Embedded Systems

1. Introduction

Lothar Thiele

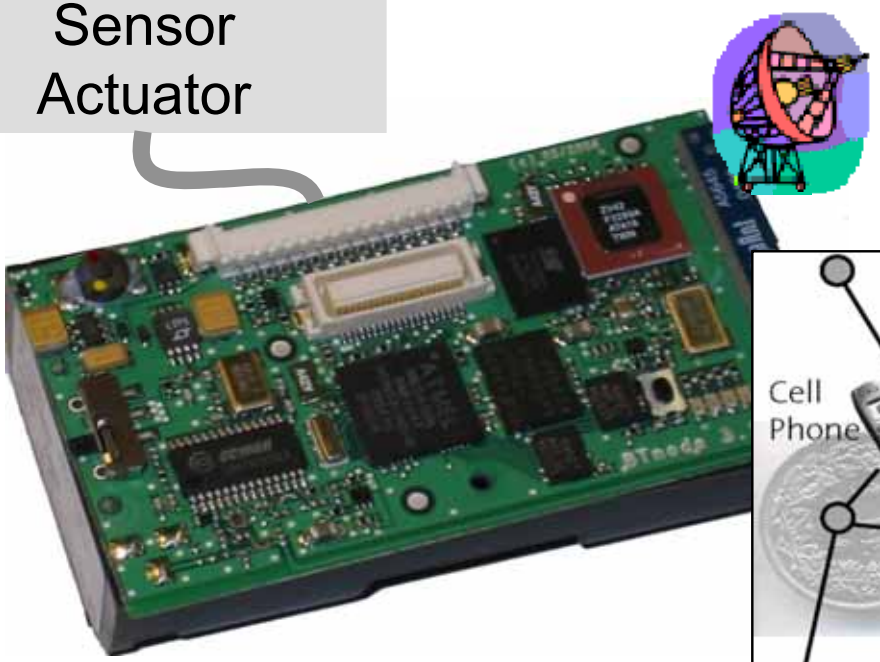
Organization

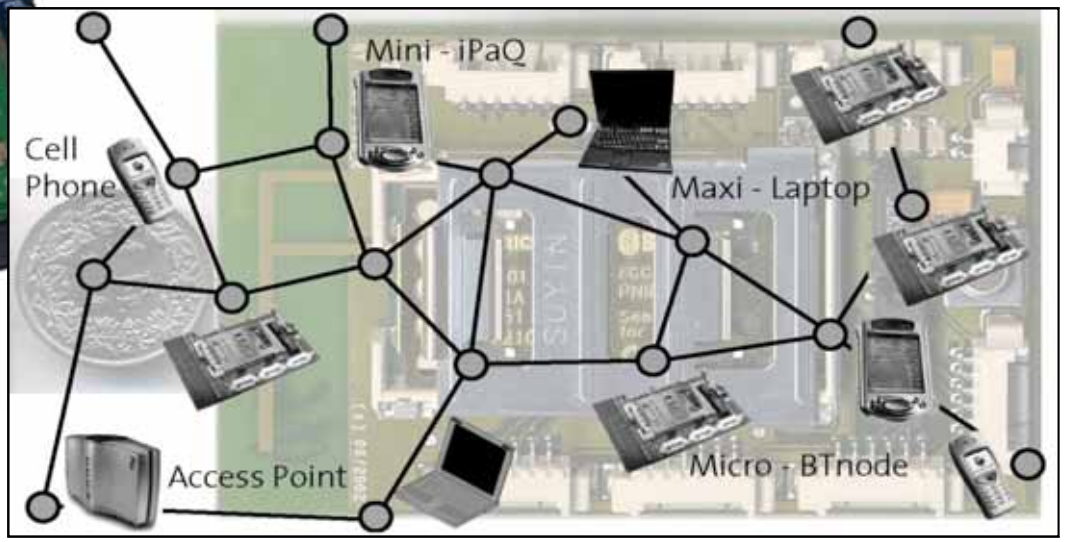
- WWW: http://www.tik.ee.ethz.ch/tik/education/lectures/ES/
- Lecture: Lothar Thiele, thiele@ethz.ch
- Coordination: Nikolay Stoimenov, stoimenov@tik.ee.ethz.ch
- References:
  - ***P. Marwedel: Embedded System Design (paperback), Springer Verlag, December 2011, ISBN: 978-94-007-0256-1.***
  - *G.C. Buttazzo: Hard Real-Time Computing Systems. Springer Verlag, 2011.*
  - W. Wolf: Computers as Components – Principles of Embedded System Design. Morgan Kaufman Publishers, 2012.
  - J. Teich: Digitale Hardware/Software Systeme, Springer Verlag, 2007.
- The slides contain material of J. Rabaey, K. Keuzer, Wayne Wolf, Peter Marwedel, Philip Koopman and from the above books of J. Teich, G.C. Buttazzo, W. Wolf and P. Marwedel.

Communicating Embedded Systems

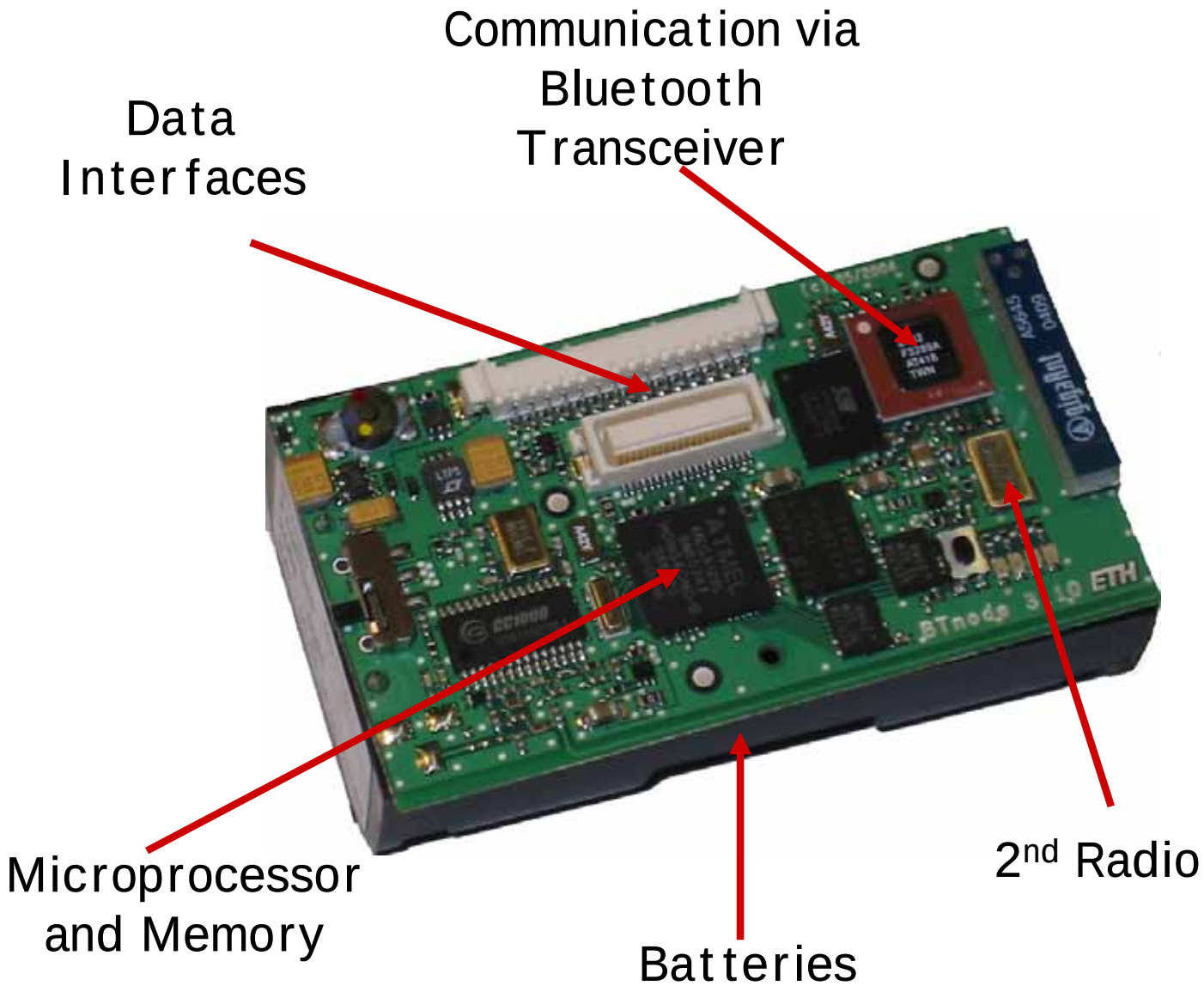
- Example: BTnodes
  - complete platform including OS
  - especially suited for pervasive computing applications

