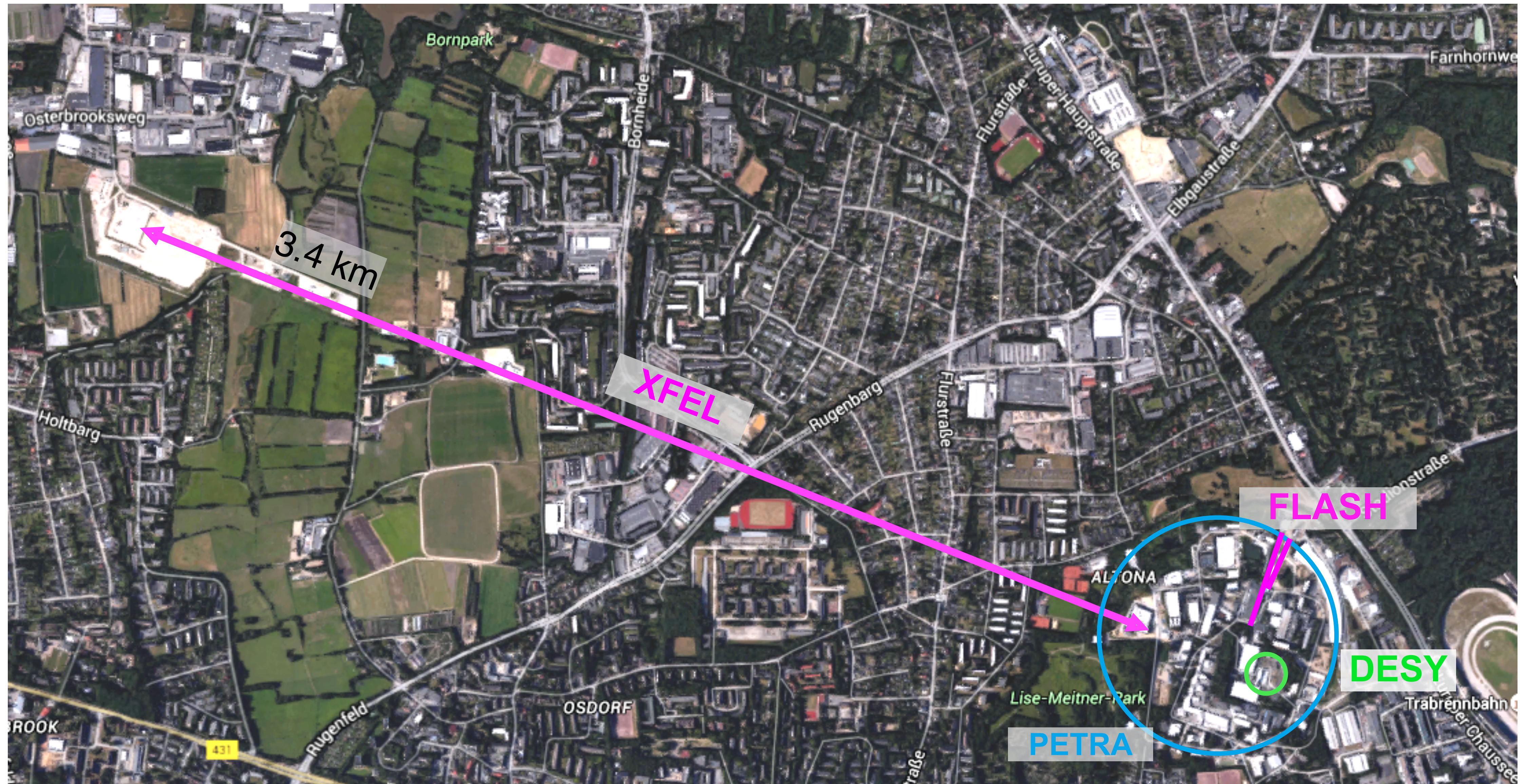# The MicroTCA Standard:
## Development of an Ecosystem for Advanced Applications
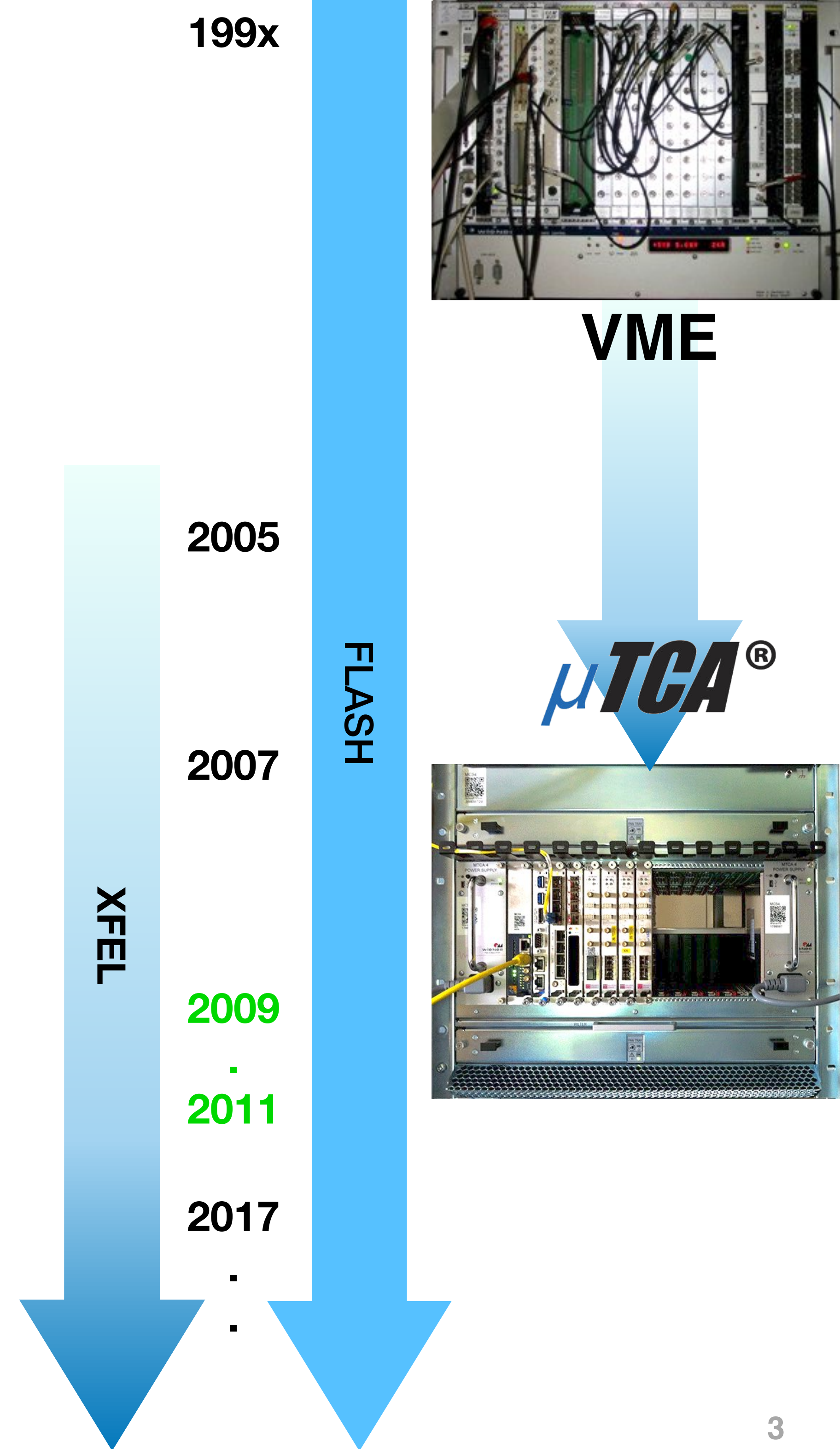
Kay Rehlich

DESY

# Motivation



**Experience as a MicroTCA user @ XFEL
and a member of the PICMG MicroTCA group**
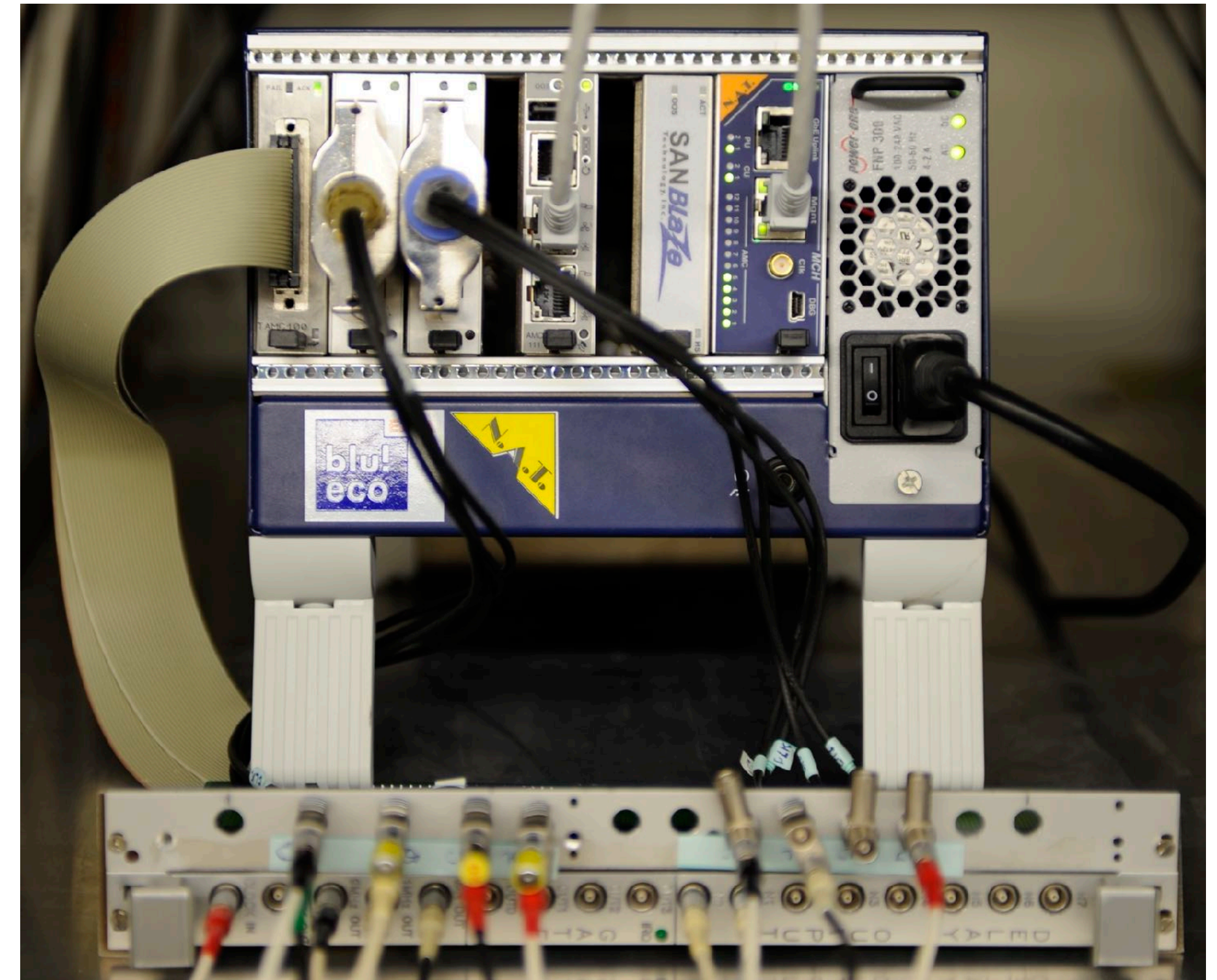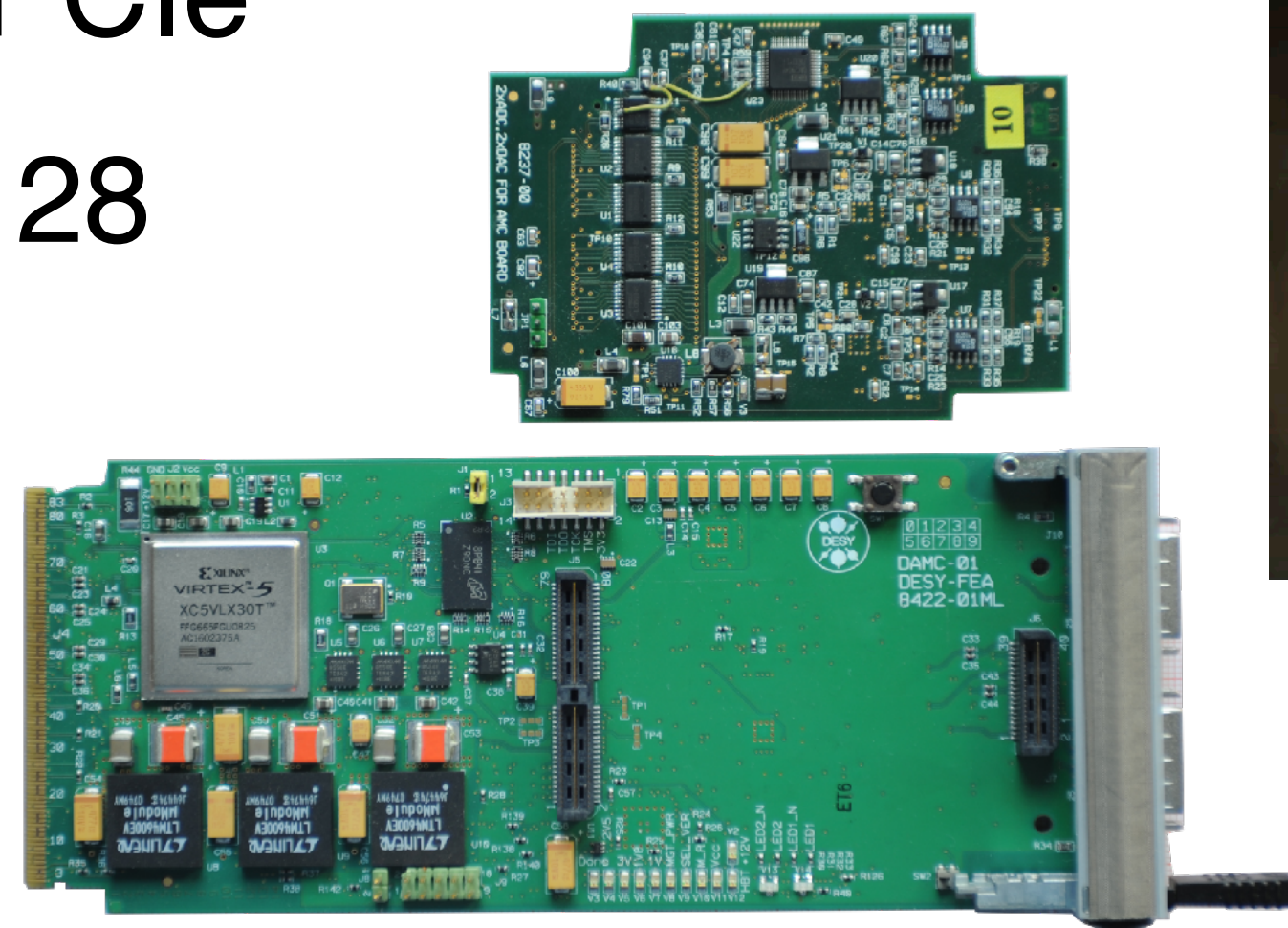
# Important Milestones

