ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Embedded Systems in UNIBO

Luca Benini[1,2] Michela Milano[1]
UNIBO[1], ETHZ[2]

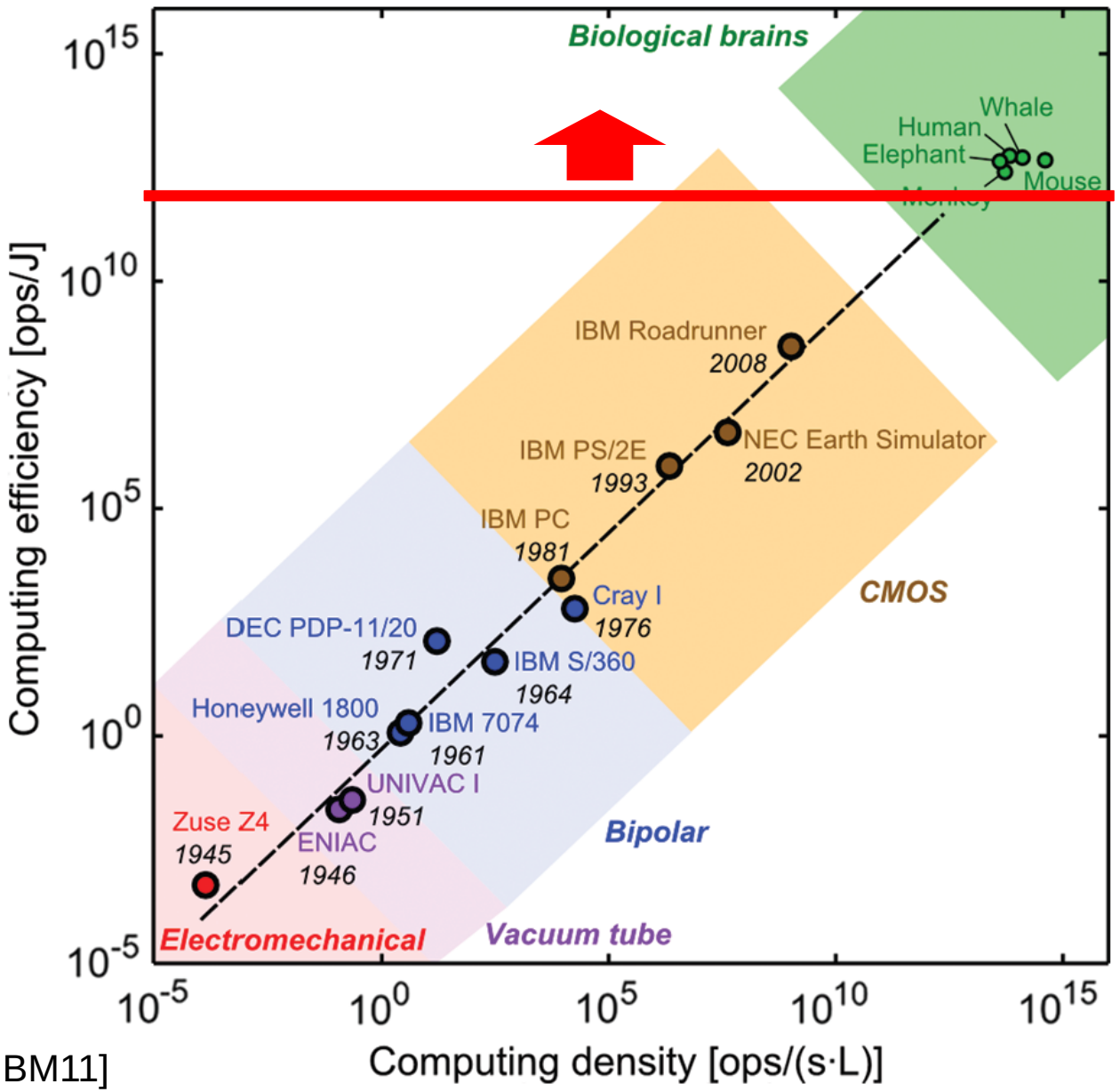
erc
European Research Council
SEVENTH FRAMEWORK PROGRAMME

NXP
life.augmented
SAMSUNG

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Brain-like Energy Efficiency

