MicroTCA.4 /4.1 Hardware Standards & Software Guidelines Progress Overview

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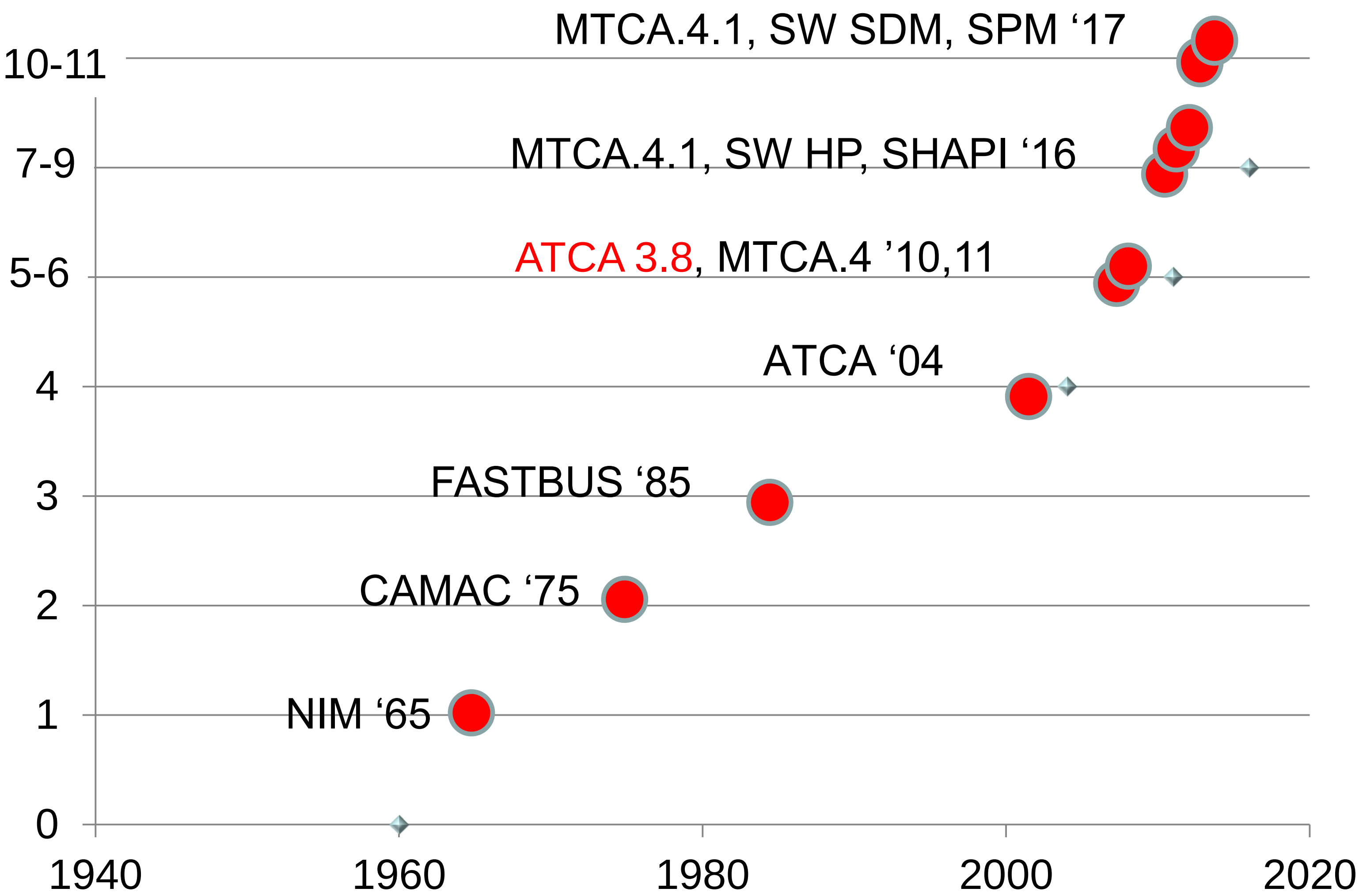
Standard Platforms for Physics

- Major Goals: Interoperable HW-SW components
  - 1. Interoperable HW-SW platform essentials, software diagnostics, interfaces
  - Lab users & Industry Collaboration to share, save on development costs
  - Speed “time to market”, lower costs by commercial availability, avoid 1-supplier traps (incl. custom lab sol’n)
  - Avoid dependence on vendor proprietary solution
  - Adaptable to new technology needs for >/= 2 decades

Physics Standards History

- Standards driven by new innovations for economic, performance advantages
- Lab-Developed Standards Timeline
  - 50 Years ago, ~1965, NIM, Nuclear Instrument Module
  - 40 Years ago, ~1975, CAMAC Data bus modules
  - 30 Years ago, ~1985, FASTBUS 10X BW bidirectional
  - 12+ Years ago, ~2004, ATCA, MTCA announced
    - Multi-GHz serial technology backplane
    - Redundancy for 0.99999 Availability at Shelf (Crate) level
    - Intelligent Platform Management Interface (IPMI)
  - 7+ Years ago- 2009 MTCA.4 HW, SW WG's begin

Physics Standards Timeline



Physics Standards History

Yrs. Ago	NAME	Features & Technology Trigger	Status
50 ('65)	NIM	Fast digital logic modules, ADCs, no data bus initially, triggered by discrete 0.7V Si switches plus new labs including SLAC	Still small commercial Instruments
40 ('75)	CAMAC	First data bus backplane, 24 bit uni-directional, 1 MHz transfers, analog-digital modules, triggered by new dense ICs	Small after-market activity exists
30 ('85)	FAST-BUS	10MHz 32bit bidirectional data bus, match bus of mainframe computers, board area 2X, spurred by µP's, FPGAs, SLD at SLAC	Defunct
8 ('09)	MTCA	Serial backplane channels up to 12 GHz, spurred by Telecom industry. Triggered by Tx-Rx GHz chip industry, serial backplanes, redundant architecture, Intelligent Platform Management Interface (IPMI) for A=0.99999; ILC & XFEL Projects	Physics adaptations launched at IHEP Real Time 2009

FASTBUS-SLD Story

- FASTBUS vs. Custom Chips
  - First pressed pin multilayer backplane developed at SLAC for use in SLD colliding beam detector
  - At same time first custom analog sampling arrays plus special logic chips developed at SLAC-Stanford made possible many front end boards inside of detectors
  - All Drift chamber, Calorimeter and Cherenkov front end electronics ended up inside the detector.
  - FASTBUS served very well on the detector platform with our first use of analog fiber-optic channels through rear transition modules to FASTBUS pre-processing cards.

PICMG xTCA for Physics 2002-16

13 years

- 2002 ATCA Announced by PICMG for Telecom industry
- 2004-06 ATCA with µTCA announced
- 2004-11 NSS-MIC paper advocating ATCA for ILC Controls
- 2005-07 Snowmass Physics controls papers DESY, SLAC
- 2005-11 Gromitz controls presentations DESY, SLAC
- 2007-06 First xTCA workshop FNAL
- 2009-06 xTCA for Physics WG's Announced IHEP IEEE Real Time
- 2011-07 MTCA.4 with RTM Approved
- 2016-11 MTCA.4.1 Approved; Hot Plug, SHAPI Guidelines submitted
- 2017 –Q1 Hot Plug, SHAPI Approved; SPM, SDM submitted

MicroTCA Glossary

Abbr.	Definition
PICMG	PCI Industrial Computer Manufacturers Group
ATCA	Advanced Telecommunications Computing Architecture
MTCA.0	PICMG baseline Mezzanine Card for ATCA carrier card system
MTCA.4	1st Physics version w/ Rear Transition Module
µRTM	Rear Transition Module
MCH	Microcontroller Hub
MTCA.4.1	Auxiliary Backplane Extension
µRTM	Rear Transition Module – no connection to Auxiliary Backplane
eRTM	Extended RTM mates to Auxiliary Backplane
eMCH	Extended MCH services Auxiliary Backplane
RPM	External Rear Power Module services Auxiliary Backplane