Sensor
Actuator





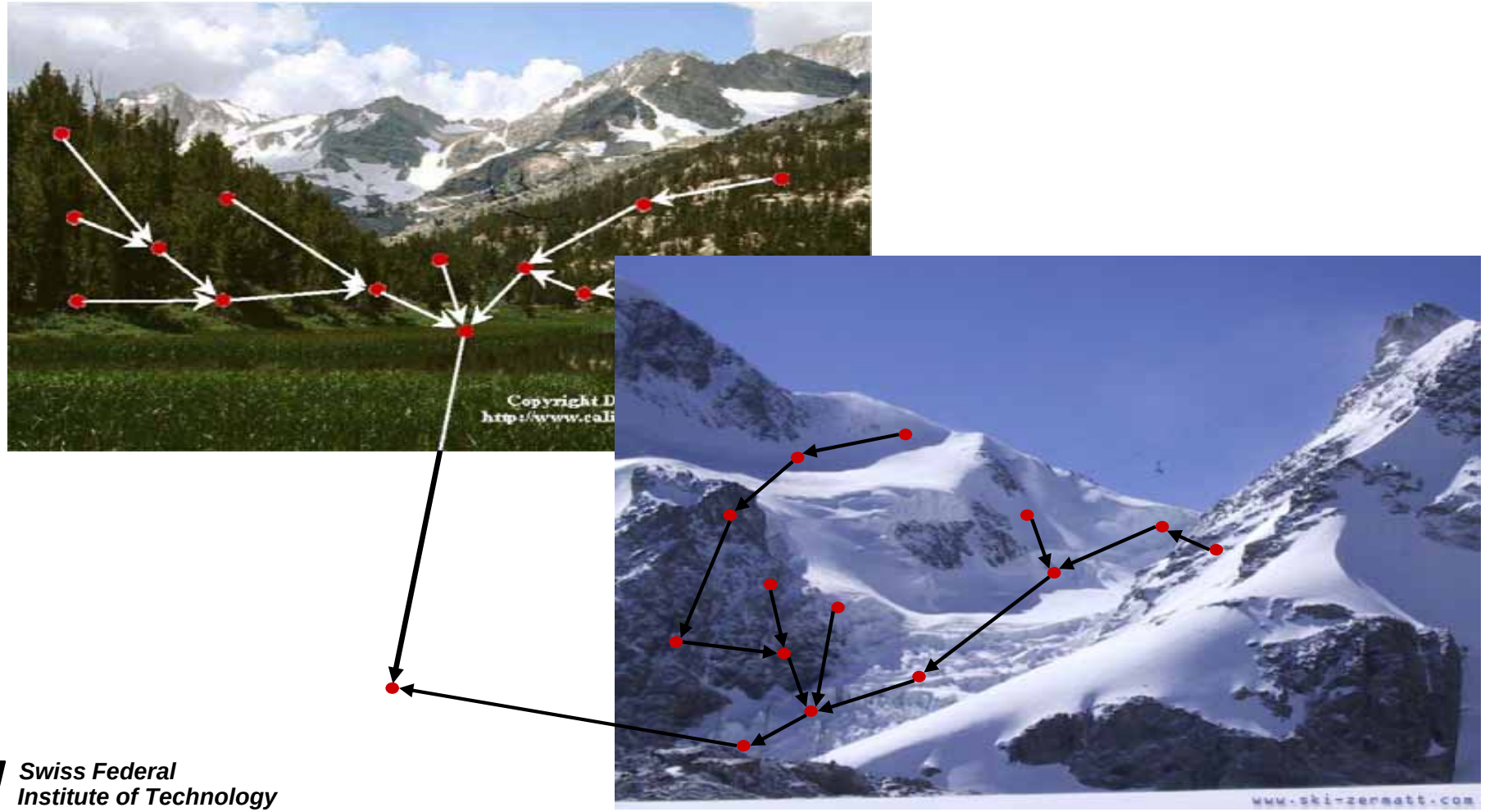
BTnode Platform



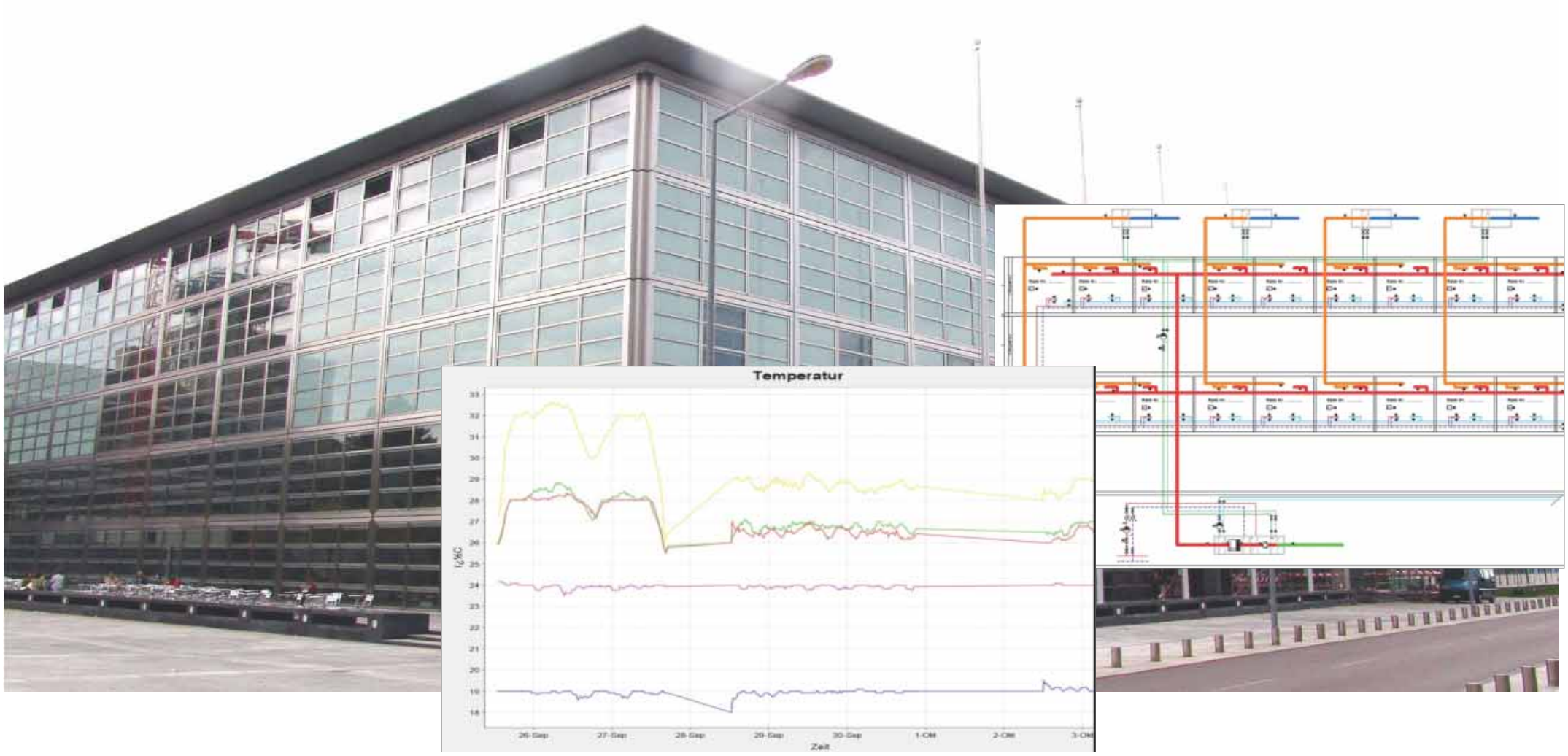
- generic platform for ad-hoc computing
- complete platform including OS
- especially suited for pervasive computing applications