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA



10^{12}ops/J

↓

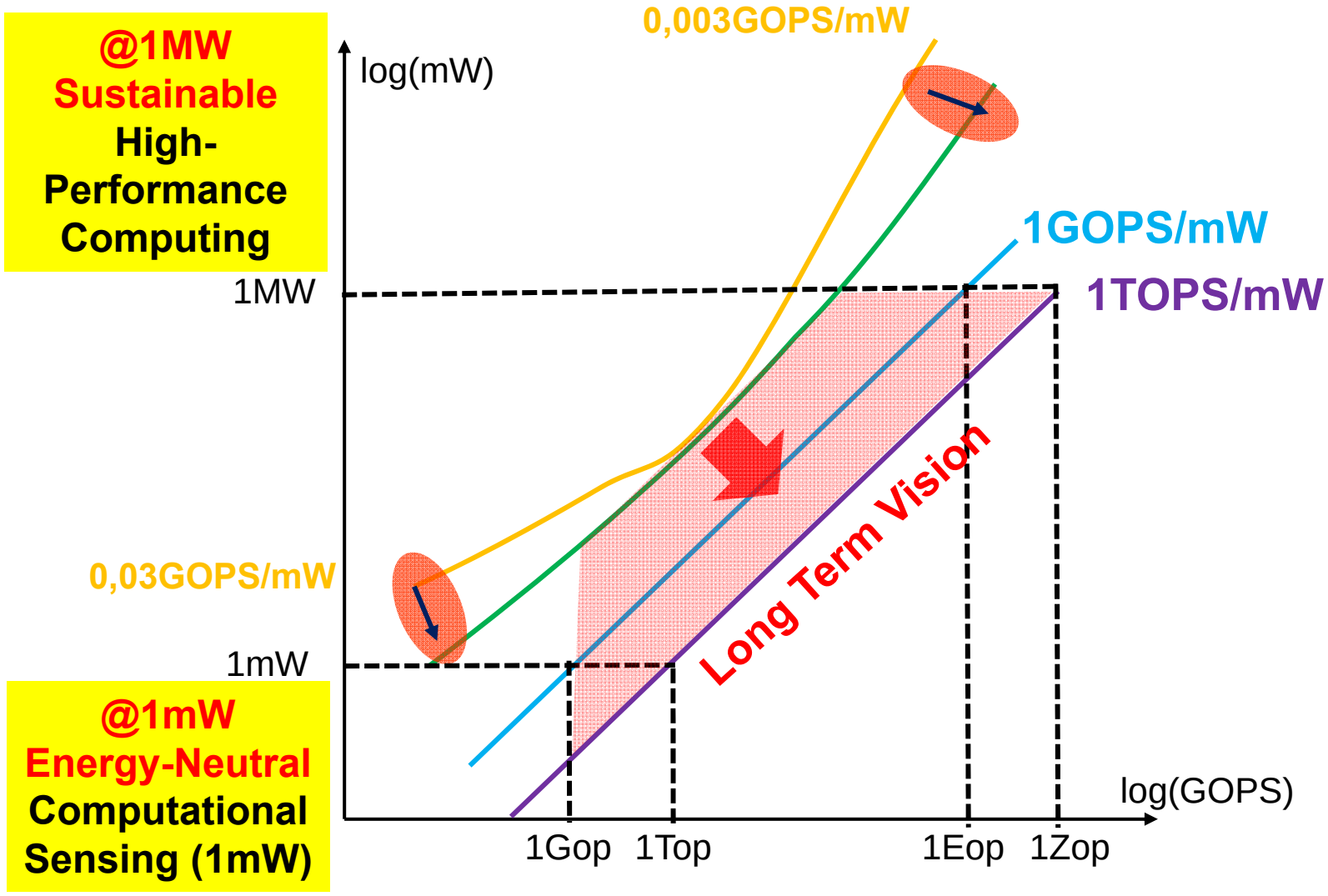
1pJ/op

↓

1GOPS/mW

[RuchIBM11]

Energy Proportionality



How?