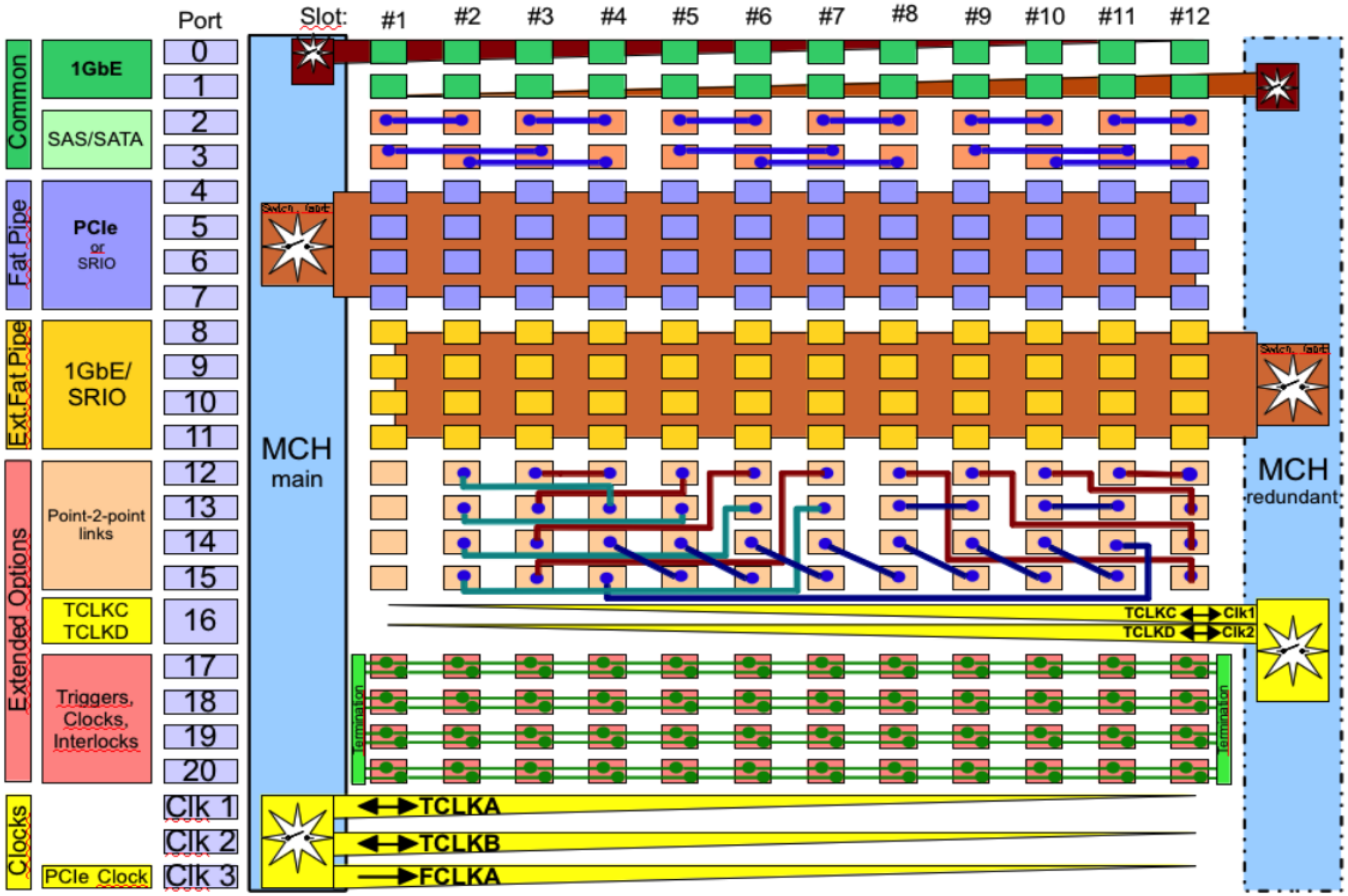
ATCA – MTCA Relationship

- ATCA
  - Large card & crate format, typ. 12 cards per crate
  - Dual redundant backplane architecture standard
  - Two Hub controllers split crate backplane in halves
  - Hot plug procedure + redundancy = 0.99999 Availability at crate level (5 minutes downtime per year)
- MTCA
  - Mezzanine card for ATCA carrier, 4 per carrier
  - Packaged in crate *of any size, shape* became MTCA.0
  - Similar dual redundant backplane developed by industry

MTCA.4 for Physics (or other)

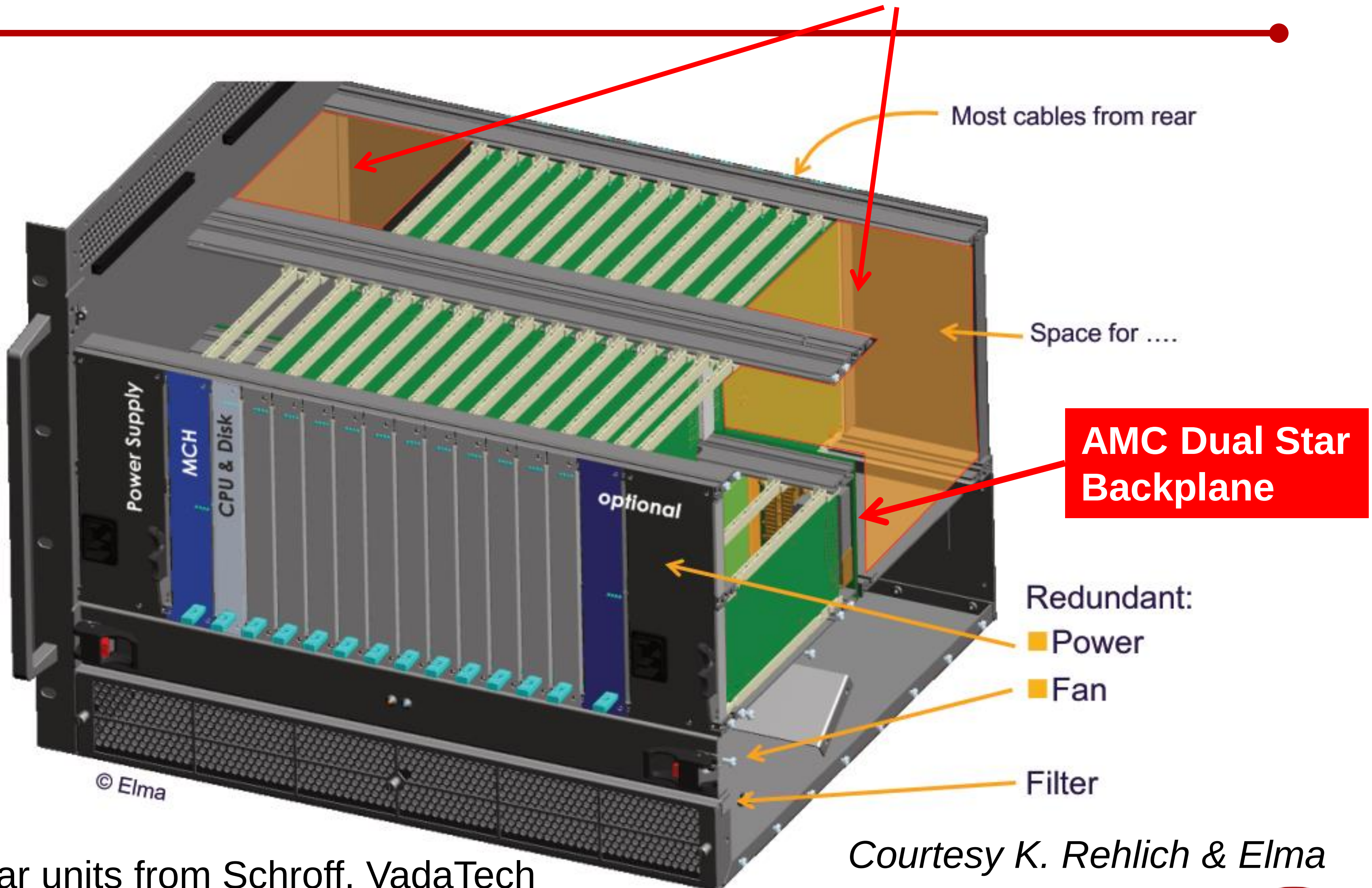
- Rear Transition Module (RTM)
  - Key feature of ATCA to get all CABLES to rear, make hot-swap easy without disturbing cables, always a risk
  - MTCA had no RTM interface designed so standards team had to design, also doubling board space per slot
- Special Backplane Additions
  - Designated precision timing and trigger lines, card-to-card lines for vector summing, interlocking
  - Designated rear interface for HS serial lines for analog, digital and mixed uses (Classes to be followed by labs and vendors for interoperability); power MTCA-RTM card