✦ **Reliability workshop ILC (30 km)**
Availability of $0.999^N$ with a huge number of subsystems

✦ **XFEL Crate-Standard workshop**
—> use MicroTCA and ATCA

✦ Building prototypes in-house and by industry

✦ **MTCA.4 PICMG standard**

✦ **XFEL operation**

199x

**VME**

2005

FLASH

μTCA®

2007

XFEL

2009

.

2011

2017

.

.

# Evaluation of MicroTCA @ XFEL: 2008 ....

We started with MTCA.0 single modules:

- TAMC100 as carrier for IP Timing

- DESY development DMAC01 to understand the standard:

  - AMC with Virtex 5 and PCIe

  - MMC code on Atmega128

  - 2* ADC 100MSPS

➡ Single modules are too small
➡ No space for signal conditioning
➡ Cables from front are not optimal

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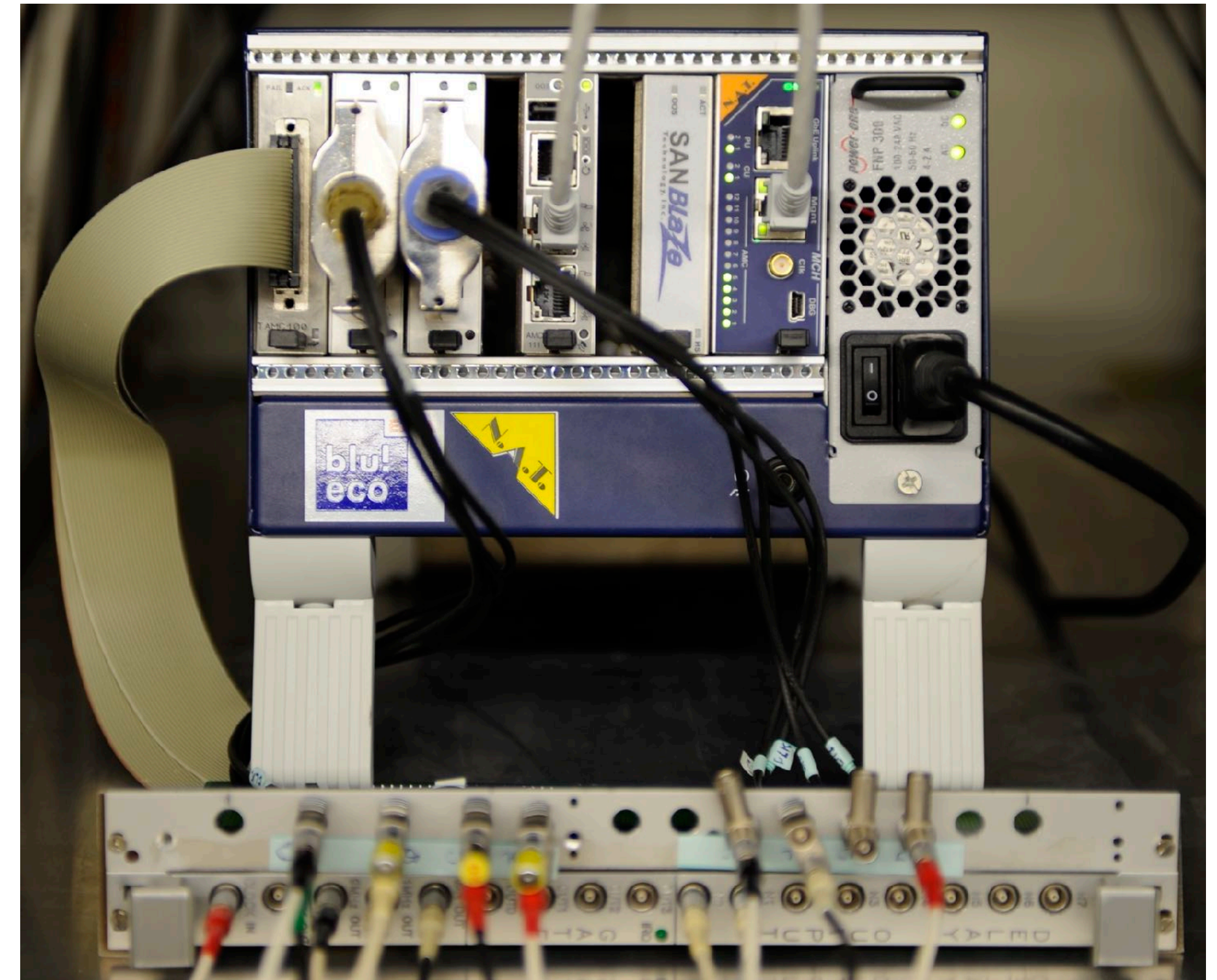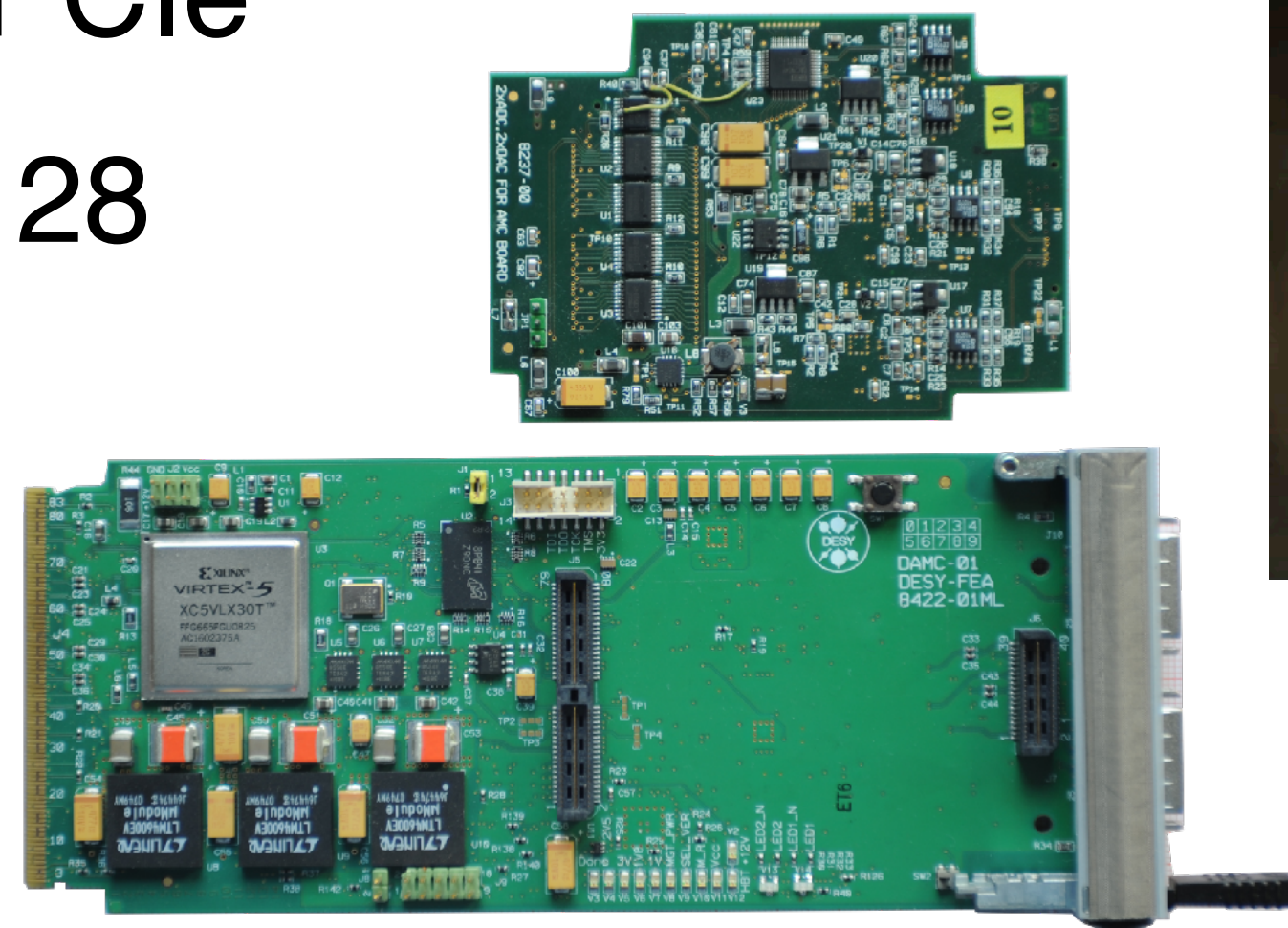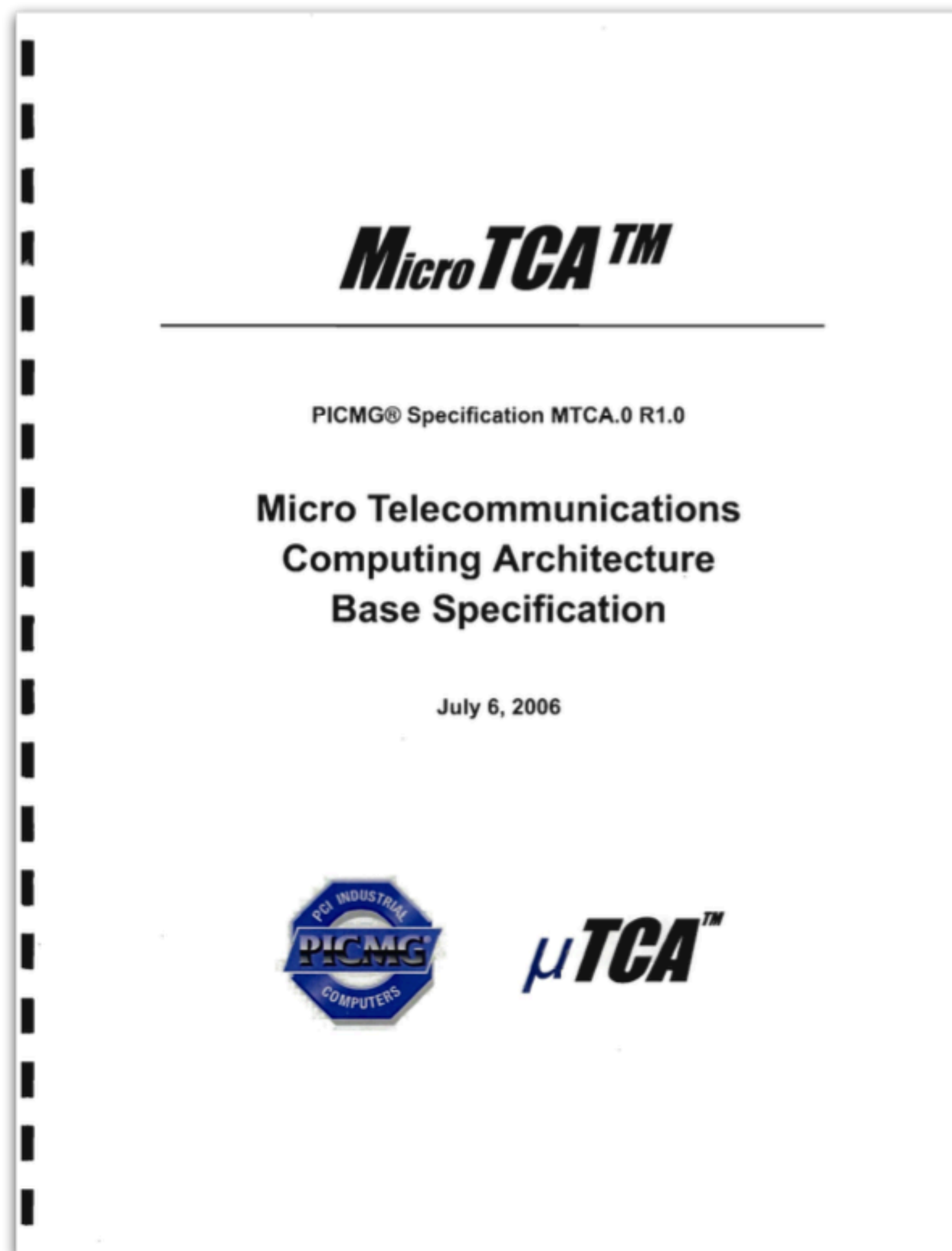
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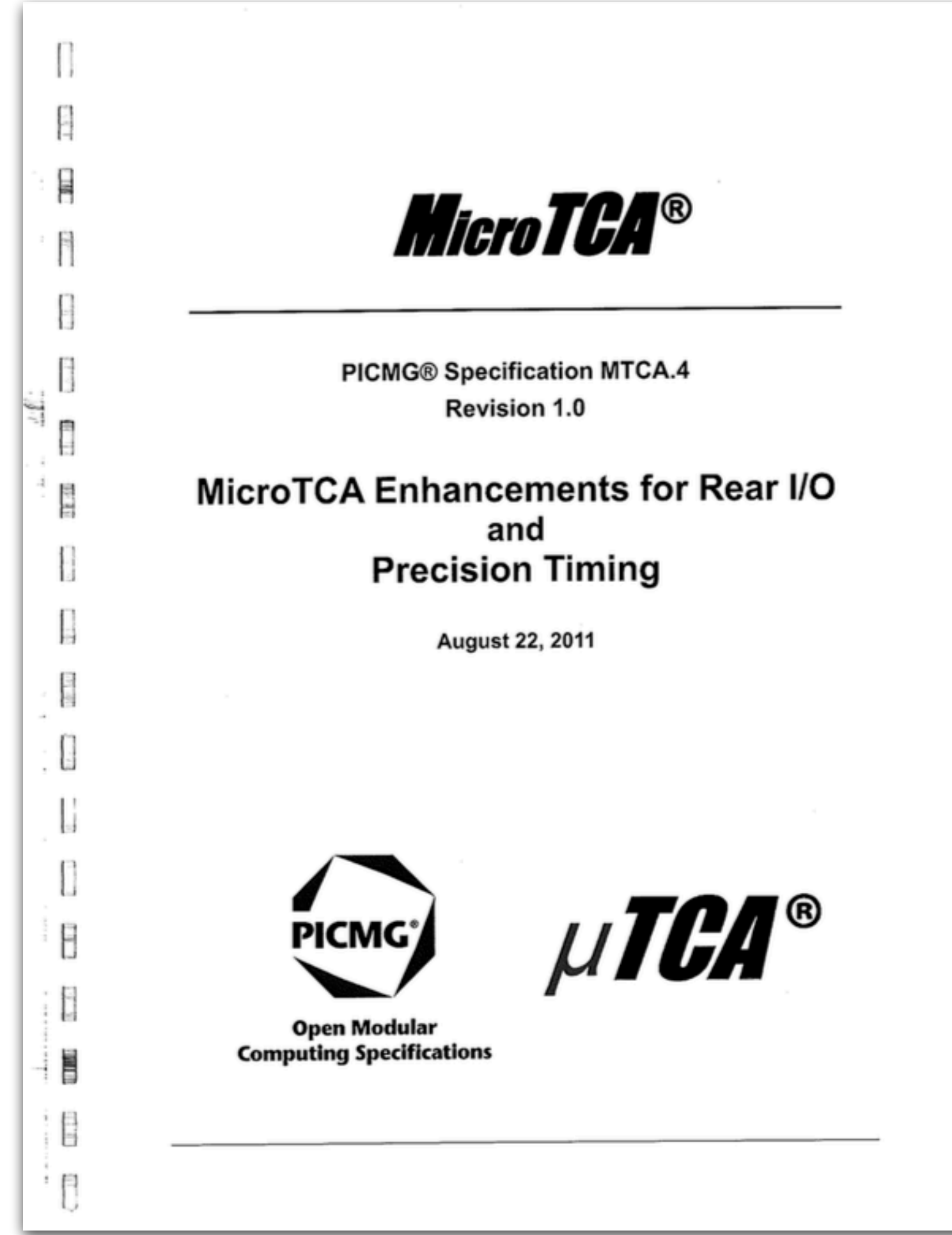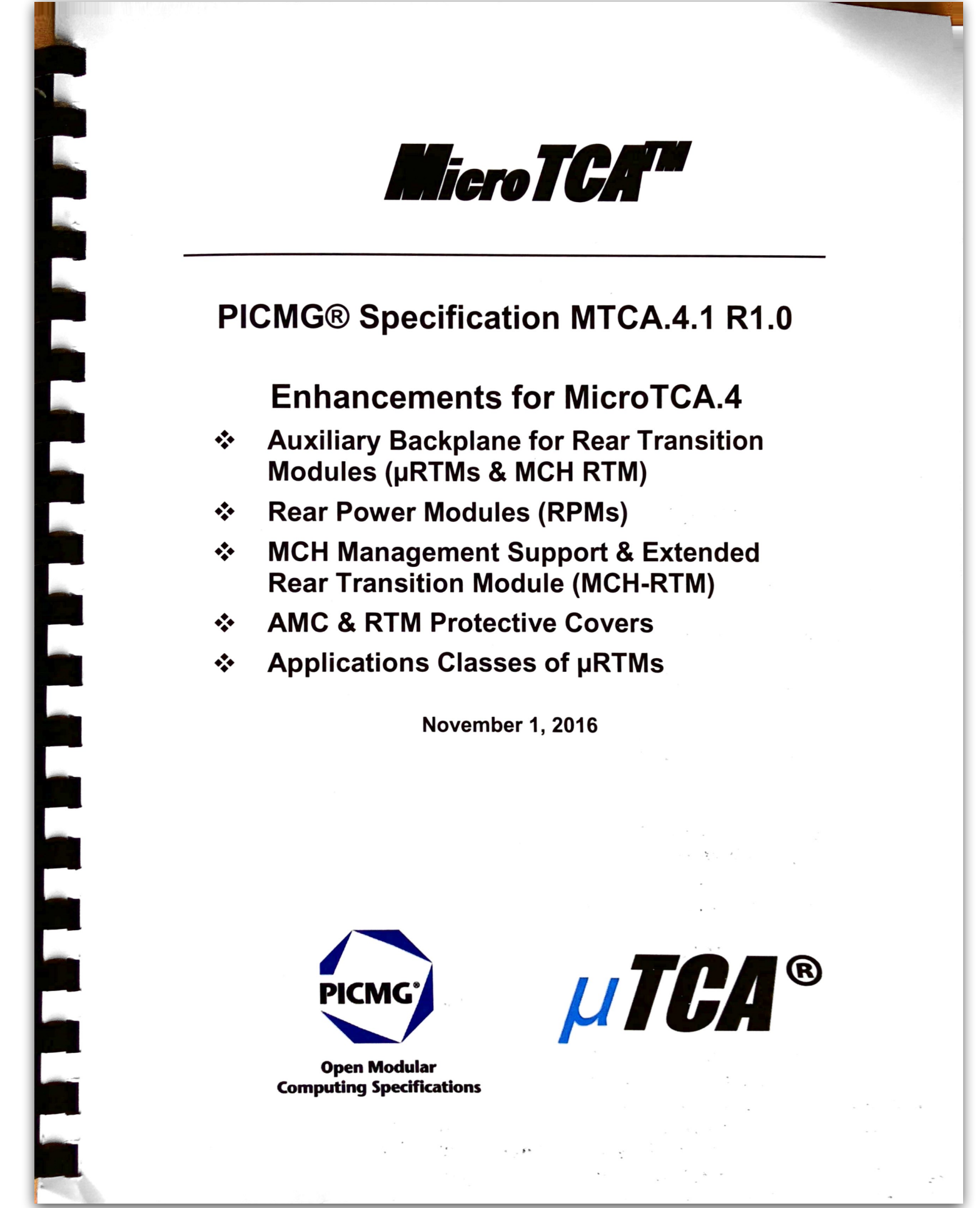
Conclusion:
Start a PICMG group
to extend the standard