Guiding Principles

Eliminate Waste

- Design for power management
- Scheduling and allocation
- Reduce off-chip I/O
- Specialized compute engines

Be Adaptive

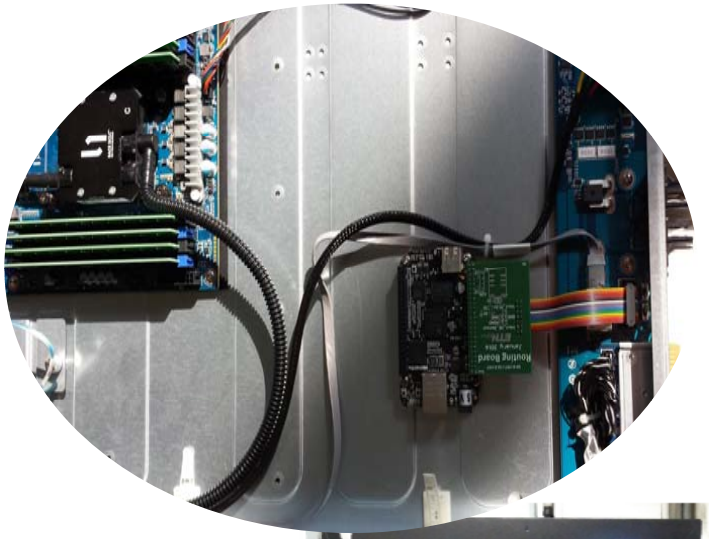
- Scale performance based on workload and constraints (e.g. MaxT) and available energy
- Dynamic (re-) configuration

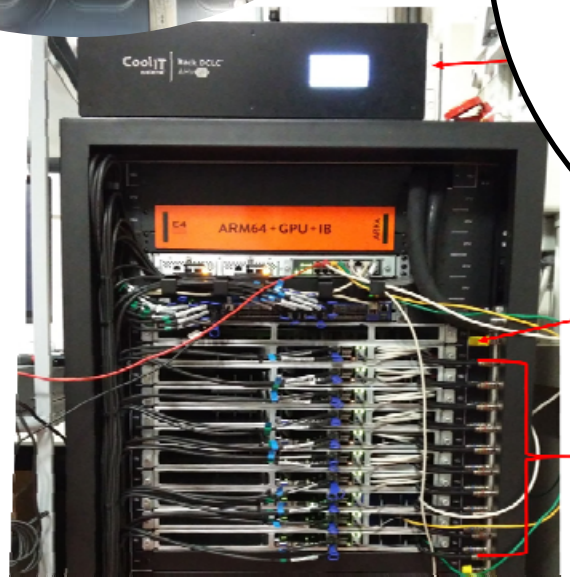
Make Use of Technology

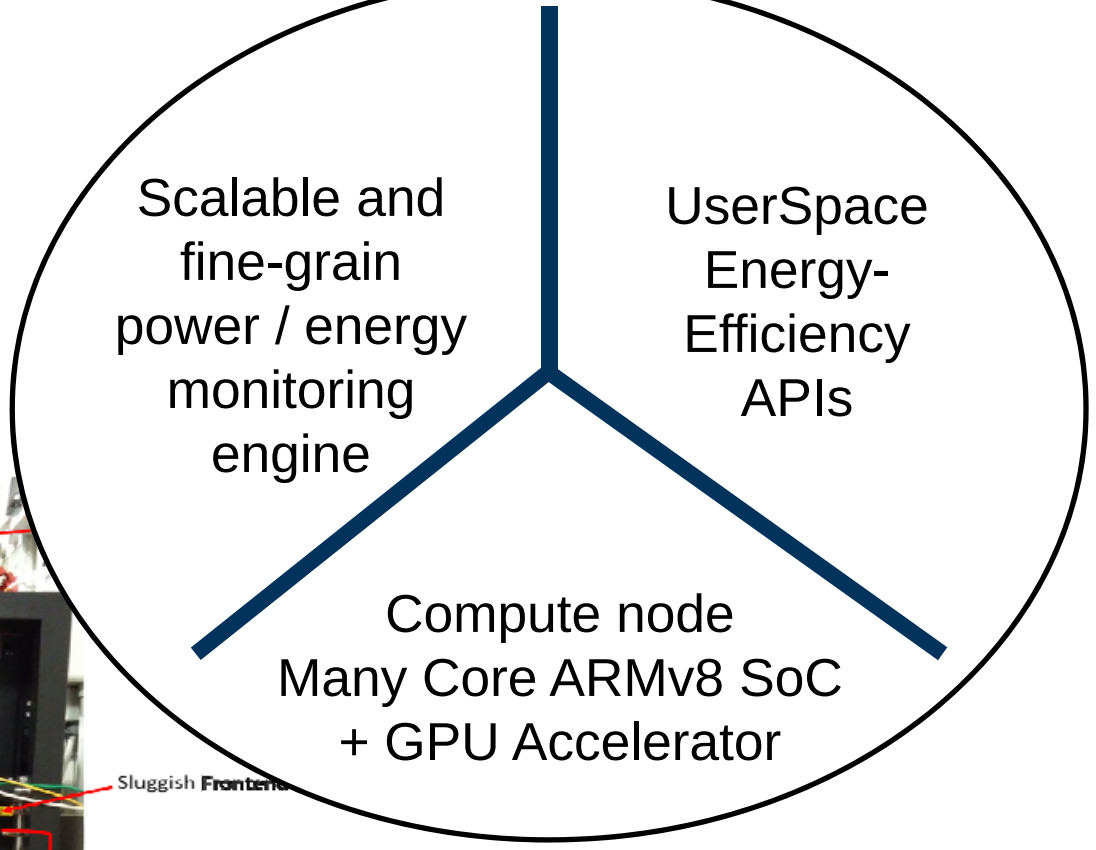
- Advanced technology nodes
- Low Power Sensors and interfaces
- Use novel storage technologies and interfaces