MTCA.4 Backplane Architecture



Courtesy K. Rehlich, DESY

MTCA.4 12-slot Shelf

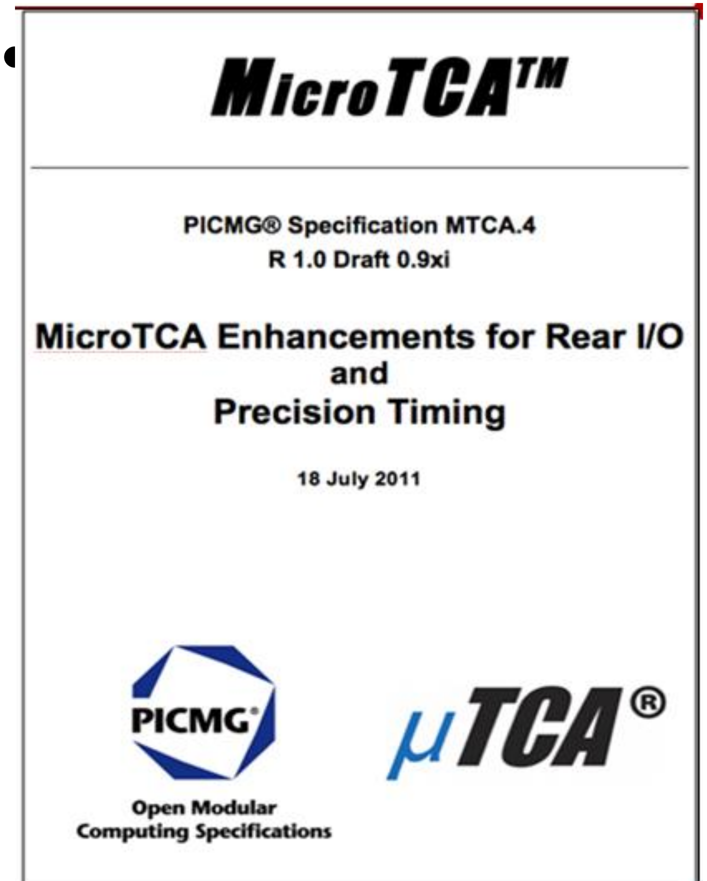


Courtesy K. Rehlich & Elma

See similar units from Schroff, VadaTech

MTCA.4 released July 2011

- MTCA.0 Extensions =>MTCA.4 for Physics*



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PICMG® Specification MTCA.4
R 1.0 Draft 0.9xi

MicroTCA Enhancements for Rear I/O
and
Precision Timing

18 July 2011

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***New** Extension Features:*

- AMC-RTM connector standardized with E-Keying, JTAG, IPMI Management & Power from AMC to RTM
- Low-jitter clock lines, point-to-point connections for vector, interlock summing
- RTM hot-swap feature same as AMC
- Linux based PCIe

Not restricted to physics use!

MTCA.4 Summary

- Hardware
  - Successful development crate and infrastructure with close collaboration of labs, industry
  - DESY XFEL application modules developed in partnership with partner labs, industry
  - Multiple suppliers now offer crates form 2-12 modules per crate
  - Lab application developments ongoing, industry growing
- Software
  - Continued work on four documents: Standard Device, Process, Hardware API and Hot Plug Guidelines

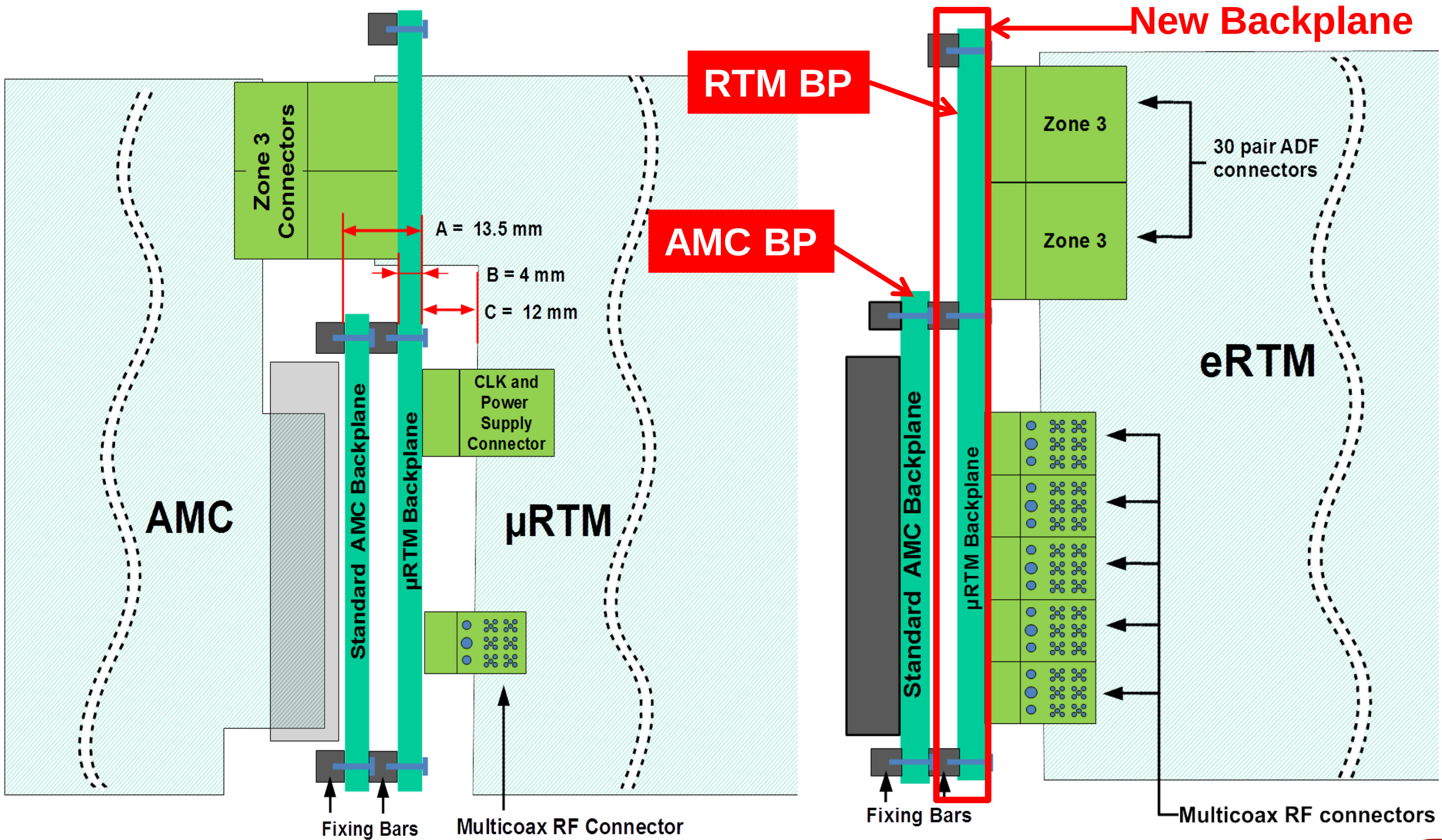
Phase II HW: Auxiliary Backplane

- Proposal from DESY Partners: Low Level RF
  - Auxiliary backplane offers huge advantages in eliminating discrete coaxial cables
  - Decided to standardize but not dictating RF section
  - User can adapt basic form factor to other uses, or can have vendor add features
- Basic Features
  - Provision for Rear Power Modules, controllable +/- analog power, RTMs with ability to drive multiple crates, etc.