Communicating Embedded Systems

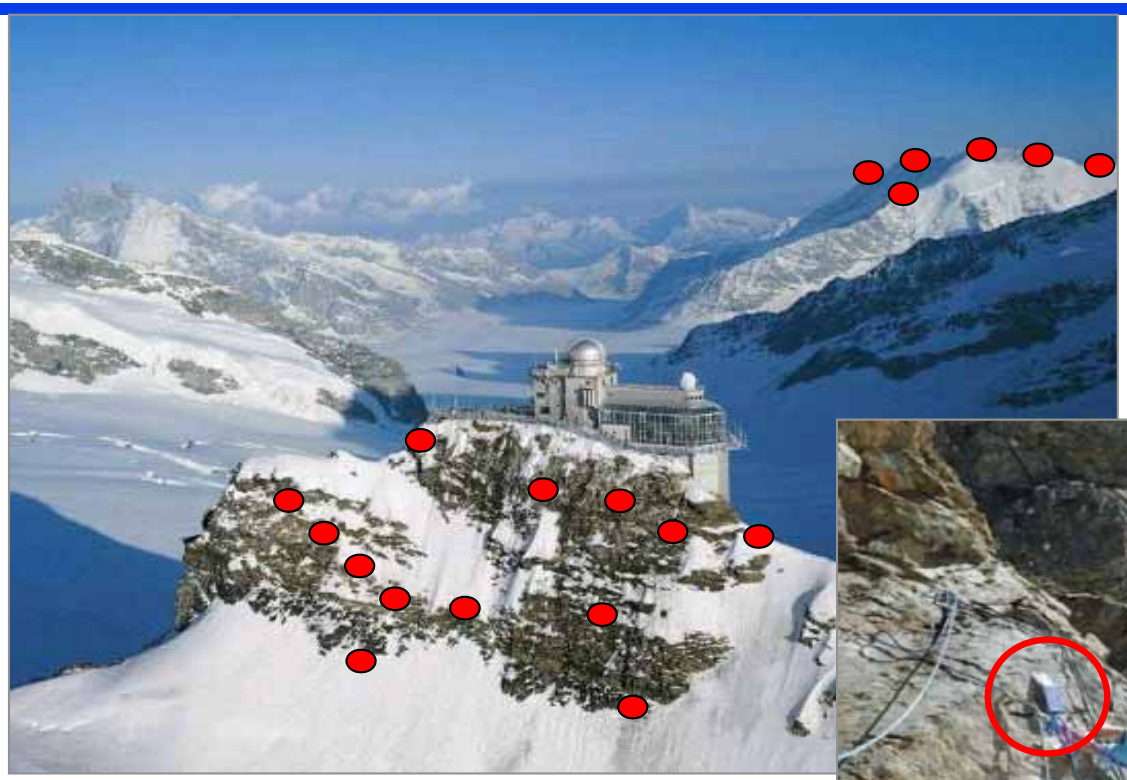
- sensor networks (civil engineering, buildings, environmental monitoring, traffic monitoring, health, industrial sites, …)
- smart products, wearable/ubiquitous computing