# We Have it All Now —> MicroTCA Specifications



**MicroTCA.0**
**2006**

**MicroTCA.4**
**2011**

**MicroTCA.4.1**
**2016**

# MicroTCA Generations: **MTCA.0** MTCA.4  MTCA.4.1

Front Side



PM PM AMC AMC AMC AMC AMC AMC AMC AMC AMC AMC AMC AMC MCH PM PM

Data

Management

Power
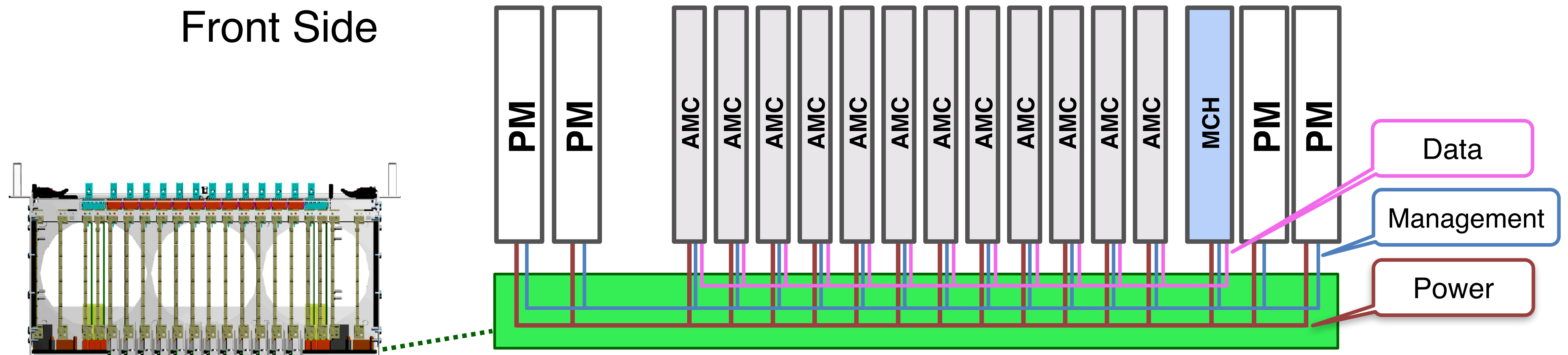
# MicroTCA Generations: MTCA.0 **MTCA.4** MTCA.4.1
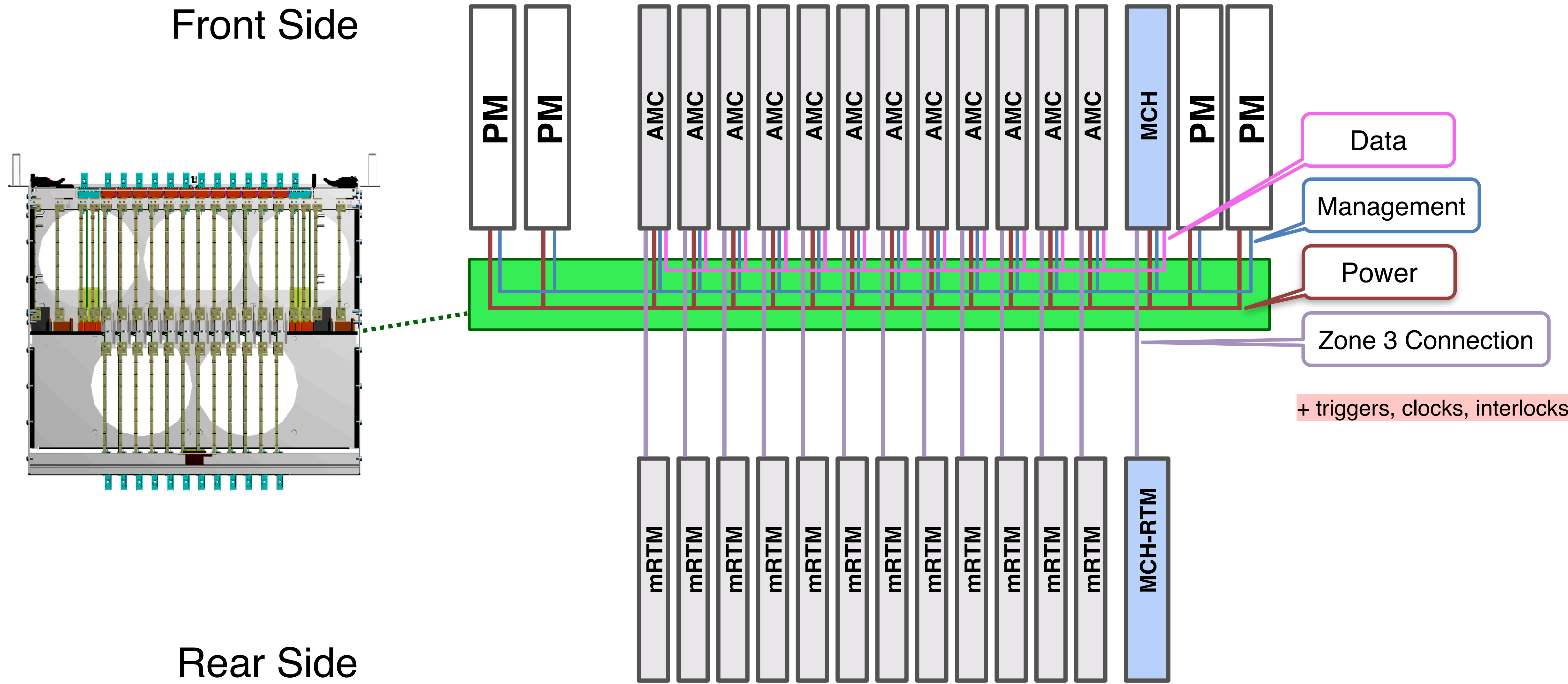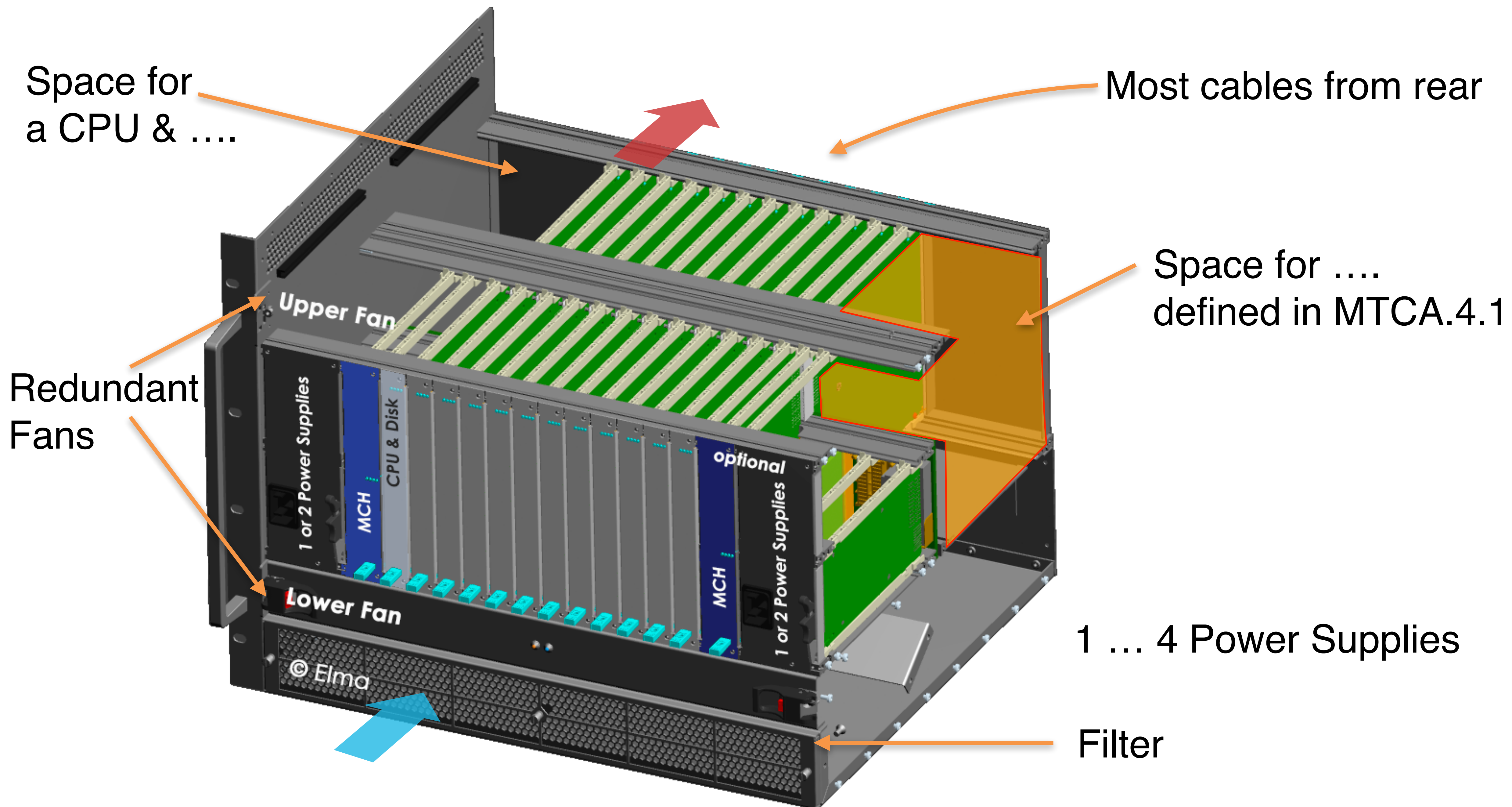
# MicroTCA Generations: MTCA.0 MTCA.4 **MTCA.4.1**
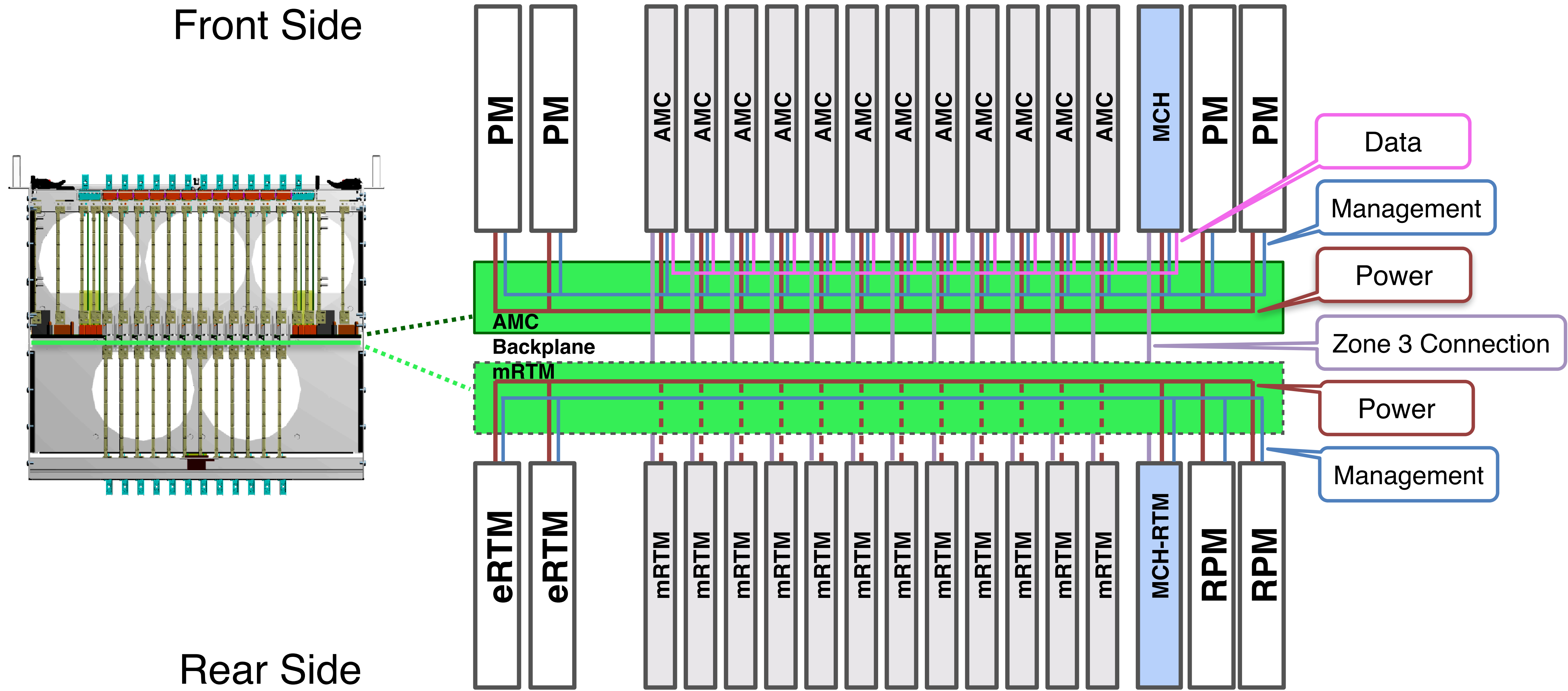
# MicroTCA.4: A Modular Crate System



Space for
a CPU & ….

