Embedded Systems

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(slides are based on
Peter Marwedel)
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Informatik 12
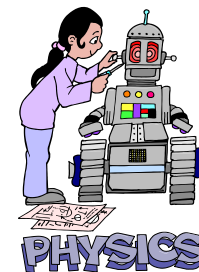

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Motivation for course (1)

According to forecasts, future of IT characterized by terms such as

- Disappearing computer,
- Ubiquitous computing,
- Pervasive computing,
- Ambient intelligence,
- Post-PC era,
- Cyber-physical systems.

Basic technologies:

- *Embedded System technologies*
- Communication technologies

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Motivation for Course (2)

*National Research Council Report (US)
Embedded Everywhere, 2001:*

"Information technology (IT) is on the verge of another revolution. …..

networked systems of embedded computers ... have the potential to change radically the way people interact with their environment by linking together a range of devices and sensors that will allow information to be collected, shared, and processed in unprecedented ways. ...

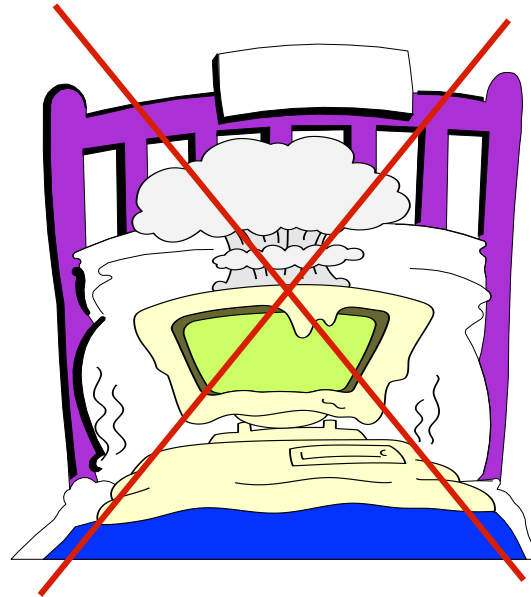The use … throughout society could well dwarf previous milestones in the information revolution."

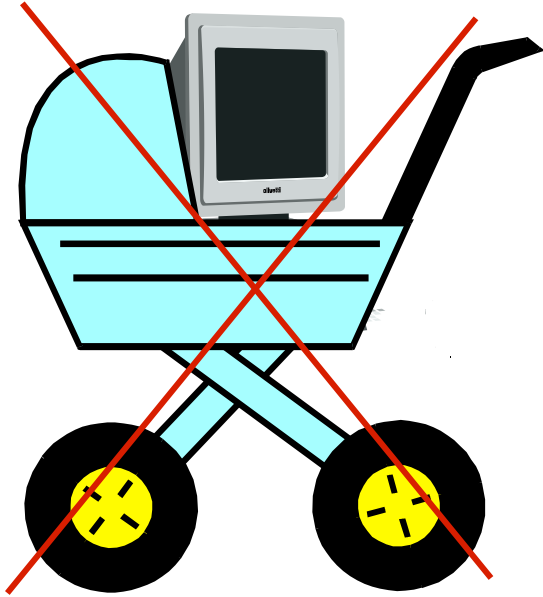© P. Marwedel, 2011

Motivation for Course (3)

☞ **The future is embedded, embedded is the future**

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What is an embedded system?

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Embedded Systems & Cyber-Physical Systems

"Dortmund" Definition: [Peter Marwedel]

Embedded systems are information processing systems embedded into a larger product