Communicating Embedded Systems

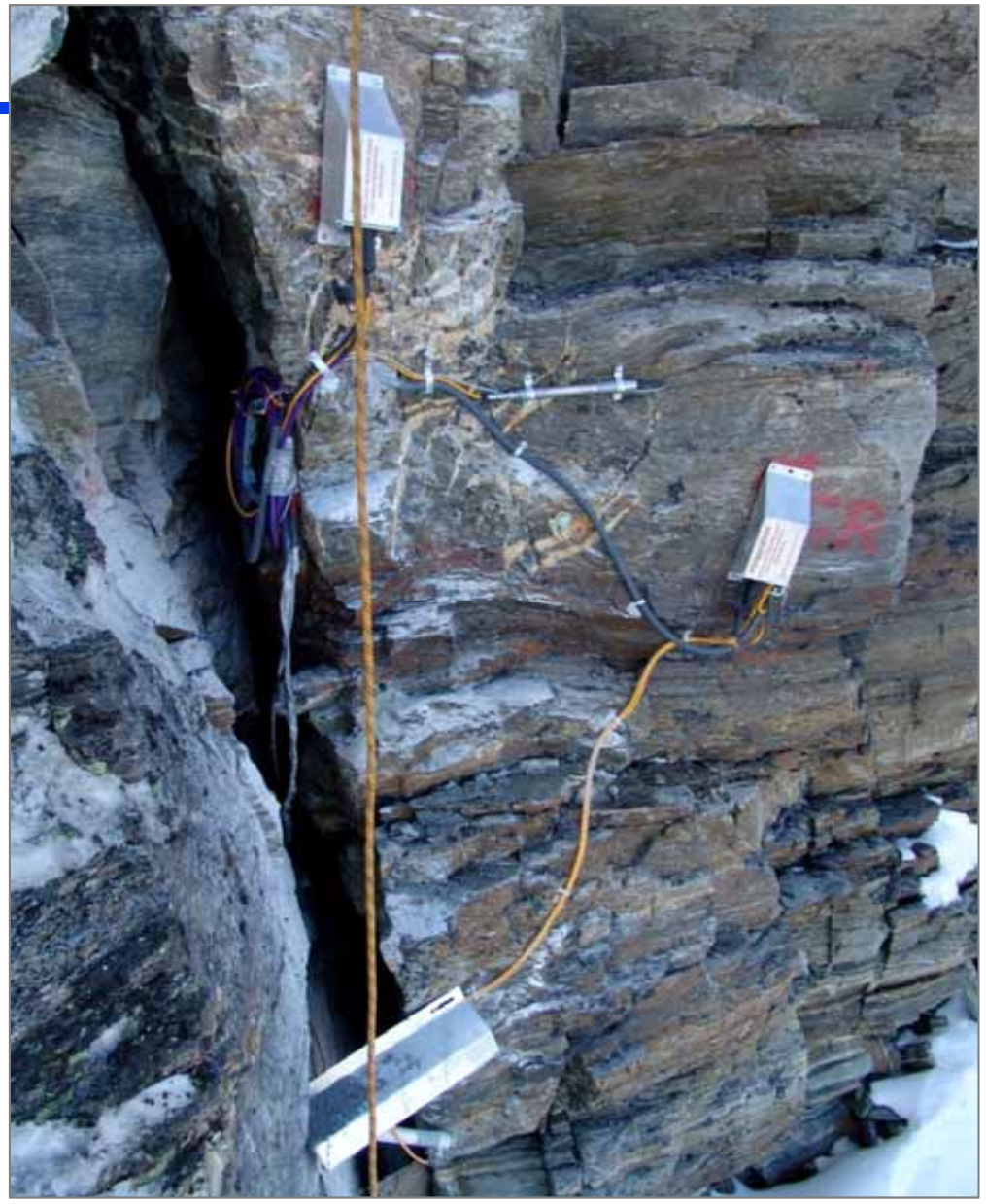


PermaSense Project



- Univ. Zurich, Univ. Basel, ETH Zurich


PERMASENSE
PERMASENSE



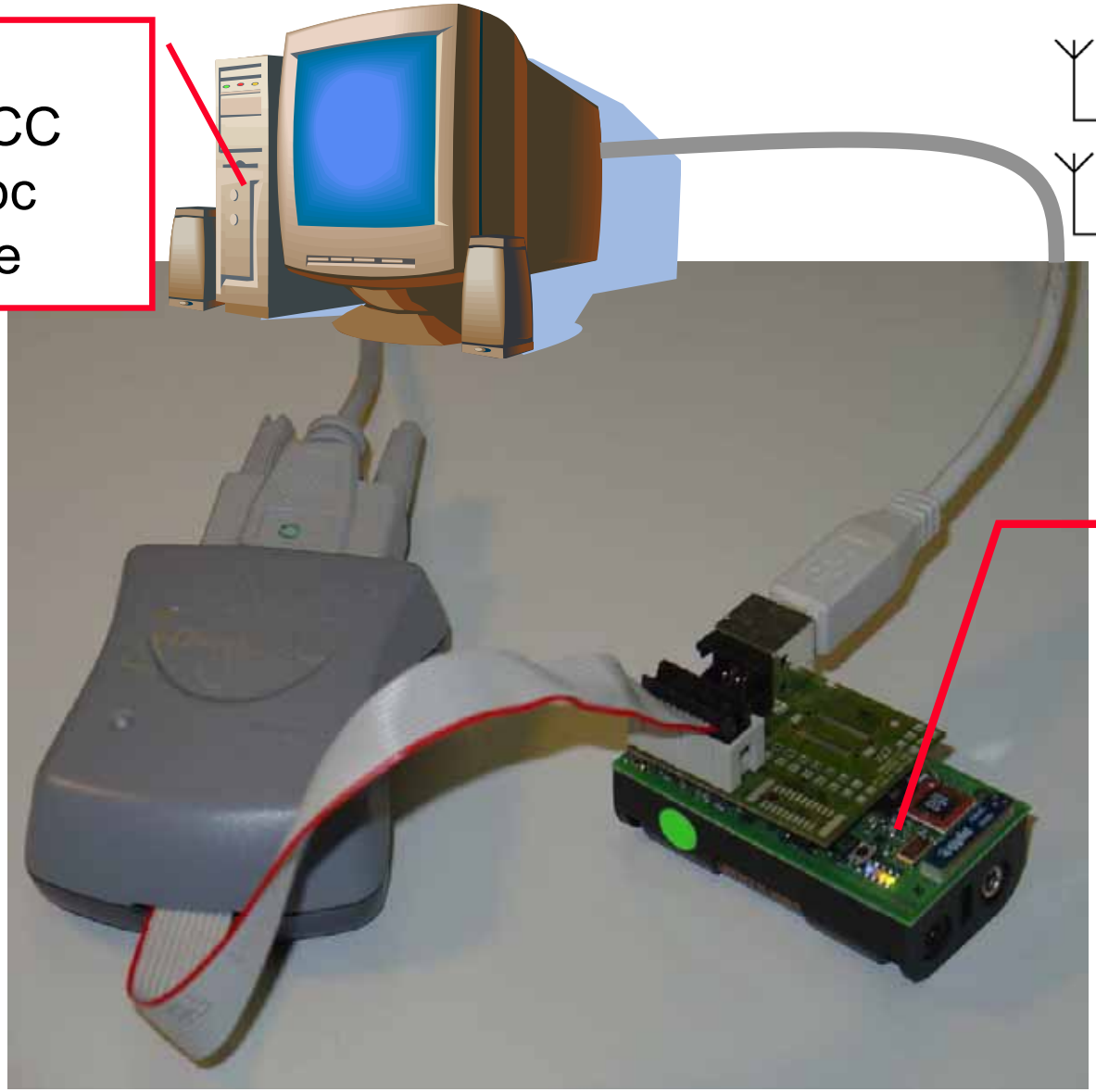
Hardware

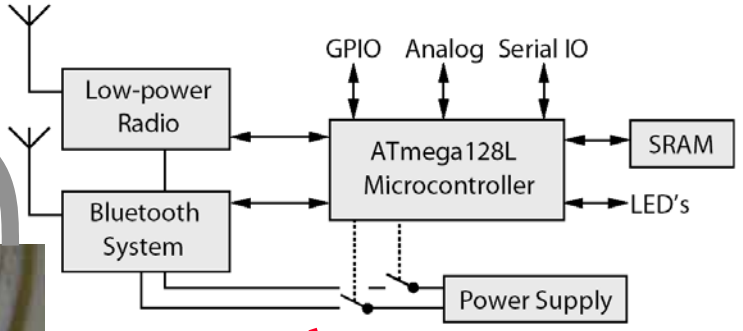

PERMASENSE
WIRELESS SENSOR NODE
FOR HIGH-MOUNTAIN
RESEARCH
INFO: +41 44 635 51 21


saft
3.6V

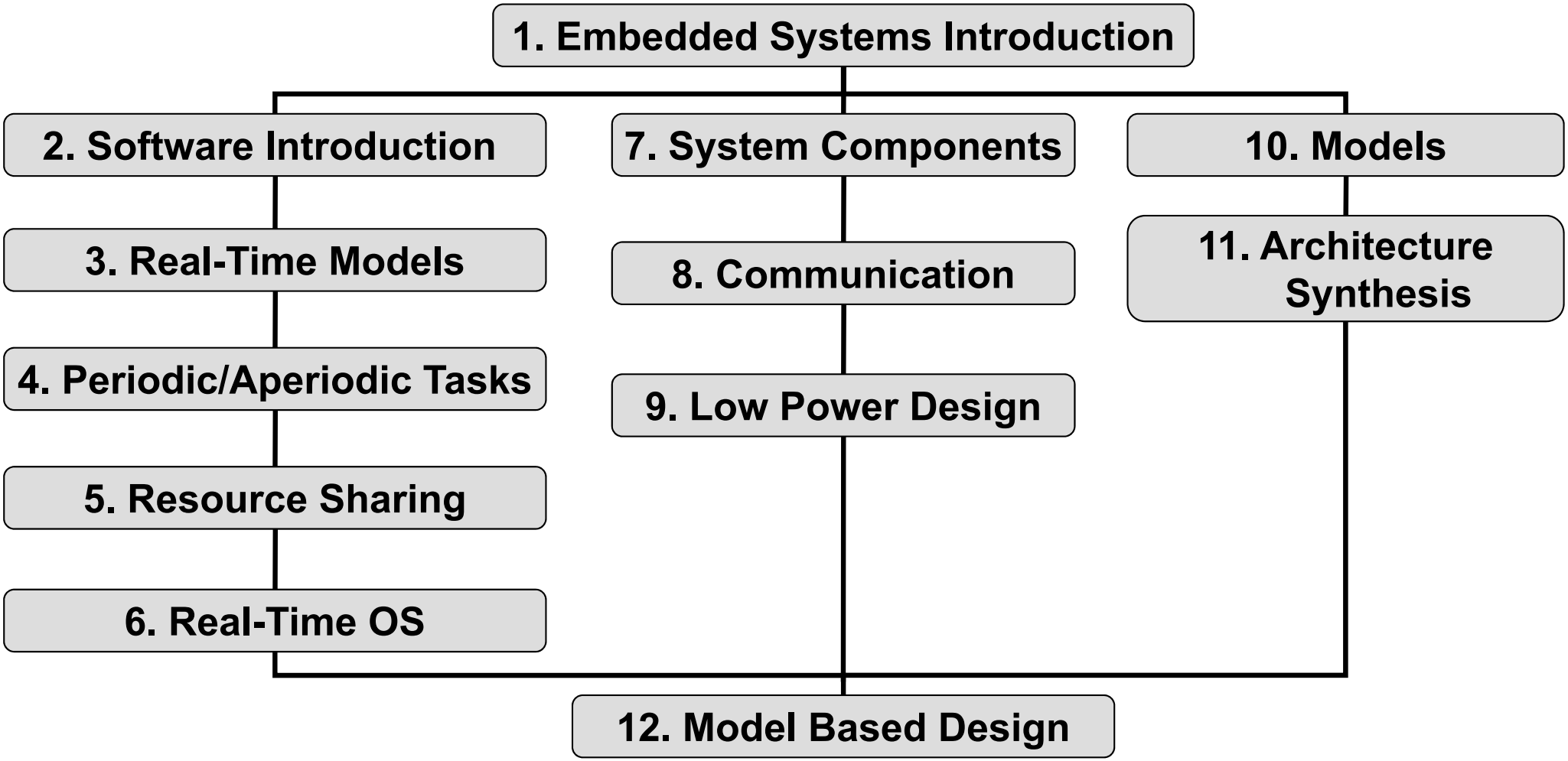
Development in ES Exercise

Linux
GNU GCC
AVR libc
Eclipse





Contents of Course



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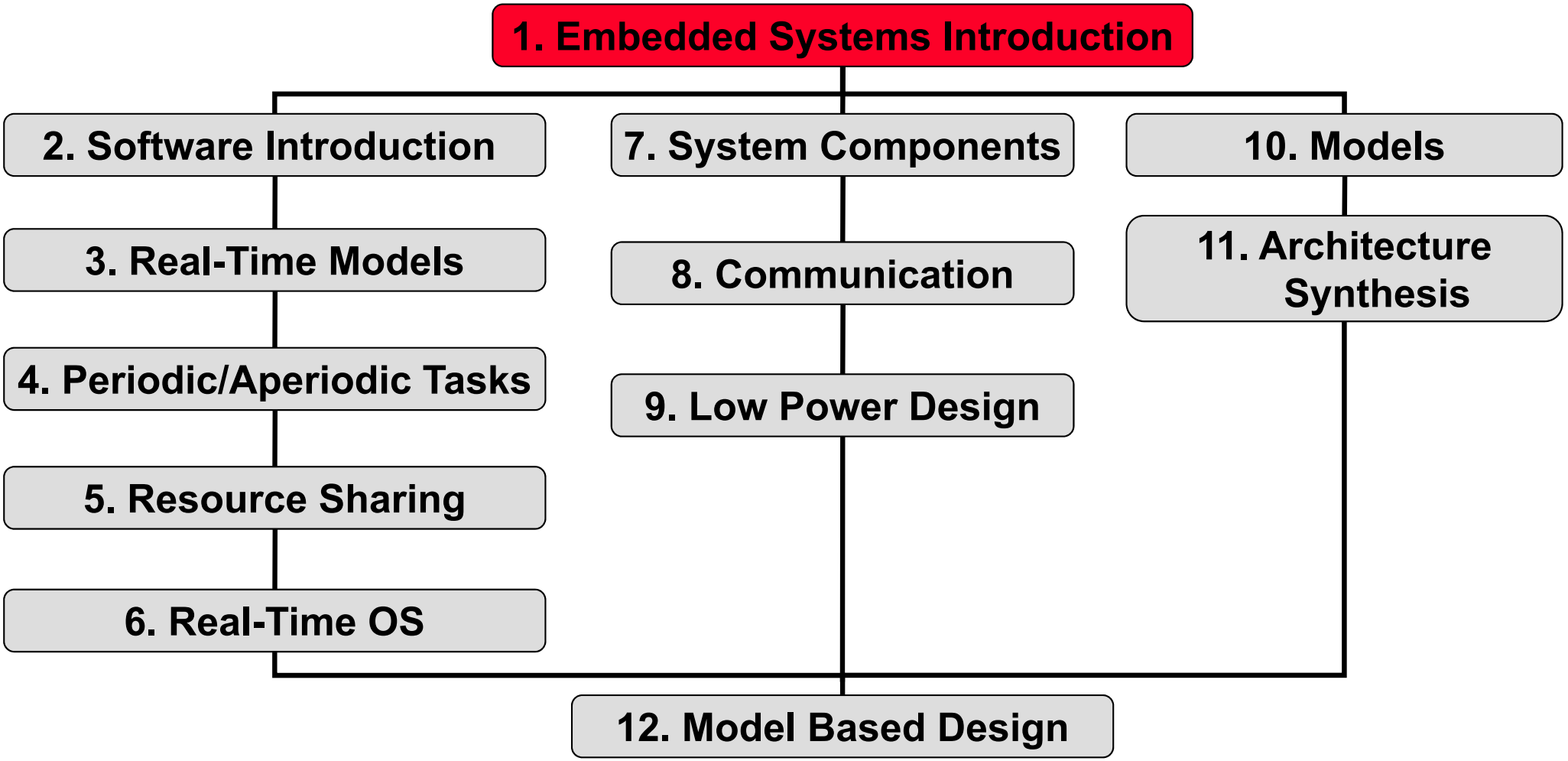
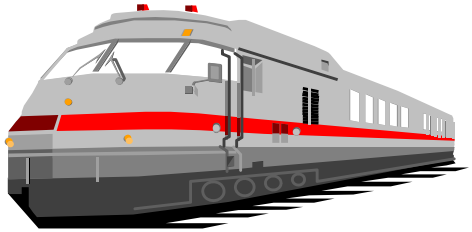