High-End ES and HPC

Co-design for Energy efficiency of ARM-V8 +GP-GPU (micro)-servers



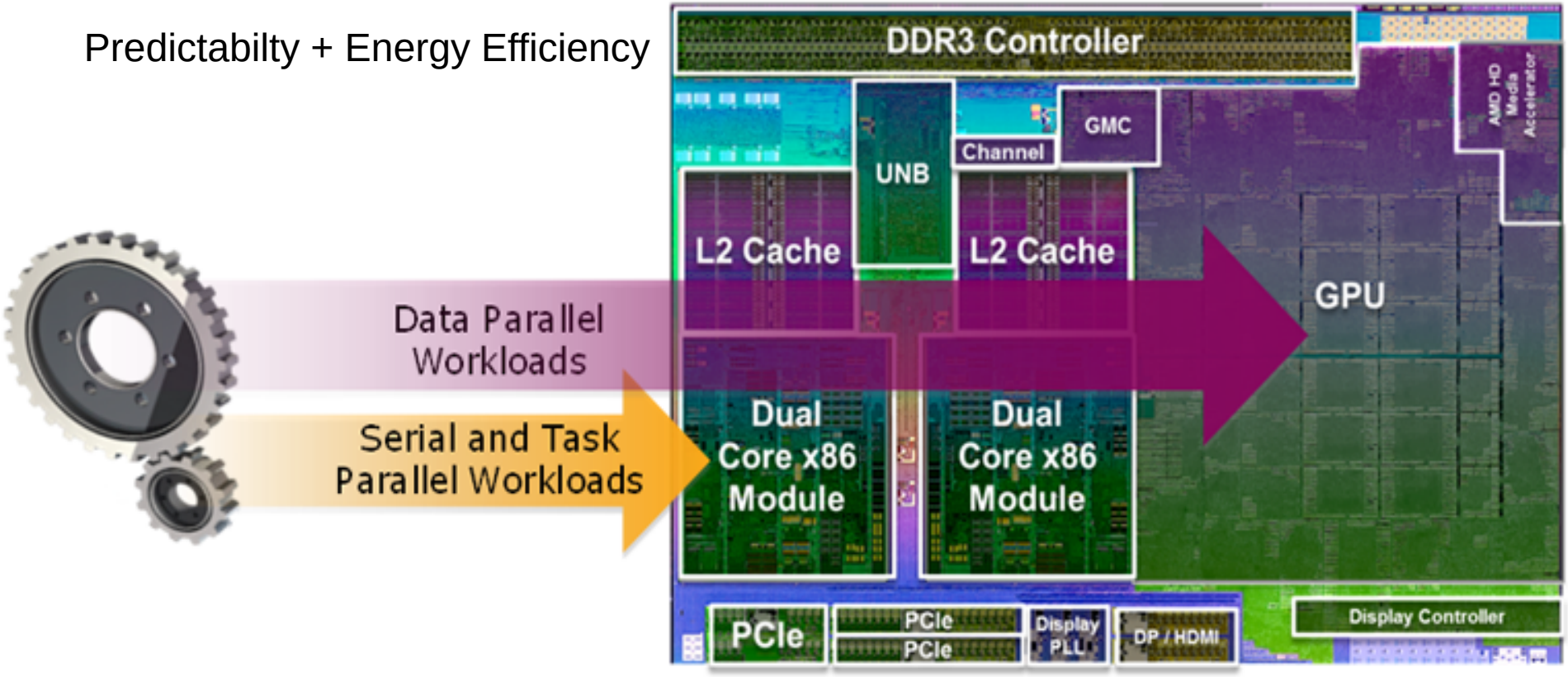




