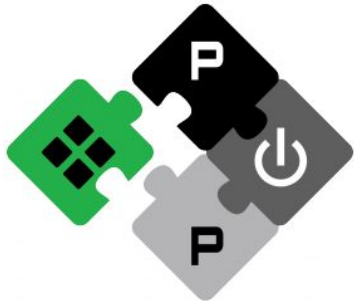


PULP PLATFORM
Open Source Hardware, the way it should be!

Bitcraze Workshop: PULP Introduction

Lorenzo Lamberti, Hanna Müller, Vlad Niculescu, Manuele Rusci,
Daniele Palossi


http://pulp-platform.org


@pulp_platform


https://www.youtube.com/pulp_platform

Team

Lorenzo

Hanna

Vlad

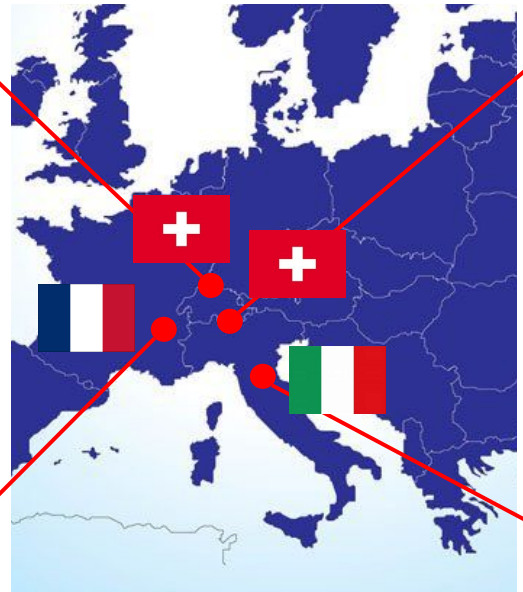
Manuele

Daniele

- Lorenzo Lamberti — *University of Bologna* — lorenzo.lamberti@unibo.it
- Hanna Müller — *ETH Zürich* — hanmuell@iis.ee.ethz.ch
- Vlad Niculescu — *ETH Zürich* — vladn@iis.ee.ethz.ch
- Dr. Manuele Rusci — *University of Bologna / Greenwaves Tech.* — manuele.rusci@greenwaves-technologies.com
- Dr. Daniele Palossi — *IDSIA Lugano / ETH Zürich* — dpalossi@iis.ee.ethz.ch

Team affiliations

Polytechnic of Zürich (ETHZ)



University of Lugano (USI/SUPSI)

Greenwaves Tech. in Grenoble (GWT)

University of Bologna (UniBO)

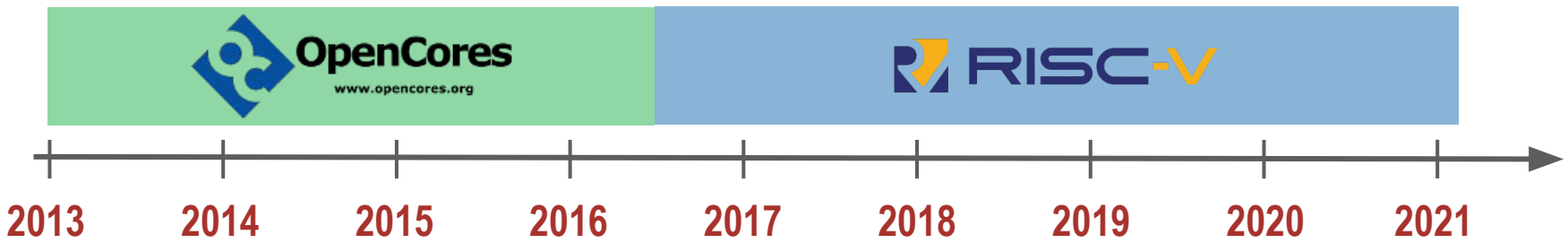
We are looking for outstanding Ph.D. candidates: https://www.supsi.ch/home_en/supsi/lavora-con-noi/2021-02-24-bando816.html

Agenda

	Topic	Time	Description	Speaker
Overview	**PULP introduction**	15’	Parallel Ultra-low Power (PULP) overview	Daniele
	GAP8 architecture	10’	System-on-Chip hardware architecture	Manuele
	AI-deck	15’	Printed circuit board overview & GAP8 SDK	Hanna
	Break	15’		
Hands-on	**Basic programming**	10’	JTAG programming & ‘Hello World’ example	Hanna
	Image manipulation	10’	Image acquisition, parallel image filter	Hanna
	Firmware integration	15’	App-layer integration, UART communication	Vlad
	Video streaming	20’	Basic Wi-Fi streaming, JPEG image compression	Lorenzo
	Conclusion	5’	Final remarks	Daniele

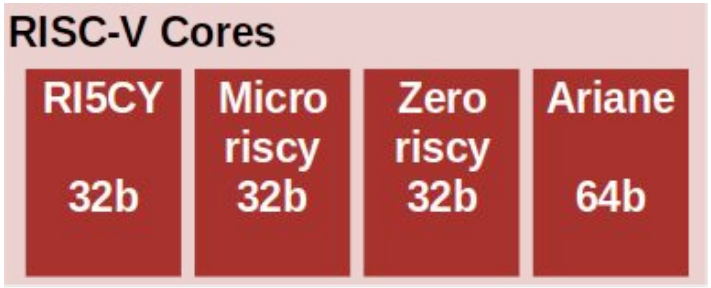
Parallel Ultra-low Power (PULP)

- The **PULP** project started in **2013**
- Collaboration between the **University of Bologna** and **ETH Zürich**
  - Large team, about 60 people, not all are working on PULP
- Academic/Research goals:
  - Create a compute platform used for **research** (e.g., autonomous nano-drones) by the PULP and other groups in **Europe** and in the **World**
  - Push **energy efficiency** of IoT computing systems as much as possible (we target research on low-power MCUs)
  - **Open-source** approach
- We wanted to start with a clean slate, no need to remain compatible with legacy systems, **no dependency with any commercial IP**
- We started with **OpenRISC** and around mid-2016 we moved to **RISC-V** ISA:
  - Larger community, more momentum