Embedded Systems

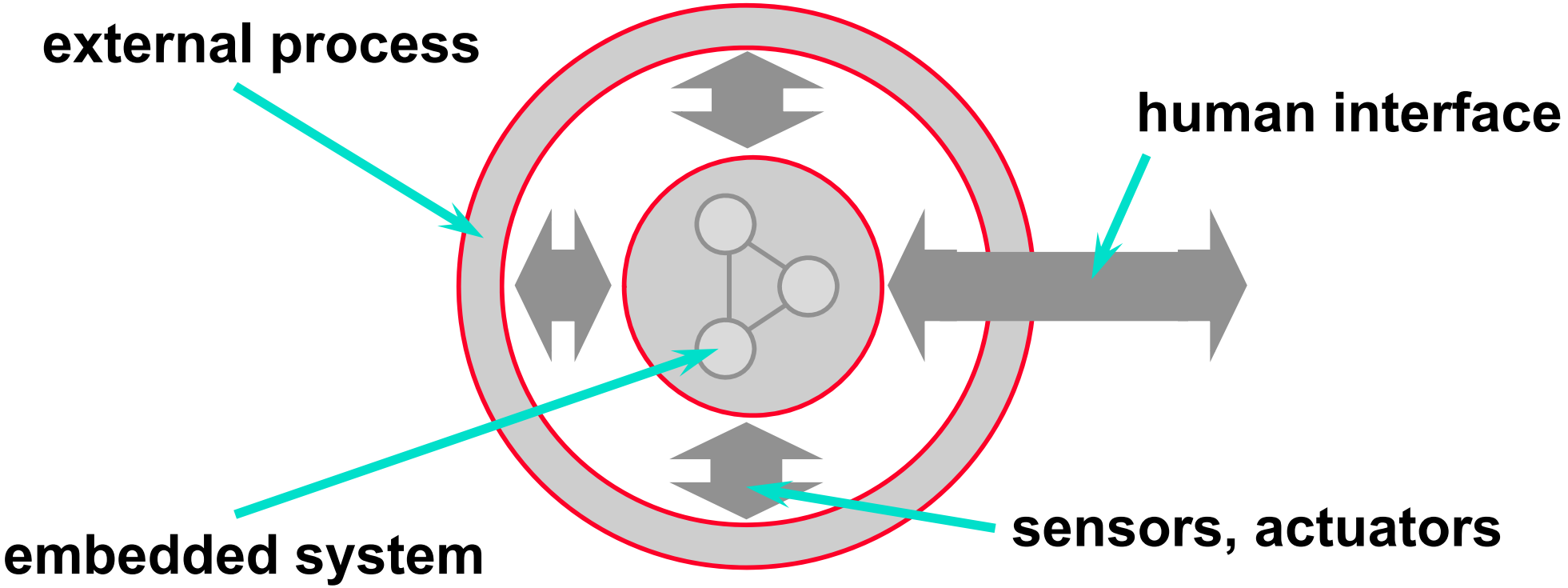
Embedded systems (ES) = **information processing systems embedded into a larger product**

Examples:



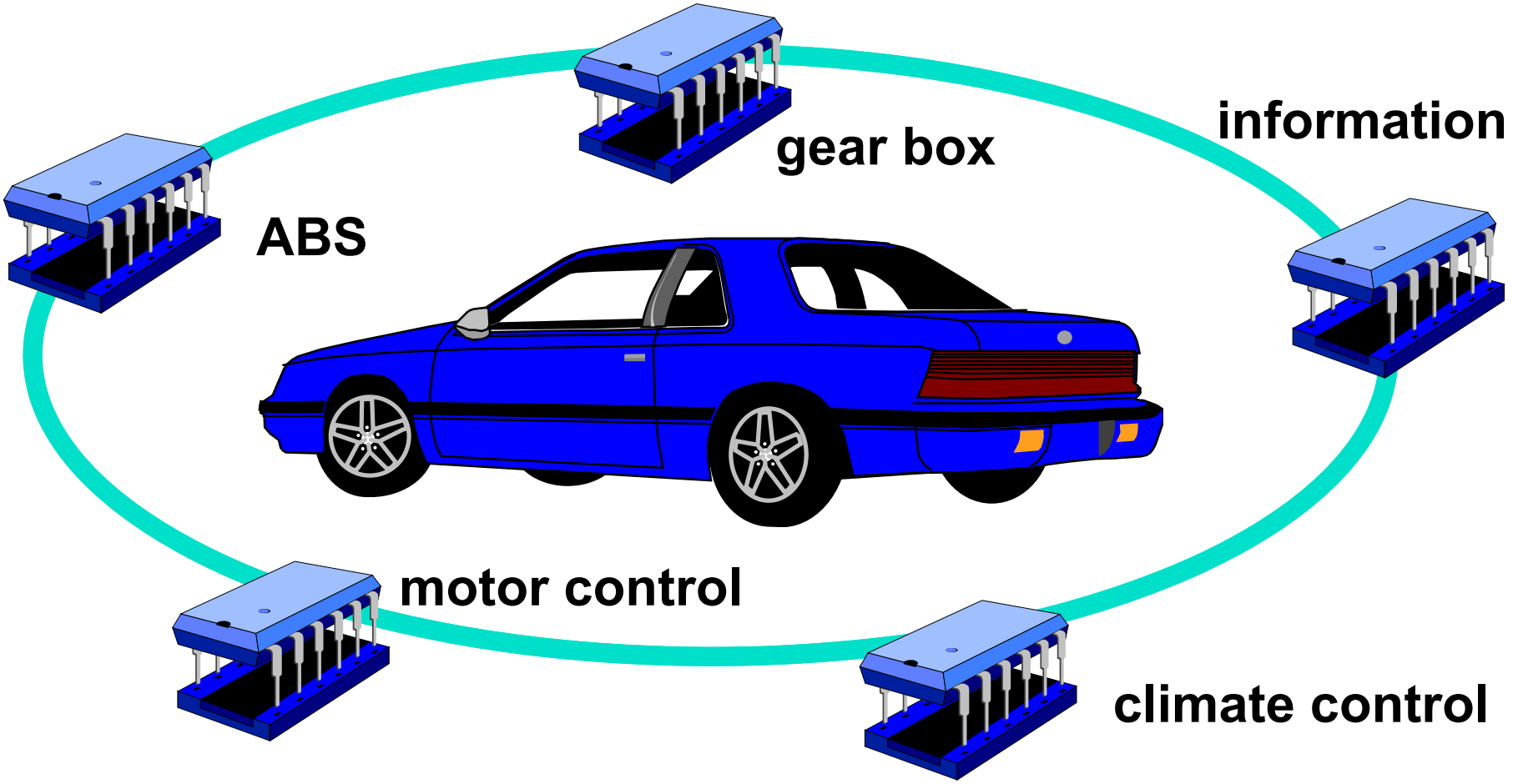
Main reason for buying is **not** information processing