Mid-Range ES Heterogeneous SoCs

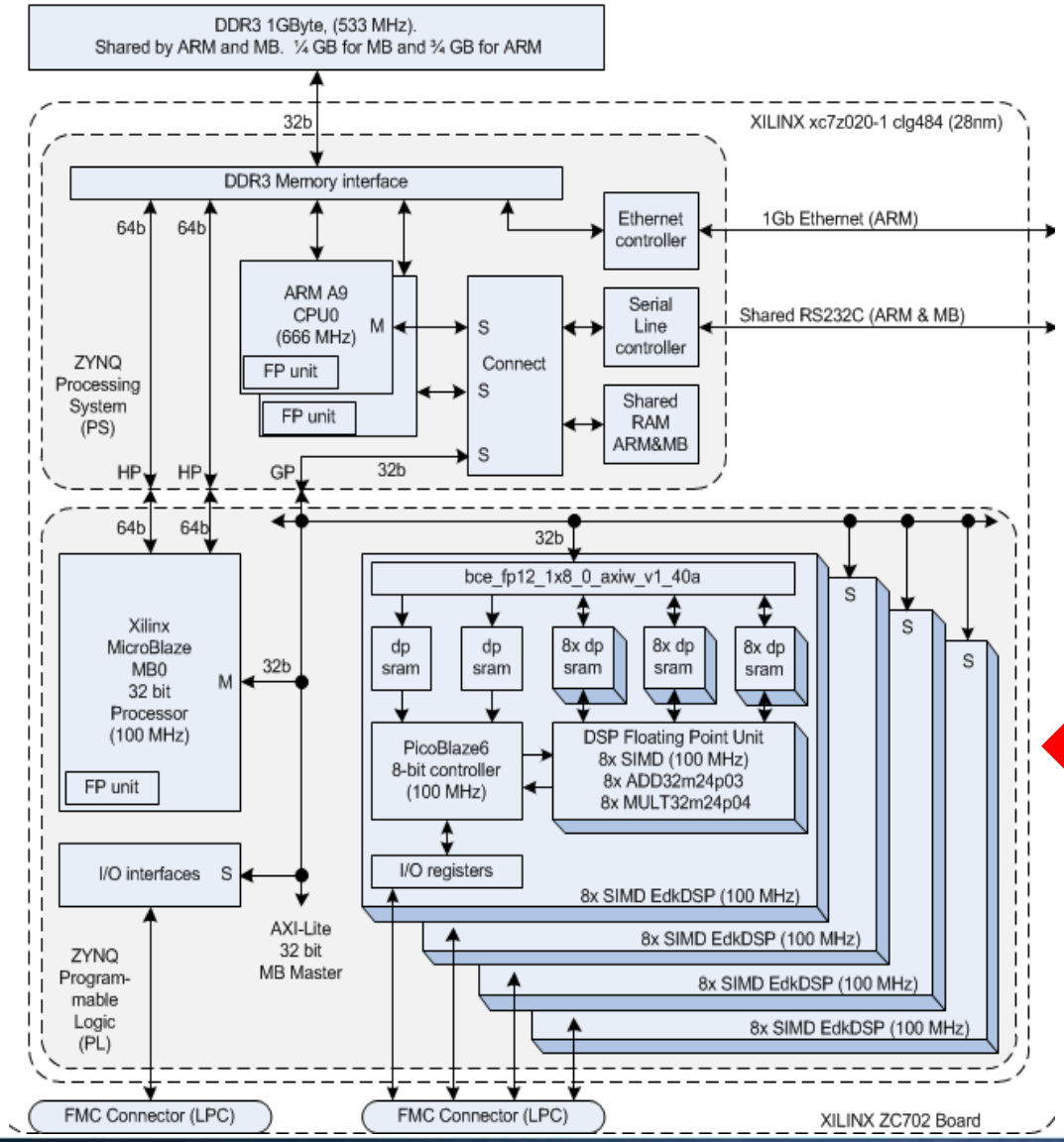
Embedded Multi-Core + GP-GPU (e.g. Nvidia TEGRA, AMD APUs)