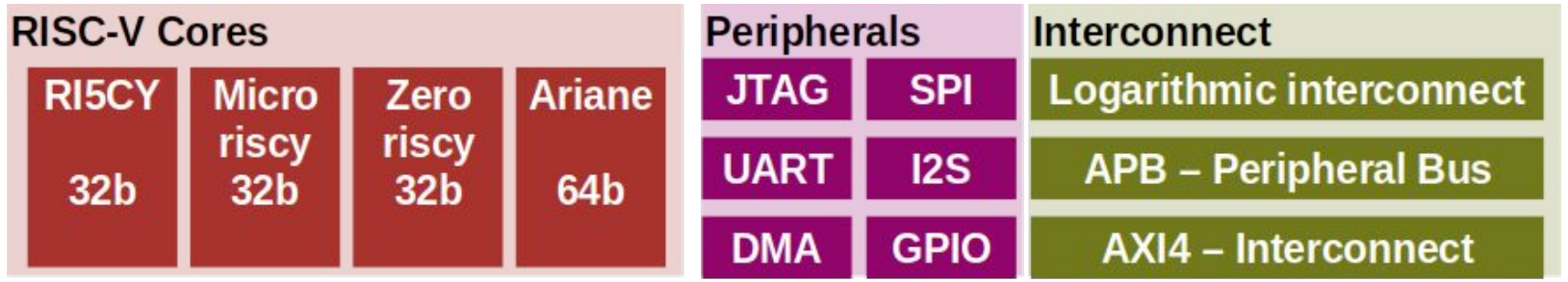


PULP ecosystem

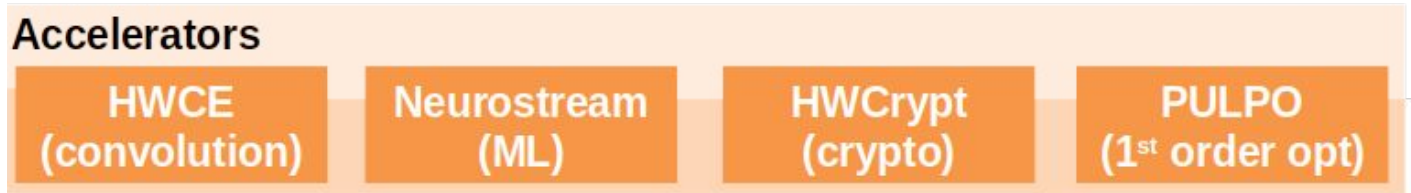
We have developed several optimized RISC-V cores