Berkeley: [Edward A. Lee]:
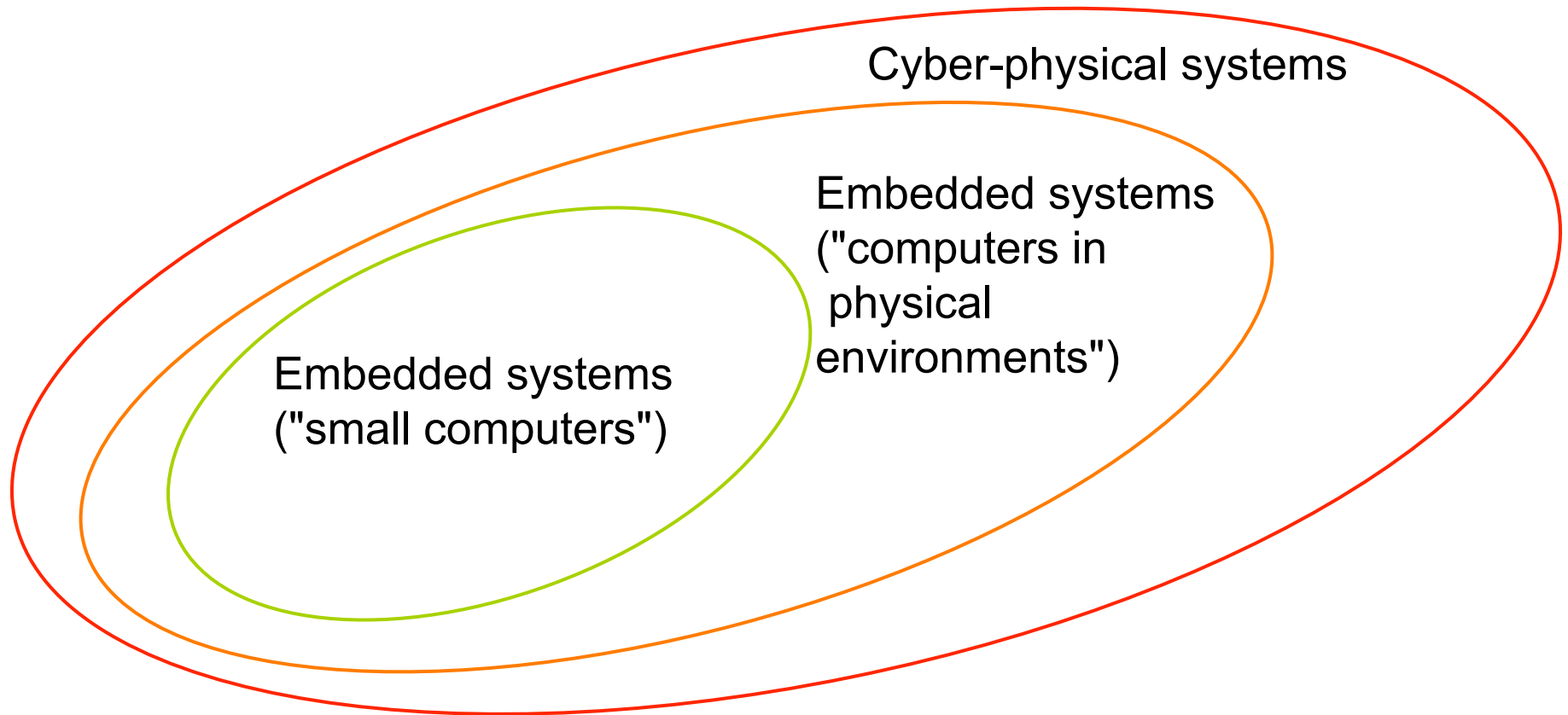Embedded software is software integrated with physical processes. The technical problem is managing time and concurrency in computational systems.

Cyber-Physical (cy-phy) Systems (CPS) are integrations of computation with physical processes [Edward Lee, 2006].

Cyber-physical system (CPS) =
Embedded System (ES) + *physical environment*

Cyber-physical systems and embedded systems

CPS = ES + physical environment

Cyber-physical systems

Embedded systems
("computers in
 physical
environments")

Embedded systems
("small computers")

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What is a *Cyber-Physical System*?

Extreme view:

