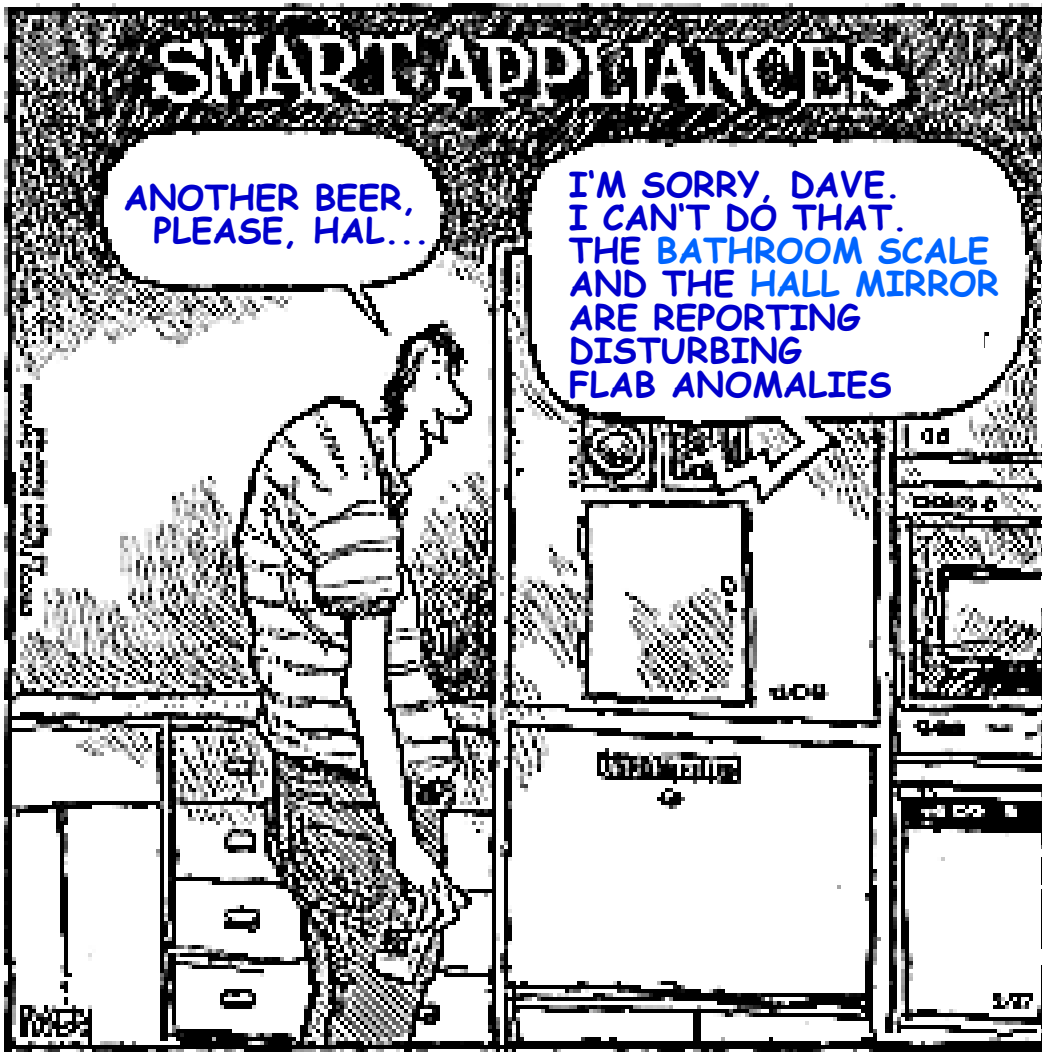   - they may have sensors

    - e.g., *location* awareness
    - or *situation* awareness

- Are responsive
    - communicate with their environment
    - require new user interfaces
        - touching, moving, using them ; speaking to them ; ...?
    - networked with other smart objects

Networked with Other Smart Objects?

Cartoon by Jeff MacNelly

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Computers Everywhere

- Clear trend:
  - 1 computer (mainframe) for many -->
  - 1 computer (PC) for everyone -->
  - many computers for everyone

what sensible applications are possible?

- Small, lightweight, cheap, mobile processors
  - in almost all everyday objects
  - embedded in the environment
  - everywhere

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Ubiquitous Computing

„In the 21st century the technology revolution will move into the everyday, the small and the invisible..."

- Mark Weiser
  - 1952 - 1999
  - XEROX PARC

Invisible Computing

- Information processing moves to the background
  - human centered: concentrate on the task, not the tool
  - the notion „computer as a tool" does no longer hold

- New picture of computing as an invisible, ubiquitous background assistance
  - specialized, invisible computers will become an integral part of the natural human environment
  - „computing without computers"

The Disappearing Computer

- Computer merges with physical objects
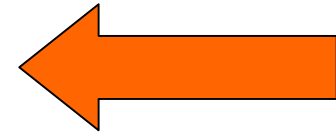
The Disappearing Computer

■ **Mark Weiser**

> ■ *„The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."*

Outline

- Smart Objects

- 5 Reasons for Ubiquitous Computing

- Information Appliances

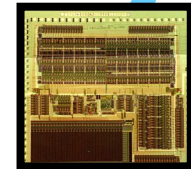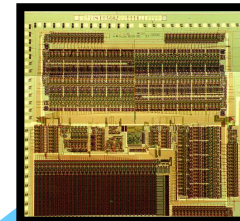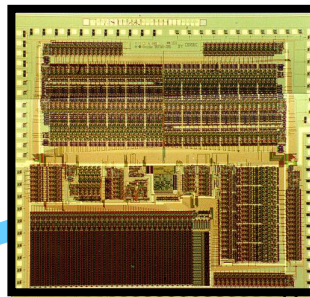- Connecting Atoms and Bits
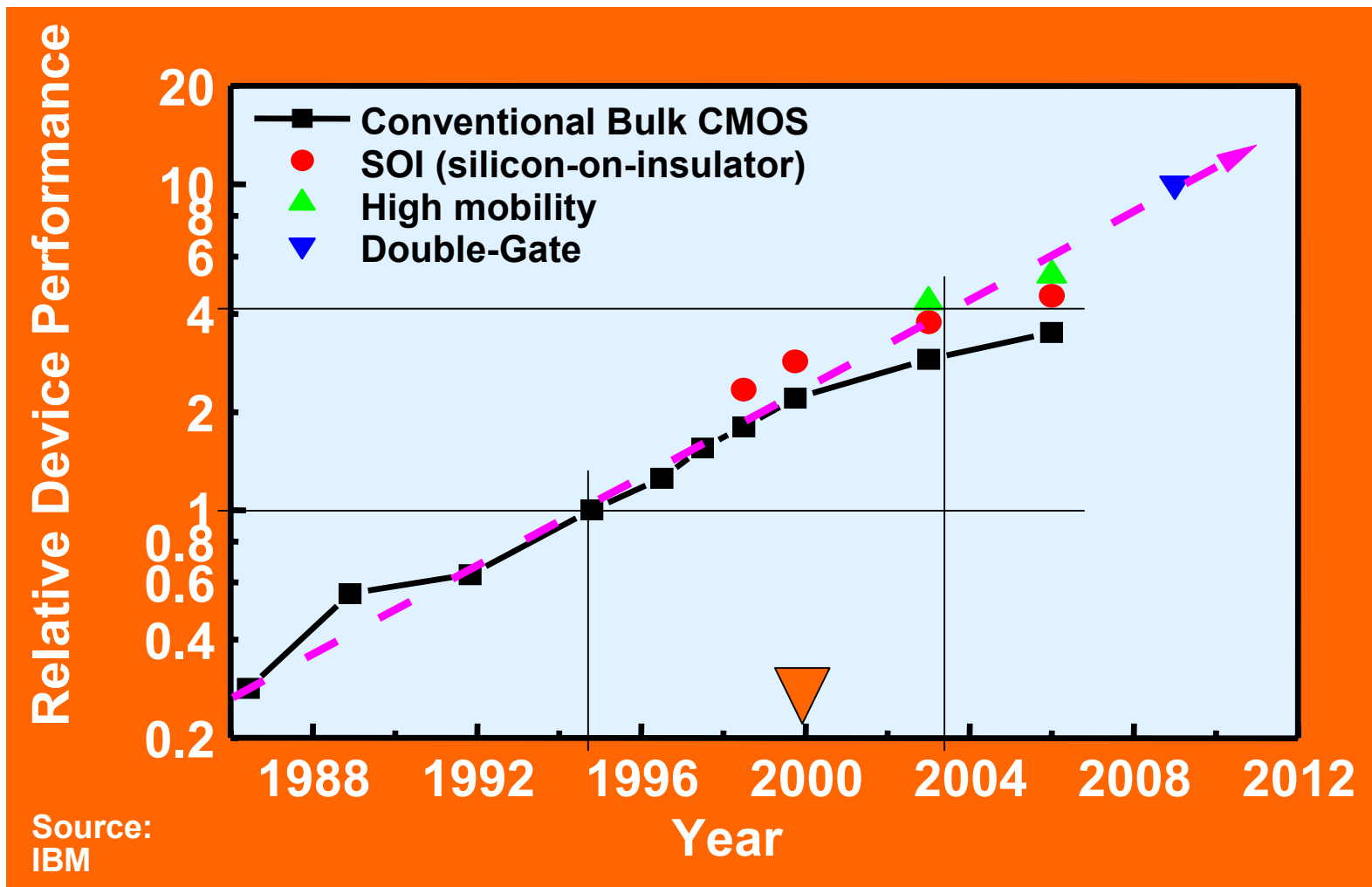
- Consequences

Five Reasons for Ubicomp

1

First Reason for Ubiquitous Computing: Moore's Law (1965)

- Processing speed and storage capacity double every 18 months
  - „cheaper, smaller, faster"

- Exponential increase
  - will probably go on for the next 10 years at same rate

Example:
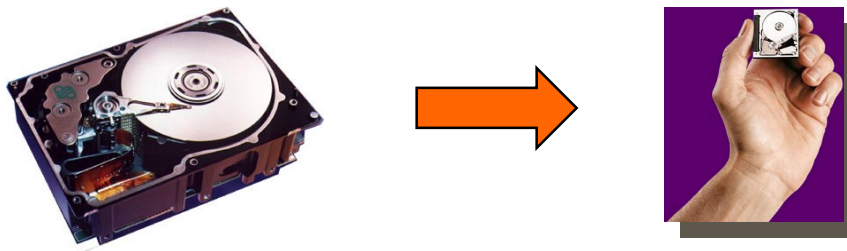# CMOS Performance Increase

F.Ma. 20

Generalized Moore's Law

- Most important technology parameters double every 1 – 3 years („Generalized Moore's Law"):
  - computation cycles
  - memory, magnetic disks
  - bandwidth