PULP ecosystem

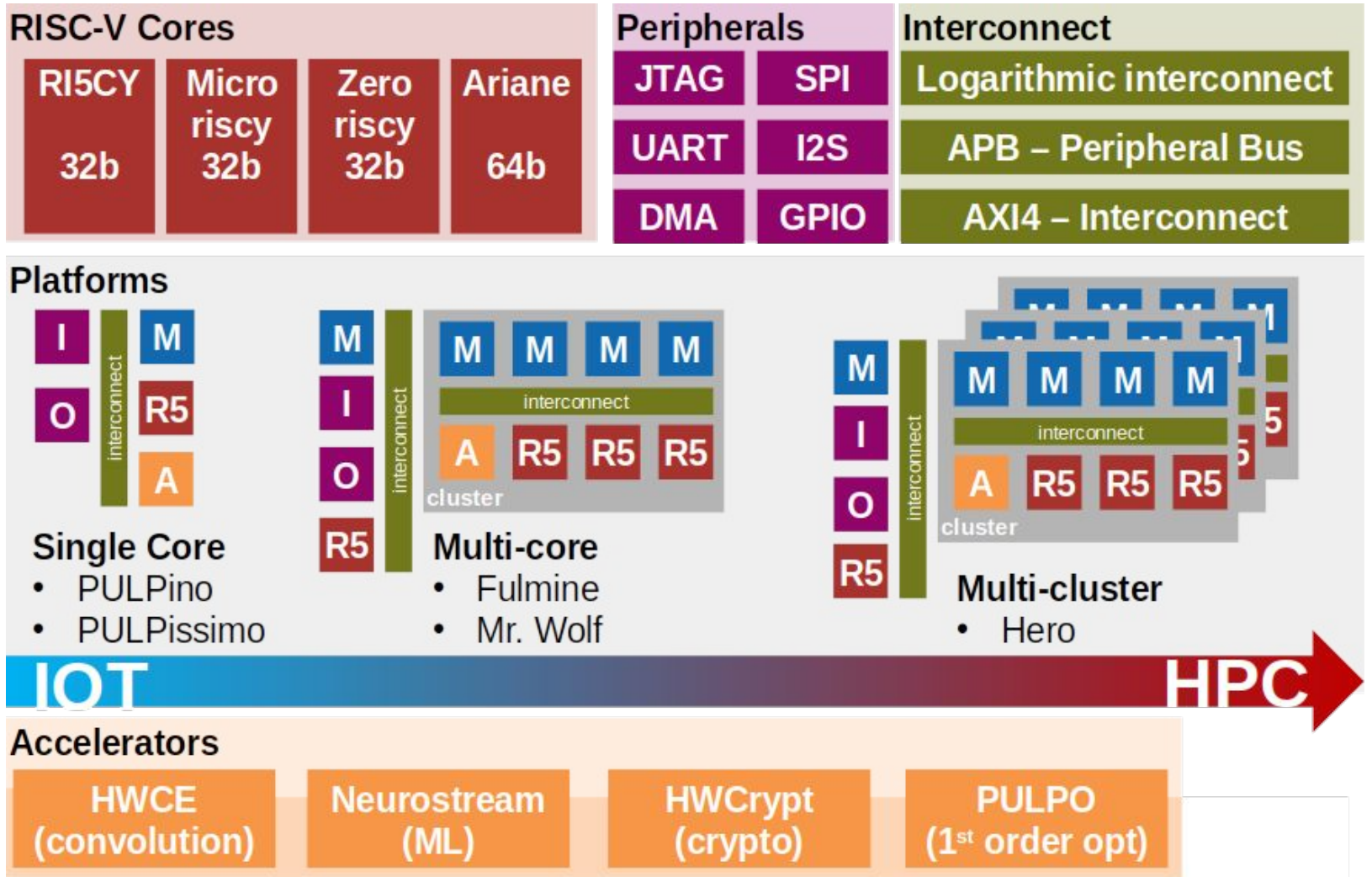


Only processing cores are not enough, we need more



PULP ecosystem

All these components are combined into platforms



PULP ecosystem

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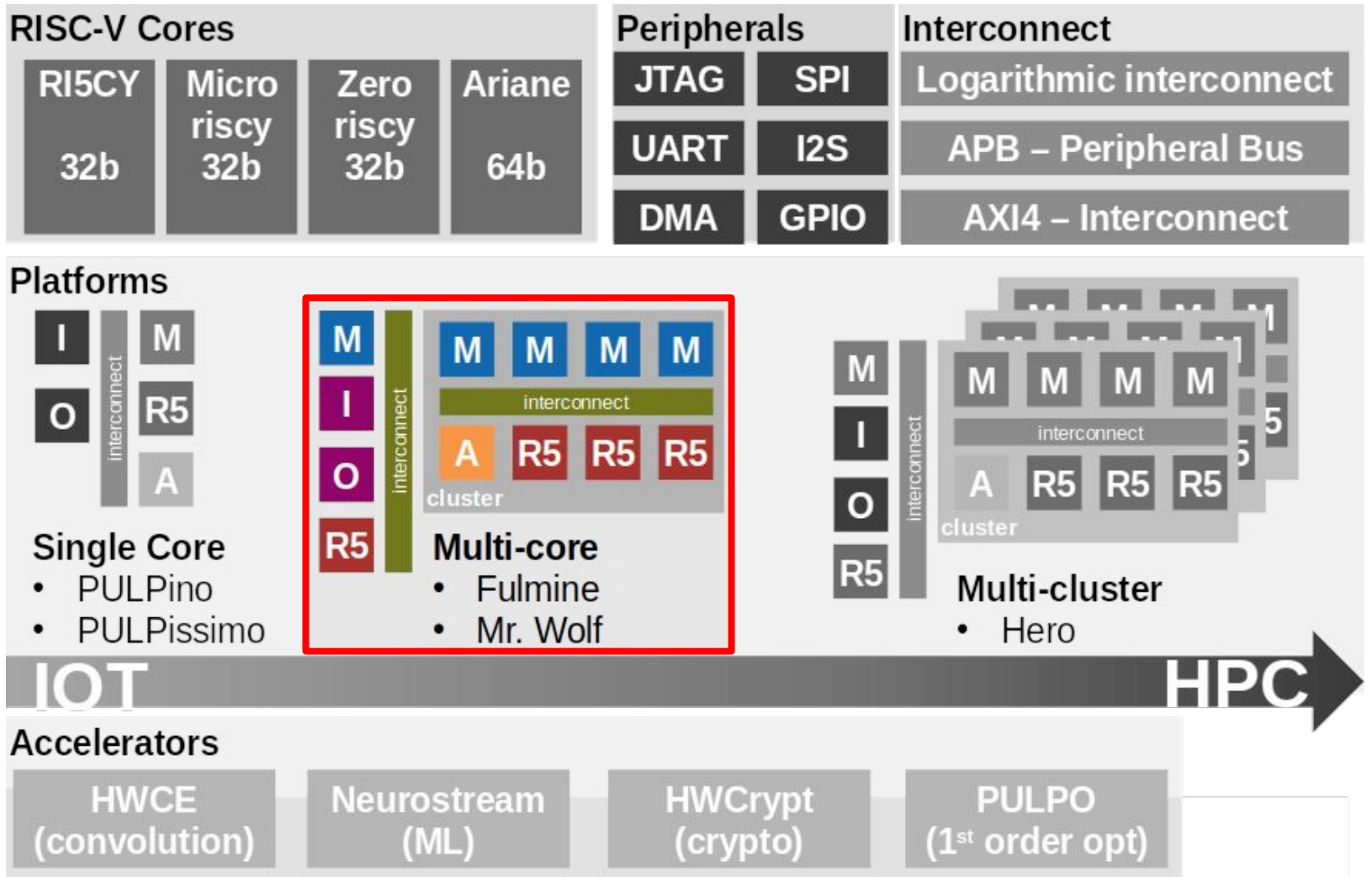
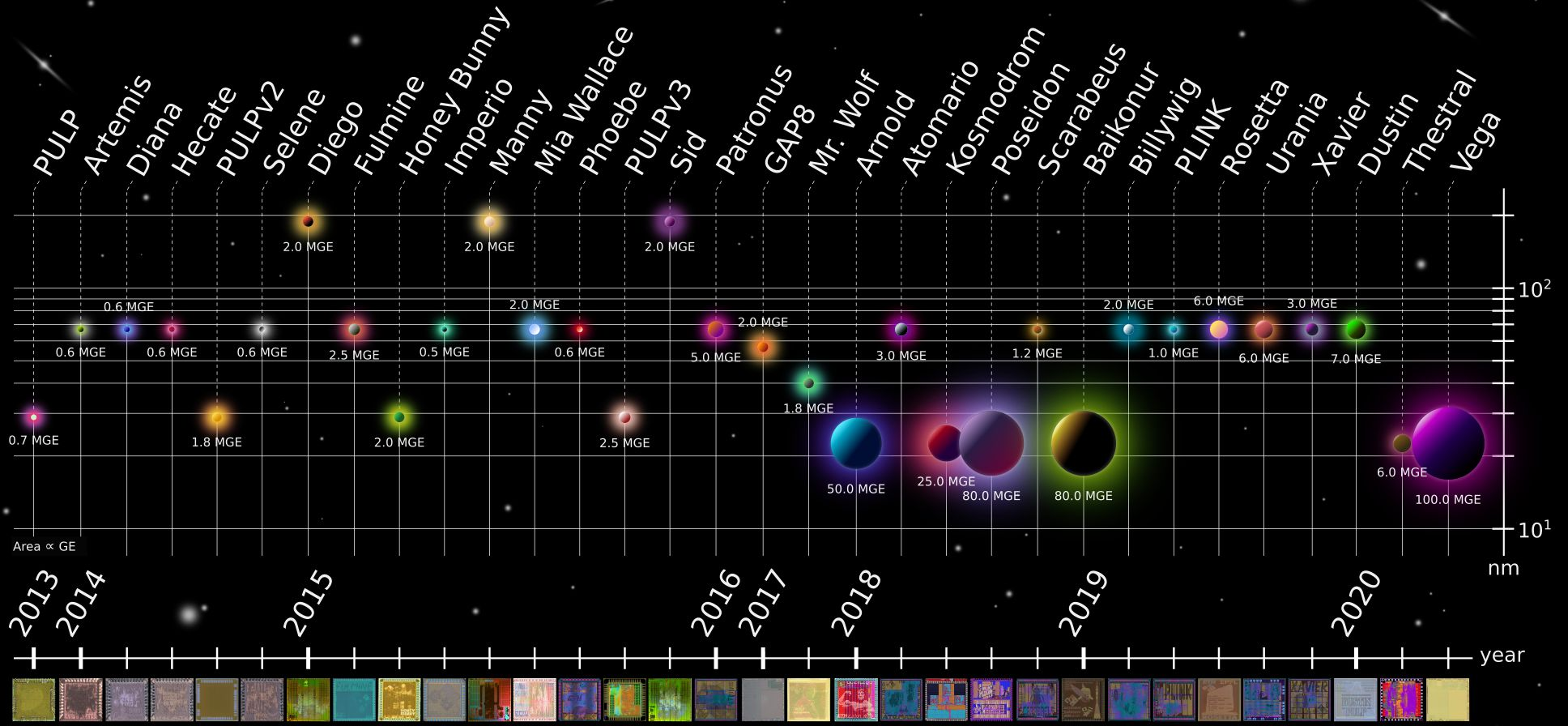