Most cables from rear

Space for ….
defined in MTCA.4.1

Redundant
Fans

Upper Fan

1 or 2 Power Supplies

MCH

CPU & Disk

optional

MCH

1 or 2 Power Supplies

Lower Fan

© Elma

1 … 4 Power Supplies

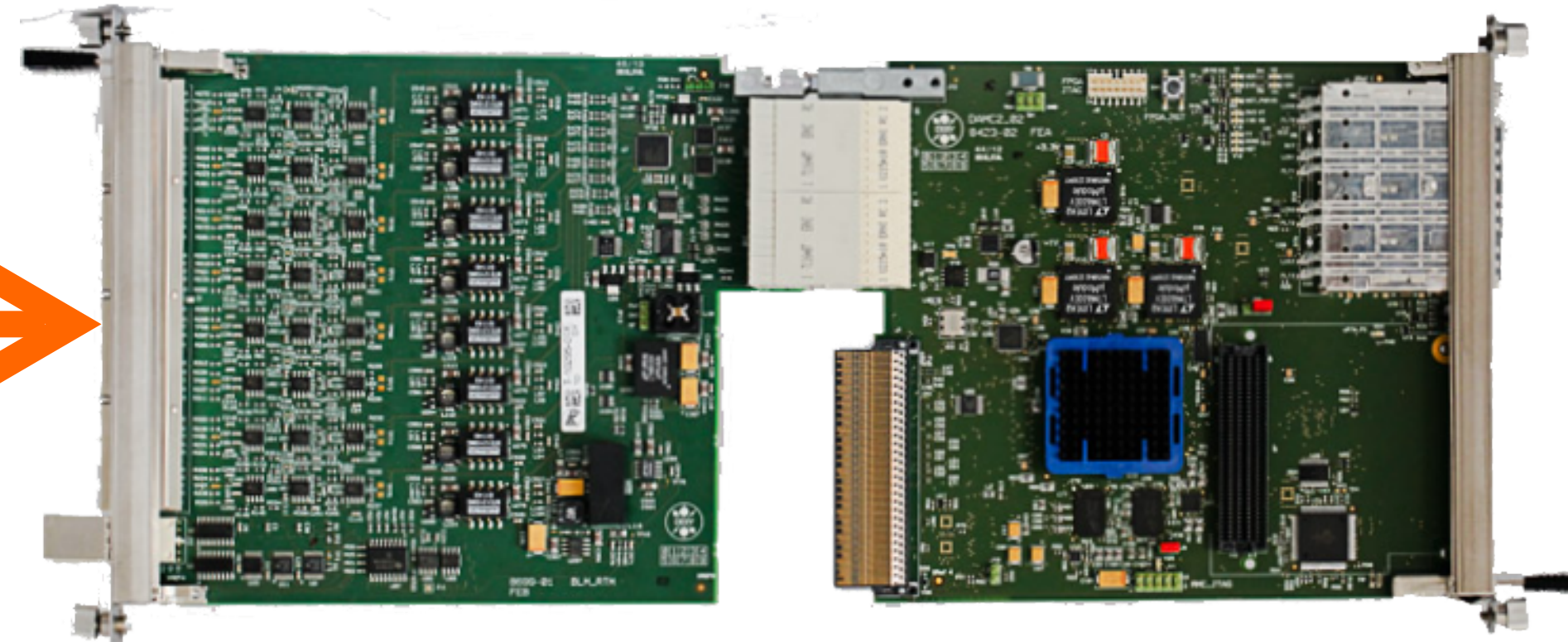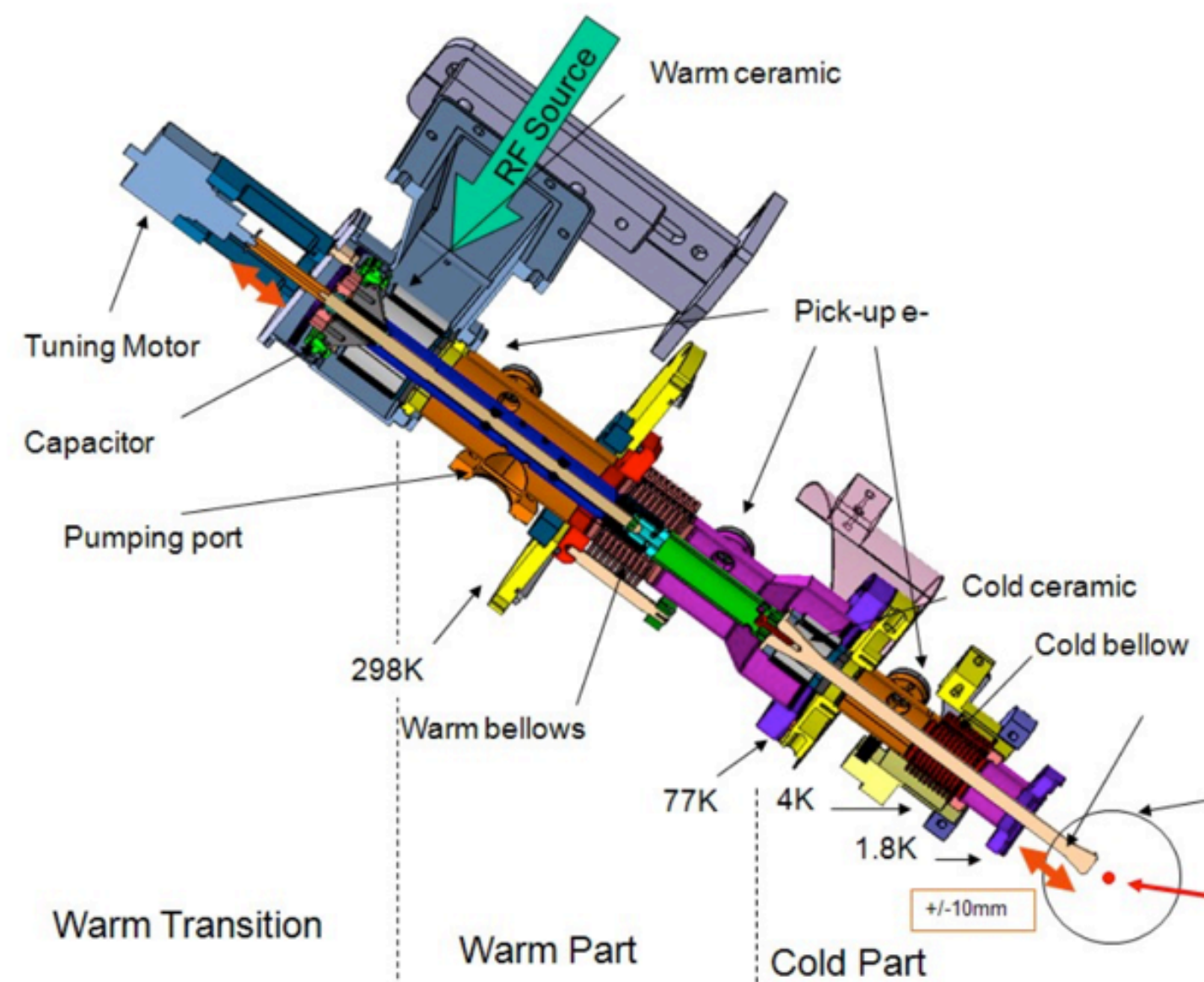Filter

# Beam-Loss and Coupler Interlock: DESY Design

~350 Multipliers



Beam Loss Monitors:
- PhotoMultiplier readout RTM
- DAMC2 with interlock logic



Coupler Interlocks:
- Analog readout RTM
- DAMC2 with interlock logic

784 Power Couplers

# Diagnostics & LLRF: Commercial ADC (10ch, 16bit, 125 MSPS)



DESY MDI
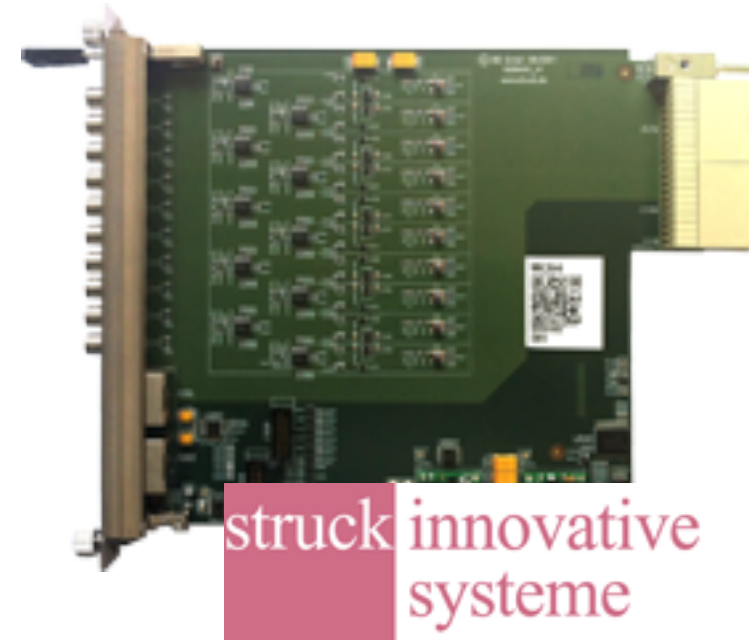
**Toroid Protection:**
- Analog readout RTM
- SIS8300 ADC

**Kicker, FC, etc. readout:**
- Amplifier RTM
- SIS8300 ADC

1.3 GHz

Kly

DESY MSK

**LLRF Controller:**
- Downconverter on RTM
- SIS8300 ADC & DAC
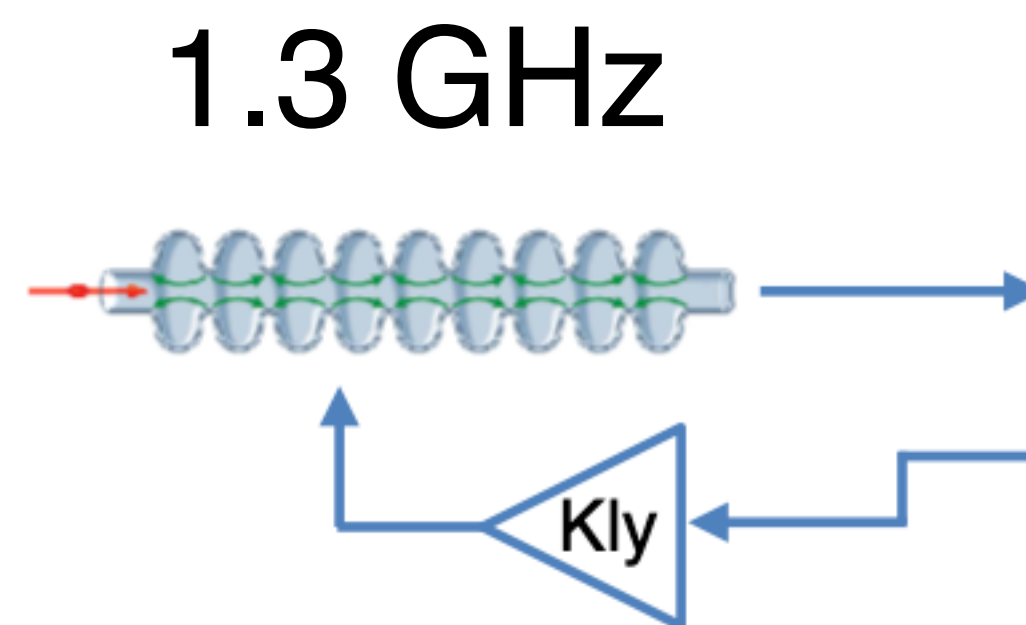
# Why did we select MicroTCA for XFEL?

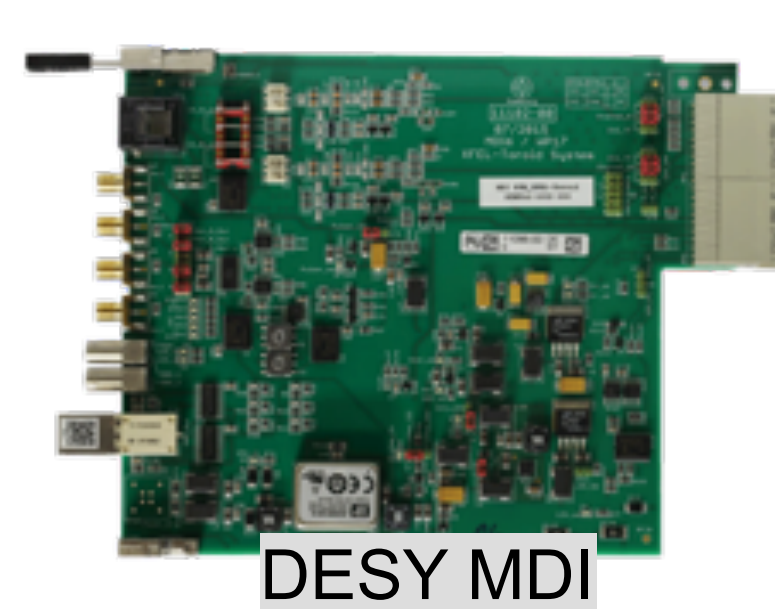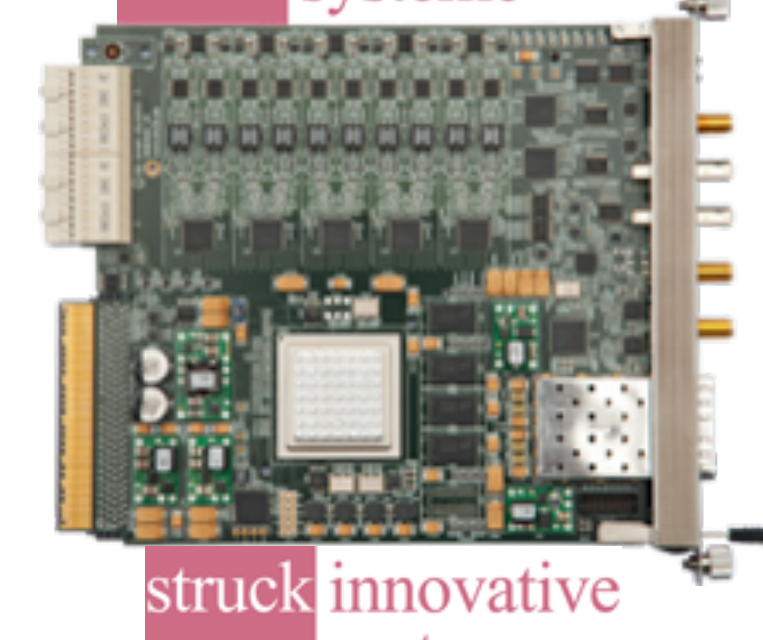- **Modularity** !!!