Digital Controls Systems, ca. 1980

Ref → Error → Controller **Cyber** → Plant **Physical** → Position

Cyber-Physical Systems, 2010+ !
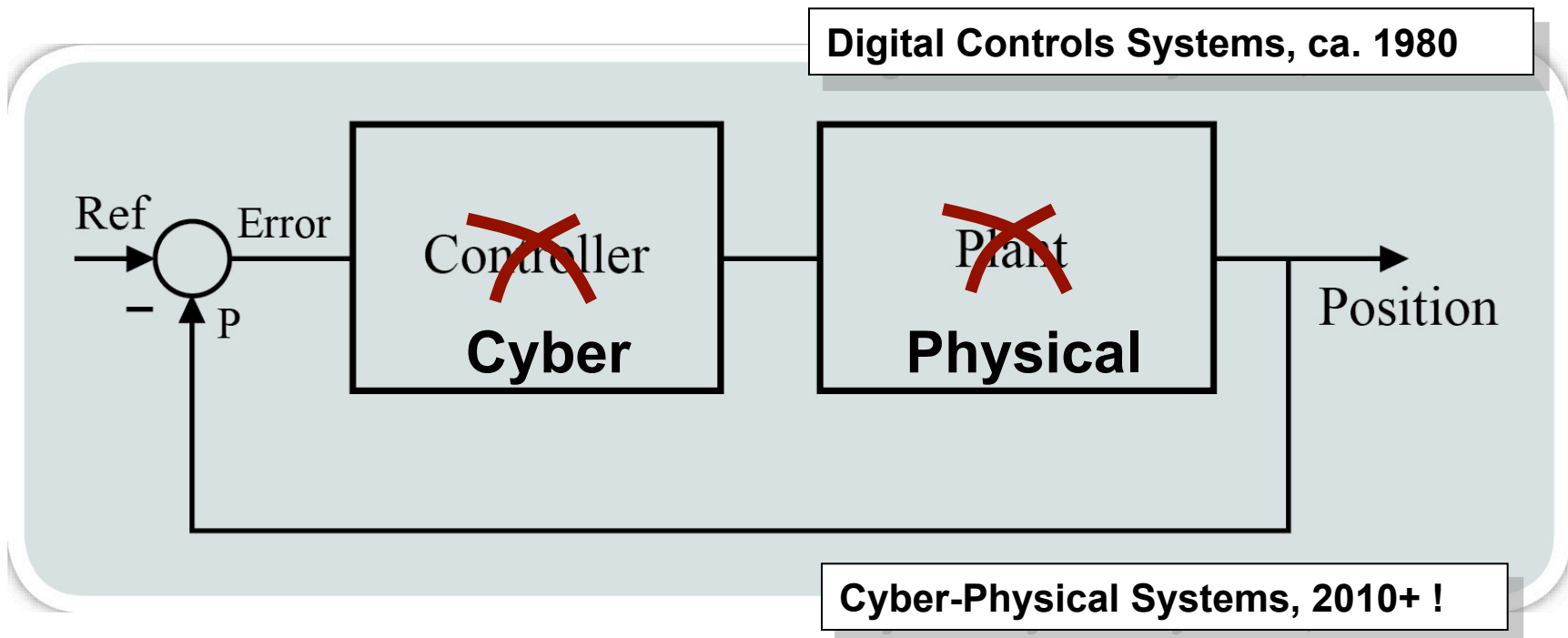
Definition according to National Science Foundation (US)

*Cyber-physical systems (CPS) are engineered systems that are built from and depend upon the **synergy of computational and physical components.***

*Emerging CPS will be **coordinated, distributed**, and **connected**, and must be **robust** and **responsive**.*

The CPS of tomorrow will need to far exceed the systems of today in capability, adaptability, resiliency, safety, security, and usability.

*Examples of the many CPS application areas include the **smart electric grid, smart transportation, smart buildings, smart medical technologies, next-generation air traffic management, and advanced manufacturing**.*