Predictabilty + Energy Efficiency



Mid-Range ES Heterogeneous SoCs

Embedded Multi-Core + FPGA (Xilinx Zynq SoCs)



Sequential
General purpose
Processing
Standard video (camera) IFs

Massively Parallel
Specialized
LS Solver (CNN accelerator)

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

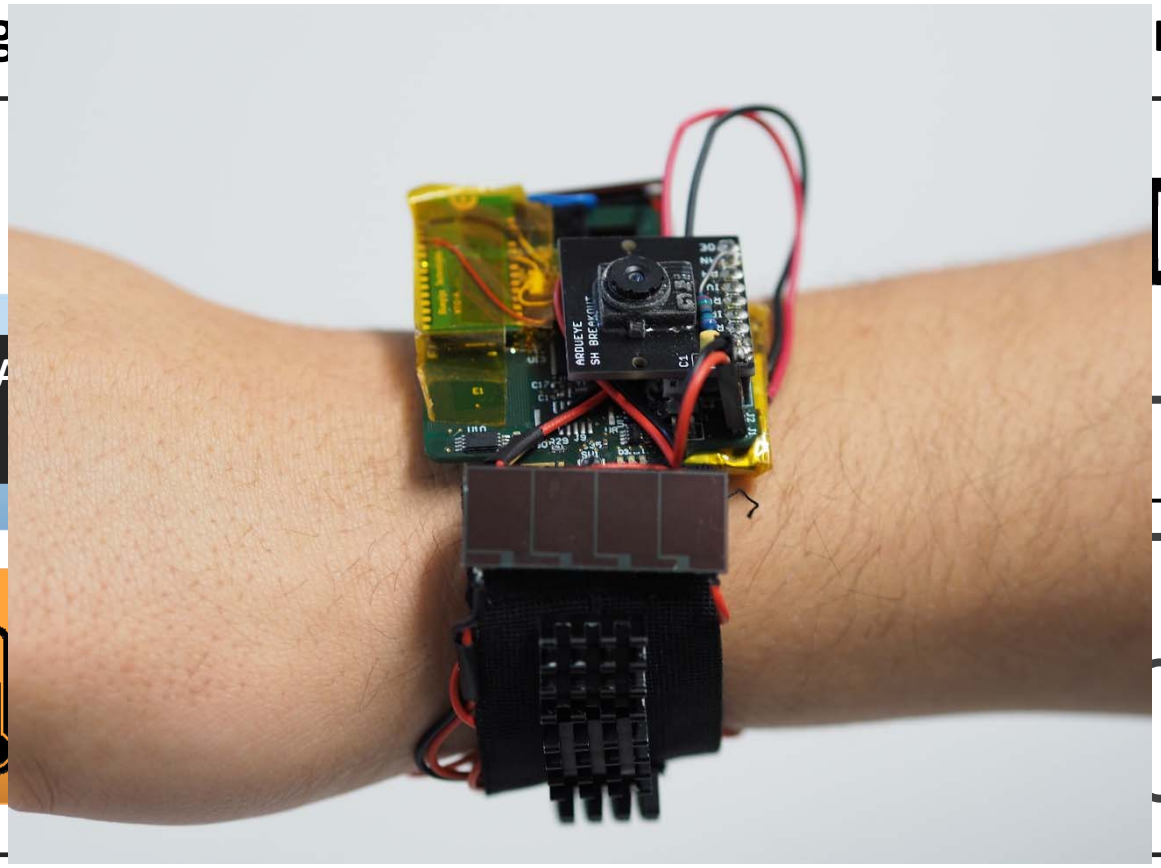
Wearable/Implantable ES

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

InfiniTime fully sustainable wearalbe ES

Power Sources → Harvesting & PM → Application Circuit

Energ … main