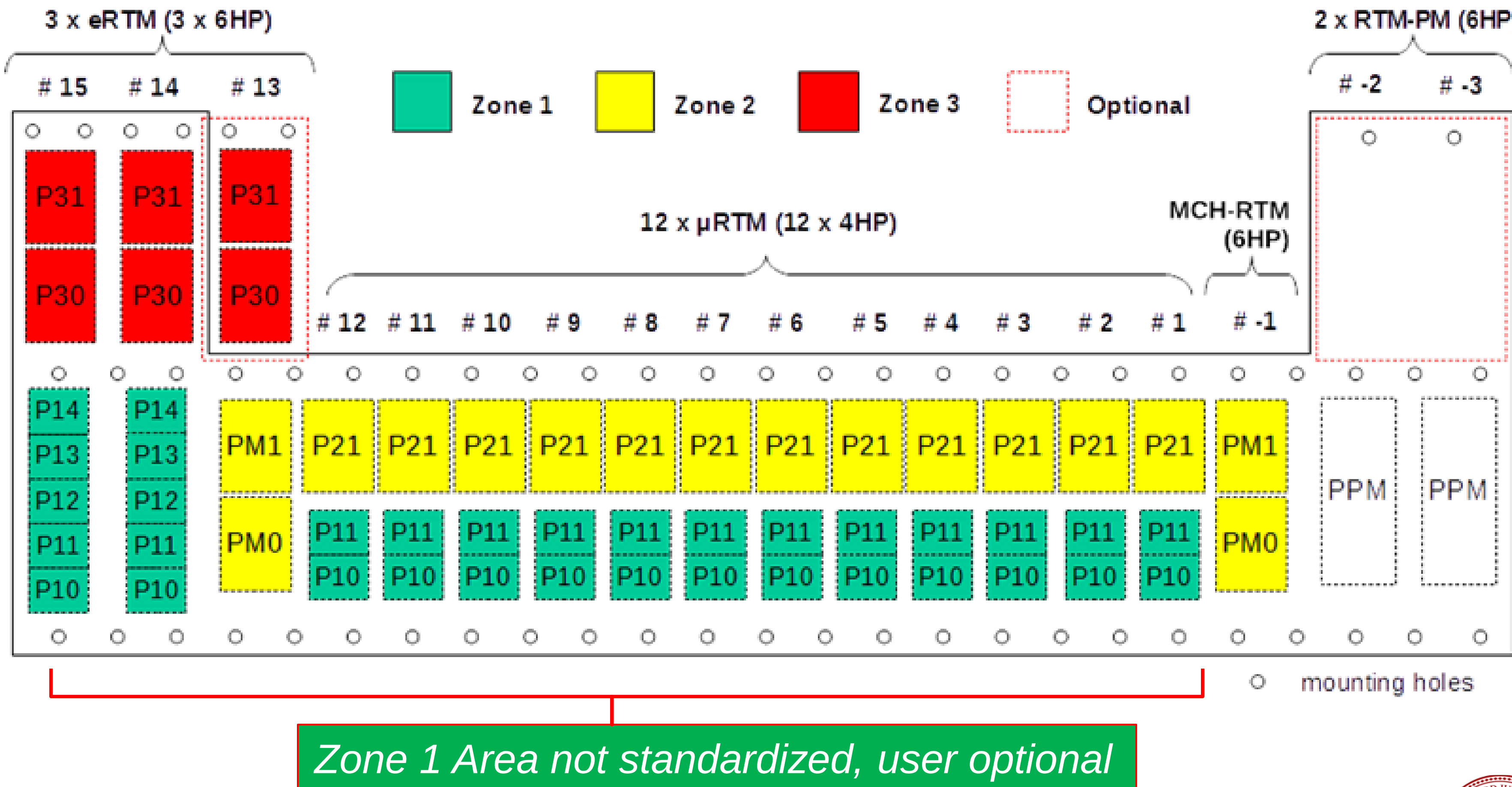
Enhancements MTCA.4 =>MTCA.4.1

- New Extensions Added for MTCA.4.1
  - 1. Auxiliary RTM Backplane with RF performance
  - 2. Rear Power Modules (RPMs)
  - 3. MCH-RTM (Rear Transition Module)
  - 4. Boards & Protective Covers
  - 5. Applications Classes of RTMs
- Motivation
  - Routing RF signals on Aux BP eliminates coax cable jungle, improves system reliability
  - For RF solutions reduces rack 3X or more
  - Uses flexible (RF application not part of standard)