- Standard hardware & software **interfaces**

- **Loose coupling** of components

  - Implement functions on the right component (architecture):

  - Do complex stuff on a standard **CPU**: faster development

  - Do real-time on **FPGA**: Allow CPU software to crash without disturbing accelerator operation

- Simplified **maintenance** and good **diagnostics** of all components

- **Remote management** is a MUST for large facilities

- **Redundancy** of key components

- Integrated and standardised **clock, trigger, interlock** distribution

- Modern **communication links** (high-speed and low noise)

RTM

AMC
w/ FPGA

CPU
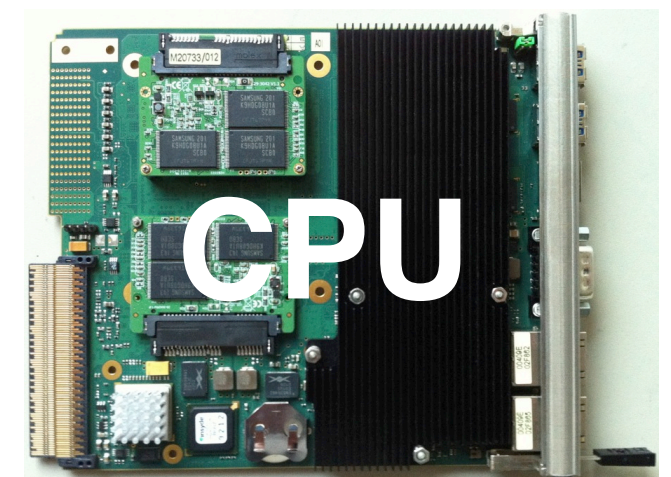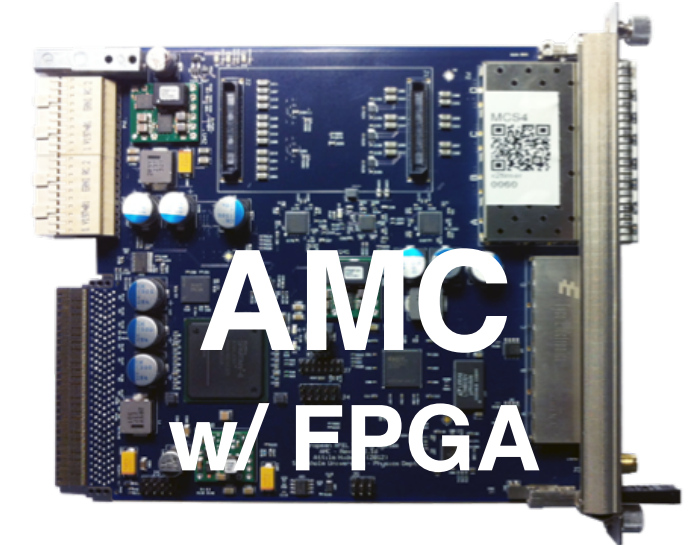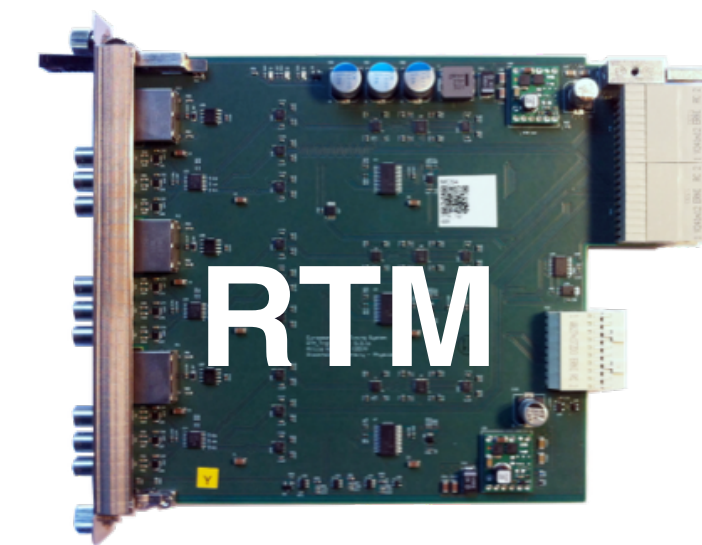
# The European XFEL Cold Linac
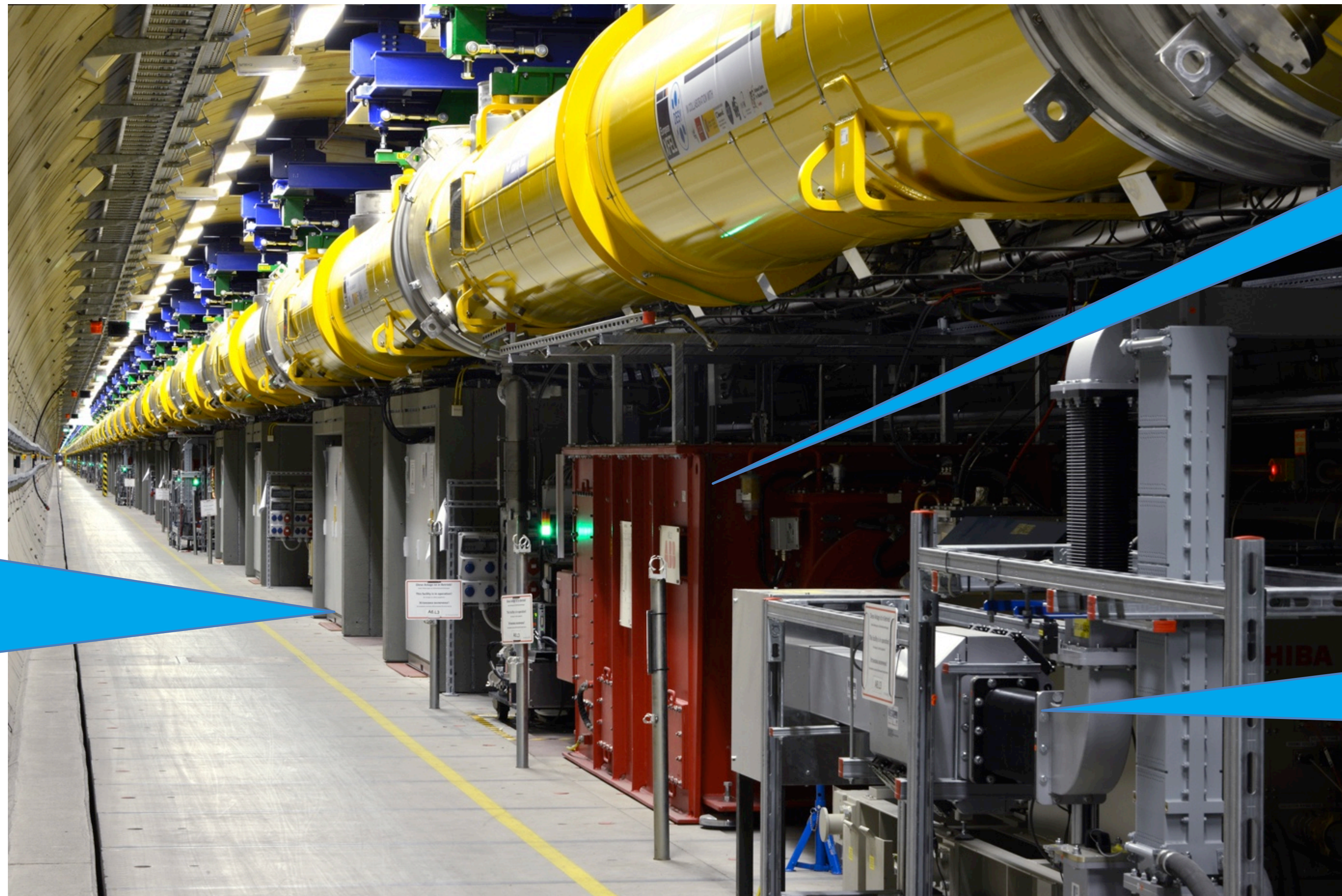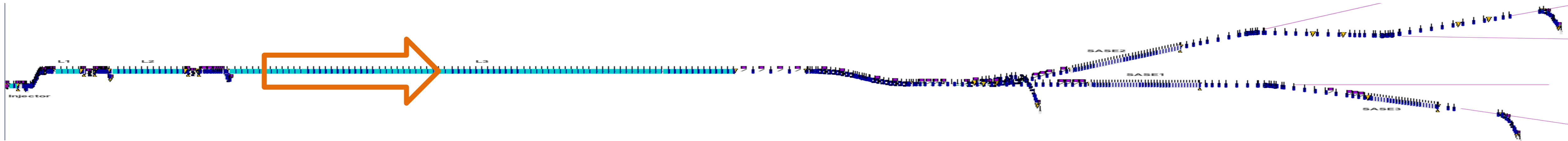


MicroTCA
in Racks for:
- Vacuum
- Cryo
- Magnets
- RF
- LLRF
- Coupler
- Diagnostics

Pulse Transformer for Klystron

10 MW Klystron with 2 Wave Guides, 1.3 GHz

Coupler Interlock Slave

LowLevel RF Slave

Coupler Interlock Master

Diagnostics Vacuum, Magnets

LowLevel RF Master

# MicroTCA Based Software Architecture (XFEL Example)
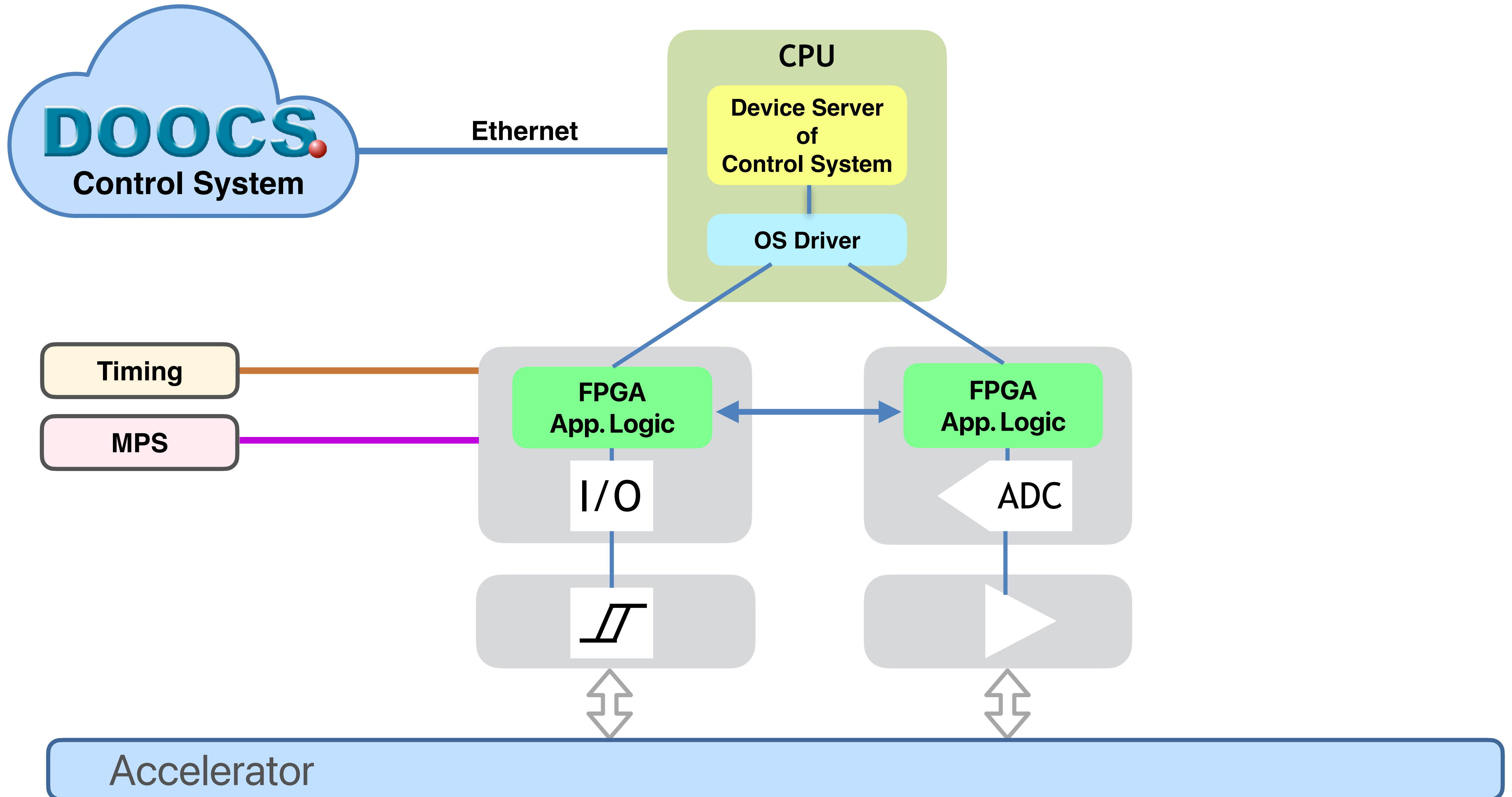
# MicroTCA Based Software Architecture (XFEL Example)