  problem: increasing cost

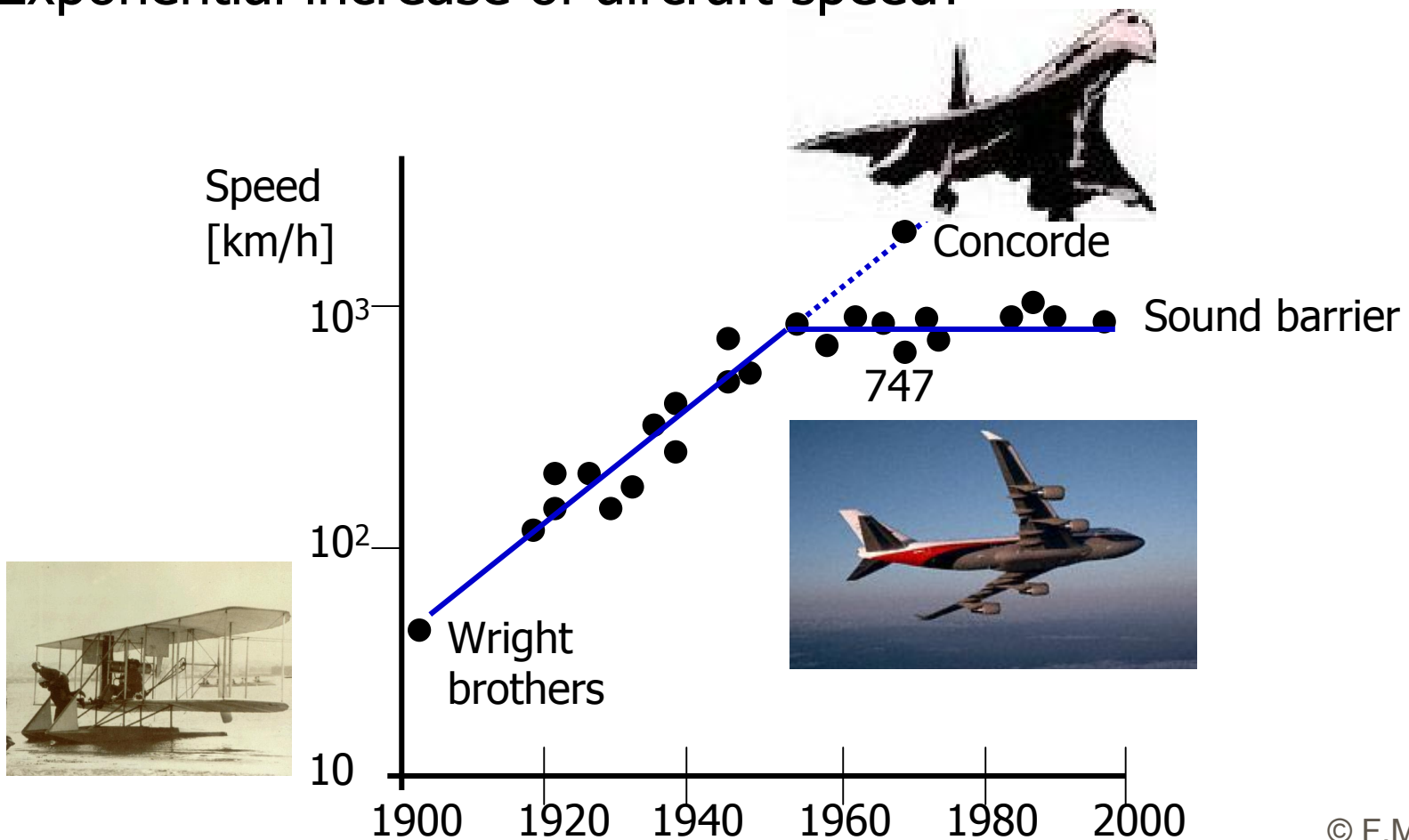- Consequence: scaling down

- But Moore's Law doesn't apply to
  - batteries
  - user mind-share

Barriers

Exponential increase of aircraft speed?

Speed [km/h]

Concorde

10^3 — Sound barrier

747

10^2

Wright brothers

10

1900 1920 1940 1960 1980 2000

Quantum Leap or Evolution?

- Thesis: further progress in
  - computing speed
  - energy usage
  - battery technique
  - communication speed
  - miniaturization
  - display technologies
  - sensor techniques
  - price
  - computer science concepts
  - ...

enables (once again) completely new applications

--> „post-PC era"

Five Reasons for Ubicomp

2

2nd Reason: New Materials

- Materials are important
  - whole eras named after materials (e.g., „Stone Age")
  - more recently: semiconductors, fibers (--> information and communication technologies)

- New materials for information technologies:
  - e.g., small capacitors with high capacity
  - better means to conserve energy
  - higher density of information storage
    - holographic, biological, molecular storages?
  - plastic laser
    - applications: opto electronics, flexible displays,…

Example: Light Emitting Polymer

- Organic semiconductors
- Plastic displays (~ 1 mm thick)
- Applications soon (e.g., curved or flexible displays)

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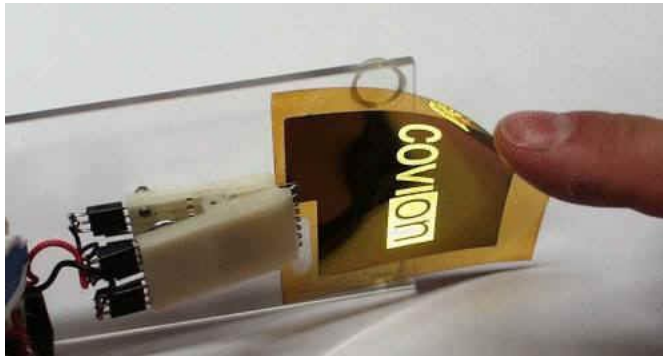
Flexible Displays:
The PC of the Future?

...of course with wireless Internet access!

But what about its energy source? (Fuel cells?)
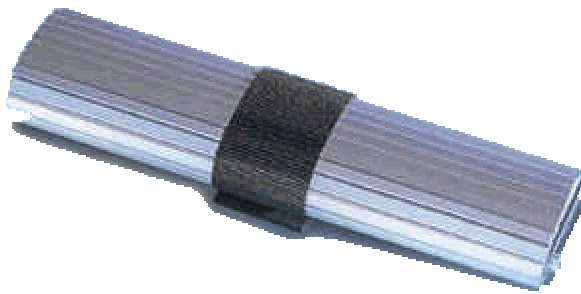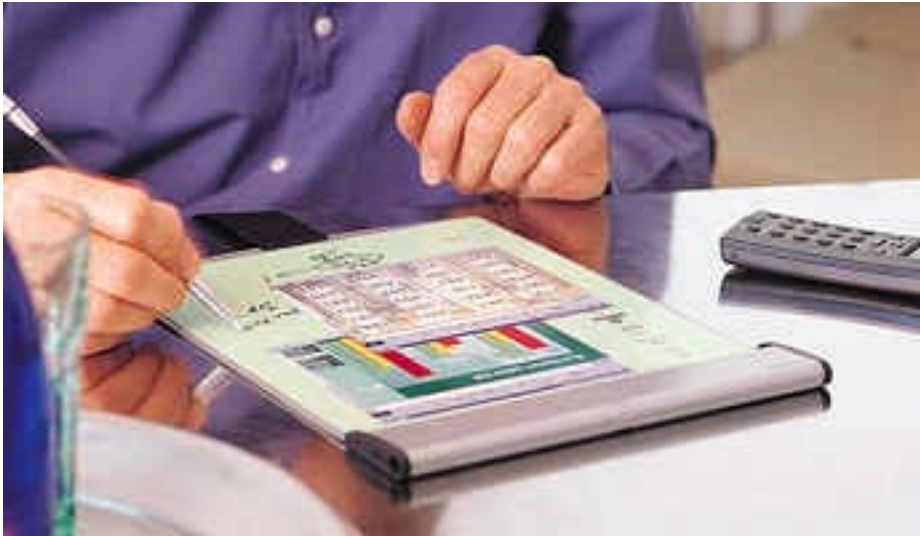
A Flexible „PC" Concept

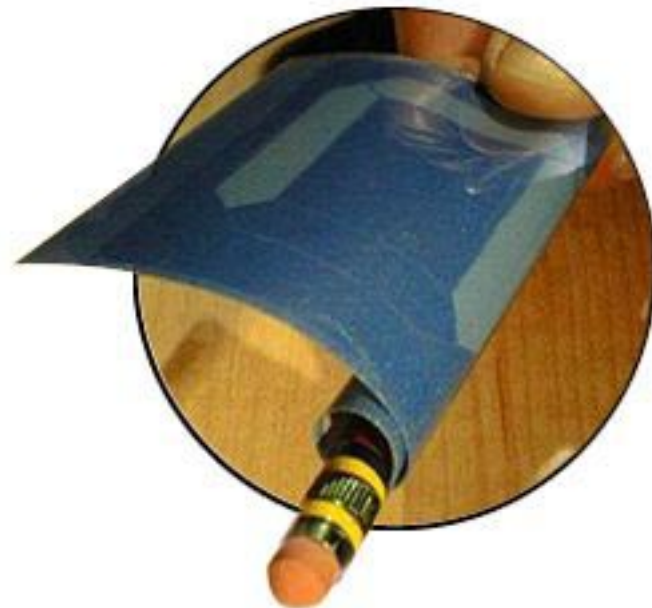
image source: Toshiba

Another Example:
Smart Paper, Electronic Ink

- Electronic ink
  - micro capsules, *white* on one side and *black* on the other
  - oriented by electrical field
  - substrate could be an array of plastic transistors

- Potentially high contrast, low energy, flexible

- Interactive: writable with magnetic pen
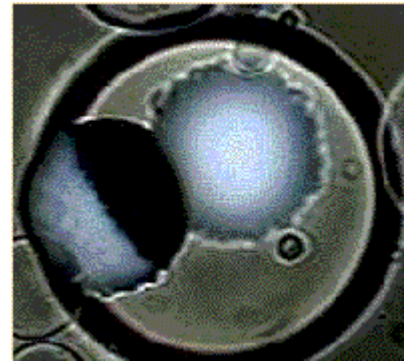
Smart Paper, Electronic Ink
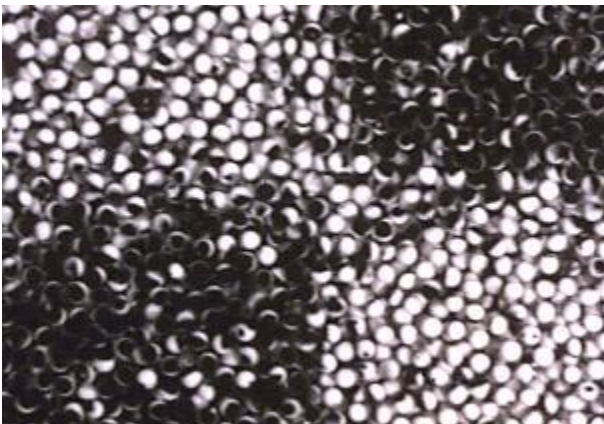
Detailed view of the micro capsules
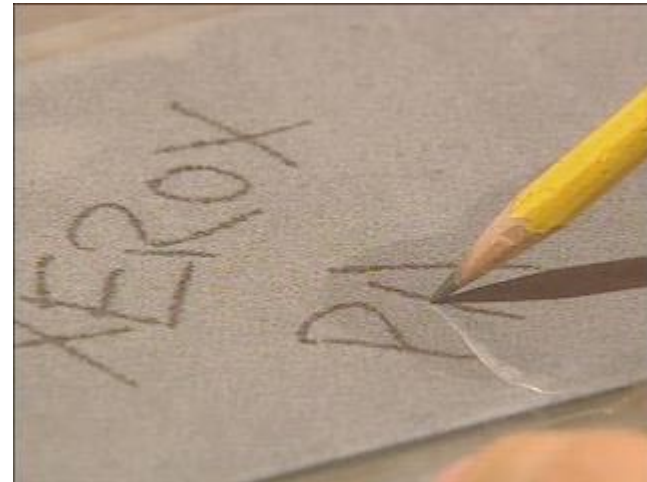
An electronically charged pencil rotates the "pixels"

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Smart Paper: Applications

This foldable and rollable interactive map
("*you are here*") is still science fiction, unfortunately

Five Reasons for Ubicomp

3

3rd Reason: Progress in Communication Technologies
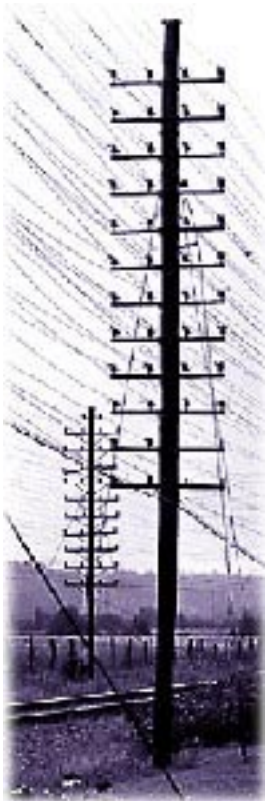
Nostalgia

- Bandwidth of single fibers ~ 10 Gb/s
  - 2002: ~ 20 Tb/s with wavelength multiplex (often at no cost for laying new cable!)