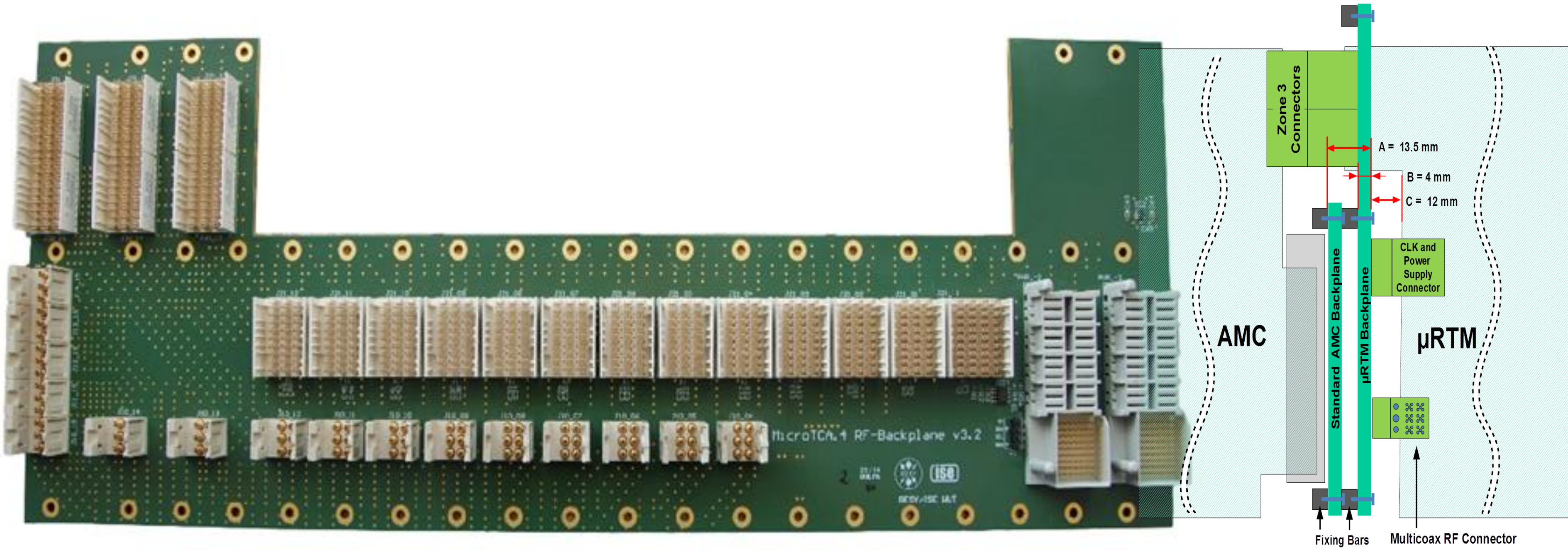
RTM Backplane mating to AMC BP

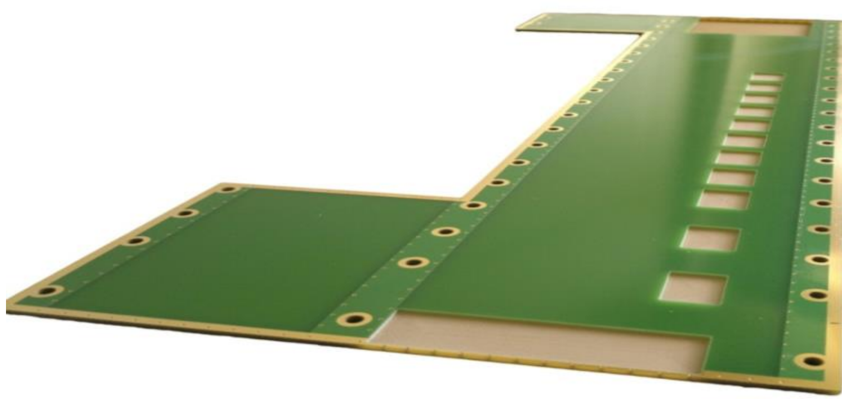


RTM Backplane Connector Zones



RTM Backplane Rear/Side Views, Shield



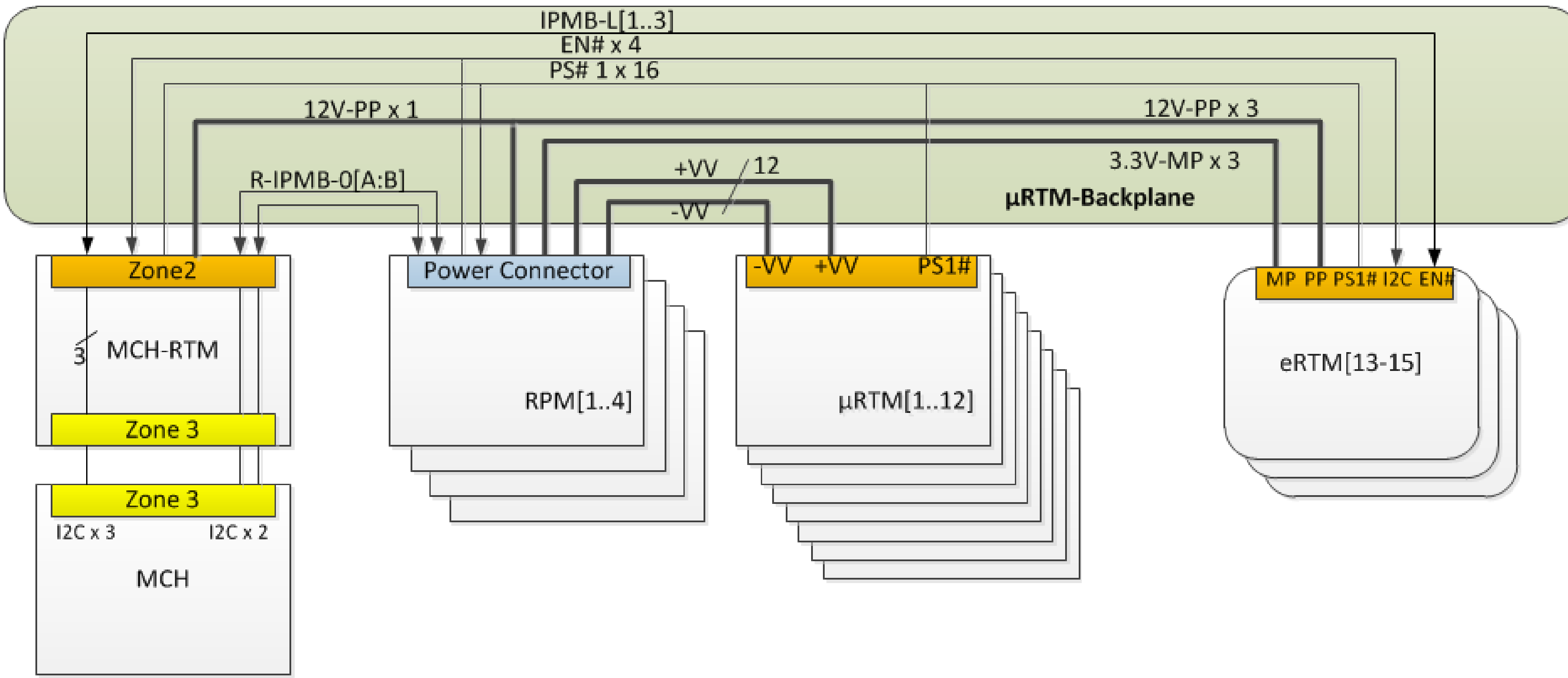


Shield protects analog circuits from digital noise from front AMC backpane

Classes of Zone 3 RTM Zones

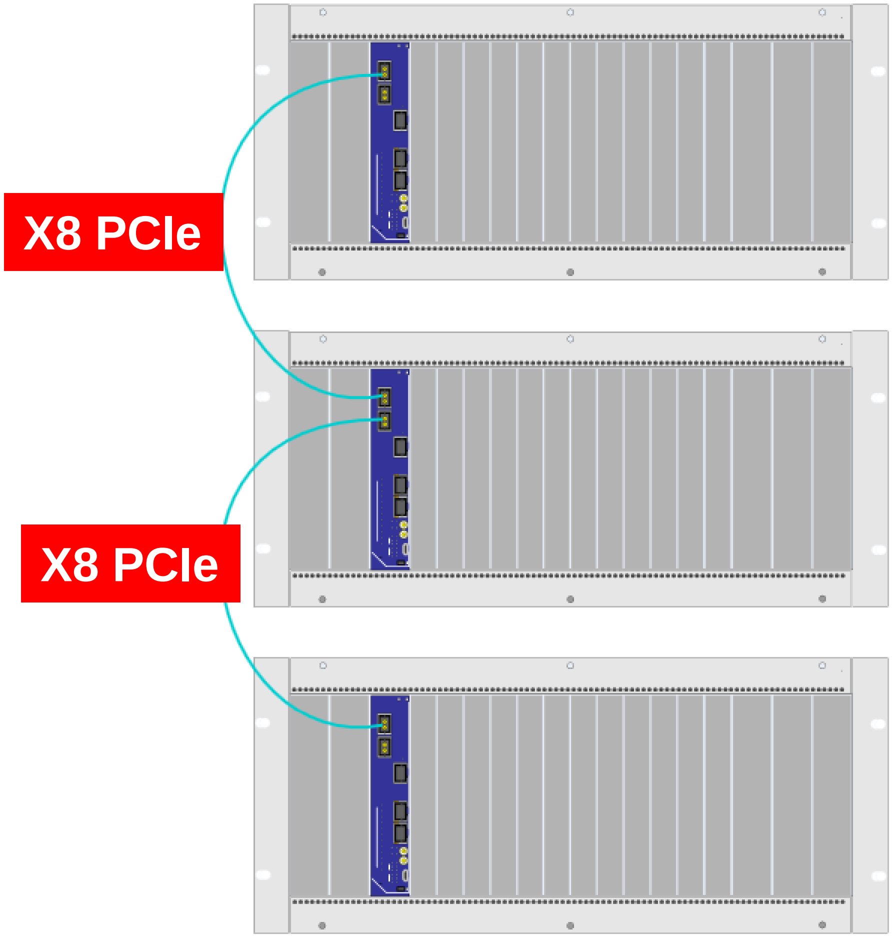
- Analog, Digital, Mixed
  - Increase interoperability with selection of lines for optimum transmission:
    - Analog differential
    - Digital
    - Clock
    - Mixed signal
    - User defined
- Classes Defined
  - A1.1, A2.1; D1.0, 1.1, 1..2, 1.3.

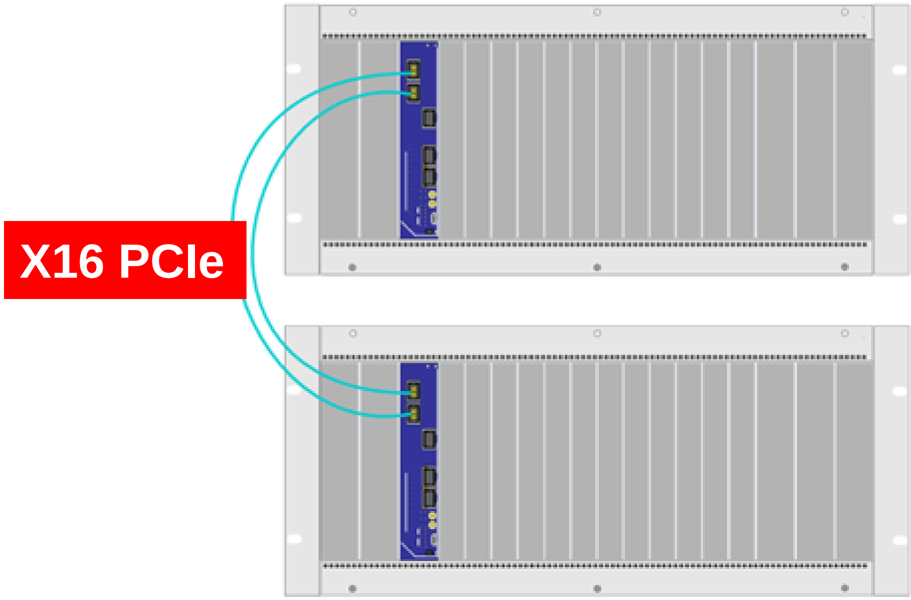
MCH-RTM Backplane Management



Greatly increased Analog via rear ±V power options, total AMC+RPM power, extension of control to additional crates

Cascading Shelves via MCH-RTM





Future Upgrade Paths

- Bandwidth of AMC backplane 10 to 40GHz
- Wider Fat Pipe with extended MCH-RTM
- Computing power on MCH RTM
- Link through MCH-RTM to other shelves

Cascade of MTCA-4 crates (example PCIexpress) to extend AMC slots

MTCA.4.1 Final Hardware

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PICMG® Specification MTCA Enhancements
MTCA.4.1 D0.8

MTCA.4.1 Enhancements for MicroTCA.4

- Auxiliary Backplane for Rear Transition Modules (µRTMs & MCH RTM)
- Rear Power Modules (RPMs)
- MCH Management Support & Extended Rear Transition Module (MCH-RTM)
- AMC & RTM Protective Covers
- Applications Classes of µRTMs

September 16, 2016

PICMG
Open Modular Computing Specifications

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- *MTCA.4.1 Enhancements*
- *Name* suggested by PICMG
- Approved, adopted, printed November 2016
- 160 pages

Software Guidelines Goals

- Goal:
  - Maximize Interoperability of basic software in common use for all applications
  - Hard copies available from PICMG
  - Repository accessible to all users (Github at DESY)
  - Guidelines, not rigid standards
  - However gaining maximum advantages will require some points of standard usage if users care about portability to other lab's applications

Software Guidelines

- Prior standards
  - Very limited standardization of system SW
  - Real interoperability of lab, commercial products lost
- ATCA/MTCA Standards
  - MTCA.4 Linux PCIe platform based
  - ATCA/MTCA Intelligent Platform Management IPMI standard led by Intel, support by 200 companies
  - Out of band diagnostics & control down to board, device level; key to 0.99999 system Availability requirement
  - But true vendor interoperability including SW still lacking at board, applications level