Embedded Systems



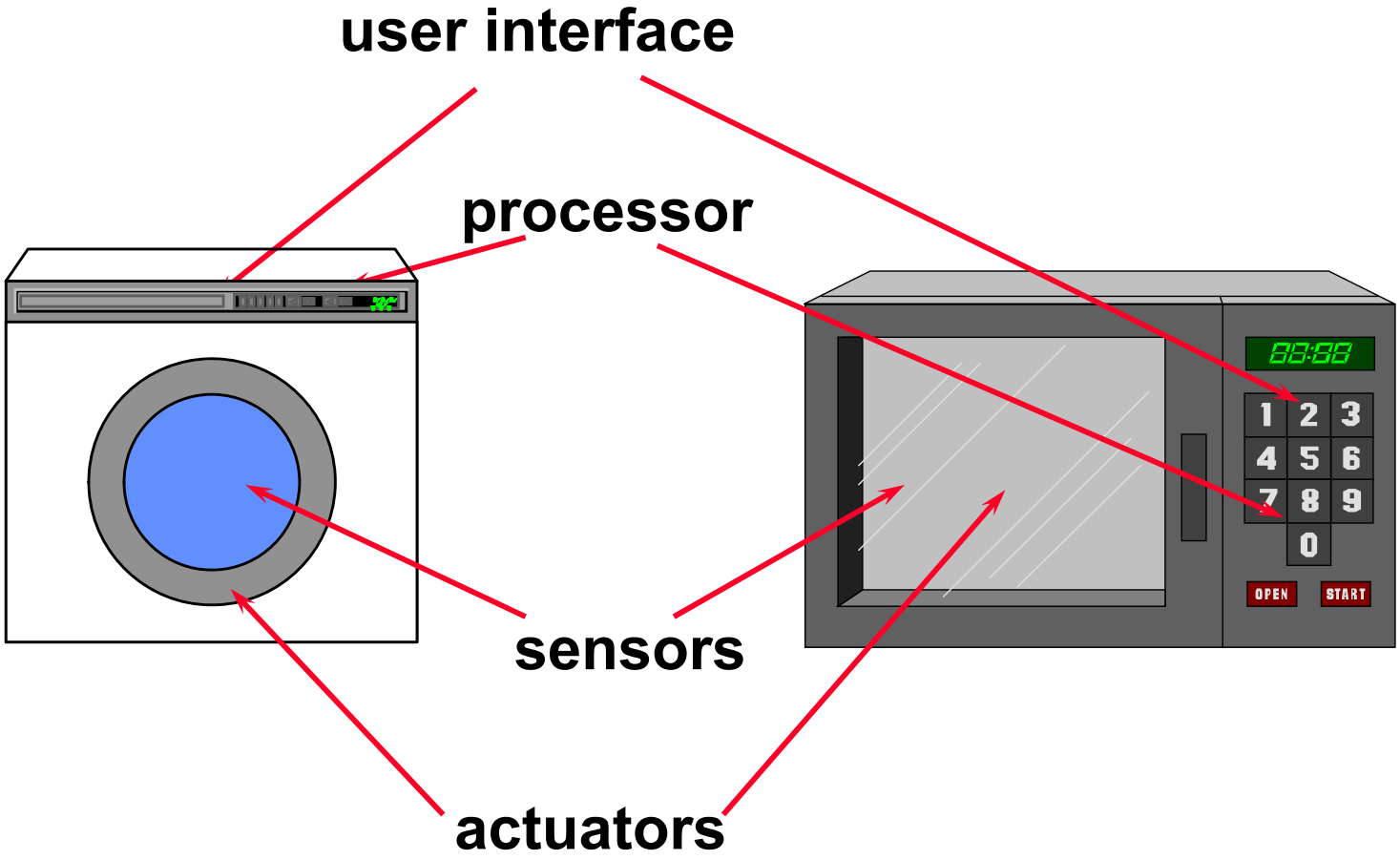
Examples of Embedded Systems

Car as an integrated control-, communication and information system.



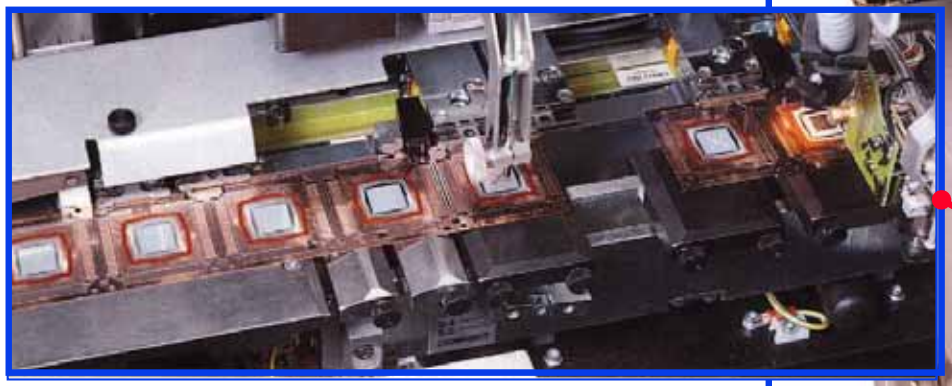
Examples of Embedded Systems

Consumer electronics, for example MP3 Audio, digital camera, home electronics, … .



Examples of Embedded Systems

Production systems



Examples of Embedded Systems

Information systems, for example wireless communication (mobile phone, Wireless LAN, …), end-user equipment, router, …

Characteristics of Embedded Systems (1)

- Must be ***dependable***:
  - ***Reliability:*** *R(t)* = probability of system working correctly provided that it was working at *t*=0
  - ***Maintainability:*** *M(d)* = probability of system working correctly *d* time units after error occurred.
  - ***Availability:*** probability of system working at time *t*
  - ***Safety:*** no harm to be caused
  - ***Security:*** confidential and authentic communication

Even perfectly designed systems can fail if the assumptions about the workload and possible errors turn out to be wrong.

Making the system dependable must not be an after-thought, it must be considered from the very beginning.

Characteristics of Embedded Systems (2)

- Must be ***efficient:***
  - ***Energy*** efficient
  - ***Code-size*** efficient (especially for systems on a chip)
  - ***Run-time*** efficient
  - ***Weight*** efficient
  - ***Cost*** efficient

- ***Dedicated*** towards a certain ***application***: Knowledge about behavior at design time can be used to minimize resources and to maximize robustness.
- ***Dedicated*** user ***interface***.

Characteristics of Embedded Systems (3)

- Many ES must meet ***real-time constraints:***
  - A real-time system must ***react to stimuli*** from the controlled object (or the operator) within the time interval dictated by the environment.
  - For real-time systems, right answers arriving too late are wrong.

> ***„A real-time constraint is called hard, if not meeting that constraint could result in a catastrophe“ [Kopetz, 1997].***

  - All other time-constraints are called soft.
  - A ***guaranteed system response*** has to be explained without statistical arguments.

Characteristics of Embedded Systems (4)

- Frequently ***connected to physical environment*** through sensors and actuators,
- ***Hybrid systems*** (analog + digital parts).
- Typically, ES are ***reactive systems***:

> ***„A reactive system is one which is in continual interaction with is environment and executes at a pace determined by that environment“ [Bergé, 1995]***

  - Behavior depends on input and current state.
    ☞ automata model often appropriate,

Comparison

- Embedded Systems
  - Few applications that are known at design-time.
  - Not programmable by end user.
  - Fixed run-time requirements (additional computing power not useful).
  - Criteria:
    - cost
    - power consumption
    - predictability
    - …
- General Purpose Computing
  - Broad class of applications.
  - Programmable by end user.
  - Faster is better.
  - Criteria:
    - cost
    - average speed