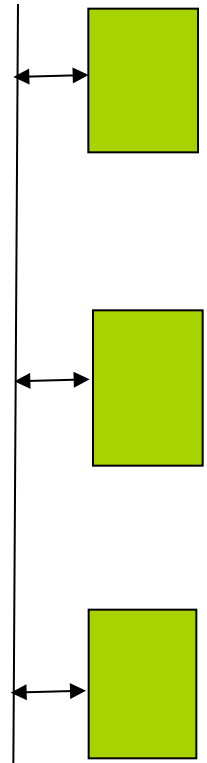# CPS: Integration of Cyber and Physics

Cyber

Physics
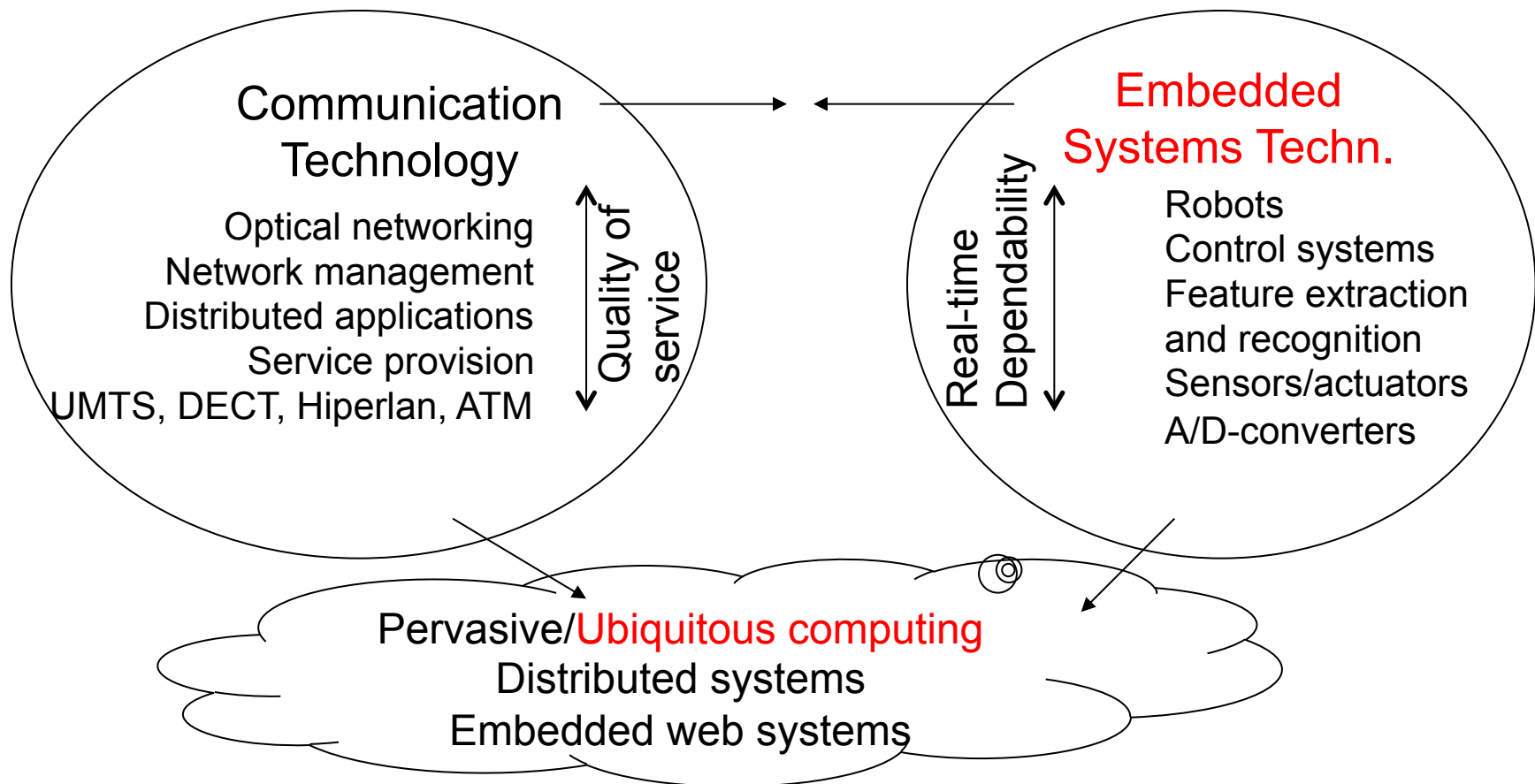
CPS

Definition according to akatech

The physical world and the virtual world – or cyber-space – are merging; cyber-physical systems are developing. Future cyber-physical systems will contribute to security, efficiency, comfort and health systems as never before, and as a result, they will contribute to solving key challenges of our society, such as the aging population, limited resources, mobility, or energy transition.

[Akatech: Cyber-Physical Systems. Driving force for innovation in mobility, health, energy and production, http://www.acatech.de/de/publikationen/stellungnahmen/kooperationen/detail/artikel/cyber-physical-systems-innovationsmotor-fuer-mobilitaet-gesundheit-energie-und-produktion.html]

Extending the motivation: Embedded systems and ubiquitous computing

Ubiquitous computing: Information anytime, any-where. Embedded systems provide fundamental technology.