PULP Silicon Prototypes

History of the PULP:

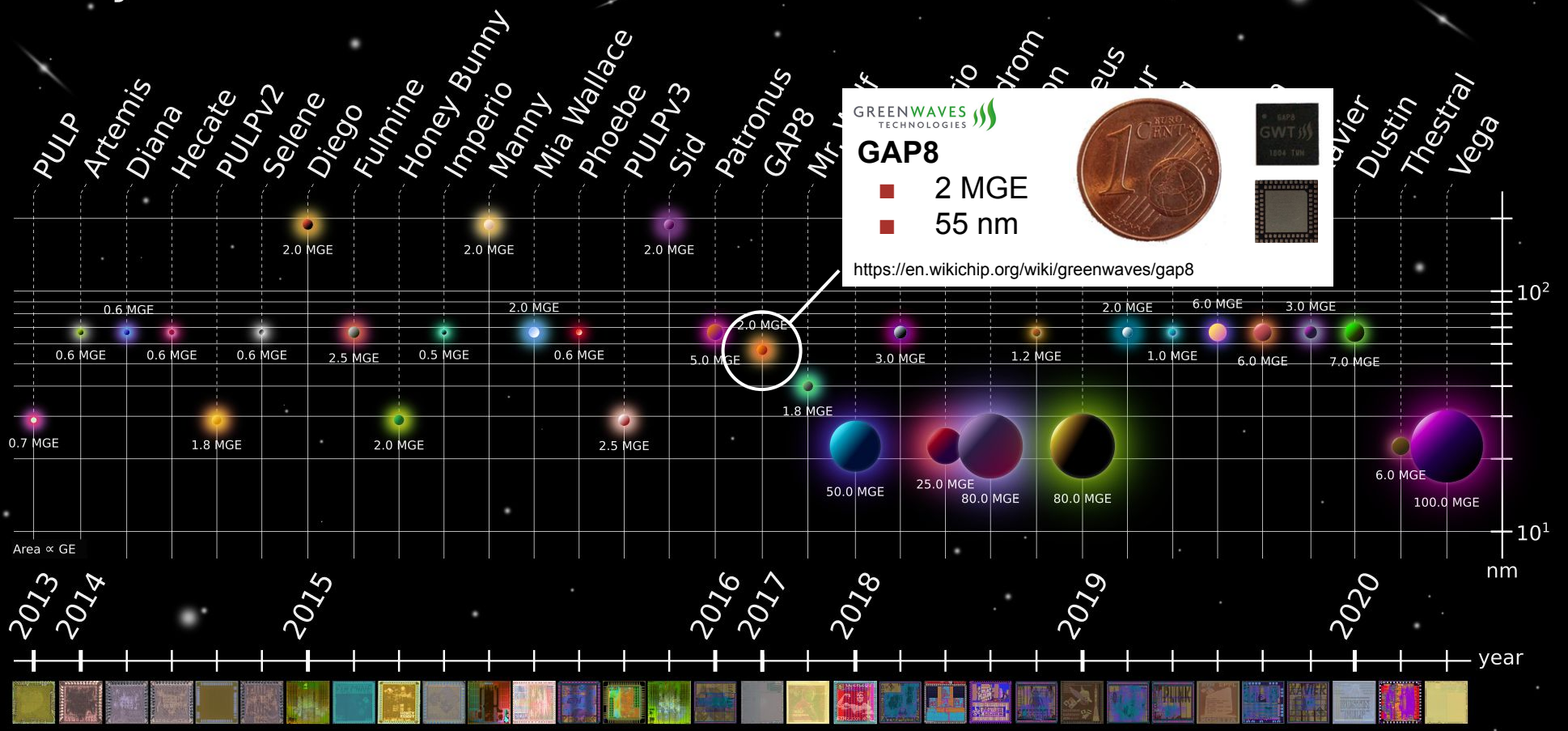


http://asic.ethz.ch/applications/Pulp.html

Credit: Daniele Palossi

PULP Silicon Prototypes

History of the PULP:



http://asic.ethz.ch/applications/Pulp.html

Credit: Daniele Palossi

Who uses PULP?