Trends …

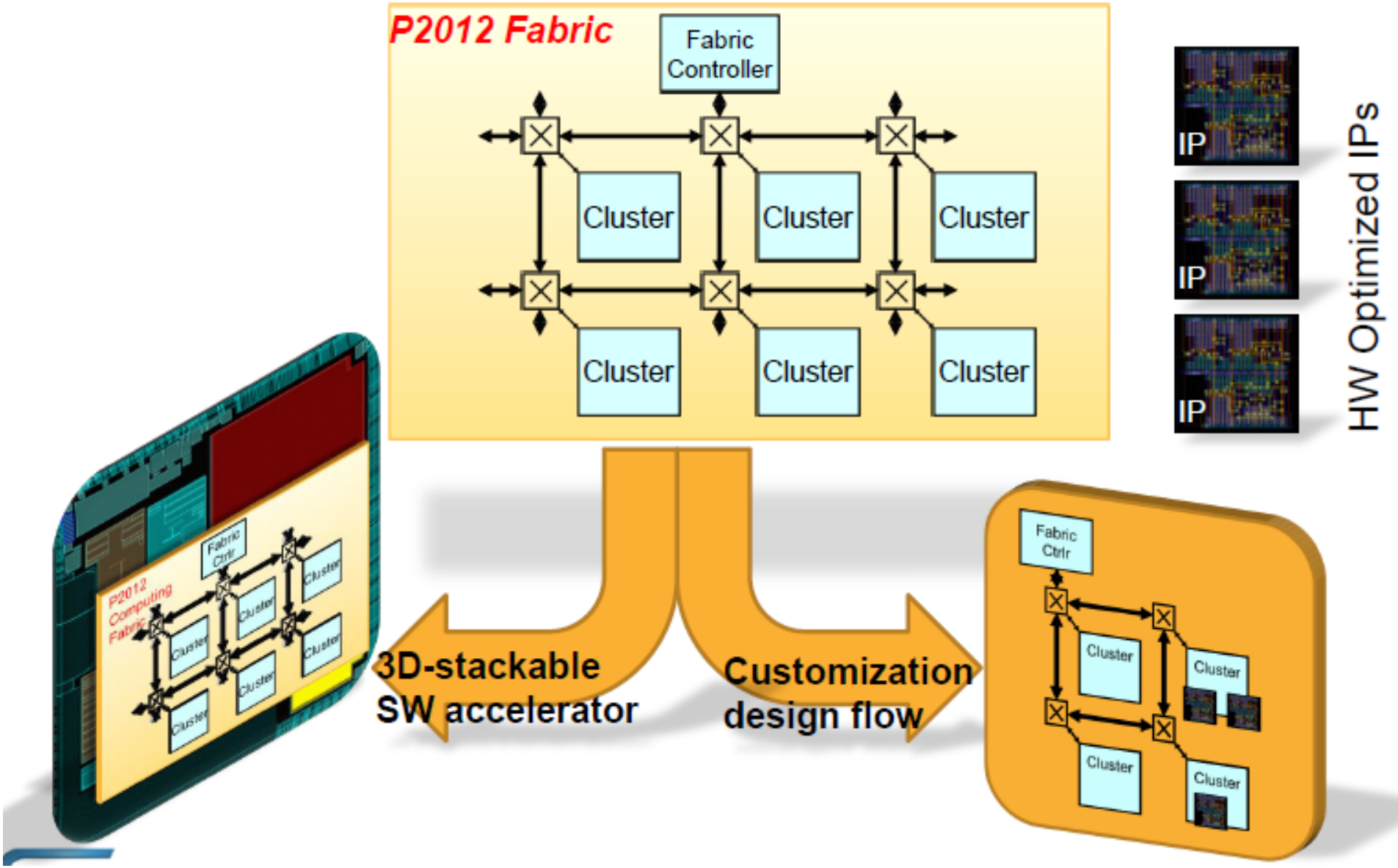
- Embedded Systems overtook market of PCs.
- Ubiquitous and pervasive computing:
  - Information anytime, anywhere; building ambient intelligence into our environment; internet of things:
    - Wearable computers
    - “Smart Labels” on consumer products
    - Intelligent buildings
    - Environmental Monitoring
    - Traffic control and communicating automobiles
  - Embedded systems provide the basic technology.

Trends …

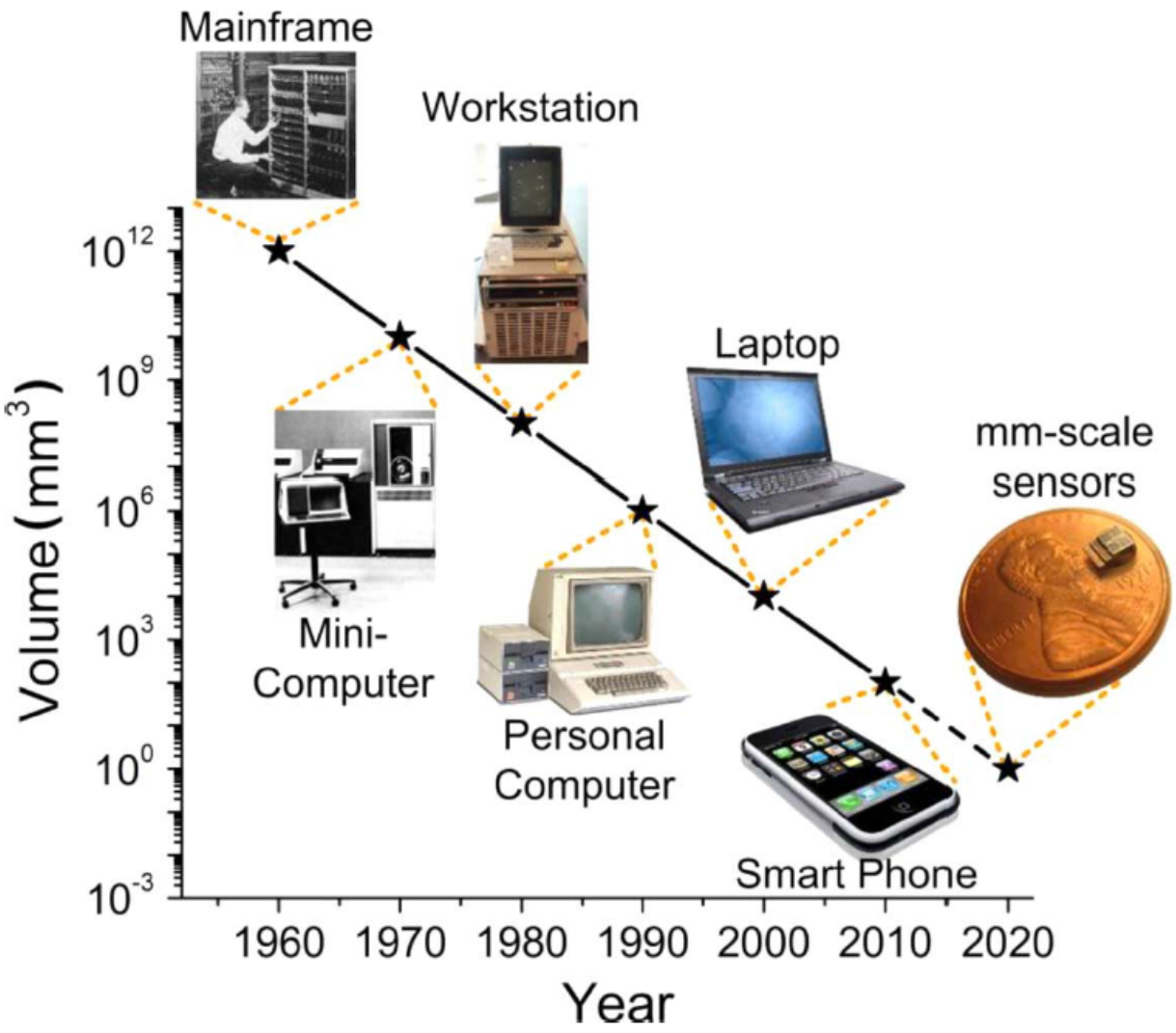
- Communicating embedded systems, very often wireless.
- Higher degree of integration on a single chip:
  - memory + processor + I/O-units + (wireless) communication
  - network on chip for communication between units
  - Multiprocessor Systems on a Chip (MPSoC)
  - Microsystems that contain energy harvesting and sensing in addition
- Software increasing (amount and complexity).

- Low power and energy constraints (portable or unattended devices). Temperature constraints (overheating). Increased interest in energy harvesting.