Communication Technology

Optical networking
Network management
Distributed applications
Service provision
UMTS, DECT, Hiperlan, ATM

Quality of service

Real-time Dependability

Embedded Systems Techn.

Robots
Control systems
Feature extraction and recognition
Sensors/actuators
A/D-converters

Pervasive/Ubiquitous computing
Distributed systems
Embedded web systems

Growing importance of cyber-physical/ embedded systems

- *49.7% of Americans own smartphones* [www.itfacts.biz, March 31, 2012]

- *…, the market for* remote home health monitoring *is expected to generate* $225 *mln revenue in 2011, up from less than* $70 *mln in 2006, according to Parks Associates.* [www.itfacts.biz, Sep. 4th, 2007]

- Funding in the 7th European Framework

- Funding in Horizon 2020

- Creation of the ARTEMIS Joint Undertaking in Europe

- Funding of CPS research in the US

- Joint education effort of Taiwanese Universities

- ….

Growing importance of cyber-physical & embedded systems (2)

- *.. but embedded chips form the backbone of the electronics driven world in which we live ... they are part of almost everything that runs on electricity* [Ryan, EEDesign, 1995]

- Foundation for the "post PC era"

- CPS & ES hardly discussed in other courses

- CPS & ES important for TU Dortmund

- CPS & ES important for many industries

- Scope: sets context for specialized courses

Importance of education

Application areas and examples

Application area automotive electronics: clearly cyber-physical

Functions by embedded processing:

- ABS: Anti-lock braking systems

- ESP: Electronic stability control

- Airbags

- Efficient automatic gearboxes

- Theft prevention with smart keys

- Blind-angle alert systems

- ... etc ...

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- Multiple networks

- Multiple networked processors

Application area avionics: also cyber-physical

- Flight control systems,

- anti-collision systems,

- pilot information systems,

- power supply system,

- flap control system,

- entertainment system,

- …

Dependability is of outmost importance.

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More application areas:

- railroad

- water ways

Dependability is of outmost importance.

Forestry machines: cyber-physical

Networked computer system

- Controlling arms & tools
- Navigating the forest
- Recording the trees harvested
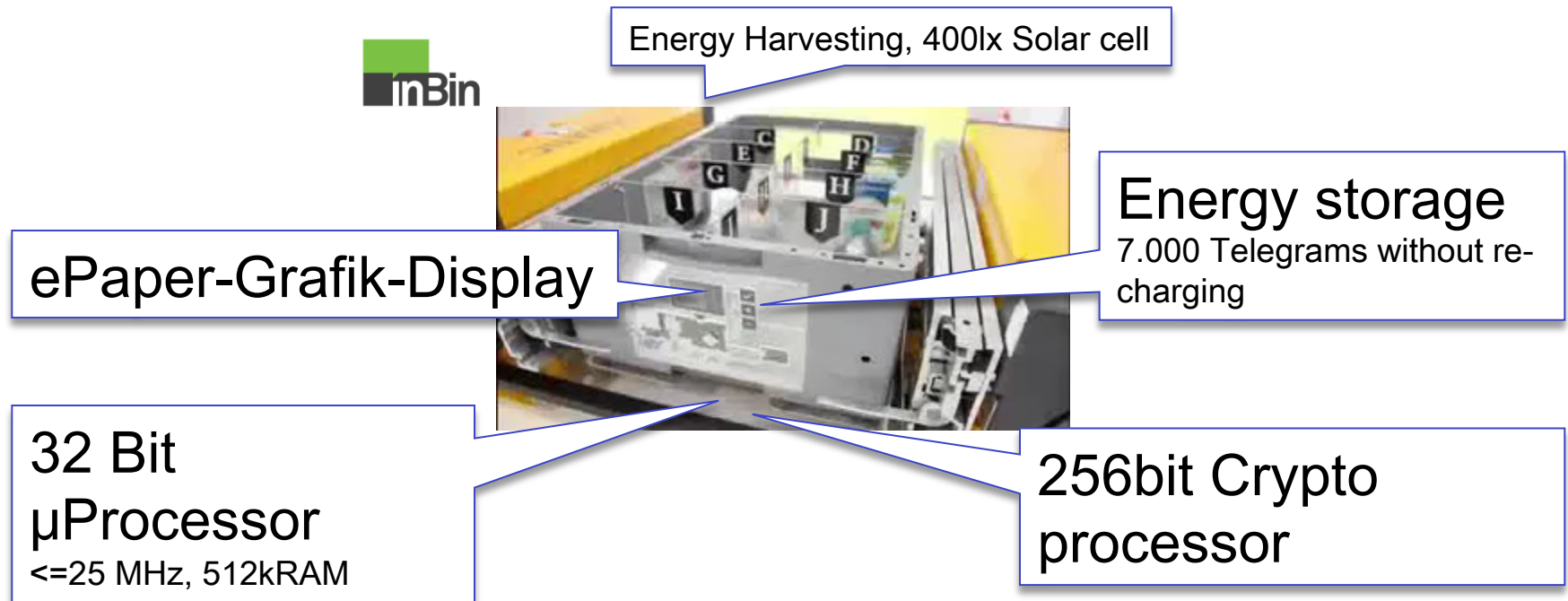- Crucial to efficient work