Industrial users:

OPENHW GROUP — PROVEN PROCESSOR IP
lowRISC
Google
IBM
NXP
GREENWAVES TECHNOLOGIES
life.augmented
GLOBAL FOUNDRIES
EMBECOSM
DOLPHIN INTEGRATION
CEVA
IQ-ANALOG
Mentor
cadence
QuickLogic
onespin
imperas
SILICON LABS
axiomise — predictable formal verification
ASHLING
ACP AG — Advanced Circuit Pursuit
Valtrix SYSTEMS
antmicro
WITTENSTEIN
THALES
semidynamics — silicon design and verification services
HENSOLDT

Direct research collaborators:

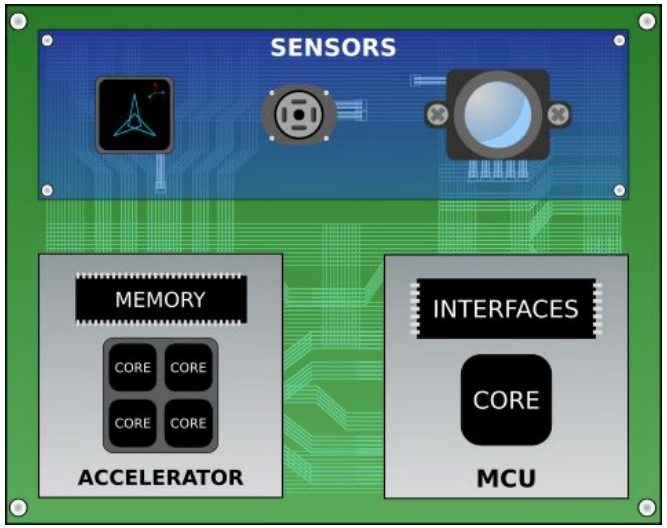
- Politecnico di Torino
- University of Cambridge
- USI Lugano
- TU Kaiserslautern
- University of Cagliari
- IBM Research Zurich
- EPF Lausanne
- CSEM Neuchatel
- Princeton University
- Technische Universität Graz
- CEA-Leti Grenoble
- Fraunhofer-Gesellschaft
- Sapienza Università di Roma

Academic users we are aware of:

- Università di Genova
- Politecnico di Milano
- Fondazione Bruno Kessler
- Lund University
- Stanford University
- UC Los Angeles
- UC San Diego
- Columbia University
- Universitat Bar-Ilan
- İstanbul Teknik Üniversitesi
- NCTU Hsinchu
- University of Zagreb, FER
- TUT Tampere
- RWTH Aachen
- IST University of Lisboa
- UFRN Rio Grande do Norte
- TU Darmstadt
- Universität Bremen
- Hongik University Seoul
- IIT Kharagpur
- LIRMM Montpelier
- University of Stuttgart
- University of Tübingen
- TU Münich
- FORTH Hellas
- Kyoto University
- Tecnologico de Costa Rica
- Chalmers Göteborg
- NTNU Trondheim
- IDSIA Manno
- FAU Erlangen-Nürnberg
- TU Dresden
- SVNIT Surat

The PULP-Shield

ULP heterogeneous model [1]



[1] F. Conti, D. Palossi, A. Marongiu, D. Rossi, and L. Benini. "Enabling the heterogeneous accelerator model on ultra-low power microcontroller platforms." IEEE DATE, *2016*.

The PULP-Shield

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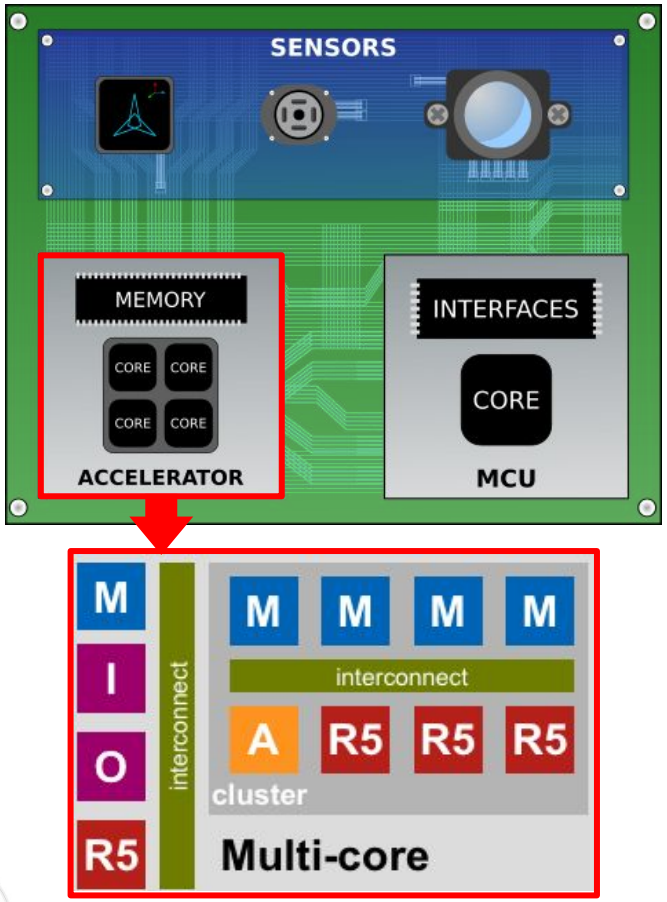