# MicroTCA Based Software Architecture (XFEL Example)



**MicroTCA Crate**

**DOOCS.**
**Control System**

Ethernet

**CPU**

**Device Server of Control System**

- Control System Interface
- "Soft" real-time & complex stuff
- Loose coupling of IO

**OS Driver**

- Reliable DMA transfer
- Interrupts

PCIe

Timing

MPS

**FPGA App. Logic**

**FPGA App. Logic**

- Real-time Processing

AMC

I/O

ADC

AMC

RTM

RTM

- Signal Conditioning

Accelerator

- High-speed FPGA <—> FPGA
- Clock, Trigger, Interlock
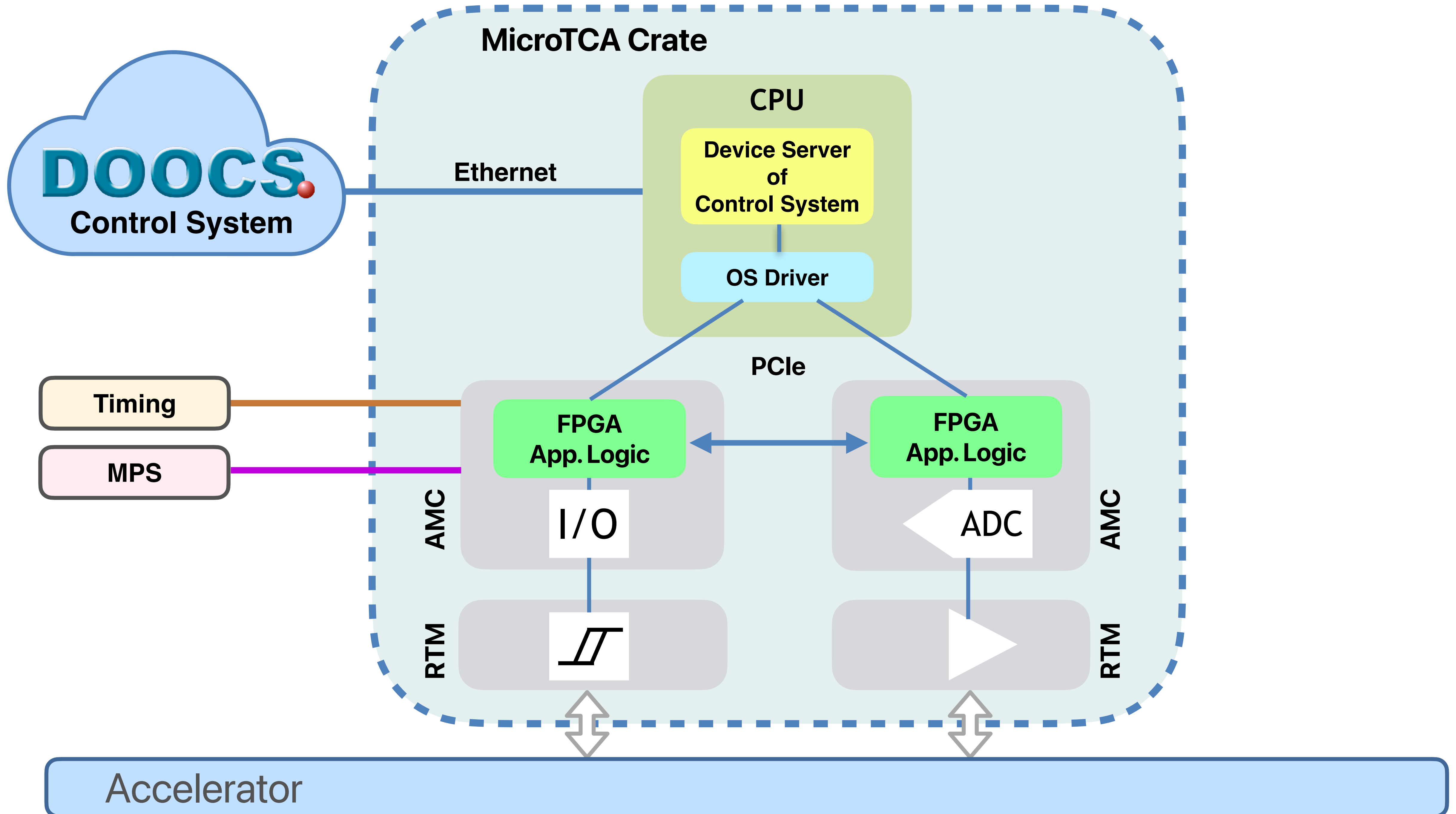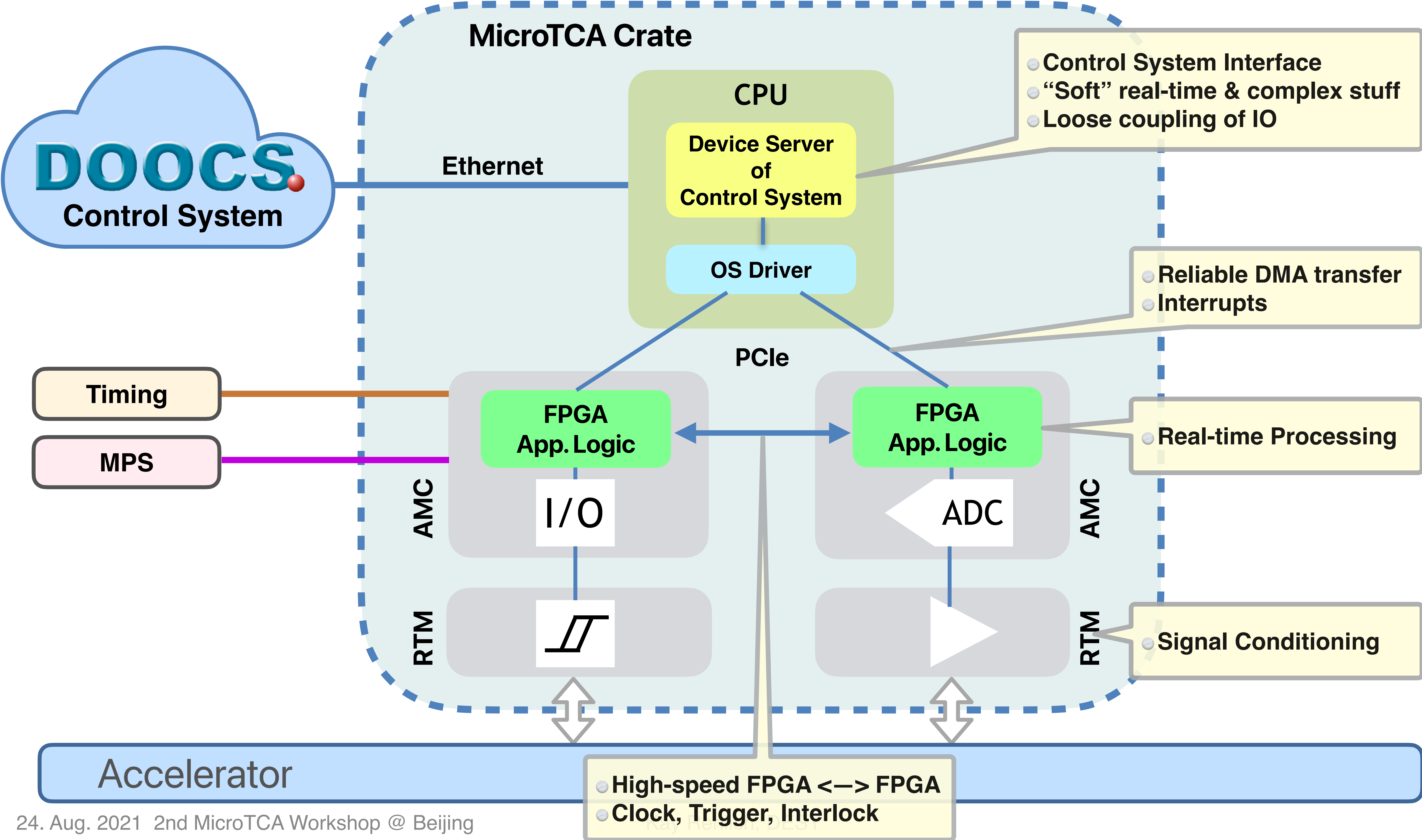
# Integration of Controls