- Powerline technique
  - coffee maker „auto-matically" connected to the Internet

A bluetooth module

- Wireless
  - mobile phone: GSM, UMTS
  - wireless LAN (> 10 Mb/s)

- Room networks , body area networks

Body Area Networks

- Very low current (some nA), some kb/s through the human body

- Possible applications:
  - car recognizes driver
  - phone configures itself when it is touched
  - micro payment: pay when touching the door of the bus
  - toaster and TV identify user
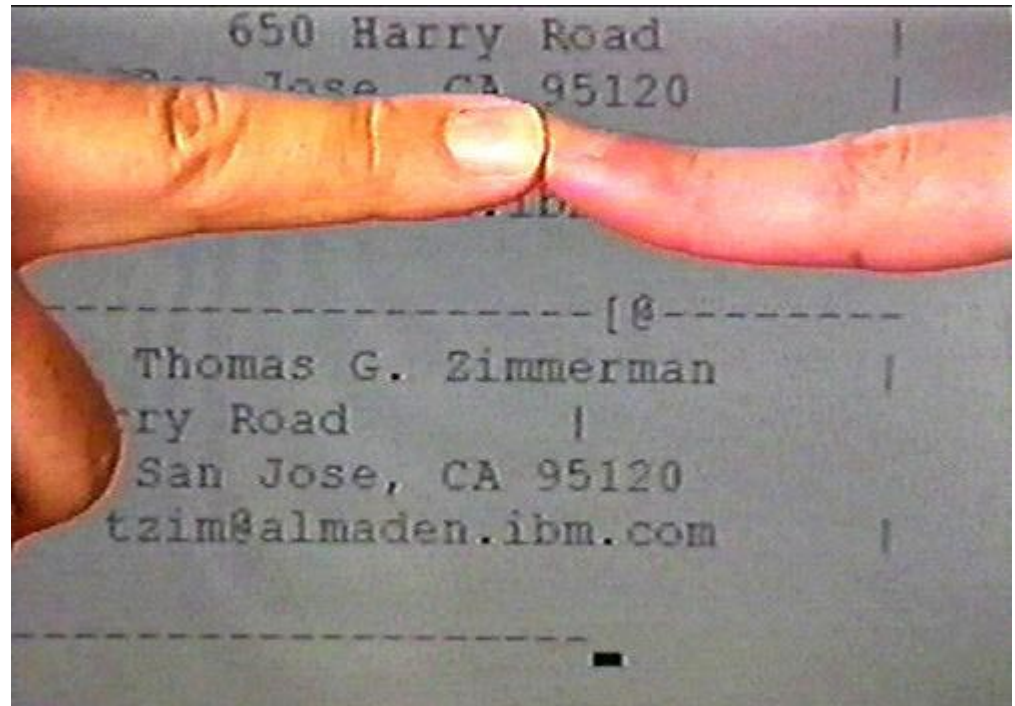
business card exchange

Five Reasons for Ubicomp

4

4th Reason: Better Sensors

- Miniaturized cameras, microphones,...
  - pattern recognition, assisted by heuristics
  - speaker recognition, speech controlled devices

- Fingerprint sensor
on mobile objects

- Autonomous perception
  - establishing contextual relations
  - recognition of objects

Example:
Standalone Radio Sensors

image source: Siemens

- No external power supply
  - energy from the actuation process
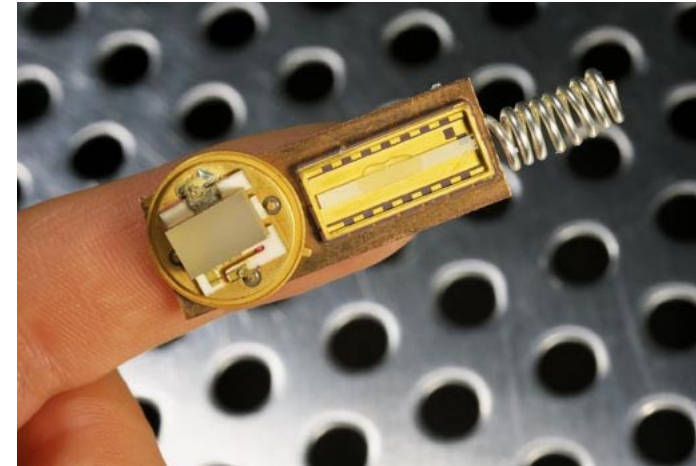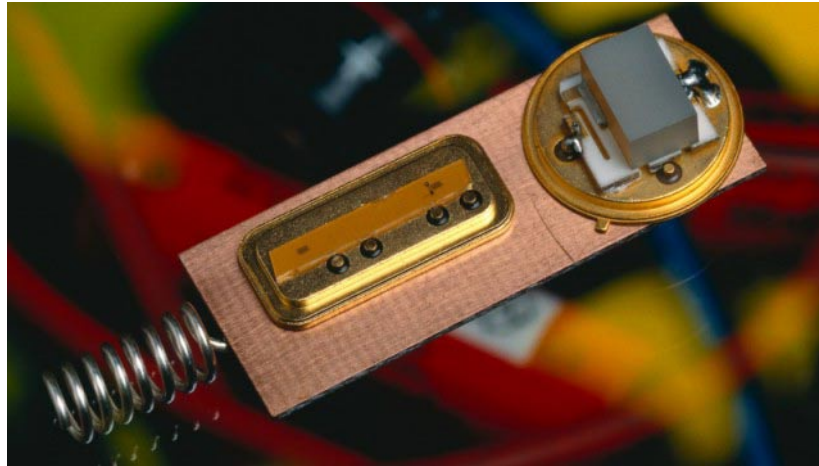 - piezoelectric and pyroelectric materials transform changes in pressure or temperature into energy
- RF signal is transmitted via an antenna (20 m distance)
- Applications: mobile devices, temperature surveillance, remote control (e.g., wireless light switch),...

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Another Example: Location Sensors

- Geographic location of increasing interest for mobile devices

POSITION
N 39°
    43'17"
W 105°
    01'26"

- Various techniques
  - GPS receivers are becoming smaller and cheaper
    - accuracy ~5 m (improvements with differential GPS)
    - new civilian European Galileo-System by 2008?
  - GSM and other mobile phone protocols
    - infrastructure soon available, accuracy > 100 m
  - inertial sensors to measure acceleration
  - measuring signal propagation delay and phase shift (infrared, microwave, ultrasonic) for indoor use

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GPS Receiver

Example: „Pathfinder" (Casio)

- accuracy: 30 m
  - variance reduction in continous mode
- 66 x 66 x 30 mm
- 140 g
- ~ 700 measurements with one battery

- Current development goal: credit card form factor
  - integration in PCMCIA card and in smart cards

Five Reasons for Ubicomp

5

5th Reason: New Concepts

- **E.g.,** spontaneous networking

  - objects in an open, distributed, dynamic world find each other and form a transitory community

  - devices recognize that they „belong together"
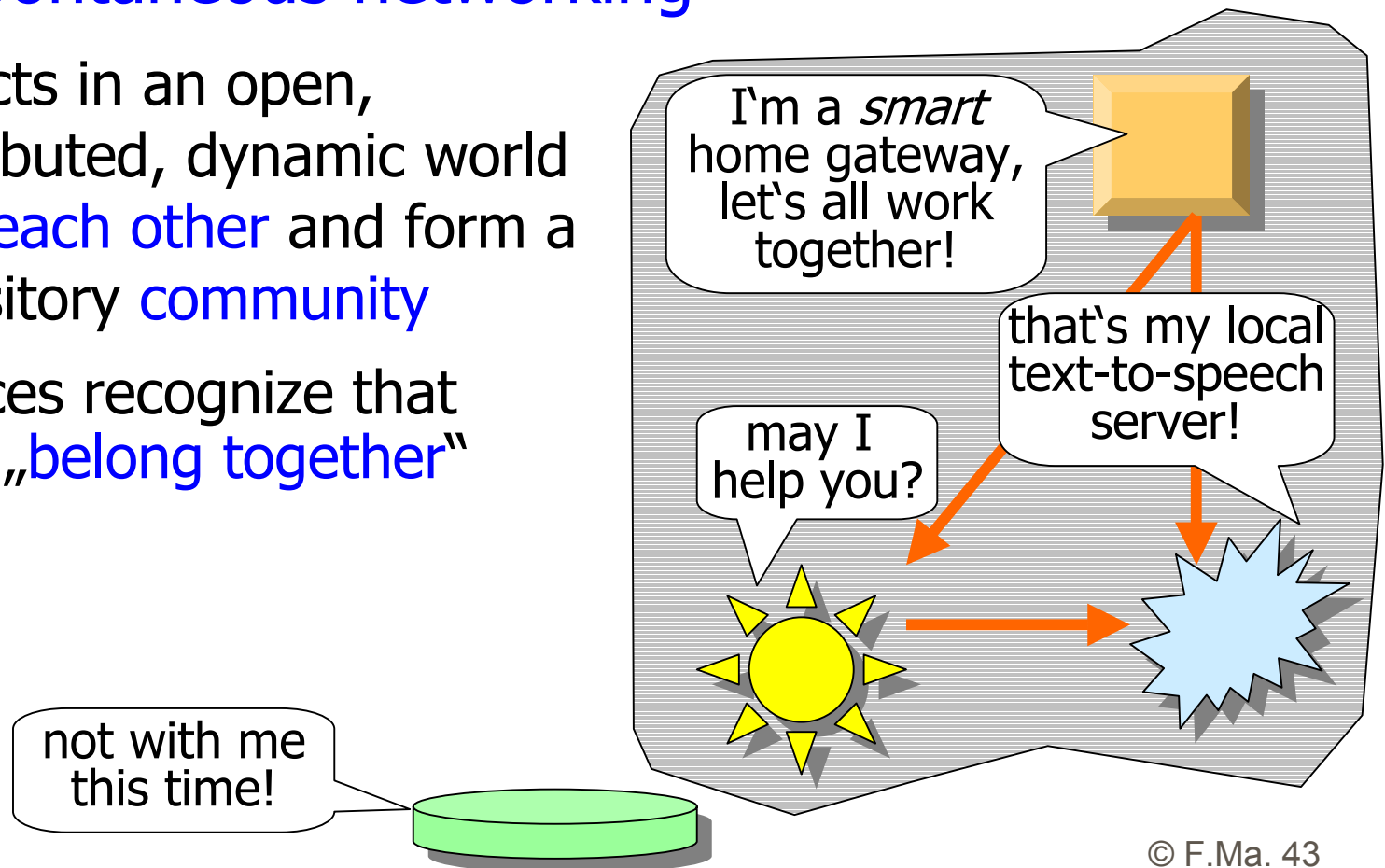
I'm a *smart* home gateway, let's all work together!

that's my local text-to-speech server!

may I help you?

not with me this time!

Outline

- Smart Objects

- 5 Reasons for Ubiquitous Computing

- Information Appliances

- Connecting Atoms and Bits

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Information Appliances

- Networked (possibly mobile) specialized devices
    - adapt to individual users and their customs

- Some applications will leave the PC
    - instant-on devices for calendar, weather forecast,…
    - example: e-book (new flat or flexible panels, e-ink)

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Information Appliances

Information Appliances: Specialization and Simplicity

„Today's desktops and palmtops are multi-purpose tools - electronic Swiss Army knives.