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The PULP-Shield

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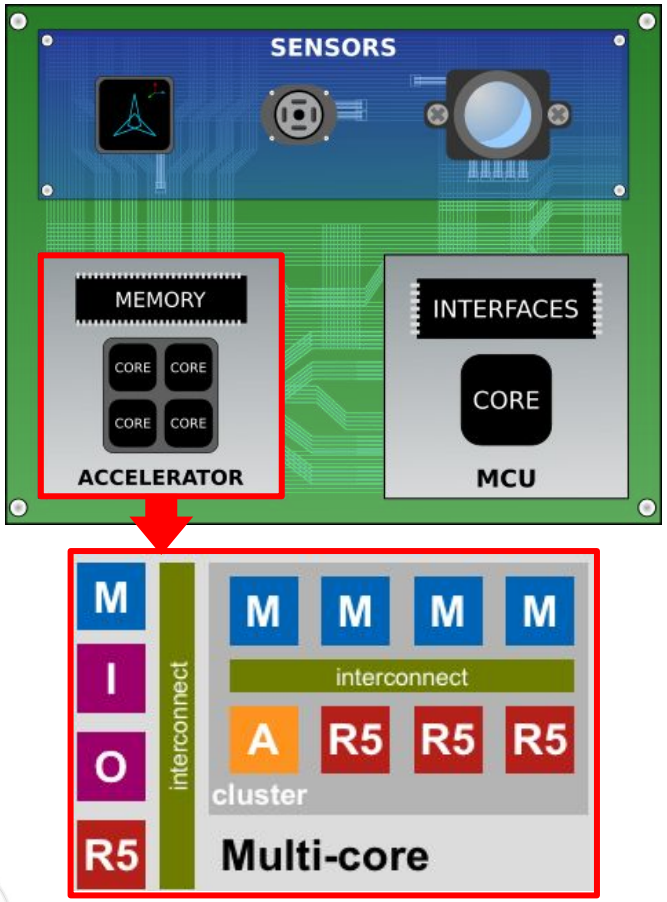
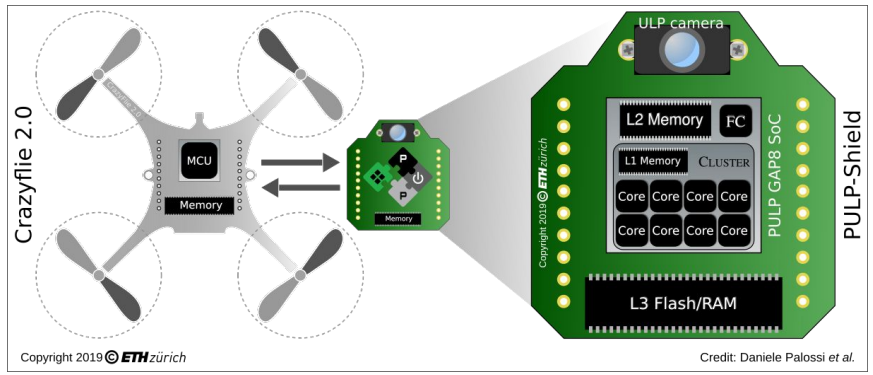
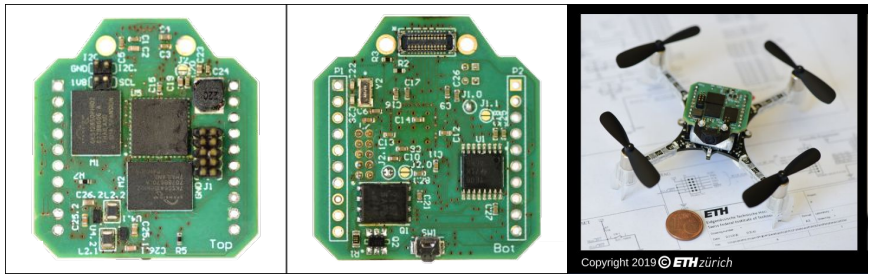


PULP-Shield [2]





- ~ 5 g – 30x28 mm
- PULP GAP8 SoC
- Off-chip DRAM/Flash
- QVGA ULP Camera
- **Open source hardware**

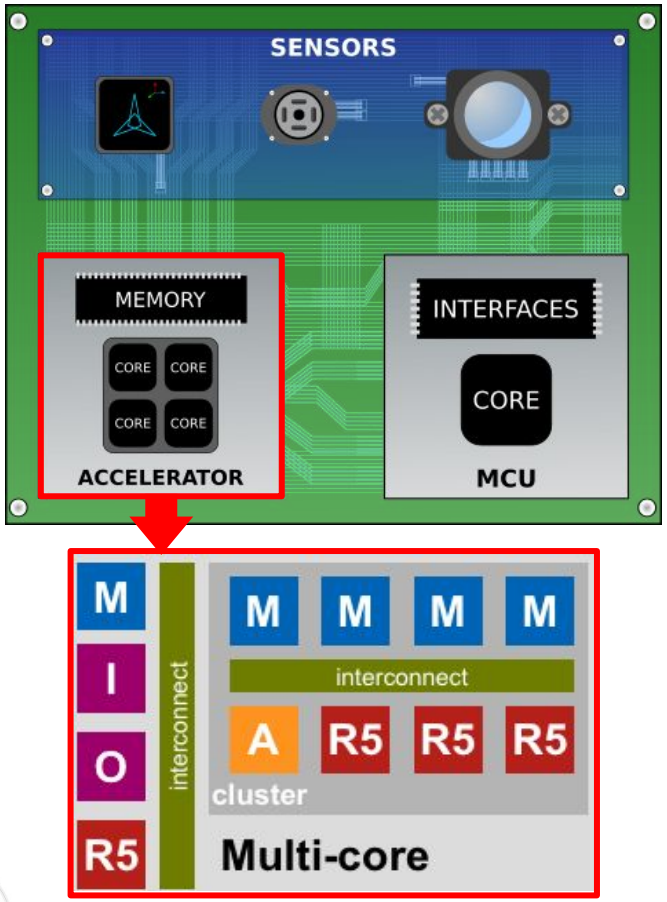
ALTIUM DESIGNER

GitHub

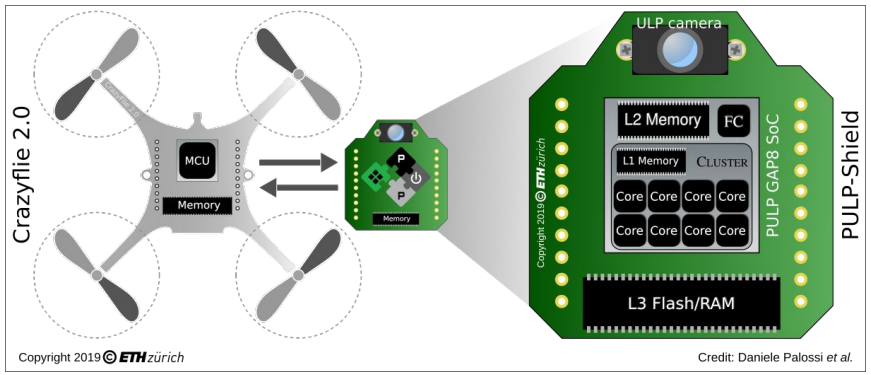
[1] F. Conti, D. Palossi, A. Marongiu, D. Rossi, and L. Benini. "Enabling the heterogeneous accelerator model on ultra-low power microcontroller platforms." IEEE DATE, *2016*.
[2] D. Palossi, F. Conti, and L. Benini "An open source and open hardware deep learning-powered visual navigation engine for autonomous nano-UAVs." IEEE DCOSS, *2019*.