Design Guide Definitions/Relations

- Standard Hot Plug Procedure (SHPP)
  - Eliminates interruption of service to replace faulty module or RTM
- Standard Process Model (SPM)
  - Platform agnostic access to thread scheduling, thread interlocks/synchronization, inter-thread communication, and timing services
- Standard Device Model (SDM)
  - Platform agnostic access to external devices
  - Integrated framework, API for stream-oriented, addressable devices
- Standard Hardware API (SHAPI)
  - Common (register-oriented) API for configuration/control/data readout on addressable devices

PCI Express Hot Plug Design Guide

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PICMG® xTCA for Physics
Revision 0.1.3

PCI Express Hot Plug Design Guide

Guidelines for designing PCI Express Hot plug software and hardware for xTCA-based physics systems

November 5, 2014

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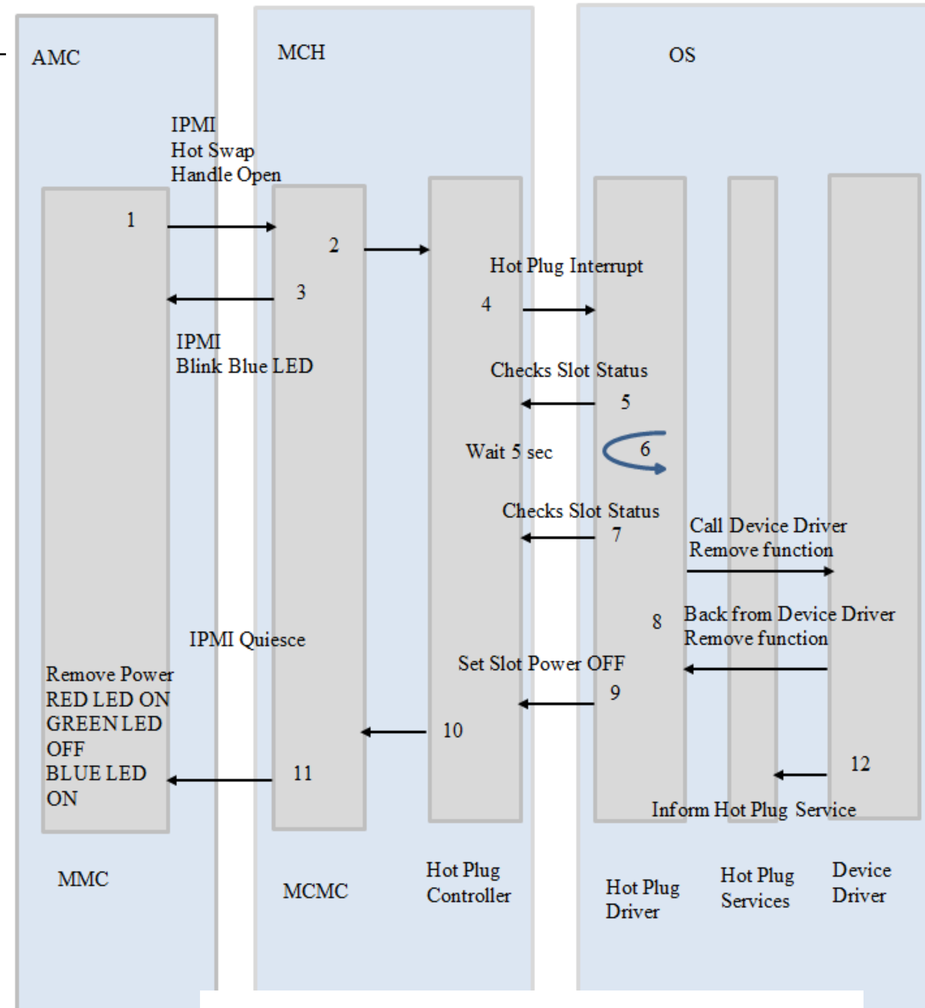
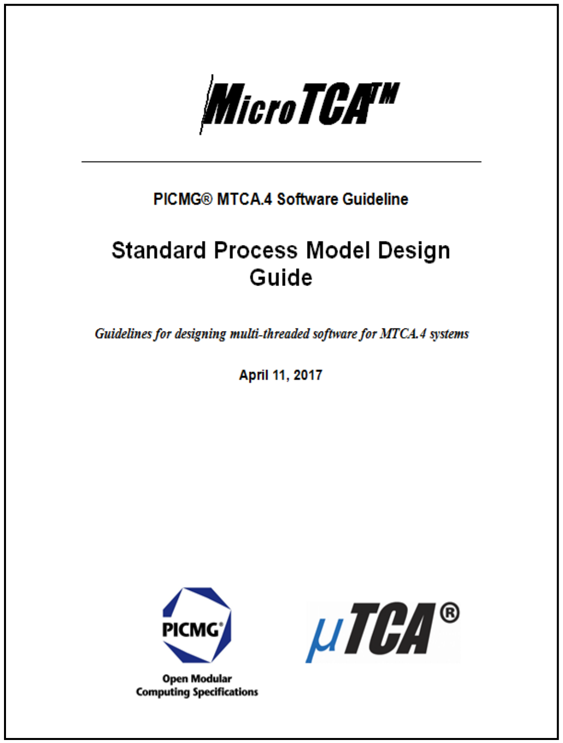


Device Removal Procedure

Standard Process Model Design Guide

- ❑ Standard operating model and Application Programming Interface (API)
- ❑ Code development to facilitate module re-use and portability
- ❑ Recommended for usage with MTCA.4 or MATCA.4.1 systems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PICMG® MTCA.4 Software Guideline