But how many of us would use a Swiss Army knife for preparing a dinner at home? It may be fine on a camping trip, but not for more routine activities where efficiency and quality are more highly valued."

From: „Portolano: An Expedition into Invisible Computing"

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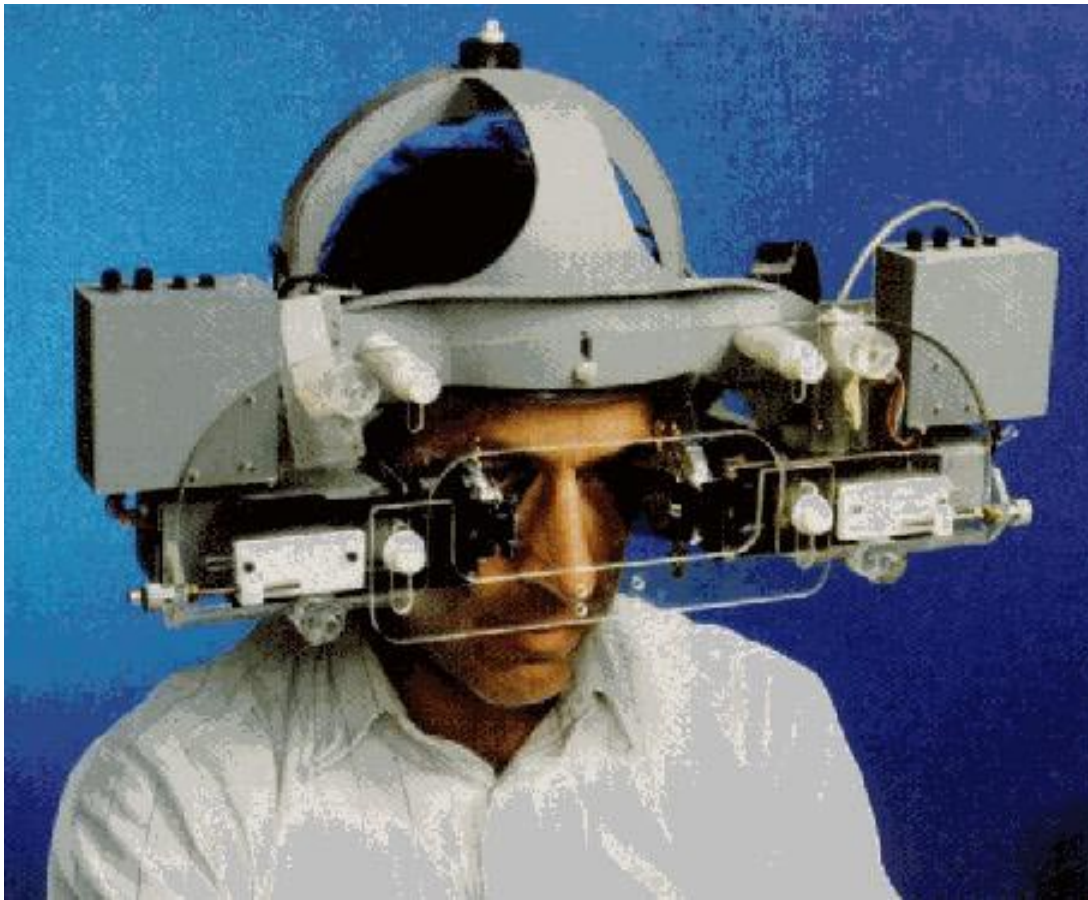
Wearable?

Wearables Today
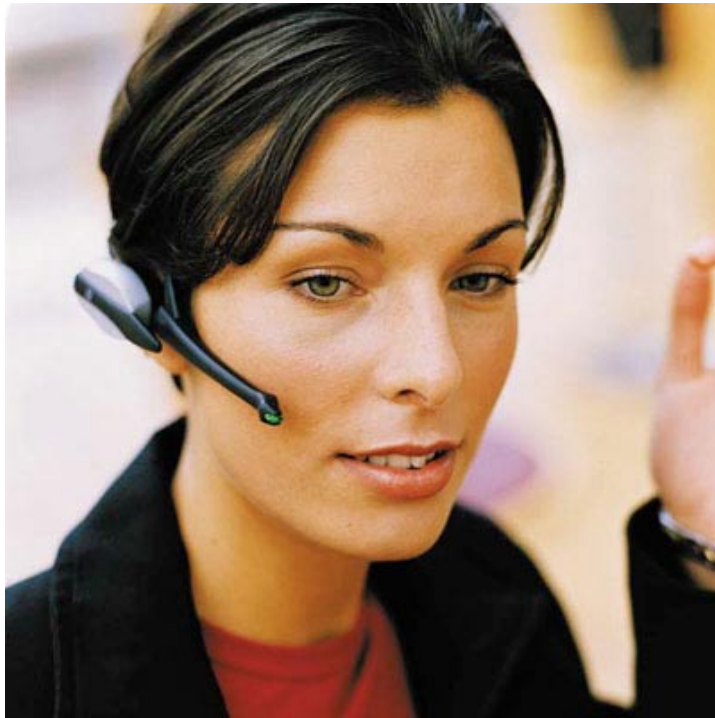
Future Wearables
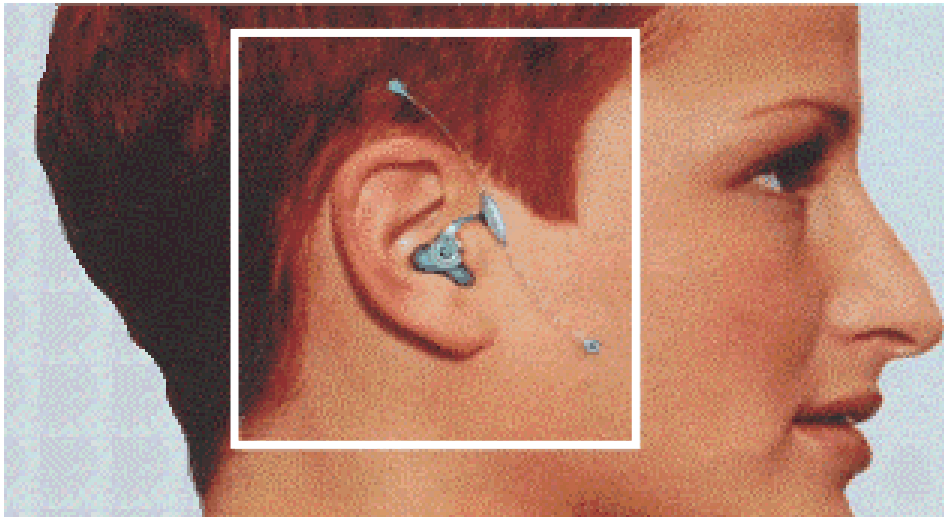
- Headsets of mobile phones as jewelry?

© F.Ma. 51
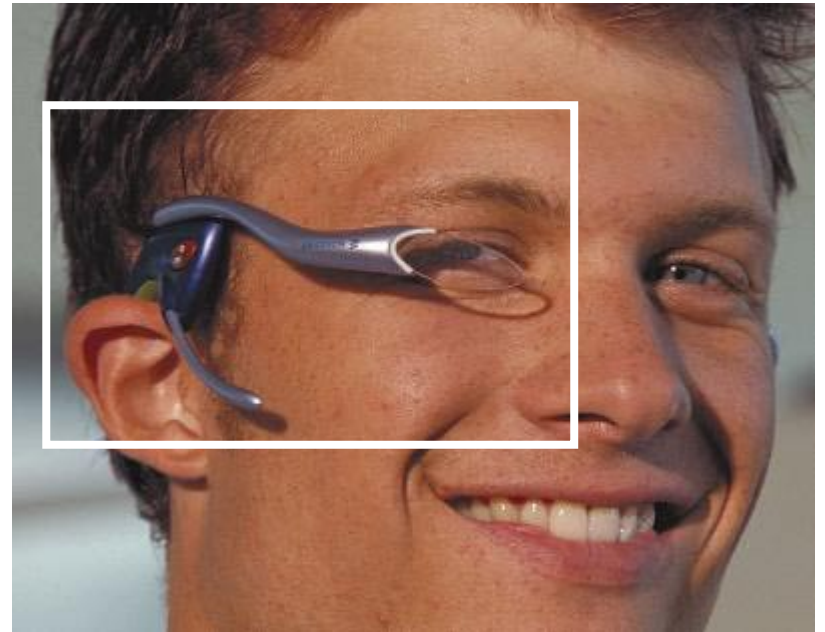
Retina Eyeglass Display?

The MicroOptical Corporation

Smart Clothing

- Conductive textiles that are also soft and warm to touch
  - integrate conductive fibers into woven materials
  - move audio, data, and power around a garment
- Conductive inks
  - print electrically active patterns directly onto fabrics
- Challenge: design fashionable clothes that people want to wear

Soft Fabric User Interfaces

e.g., textiles that change conductivity when stretched
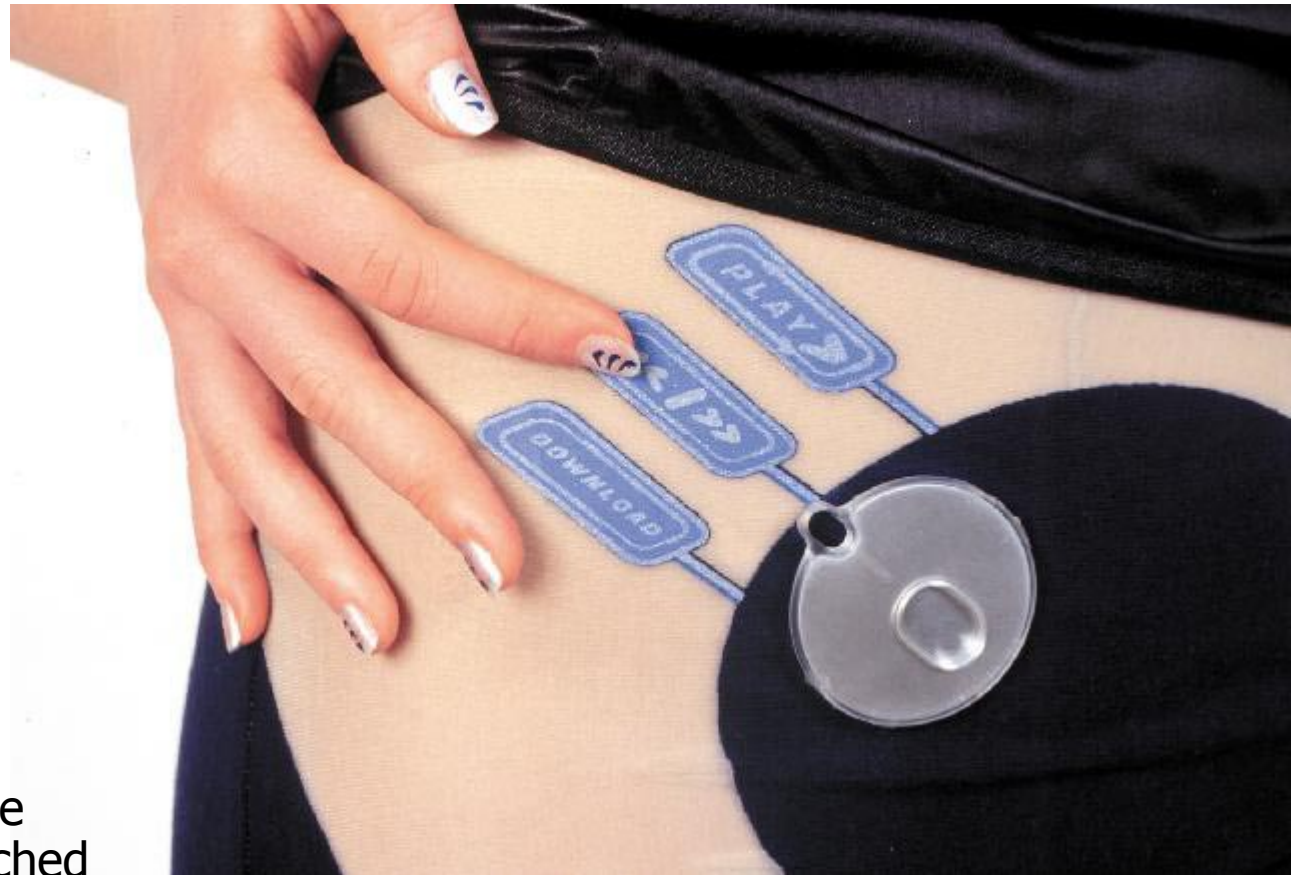
Smart Clothing

- Sensors based on fabric
  - e.g., monitor pulse, blood pressure, body temperature
- Invisible collar microphones

- Kidswear
  - integrated GPS-driven locators
  - integrated small cameras (to keep the parents calm)
  - game console on the sleeve?