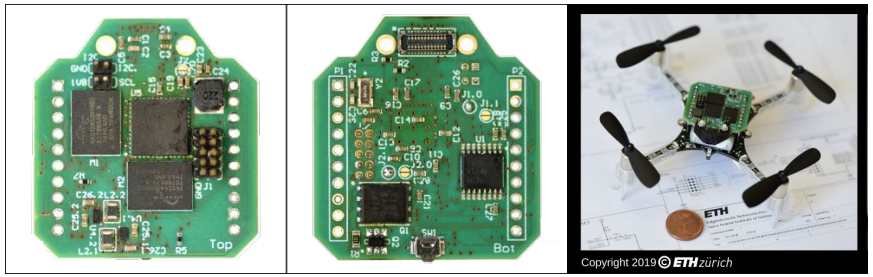
The PULP-Shield

ULP heterogeneous model [1]



PULP-Shield [2]





- ~ 5 g – 30x28 mm
- PULP GAP8 SoC
- Off-chip DRAM/Flash
- QVGA ULP Camera
- **Open source hardware**

ALTIUM DESIGNER

GitHub

AI-Deck

- ~ 8 g – 40x28 mm
- PULP GAP8 SoC
- 8/64 MB DRAM/Flash
- QVGA ULP Camera
- WiFi module

[1] F. Conti, D. Palossi, A. Marongiu, D. Rossi, and L. Benini. "Enabling the heterogeneous accelerator model on ultra-low power microcontroller platforms." IEEE DATE, *2016*.
[2] D. Palossi, F. Conti, and L. Benini "An open source and open hardware deep learning-powered visual navigation engine for autonomous nano-UAVs." IEEE DCOSS, *2019*.

The AI-Deck

Crazyflie + AI-Deck

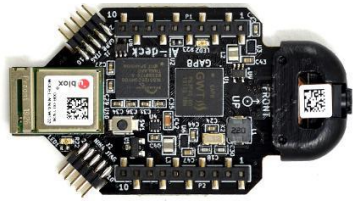
Crazyflie (STM32)

Radio:
Nordic BTLE

nRF51 2.4GHz
Data rate: 0,25/1/2 Mbit/s

UART Link

Data rate: 1 Mbit/s



AI-Deck (GAP8)

Radio:
NINA Wi-Fi

NINA-W102 2.4 GHz
Data rate: 6-54 Mbit/s

Radio dongle

Wi-Fi card

The AI-Deck

Crazyflie (STM32)

Radio:
Nordic BTLE

nRF51 2.4GHz
Data rate: 0,25/1/2 Mbit/s

Crazyflie + AI-Deck

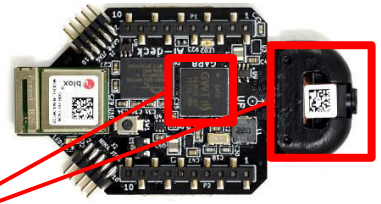
UART Link

Data rate: 1 Mbit/s

Radio dongle

Wi-Fi card

Hands-on 1-2: GAP8
programming & camera



AI-Deck (GAP8)

Radio:
NINA Wi-Fi

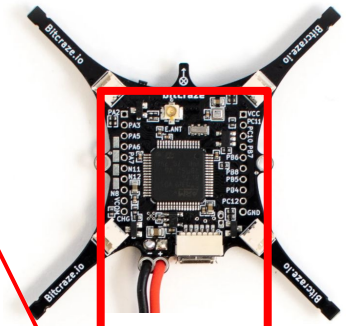
NINA-W102 2.4 GHz
Data rate: 6-54 Mbit/s

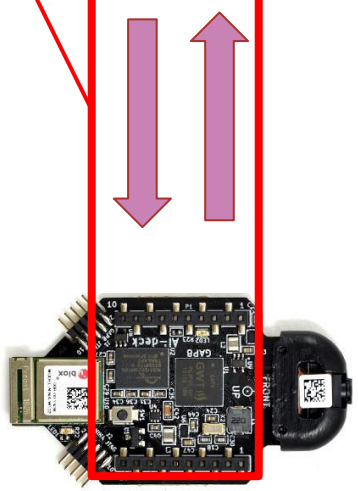
The AI-Deck

Hands-on 3: integration & UART

Crazyflie + AI-Deck

Crazyflie (STM32)





AI-Deck (GAP8)

Radio:
Nordic BTLE

nRF51 2.4GHz
Data rate: 0,25/1/2 Mbit/s

UART Link

Data rate: 1 Mbit/s

Radio:
NINA Wi-Fi

NINA-W102 2.4 GHz
Data rate: 6-54 Mbit/s

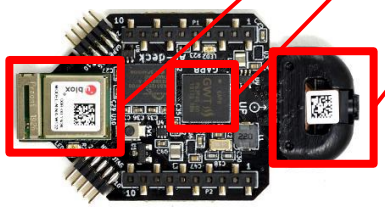
Radio dongle

Wi-Fi card

The AI-Deck

Crazyflie (STM32)

Crazyflie + AI-Deck



AI-Deck (GAP8)