Logistics

Applications of embedded/cyber-physical system

technology to logistics:

- Radio frequency identification (RFID) technology provides easy identification of each and every object, worldwide.

- Mobile communication allows unprecedented interaction.

- The need of meeting real-time constraints and scheduling are linking embedded systems and logistics.

- The same is true of energy minimization issues

Internet of Things

Internet of things and services

Energy Harvesting, 400lx Solar cell

Energy storage
7.000 Telegrams without re-charging

ePaper-Grafik-Display

32 Bit
µProcessor
<=25 MHz, 512kRAM

256bit Crypto processor

Innovationspartner:
Würth Industrie Services GmbH
Debrunner Koenig Management AG

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Fabrication

Production resources are self-configuring and distributed *social machines*

Industry 4.0

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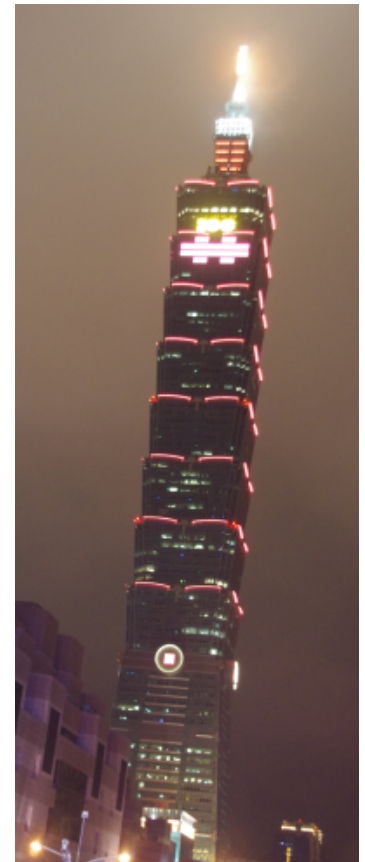
Structural safety