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Real World and Virtual Worlds: How to Bridge the Gap?
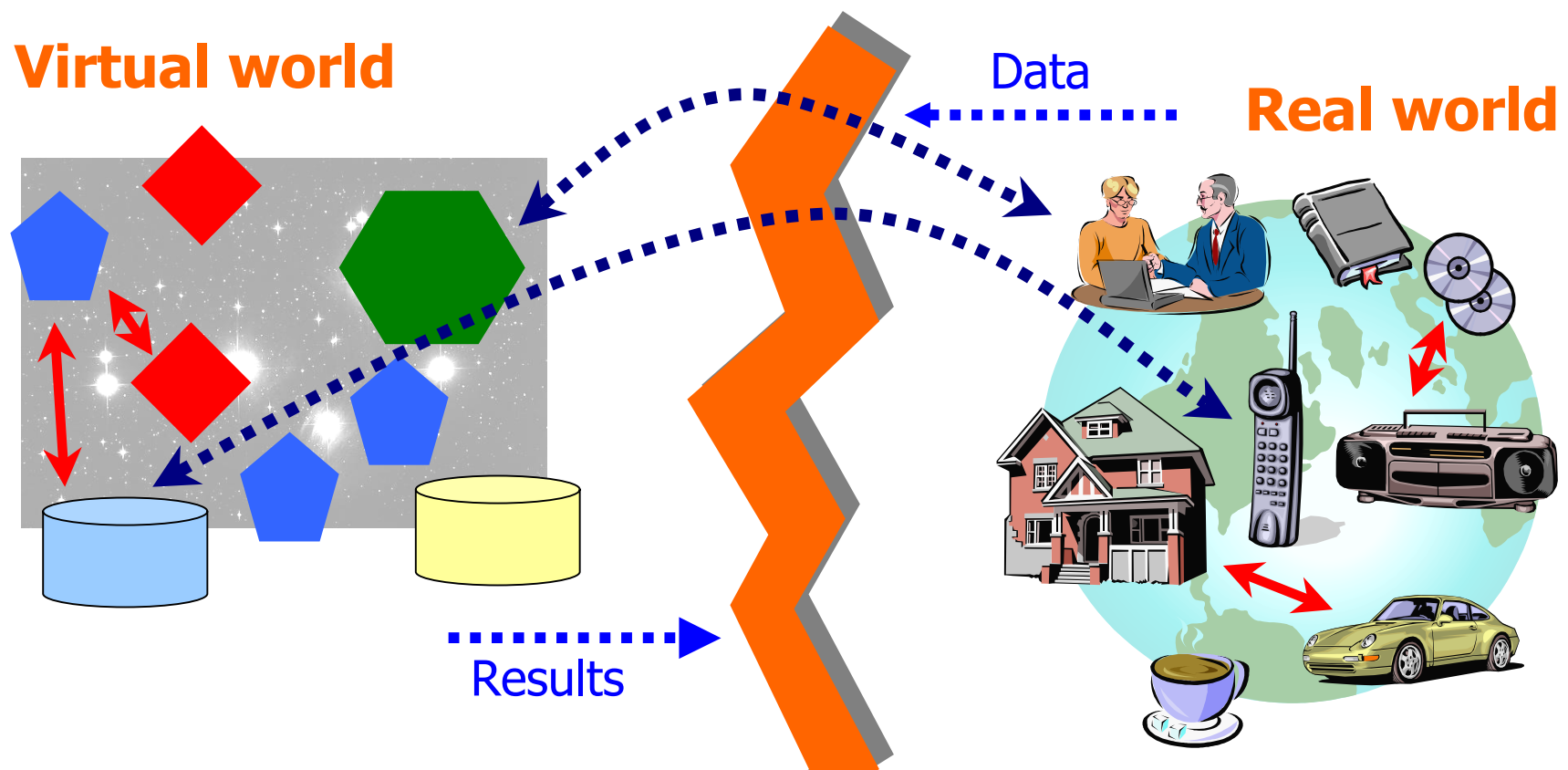
Virtual world

Data

Real world

Results

Narrowing the Gap

Virtual world

files   data
bases

manual
data entry

bar code
labels

Real world

time

Narrowing the Gap

Virtual world

files   data bases   virtual counterparts

manual data entry

bar code labels   RFID tags

Real world

time
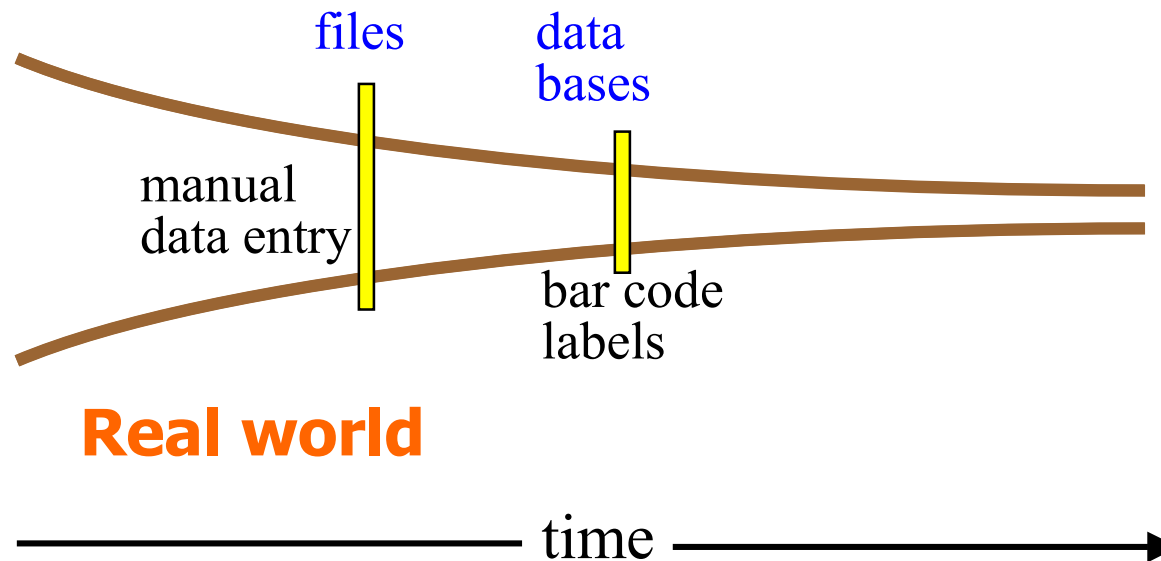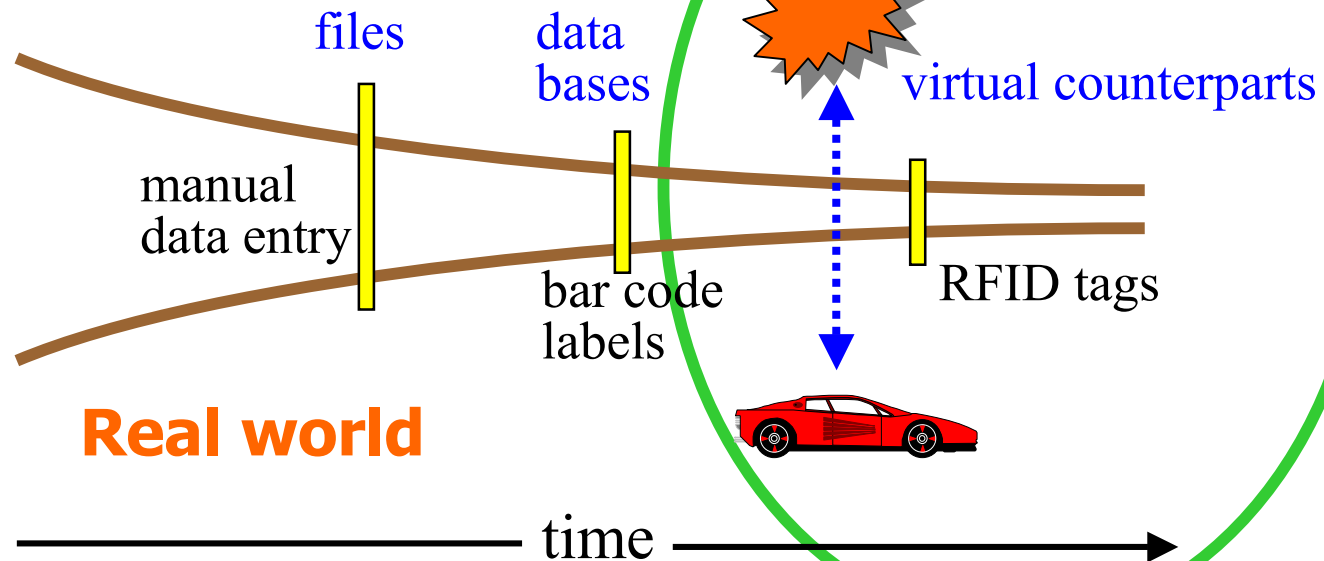
- Why not attribute every object a unique representation in cyberspace?
  - „virtual counterpart"

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Making Things Smart with Virtual Counterparts

Virtual world
(Internet,
Cyberspace)

virtual counterparts

pure virt. object
(e.g. email)