User Interface

# Integration of Controls & Management



User Interface

Management

Controls

IPMI-Server

Ethernet

MicroTCA Crate

IPMI / HPM.1

Slot Management

MCH

FPGA

PCIe

Timer-Server

MAP file

LINUX Driver

CPU
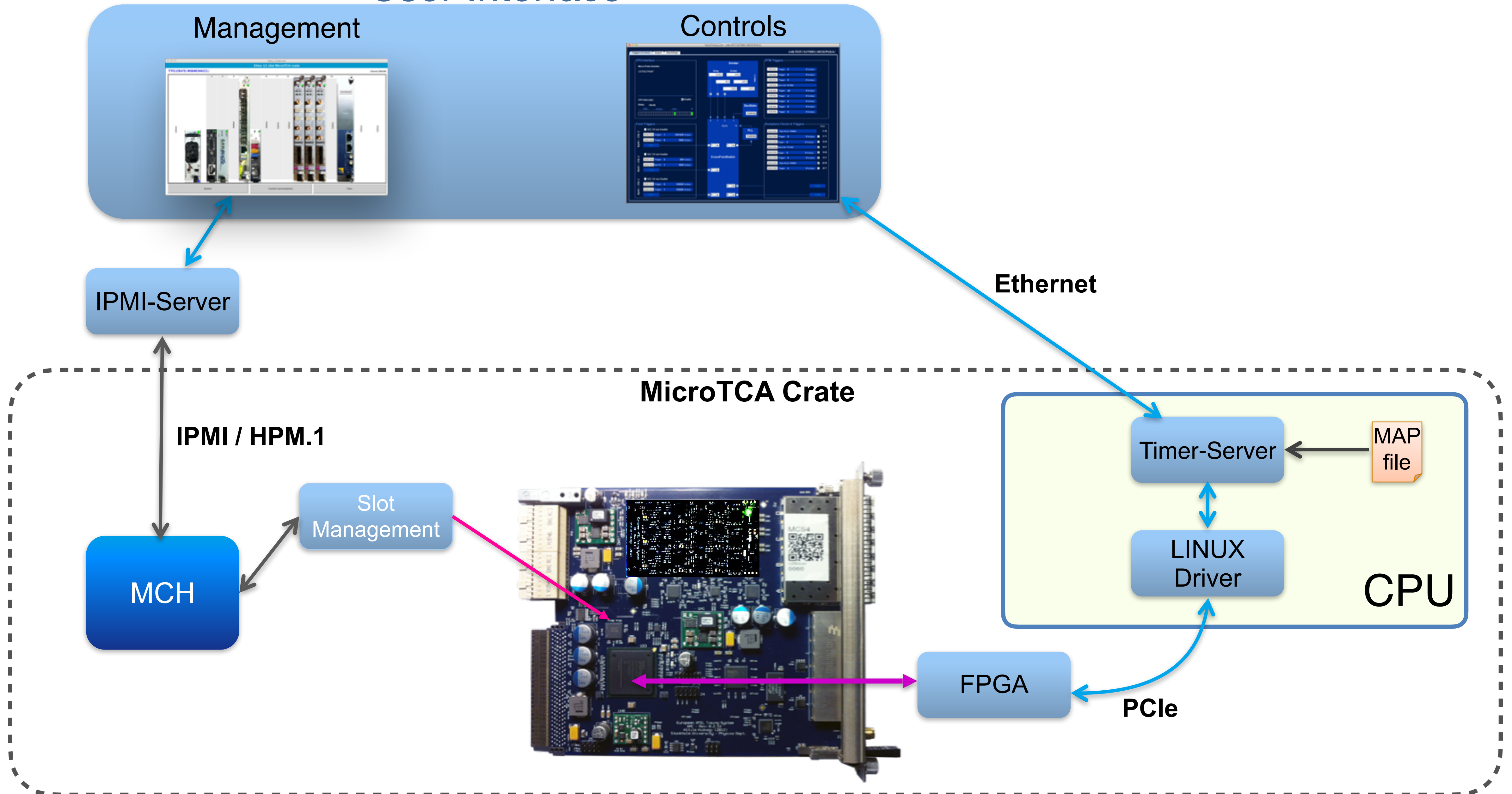
# Integration of Controls & Management & Development
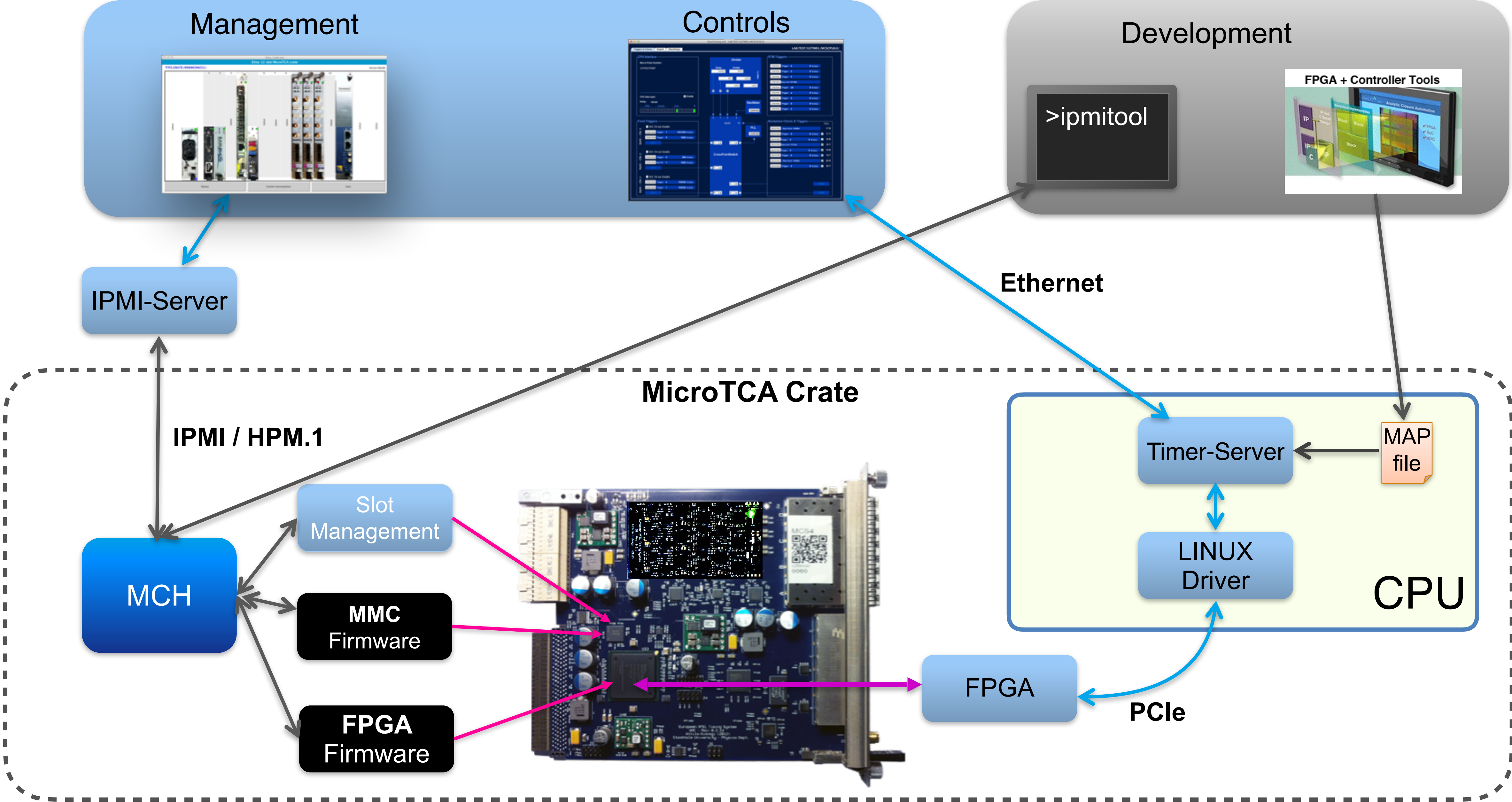
# Things You Need: as User / as AMC Developer

**MicroTCA Crate**

- Server or IOC
  - From community
  - Or your development

✓Comes with the system (MCH)

Timer-Server

MAP file

Slot Management

LINUX Driver

CPU

MCH

MMC Firmware

FPGA

PCIe

✓Comes with MMC Stamp
- Open Source

✓Comes with the AMC
- You develop it w/ help of a Board Support Pkg

✓Comes with the AMC
- Open Source, e.g.: https://github.com/MicroTCA
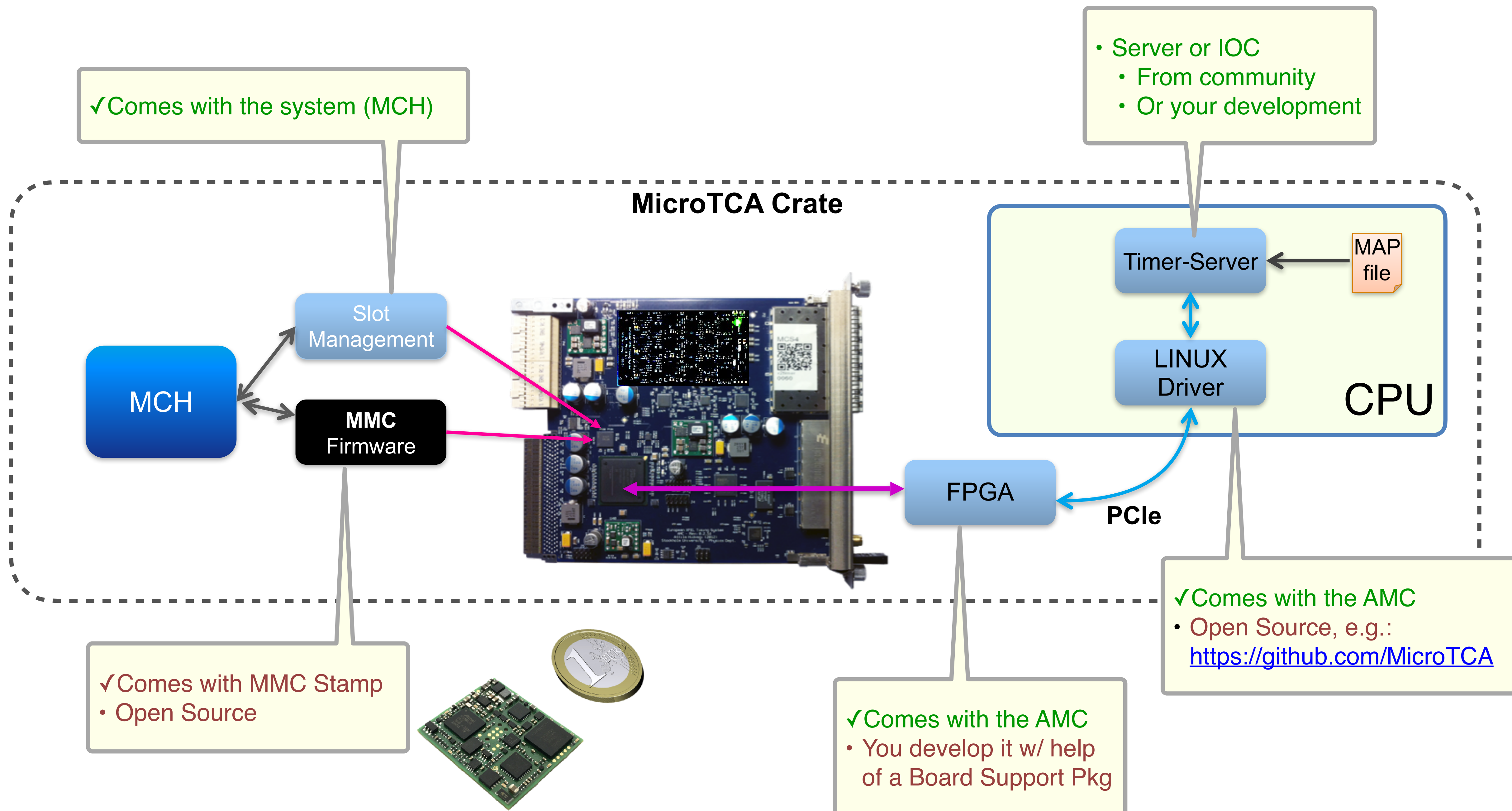
# PICMG Standards: How to Contribute?

- To participate: your organisation must be a PICMG member

  - PICMG has 4 levels of membership:
    Affiliate, **Associate, Executive, University** (1000 … 3000 $ / year)

- ≧ 3 executive members can start a **new working group:**

  - Prepare a Statement Of Work (SOW)

  - PICMG CTO review

  - Call for participation and form a committee

  - Chairperson, editor and secretary election

  - Specification work (under Intellectual Rights Policy)

  - Draft specification goes to CTO and member review & ratification process

- To **participate in a running group:**

  - The organisation and individuals have to be voted-in by the group members

# Summary

- **XFEL** operation experience:

  - Based on ~ 250 MicroTCA crates

  - Full HW / SW integration in MPS, Timing, Subsystems

  - Very fast startup and reliable operation

> We. 16:20 Julien Branlard
> *Experience w/ LLRF @ DESY*

- **PICMG** standard:

  - Brings together worldwide knowledge from industry & research institutes

  - Updates in accordance with technology (backward compatible !)

    —>  new working group: "MicroTCA Next Generation"

> We. 19:40 Heiko Koerte
> *PICMG MTCA Next Generation*

# Backup

# **PICMG**\* [PCI INDUSTRIAL COMPUTER MANUFACTURER'S GROUP]

Founded 1994 as a non-profit consortium
- Focus on open standards for embedded computing
- ~ 150 members companies

Deep engineering expertise in member companies:
- Electronic, mechanical, packaging, and thermal design
- High speed signaling and simulation
- Software and High Availability skills

Rigorous Intellectual Property policies
- Patent landscape known to implementers
- No PICMG standard requires a license to implement (so far)

Over 50 standards released to date
- More than $10B in global revenue
- Wide range of technologies including small form factor, networking, high-availability architectures, rugged computing and management

\* Pronounced "Pick-M-G" or "Pick-Mig"

# OVERVIEW: 25 YEARS OF SPECIFICATIONS

**Key Principles**
- Modular
- Scalable
- Interoperable

**Results to date**
- 100s of participating companies
- 100s of thousands of work hours
- Global organization
- Over 50 specifications
- Billions of dollars in PICMG compliant products

Collaboration will always be critical to PICMG

© **Jess Isquith**
President, PICMG
jess@picmg.org

# SAMPLE OF MEMBERSHIP (~150 TOTAL)

© **Jess Isquith**
President, PICMG
jess@picmg.org

# A Typical MicroTCA System @ XFEL