Standard Process Model Design Guide

Guidelines for designing multi-threaded software for MTCA.4 systems

April 11, 2017

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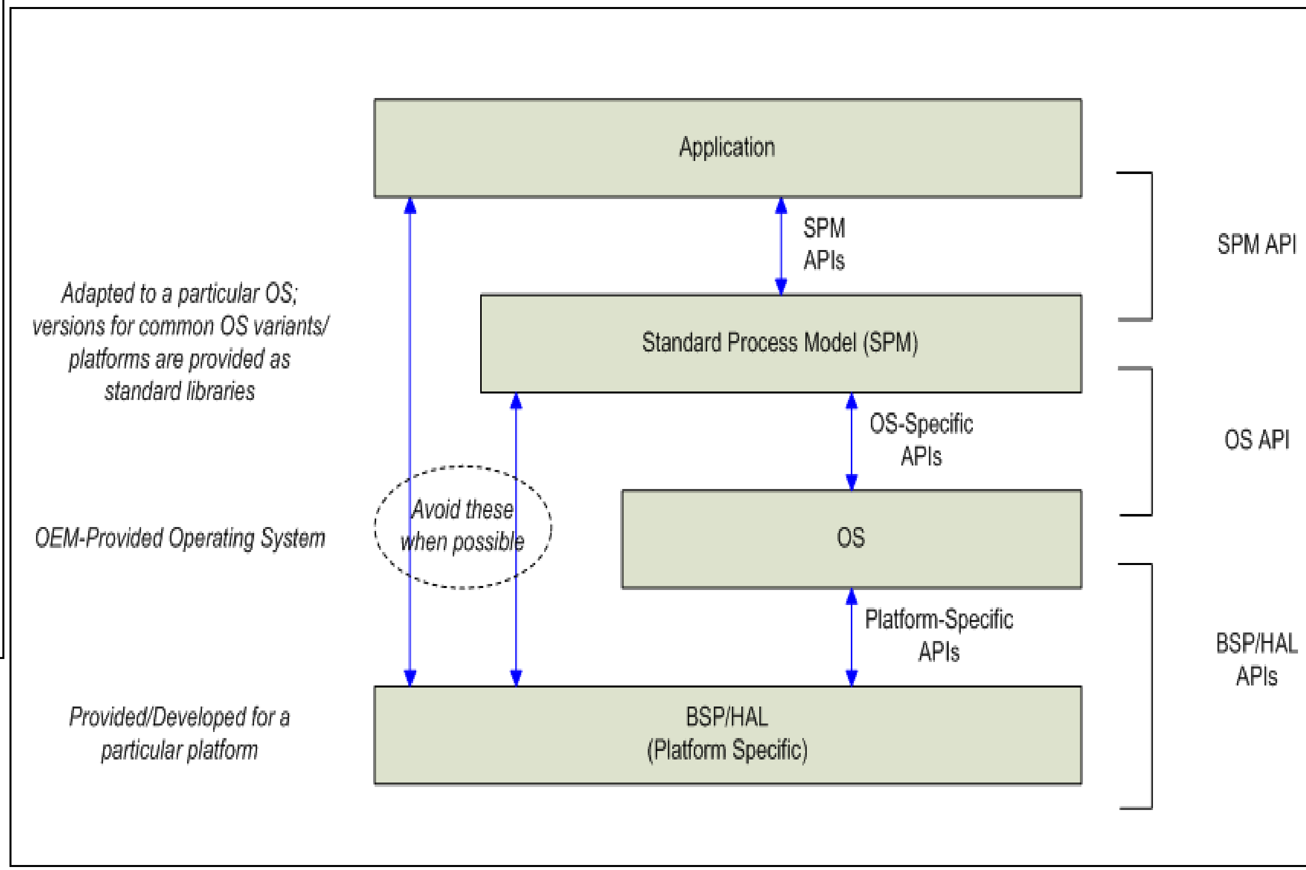
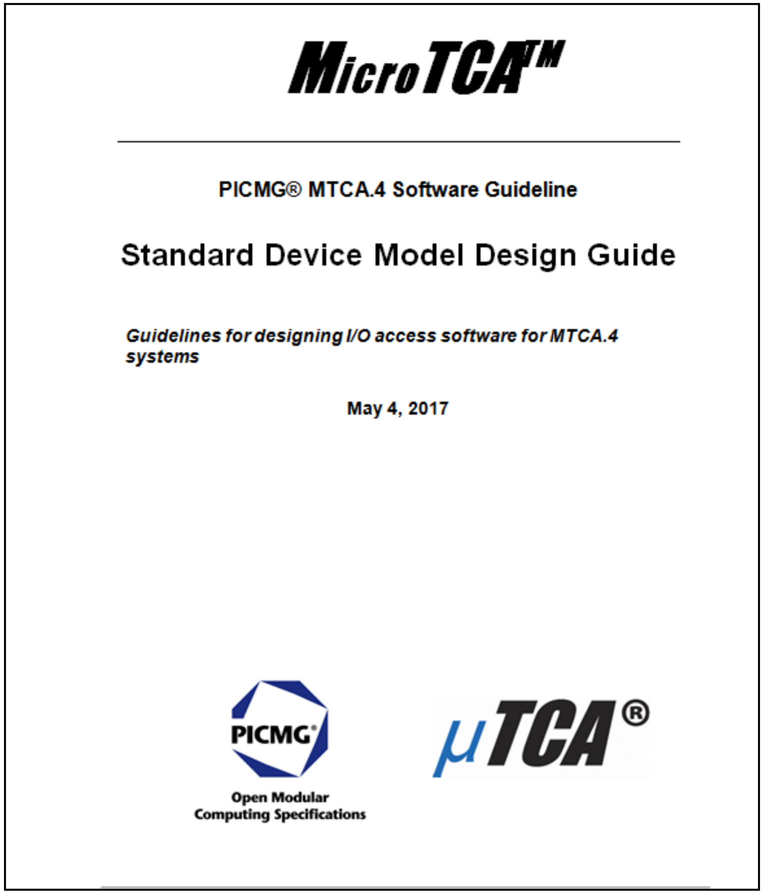


Process Model Hierarchy

Standard Device Model Design Guide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PICMG® MTCA.4 Software Guideline

Standard Device Model Design Guide

Guidelines for designing I/O access software for MTCA.4 systems

May 4, 2017

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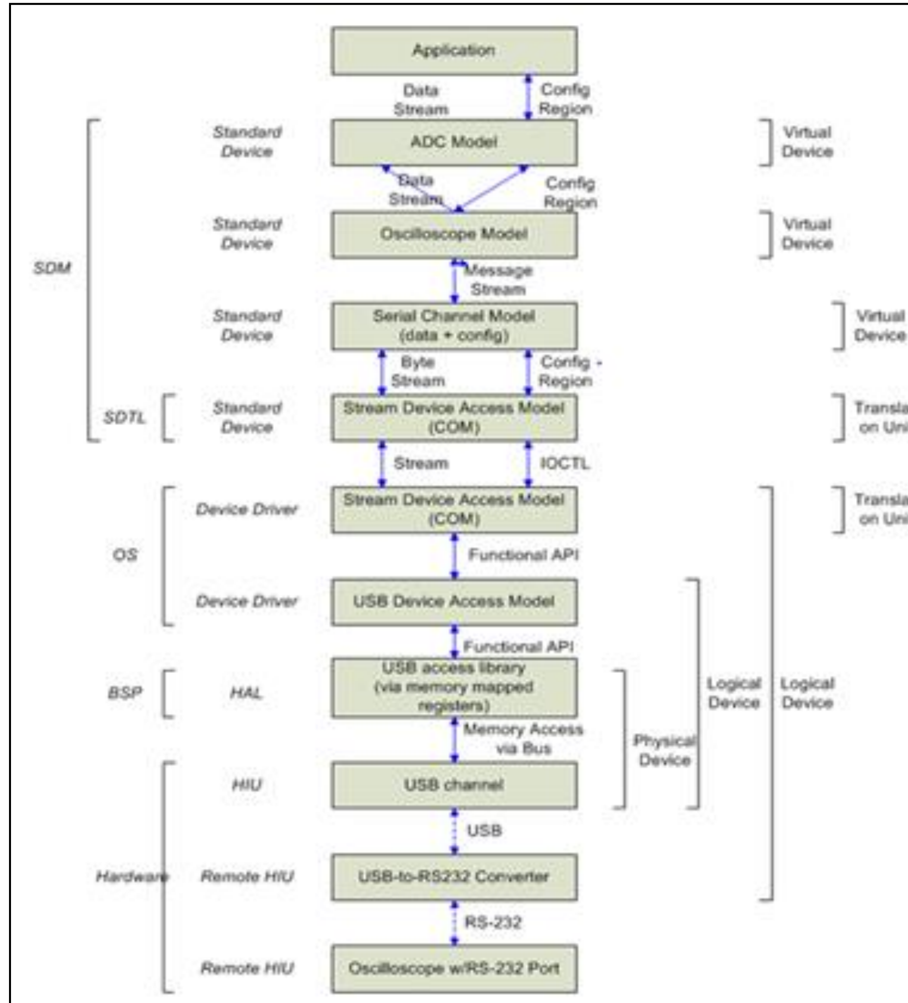
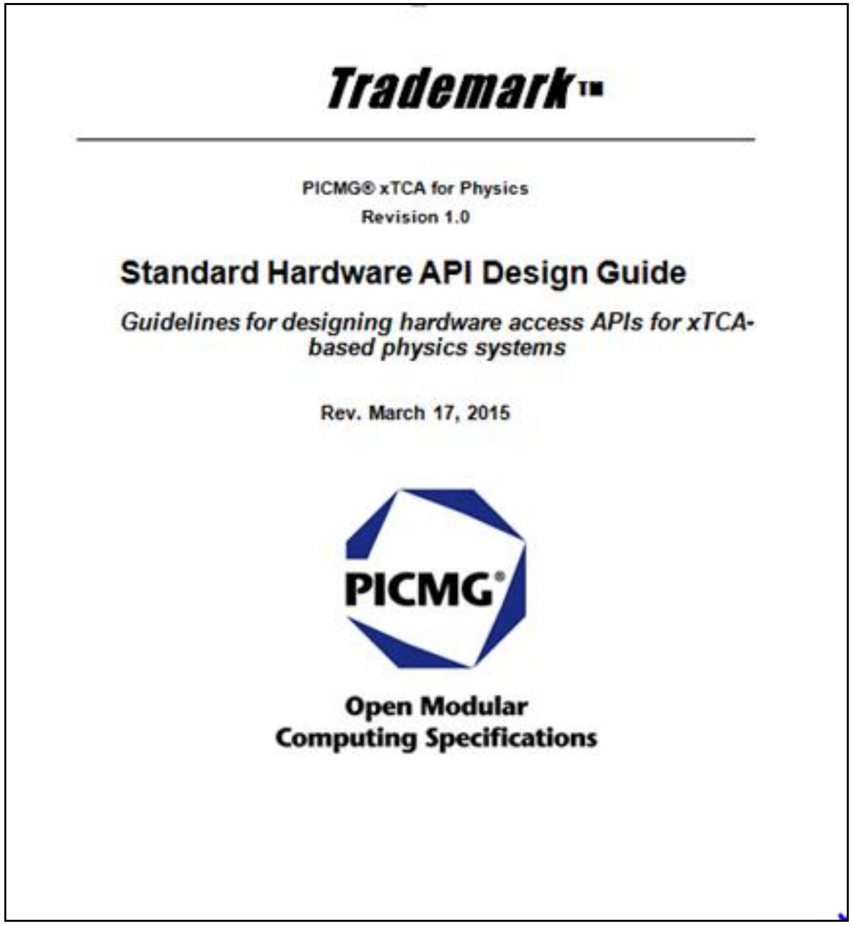
Device Model Nomenclature