Real world

© F.Ma. 61
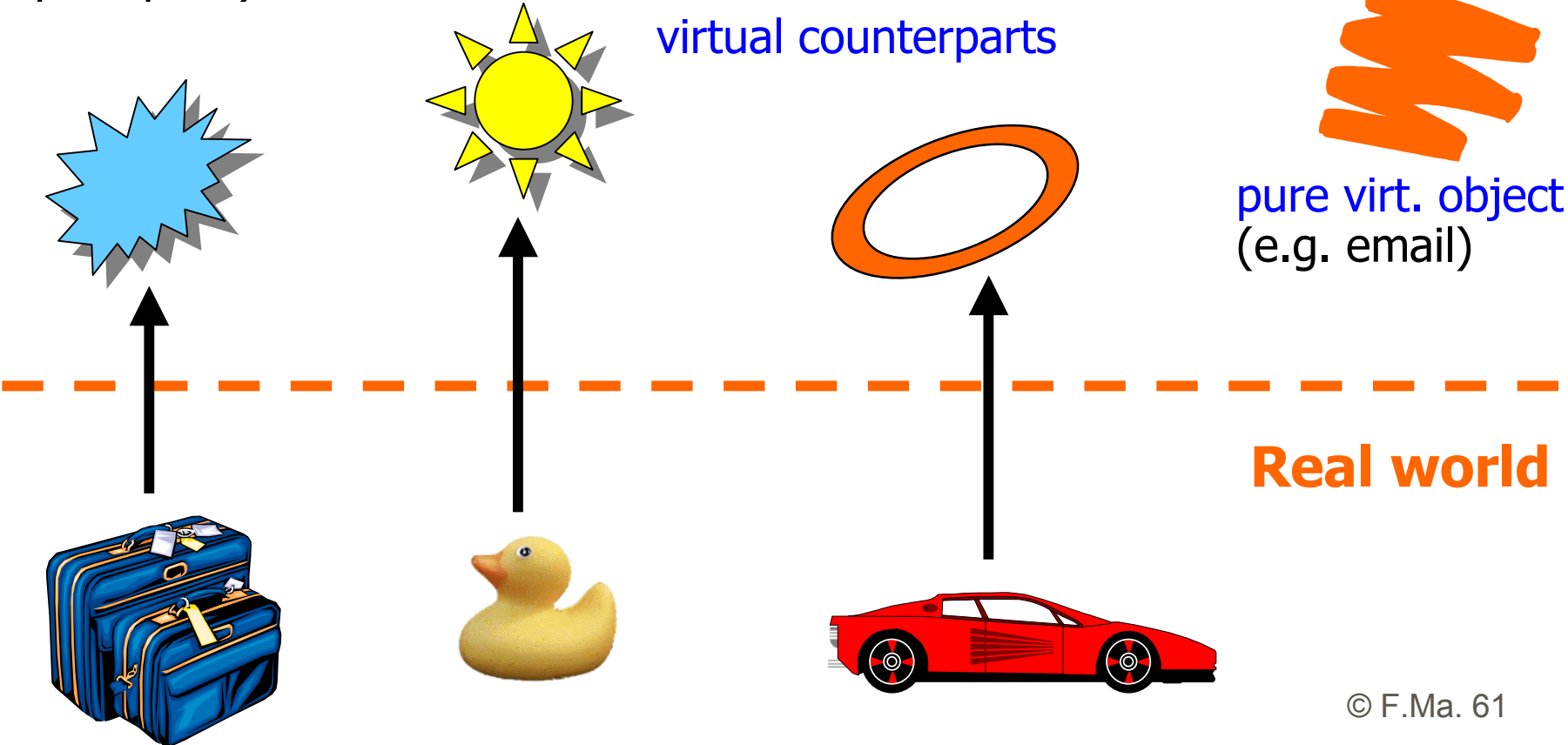
Virtual Counterparts as Artifact Memories

1) Aug. 3rd, 2001: ....
2) Aug. 5th, 2001, 10:34 .....
3) Aug. 5th, 2001 10:37 ...
4) ...

Counterparts act as **memories** for their artifacts

Updates triggered by **events**

Queries from the real world return memory content

Arrived in room 564 Bayview Hotel

10:34, Sue K. opens bag

who? where? when?

Sensors generate events

© F.Ma. 62
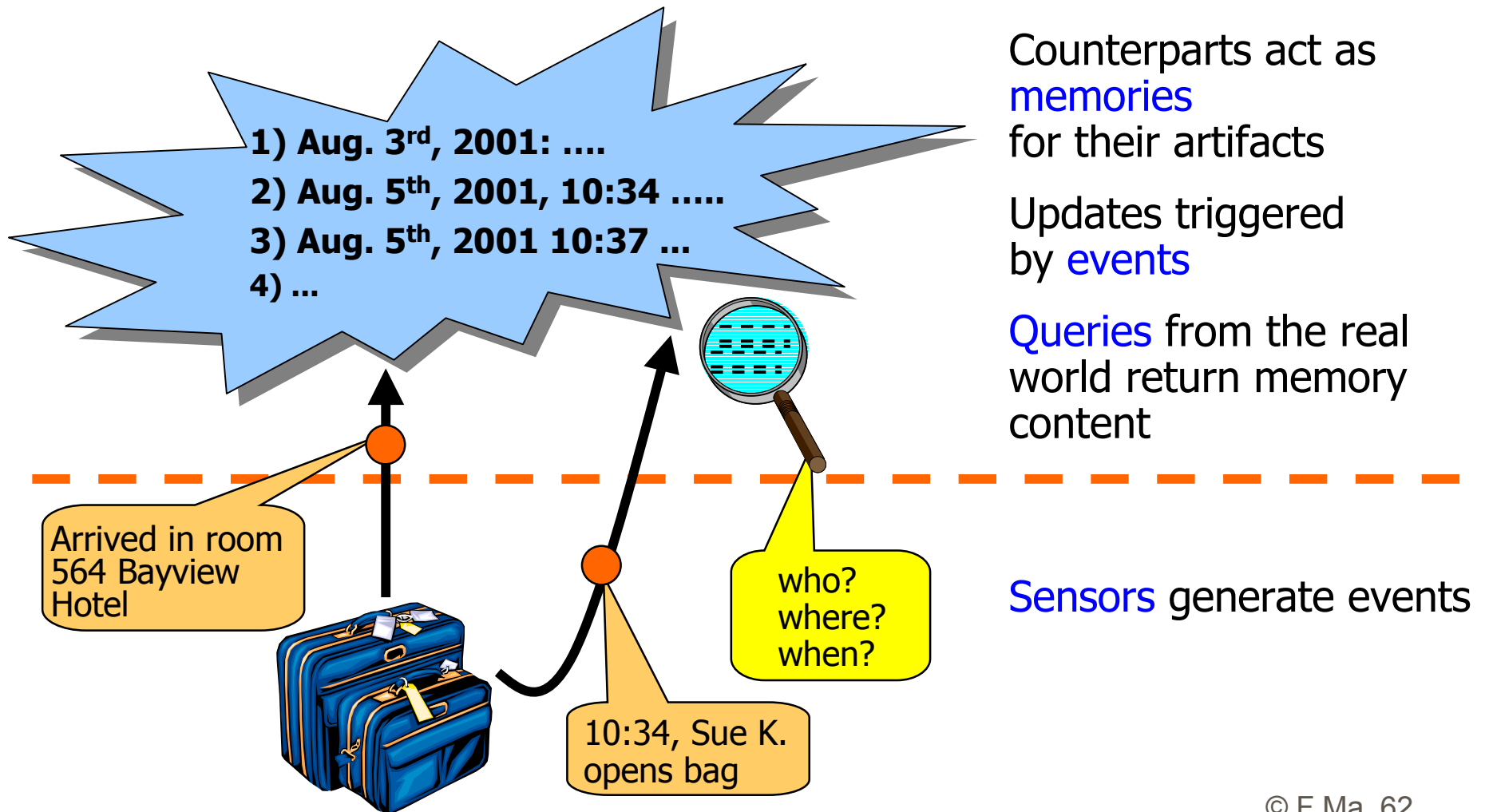
What Happened?
Who? Where? When?

label

1

display
instrument
and label
reader

object of the
real world

HTTP get

2

Internet

WWW
server

Bought on 20 Aug 2001; last travel: to
London Sep 2003; contained shirt no.
1342 and 1349; was on 17 Nov 2002 in
Hotel Atlantic, room 317 ...
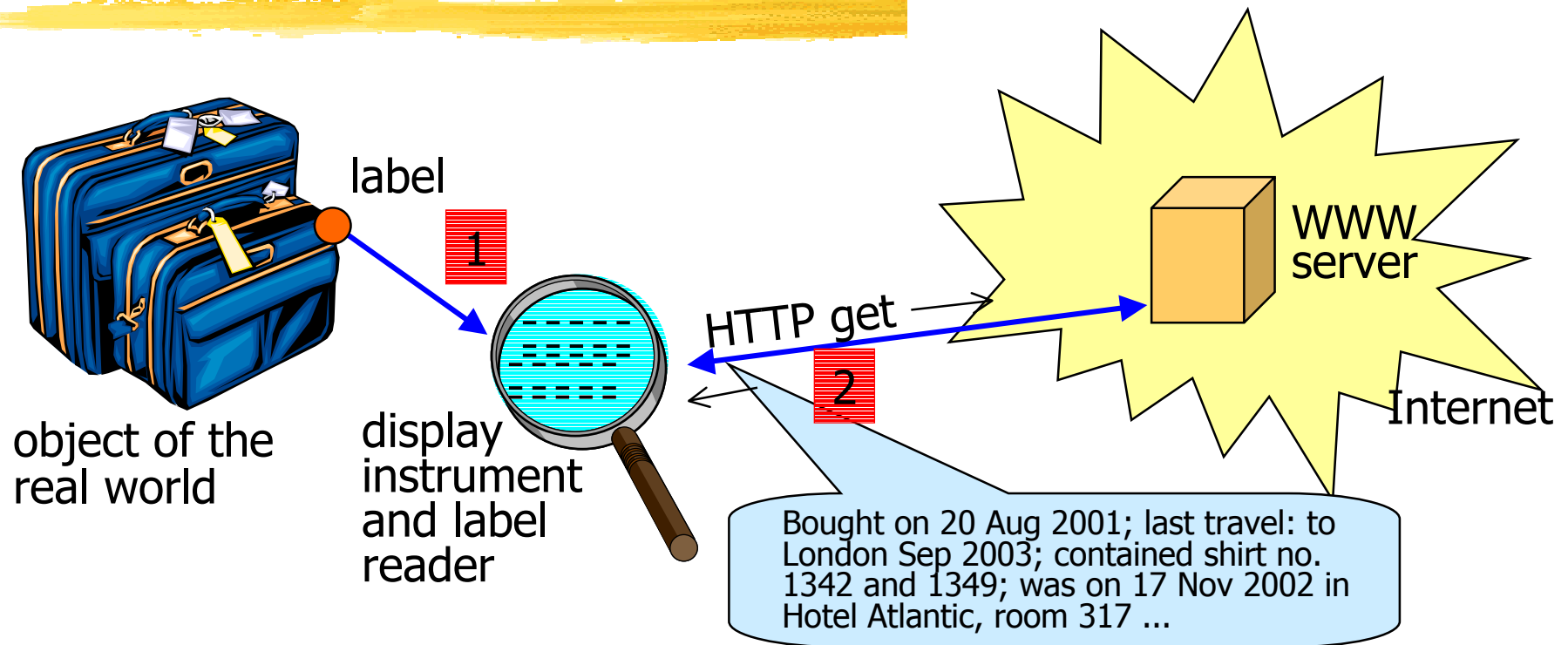
- Label = Internet-URL (pointing to the bag's „home page")
  - e.g., recipe „on" food for microwave oven
  - label could be an RFID (i.e „smart label")

© F.Ma. 63

RFID: „Radio Frequency Identification"

- **Identify** objects from **distance**
  - small IC with RF-transponder
- **Wireless energy supply**
  - ~ 1 m
  - magnetic field (induction)
- **ROM** or **EEPROM** (writeable)
  - ~ 100 Byte
- Price ~ **$ 0.1 ... $ 1**
  - consumable and disposable

image source: Portolano project

RFIDs as „Smart Labels"