Sensors + data analysis

Möhne lake dam

Kilauea, Hawaii

Bridge at Vancouver

Taipeh 101

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Smart Home

- Zero energy building, generates as much energy as it consumes

- Provides safety and security

- Supports owners

- Provides maximum comfort

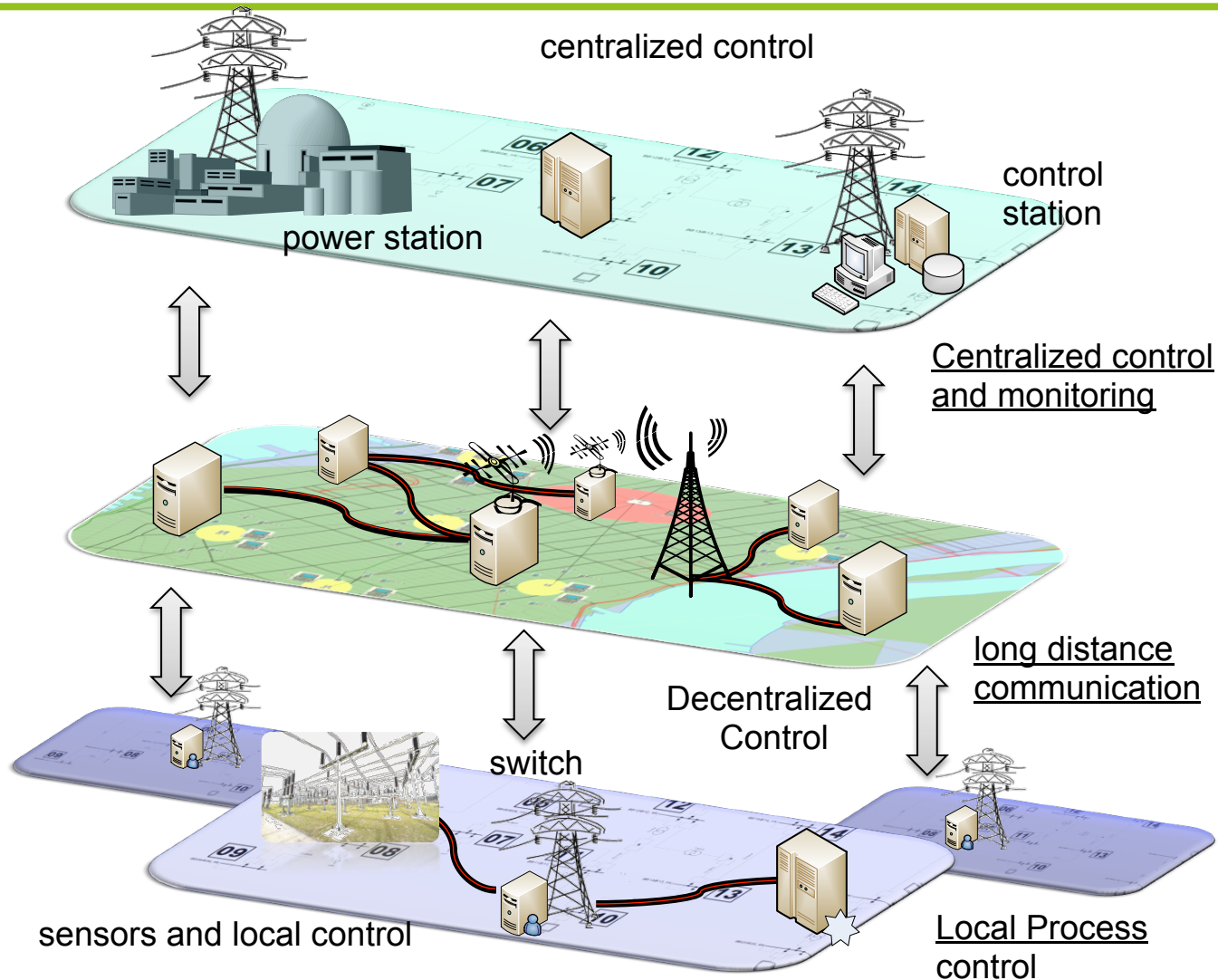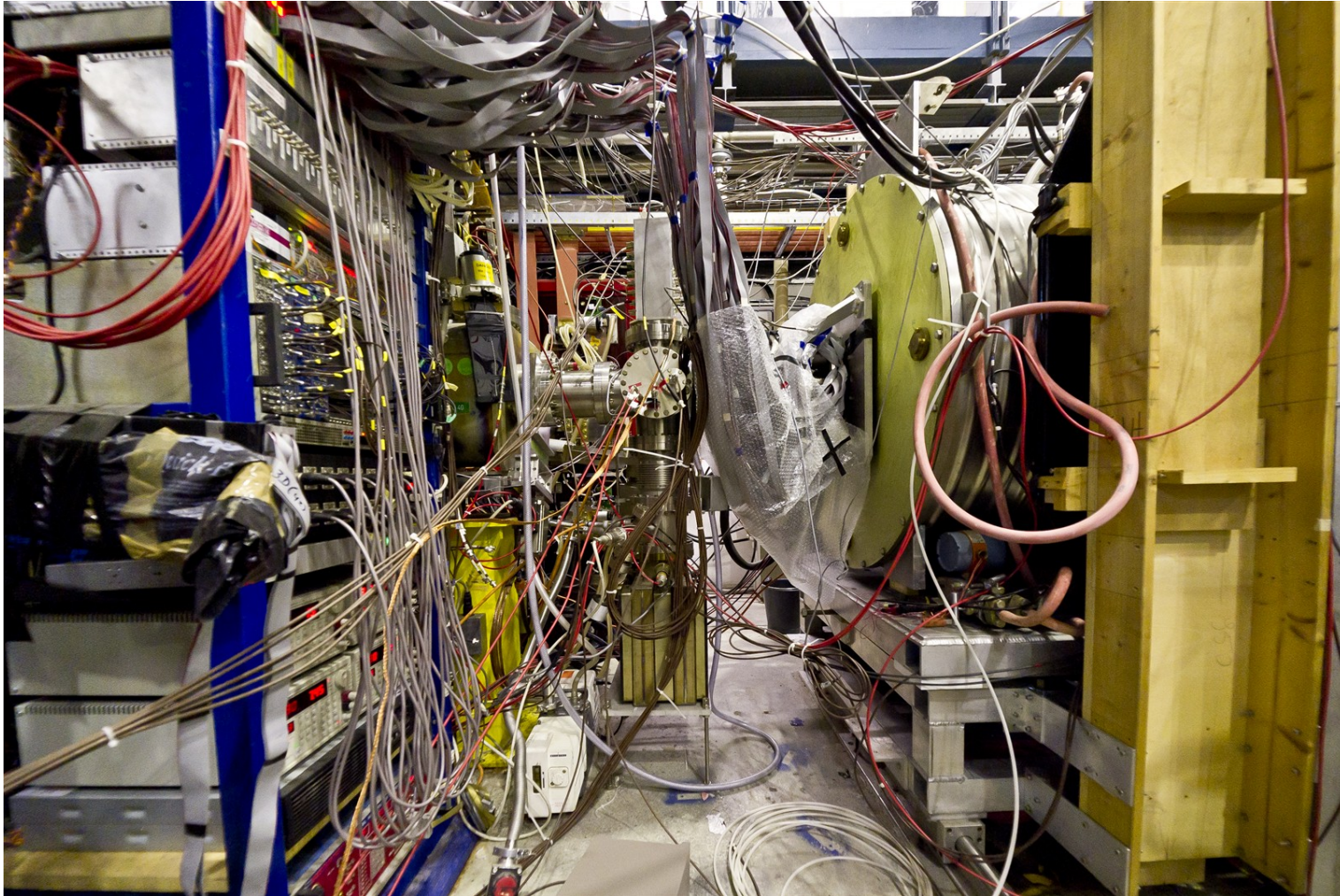- ambient assisted living