Standard Hardware API Design Guide



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PICMG® xTCA for Physics
Revision 1.0

Standard Hardware API Design Guide

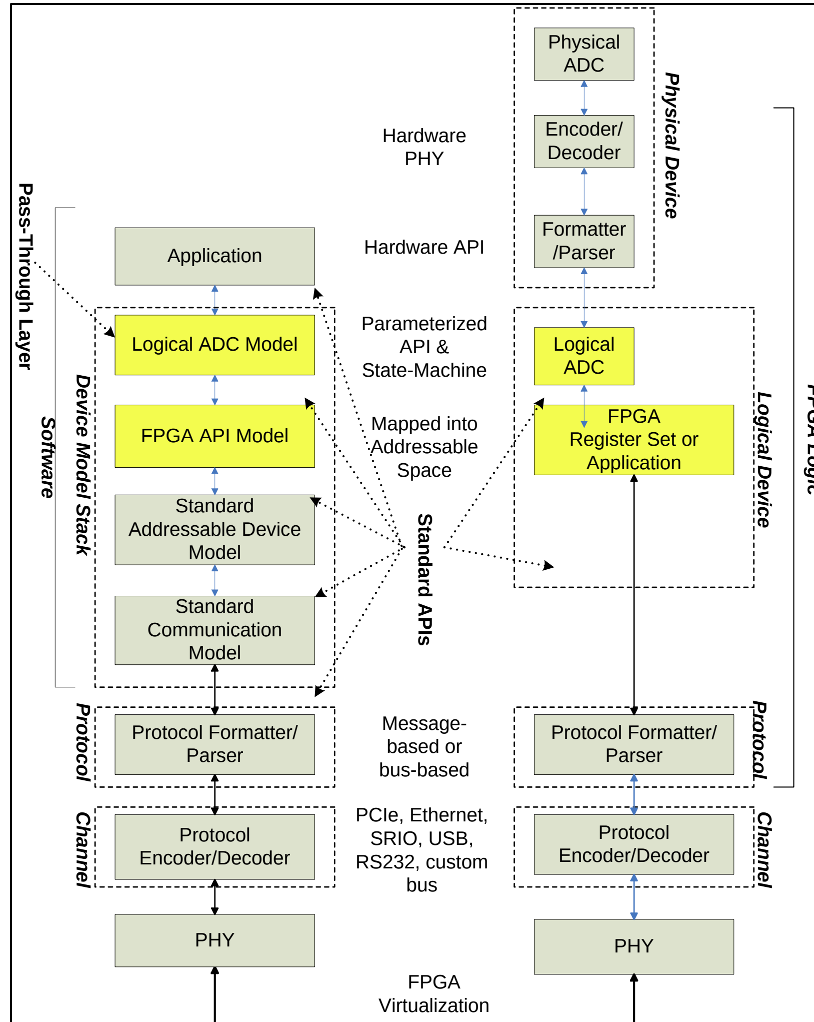
Guidelines for designing hardware access APIs for xTCA-based physics systems

Rev. March 17, 2015

PICMG®

Open Modular Computing Specifications

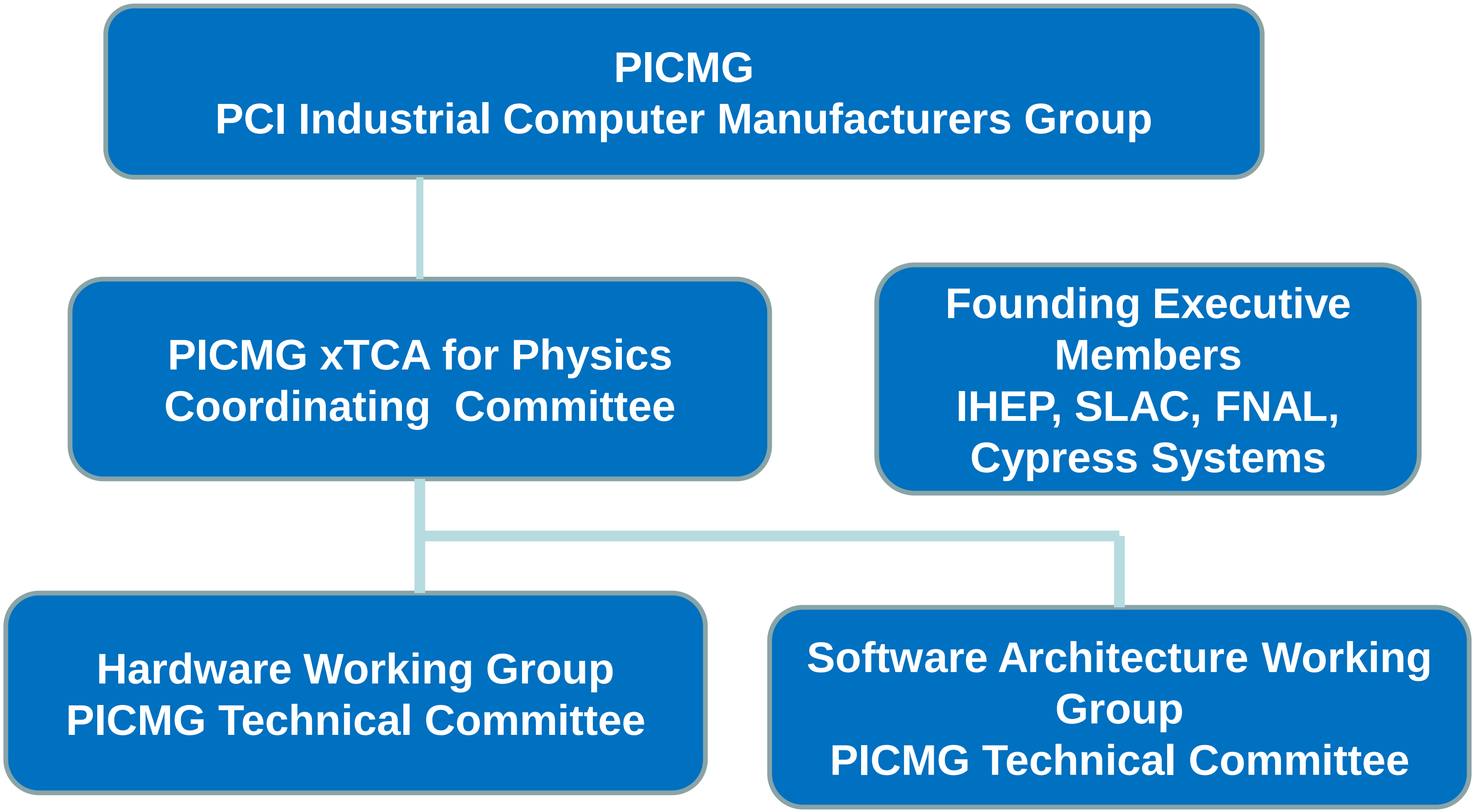
Hardware API Model Nomenclature



2015-17 SW Progress Summary

- MTCA.4.1 Enhancements to MTCA.4
  - Full PICMG adoption November 2016
- Software Guidelines
  - Standard Hot Plug Procedure, Standard Hardware API
  - Full PICMG adoption November 2016
  - Standard Device Model, Standard Process Model
  - Submitted for PICMG adoption May 2017
- Proposed
  - SW Guideline for *EPICS use cases* for SDM, SPM, SHAPI: *New volunteer user design team needed*

PICMG xTCA for Physics Organization



Summary Comment on Lab Standards

- Early lab standards were driven mostly by needs of *Detectors*, not accelerator controls
- MTCA.4, 4.1 designed for both
- ATCA finding some use in new LHC upgrades; choice depends on collaborators agreement
- MTCA finding use at several new labs/upgrades for controls, e.g. ESS, PLS
- Collaboration on detector applications, sharing solutions being encouraged at a number of labs including CERN, DESY

Key Contributors

Hardware WG

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- E. Williams

Laboratories

- DESY
- XFEL
- IHEP
- ITER
- SLAC
- IPFN Lisbon
- IN2P3 Saclay
- ESSB Portugal

- **Companies**
- Triple Ring
- Pentair Schroff
- Elma
- NAT
- TEWS
- PowerBridge
- VadaTech