- **Flexible tags**
  - laminated with paper
  - self-adhesive
  - printable (e.g., barcode)

image source: Portolano project

Smart Labels
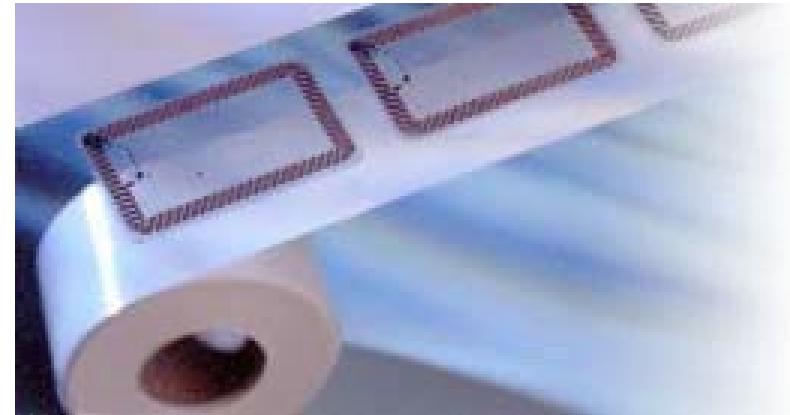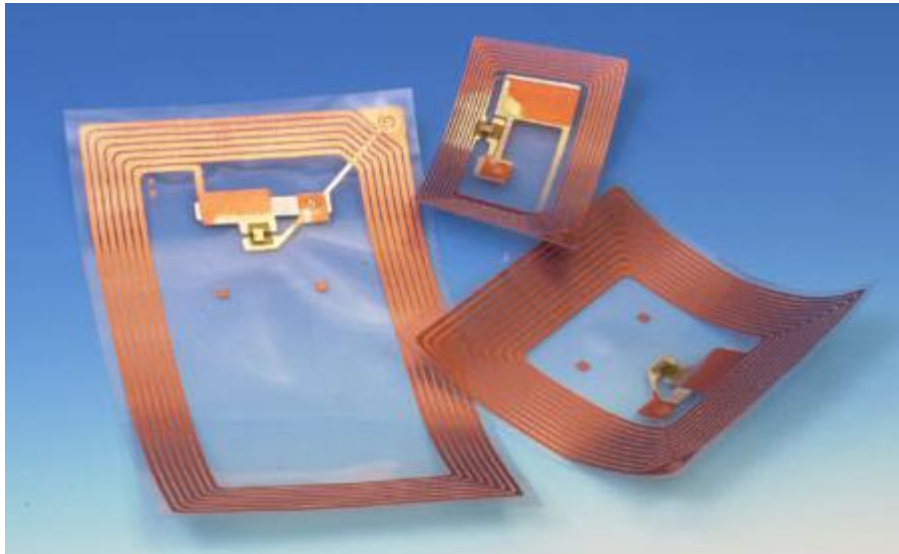
- Chip (without antenna):
  ~ 2 mm x 2 mm x 10 μm
  - fits into 80 μm thick paper!

- Antenna:
  - copper, or
  - printed with conductive ink, or
  - on CMOS waver (micro galvanic „coil on chip")

Components of an RFID System

energy

data

RFID „reader"

antenna

RFID tag

~ 1 m

2 x 2 mm

~ 3 cm

application

© F.Ma. 68
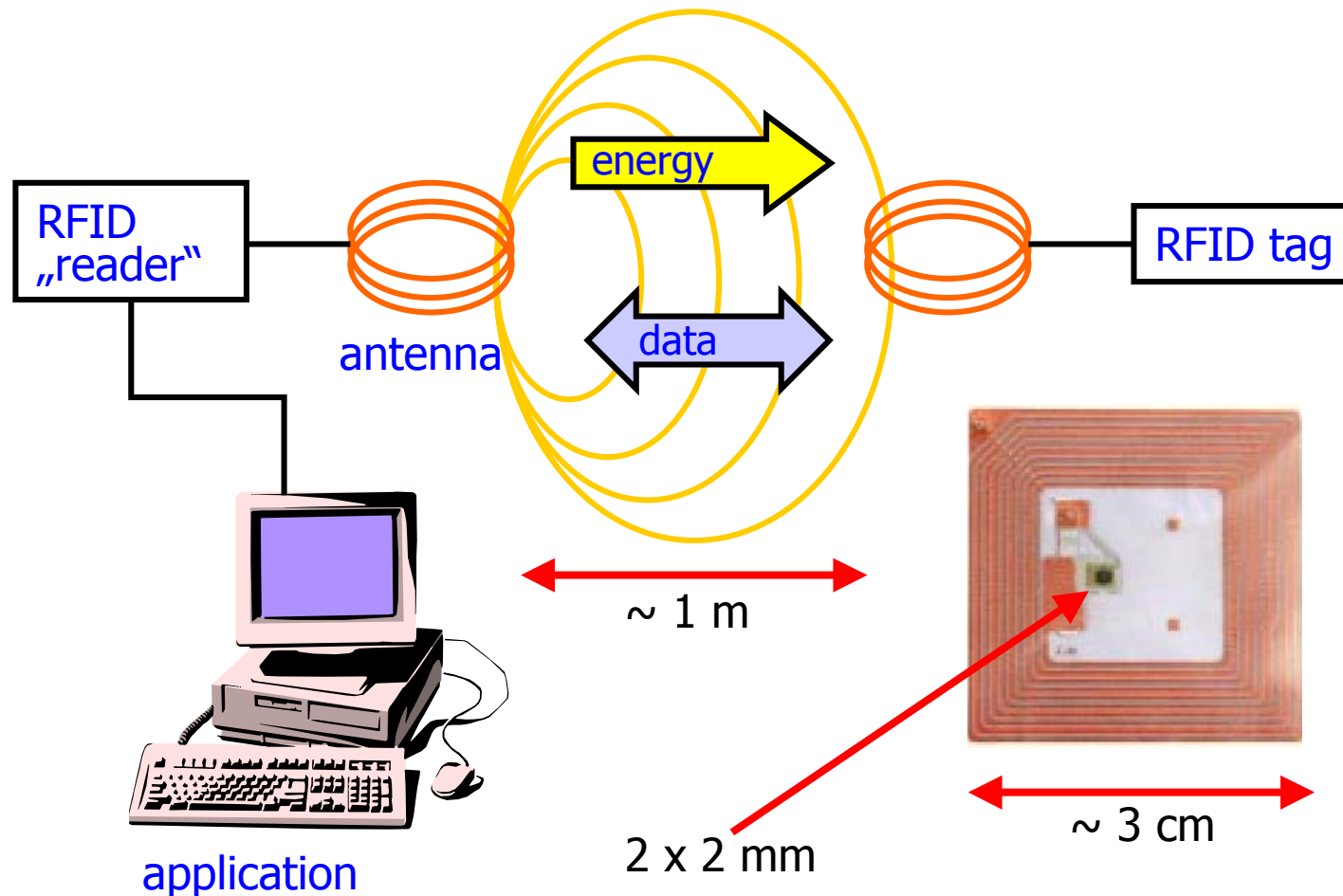
Patent US06018299

Radio frequency identification tag having a printed antenna and method

Motorola Inc, issued 01/25/2000

„A radio frequency identification tag includes a radio frequency identification tag circuit chip coupled to an antenna including a conductive pattern printed onto a substrate. The substrate may form a portion of an article, a package, a package container, a ticket, a waybill, a label and/or an identification badge…“

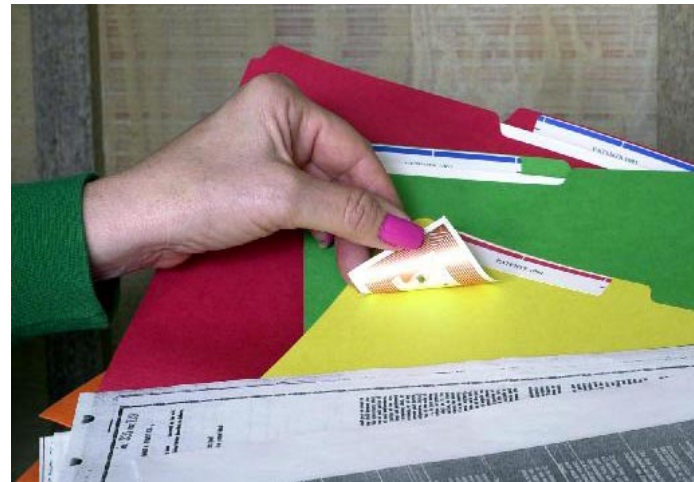# Application Domains for RFIDs

- Electronic article surveillance
    - „EAS" - anti-theft functionality
- Inventory control
    - shops or mini bar in hotel rooms
- Libraries, video rental
- Baggage labels

© F.Ma. 70

Application Domains for RFIDs

- Access token (e.g., ski pass)
- Ear clips for animals
- Transport of mail and parcels
- Tracking of goods
- „Radio signature" of documents
- ...

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Commercial Interest in Linking „Atoms to Bits"

- Connect the real world to the digital world
  - e.g., by using bar code readers or RFID readers

- Number is transformed to an URL, associated Web page is returned

- Identify object instance, not object type (e.g., UPC)

Application Scenarios

- Get information about real objects
  What is contained in this medicine? Listen to music found in an ad.

- Smart assistant
  What parts need maintenance? What is the layout of this machine?

- Context awareness
  Is this tool available here?

- Smart home, car, office, ...
  Adapt to people's preferences

- ...

Clicking on Real-World Objects?

- PDAs, mobile phones, and wireless internet appliances become request devices for information
  - find information
  - order products
  - ...

„BarMailer", a snap-in bar code reader for mobile phones

- Bar code reader connected to a mobile phone
  - send codes via SMS to bar-mail server
  - server may also send back an e-mail

© F.Ma. 77

„Cross Convergence" Scanner and Pen

writing end

scanning indicator

scanning button

scanning function end
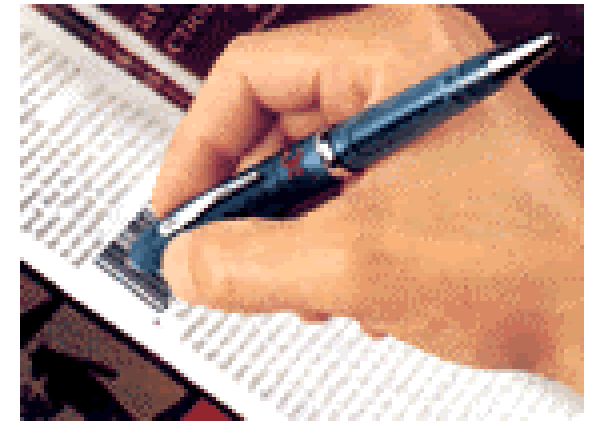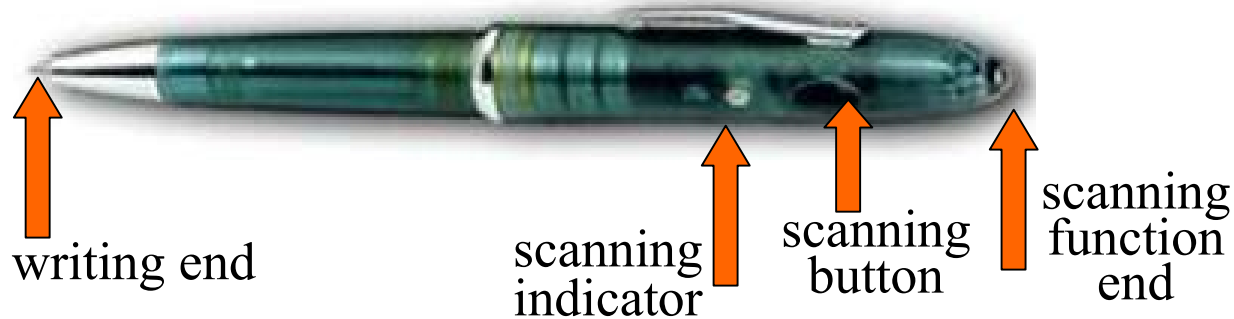
- Mobile scanner and pen, $89.90
- Allows to link from a printed page directly to the Web
  - scans barcodes on printed material

CueCat

- Bar code scanner (shape of a cat)
  - LED based; attaches to the computer via the keyboard port

- 10 million free scanners distributed in the US by the end of year 2000
  - 50 millions planned in 2001
  - estimated cost of $ 5 - $ 10 per CueCat
  - someone spends at least $ 500 000 000

- Sends the Web browser directly to the „right" location when scanning the bar code of an ad in a magazine
  - „our revenue model is being the gate keeper between codes and their destination online"

Patent US5978773

„System and method for using an ordinary article of commerce to access a remote computer.“