3.3 V

Multi-Harvester

TEG

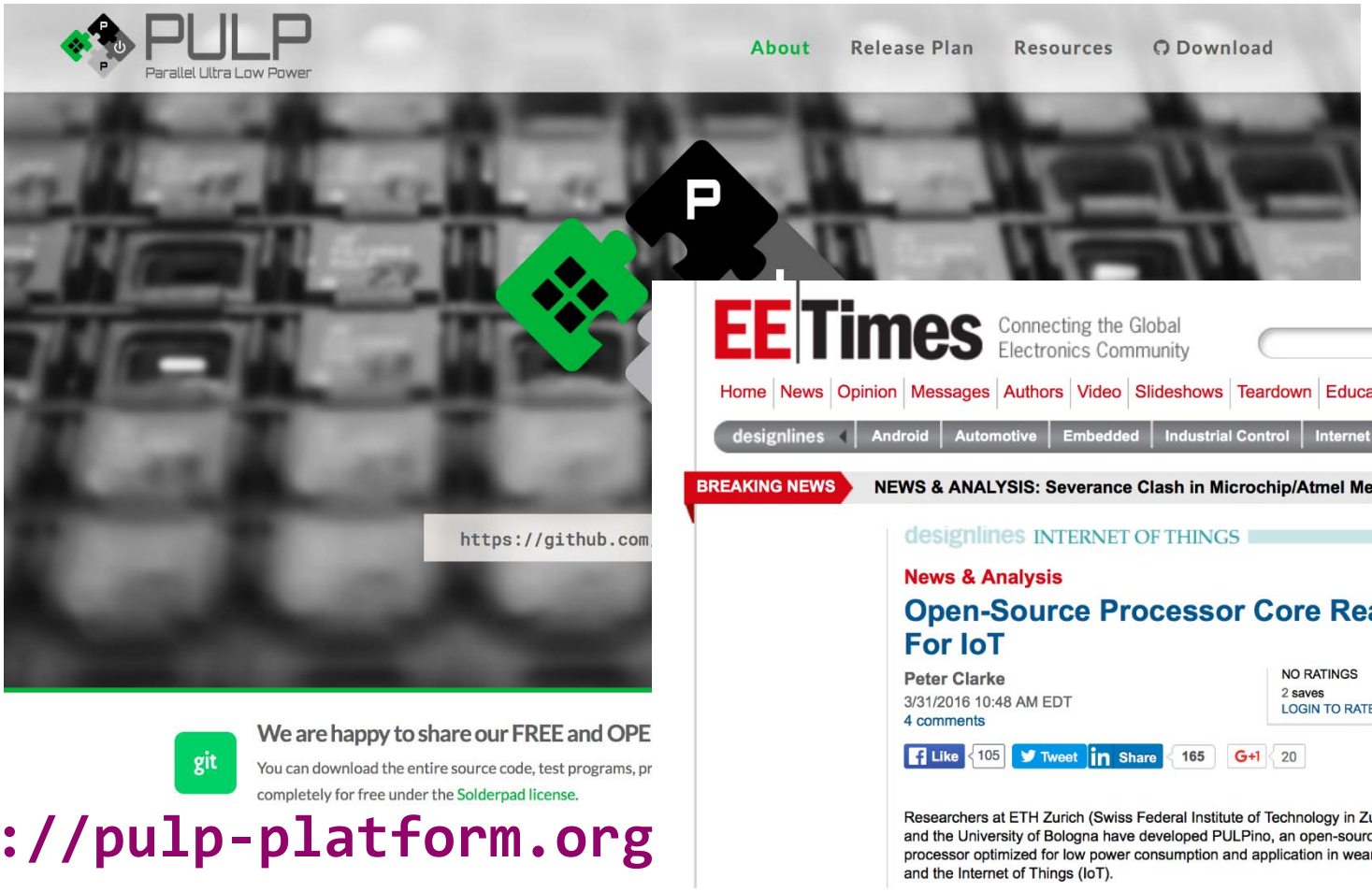
Technology Platforms: SW

- Programming models
  - Dataflow (in the past)
  - OpenMP, OpenVX (today)
  - Approximate (transprecision) OpenMP (tomorrow)
- Allocation and Scheduling
  - Task graphs
  - Stochastic graphs
  - Data-flow graphs
  - Cyclic Graphs
- MP-OPT tool

Refer to Michela, Giuseppe, Alessio's resentations

Technology Platforms: HW

Open-source HW and SW for near-sensor analytics



http://pulp-platform.org

Refer to Luca and Franceso presentations