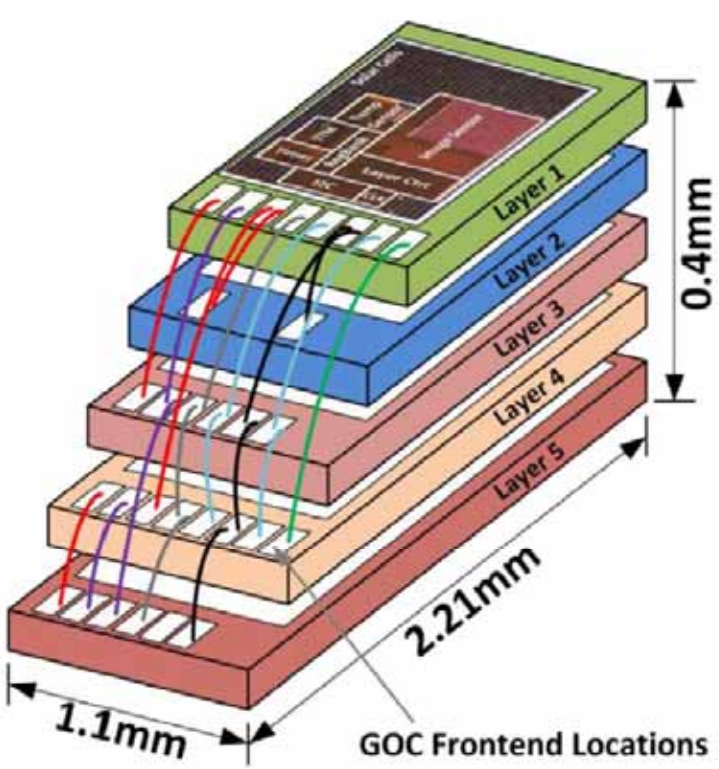
Example ST2012/STHORM

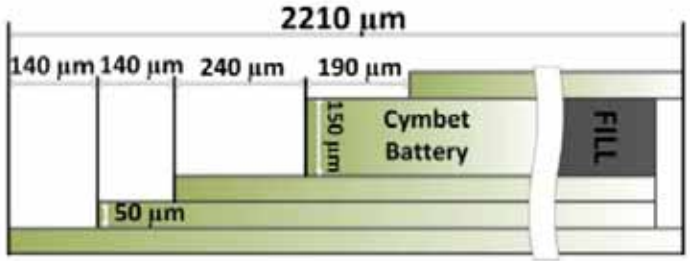


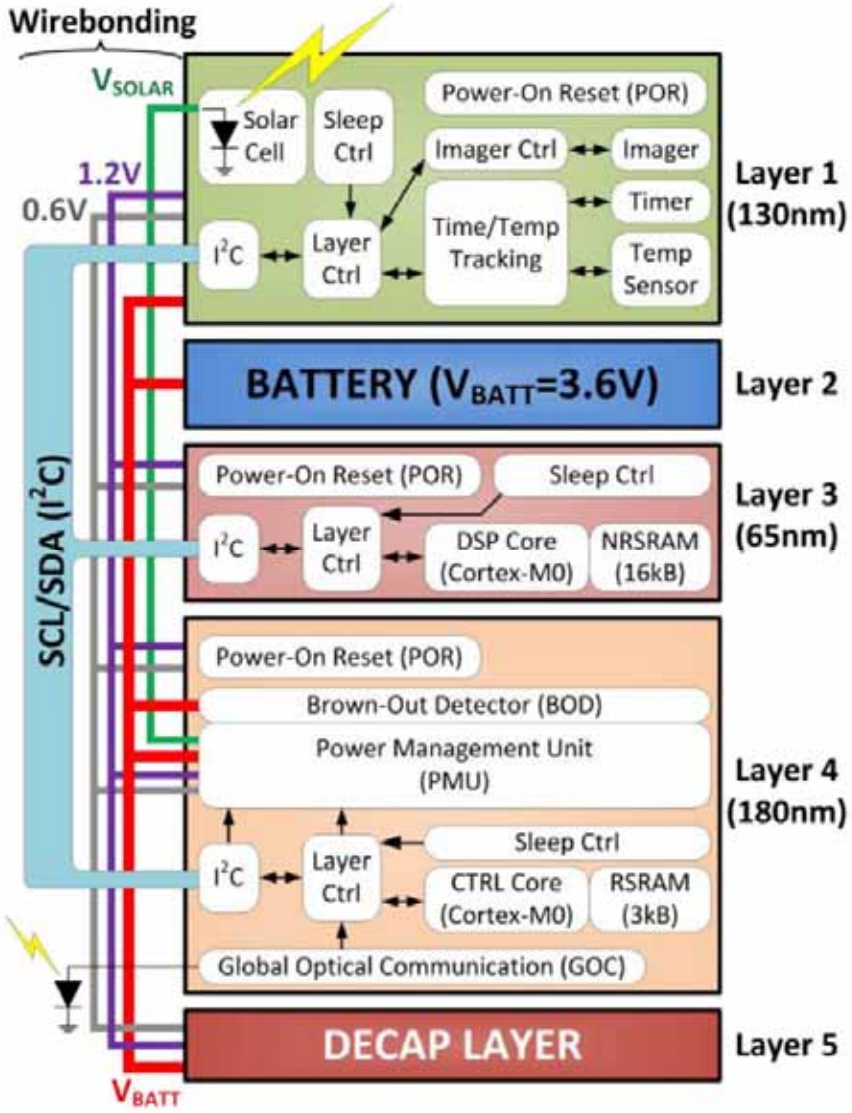
Zero Power Systems and Sensors



Zero Power Systems and Sensors







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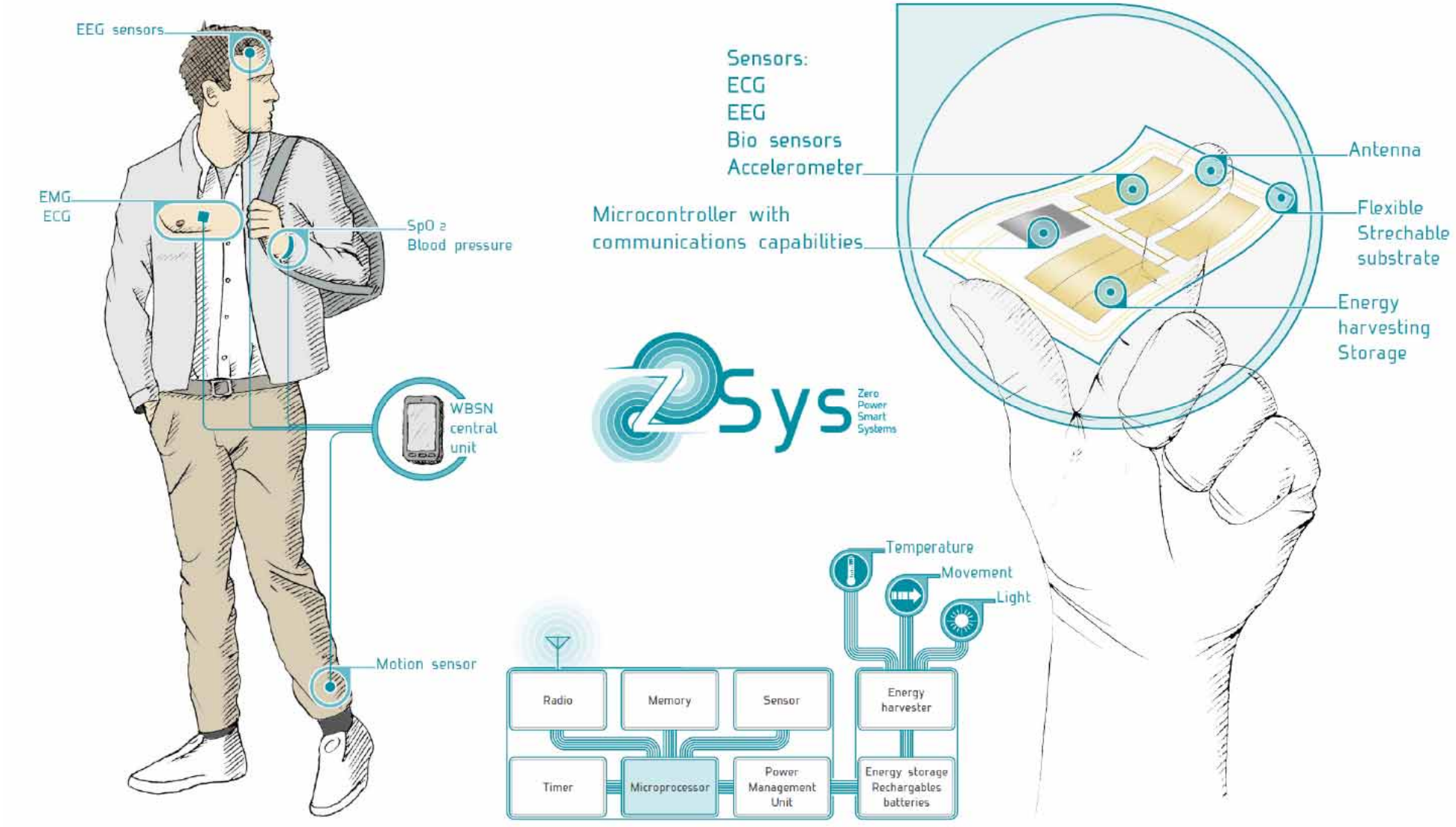
Zero Power Systems and Sensors



Z-Sys and Guardian Angel Research Proposals 2013