NeoMedia Technologies, Inc., Fort Myers, FL
Issued / Filed Dates: Nov. 2, 1999 / Oct. 3, 1995

Patent US5978773

„System and method for using an ordinary article of commerce to access a remote computer.“
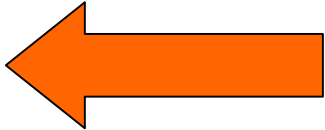
NeoMedia Technologies, Inc., Fort Myers, FL
Issued / Filed Dates: Nov. 2, 1999 / Oct. 3, 1995

A system and method for using identification codes found on ordinary articles of commerce to access remote computers on a network. In accordance with one embodiment of the invention, a computer is provided having a database that relates Uniform Product Code ("UPC") numbers to Internet network addresses (or "URLs"). To access an Internet resource relating to a particular product, a user enters the product's UPC symbol manually, by swiping a bar code reader over the UPC symbol, or via other suitable input means. The database retrieves the URL corresponding to the UPC code. This location information is then used to access the desired resource.
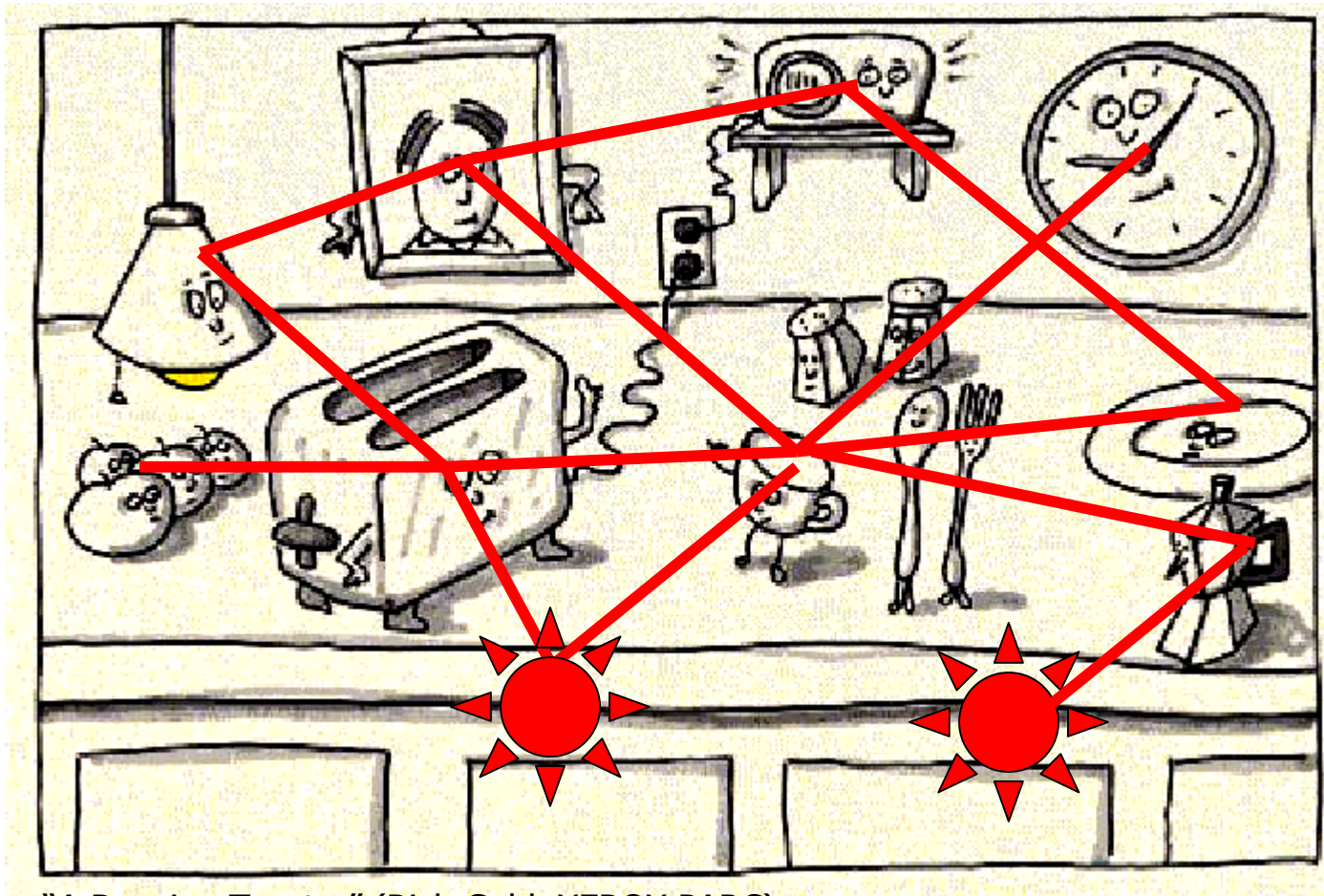
Outline

- Smart Objects

- 5 Reasons for Ubiquitous Computing

- Information Appliances

- Connecting Atoms and Bits

- Consequences

Infrastructure for Smart Objects

"A Dancing Toaster" (Rich Gold, XEROX PARC)

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Why Infrastructure for Smart Objects?

How do we organize billions of mobile smart objects that are highly dynamic, short living,…?

- **Guarantee**
  - security
  - privacy
  - availability
  - reliability
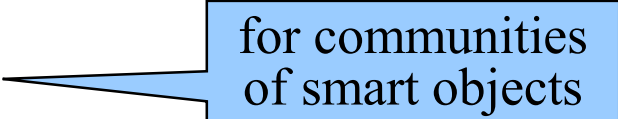
  for **applications** built with smart objects

- Provide **services**
  - location („where am I?")
  - context („are we in a meeting?")
  - event delivery („tell me when... happens")
  - brokering („find a something that...)
  - directory
  - registry
  - …

  for smart objects

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More Infrastructure Tasks

- Enable [for communities of smart objects]
  - spontaneous networking
  - cooperation among smart objects
  - communication
  - mobility
  - service creation
  - service discovery ("is a service available that ...?")
  - ...

  Challenge for practical computer science research!

- Facilitate linking the real world to the virtual world

The European „Disappearing Computer" Initiative

- New information artifacts
  - possibly with sensors,
    micro mechanical systems,
    wireless connections,...

- Emerging new functionality
  from collections of interacting artifacts
  - awareness of other artifacts in the environment

- Emphasis: new people-friendly environments
  - design of new user interfaces

- 16 trans-European projects started in 2001
 - more will follow

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Ubicomp - Applications?

- Travel, mobility
    - travel planning, navigation, traffic guidance
    - spontaneous networks for traffic signalization
    - replacement of classical traffic signals
- Health
    - sensors for health monitoring
- Entertainment, leisure, fun
- Work, office
- E-commerce
- ...

„We are always very bad at predicting how a given technology will be used and for what reasons"

-- Bran Ferren, Chief Disney Imagineer

Impact: Evolution vs. Revolution

- Technique and science have a major impact on our society and the world we live

  - historically: industrialization, electricity, trains and automobiles, electronic mass media

  - implies therefore eventually also ethical questions

  - social adaptation to technical impacts needs some time since this is an evolutionary process (willingness to learn, generational aspects,…)

Performance

„revolutio-nary" new application domains

Time

Impact
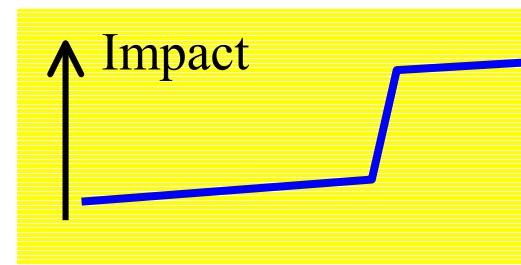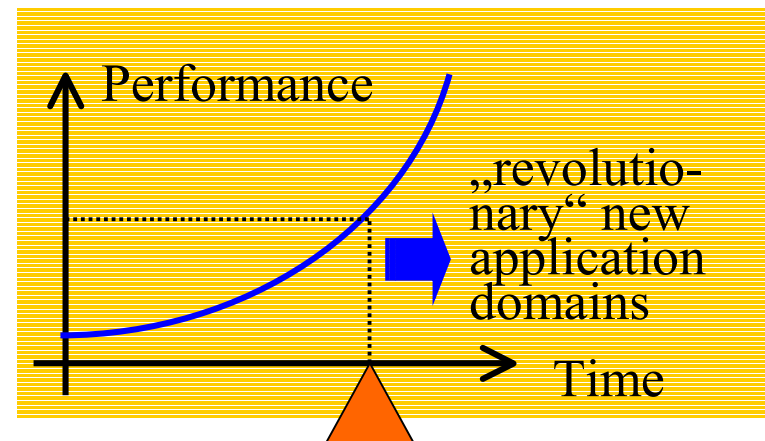
Privacy in a Ubicomp World?

- Privacy is already a concern with the WWW
  - what do they do with my personal data?
  - are my page visits and mouse clicks analyzed?
- Much more dramatic in a ubicomp world!
  - many events of very elementary actions are registered
  - could be assembled to perfect profiles

Bought on **20 Aug 2001**; last travel: to **London** Sep 2003; contained shirt no. 1342 and 1349; was in **Hotel Atlantic**, **room 317** on 17 Nov 2002 …
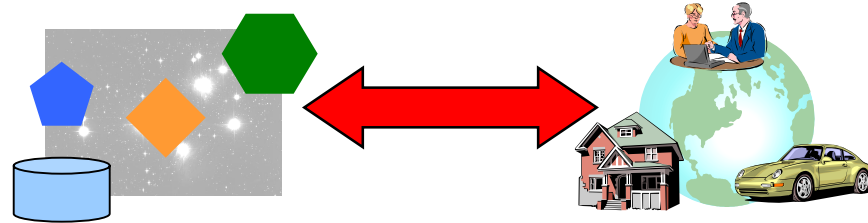
- information fusion
- data mining
- search engines

- How do we address this privacy issue?
  - technical solutions, laws, social processes,…?

Two Worlds that Collide ?

- If there is tight interaction between the physical and the virtual world – what happens?
  - what is gained?
  - what is lost
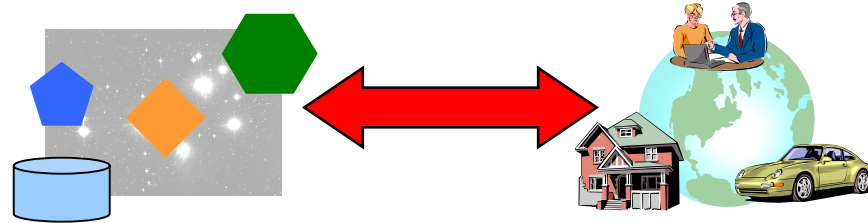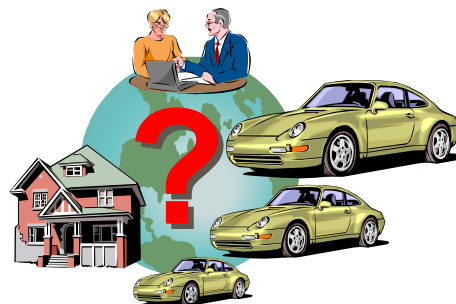
Two Worlds that Collide ?

- If there is tight interaction between the physical and the virtual world – what happens?
  - what is gained?
  - what is lost?

- Can we make a better world, or just better business?
- Which techniques are needed? Which are suitable?
- What are the limits?

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Conclusions

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- **Technical progress** (Moore's Law...) goes on
  - cooperating smart objects become reality
- **Consequences** yet unclear
  - applications?
  - privacy?
- **Economy**
  - whole new industry to build and manage an intelligent infrastructure (e.g., „e-utilities")

As we appraoch 2001, we are in the Information Age, not in the Space Age!
Randy Katz, UC Berkeley