Radio:
Nordic BTLE

nRF51 2.4GHz
Data rate: 0,25/1/2 Mbit/s

UART Link

Data rate: 1 Mbit/s

Radio:
NINA Wi-Fi

NINA-W102 2.4 GHz
Data rate: 6-54 Mbit/s

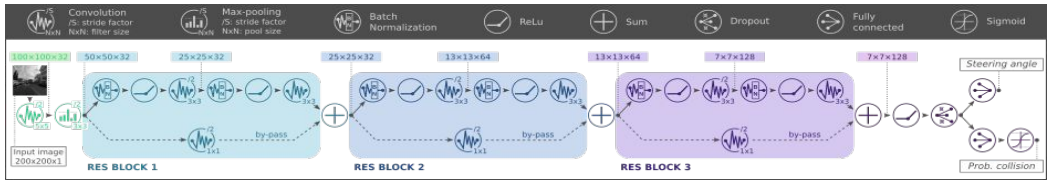
Hands-on 4: Wi-Fi image streaming

Radio dongle

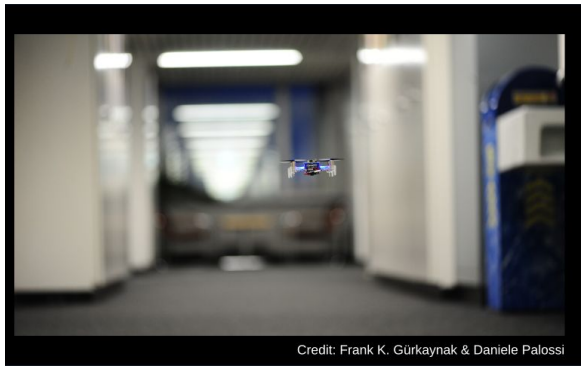
Wi-Fi card

AI-based applications (not in this workshop)

PULP-Dronet:



Task:	Lane detection / Obstacle avoidance
CNN:	41 MMAC/frame
Onboard:	6fps@45mW / 18fps@272mW
Device:	PULP-Shield (GAP8)
arXiv.org	https://arxiv.org/abs/1805.01831

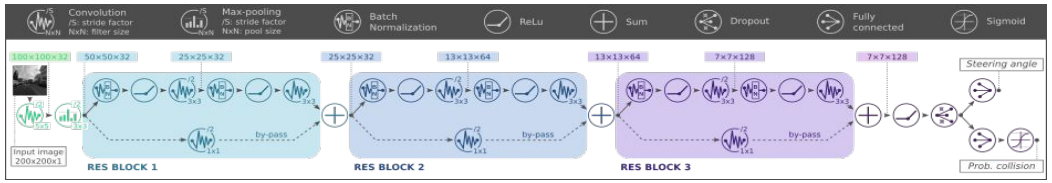

Credit: Frank K. Gürkaynak & Daniele Palossi

GitHub
https://github.com/pulp-platform/pulp-dronet

YouTube
https://www.youtube.com/watch?v=JKY03NV3C2s

AI-based applications (not in this workshop)

PULP-Dronet:



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CNN:	41 MMAC/frame
Onboard:	6fps@45mW / 18fps@272mW
Device:	PULP-Shield (GAP8)
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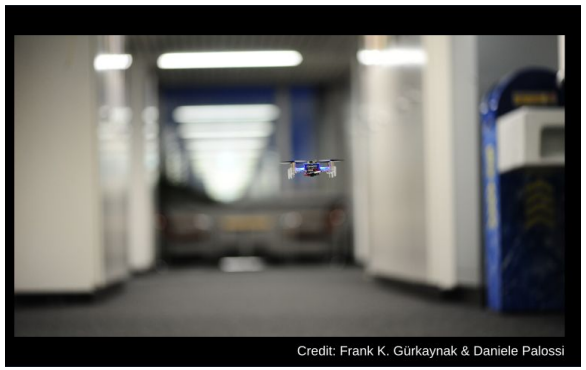
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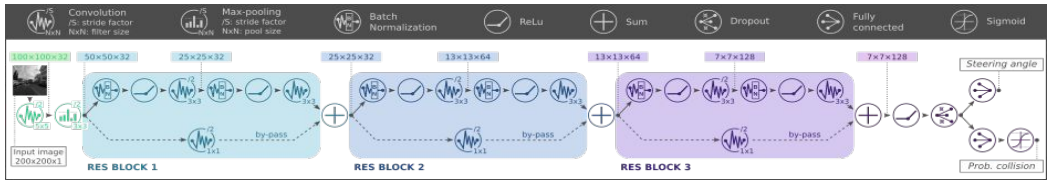
https://www.youtube.com/watch?v=JKY03NV3C2s

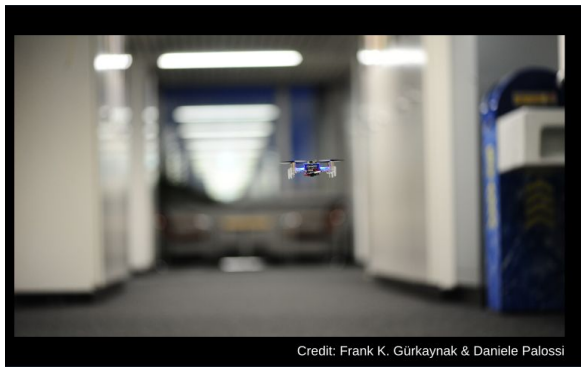
PULP-Dronet v2 for the AI-Deck coming soon on GitHub

AI-based applications (not in this workshop)

PULP-Dronet:



Task:	Lane detection / Obstacle avoidance
CNN:	41 MMAC/frame
Onboard:	6fps@45mW / 18fps@272mW
Device:	PULP-Shield (GAP8)
arXiv.org	https://arxiv.org/abs/1805.01831



GitHub
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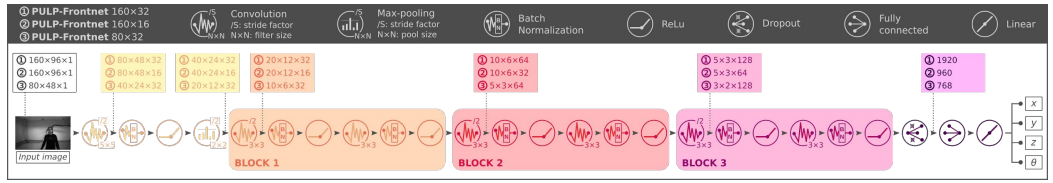
YouTube
https://www.youtube.com/watch?v=JKY03NV3C2s

PULP-Dronet v2 for the AI-Deck coming soon on GitHub

PULP-Frontnet:



Task:	Human pose estimation
CNN:	14 / 4.3 / 4 MMAC/frame
Onboard:	48fps@20mW / 135fps@86mW
Device:	AI-Deck (GAP8)
arXiv.org	https://arxiv.org/abs/2103.10873

GitHub
Coming soon!

YouTube
Coming soon!

Thanks for your attention.