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Smart Medicine

- **Diagnosis**
- **Support of therapy**
  - Surgery
  - Aids, e.g. Artificial eye:
    - Camera attached to glasses; computer worn at belt; output directly connected to the brain, was at [www.dobelle.com]
    - Translation into sound; claiming much better resolution, http://www.seeingwithsound. com/ etumble.html

- **evaluation**
- **risk analysis**
- **Information about patients**

Smart Grid

centralized control

power station

control station

Centralized control and monitoring

Decentralized Control

long distance communication

switch

sensors and local control

Local Process control

Integration of Physics and Cyber in Physical Experiments

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Smart Beer Glass

Capacitive sensor for fluid level

8-bit processor

Contact less transmission of power and readings

Inductive coil for RF ID activation & power

Integrates several technologies:
- Radio transmissions
- Sensor technology
- Magnetic inductance for power
- Computer used for calibration

Impossible without the computer
Meaningless without the electronics

CPU and reading coil in the table. Reports the level of fluid in the glass, alerts servers when close to empty
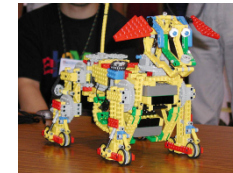
More application areas

- Telecommunication

- Consumer electronics

- Robotics

- Public safety

- Military systems

Mostly cyber-physical

Connecting previously isolated systems