CHALLENGES FOR EMERGING NEW ELECTRONICS STANDARDS FOR PHYSICS*

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Abstract

A unique effort is underway between industry and the international physics community to extend the Telecom industry's Advanced Telecommunications Computing Architecture (ATCA and MicroTCA) to meet future needs of the physics machine controls, instrumentation and detector communities. New standard extensions for physics are described which have been designed to deliver unprecedented performance and high subsystem availability for accelerator controls, instrumentation and data acquisition. Key technical features include an out-of-band imbedded standard Intelligent Platform Management Interface (IPMI) system to manage hot-swap module replacement and hardware-software failover. New software standards or guidelines are in development which will extend the reach of platform independent software standards to simplify design of low level drivers. Efforts to make the new standards broadly available in the marketplace through lab-industry collaboration are discussed.

INTRODUCTION

Several hurdles face the development and market acceptance of any new standard. In the case of earlier distinctly lab standards like NIM, CAMAC and FASTBUS the physics market itself banded together a priori to express a need and then develop an in-house standard. Success was guaranteed mainly by a simultaneous high rate of growth of both new labs and new front end and computing chip technologies. These standards were not universally adopted but had a reasonably high acceptance rate over several decades. As time went on the VME standard took over in the labs, supported by a strong military market focus. In 1994 ATCA and MicroTCA telecom standards were released and several labs working on next-generation machines became convinced that it was time for extension of this high availability high performance platform into physics controls, instruments and data acquisition. In early 2008 DESY made a decision to explore the platform for the recently approved X-Ray Free Electron Laser (XFEL). At the same time the International Linear Collider (ILC) R&D team chose ATCA as its technical and cost model. In early 2009 several labs joined the PCI Industrial Computer Manufacturer's Group (PICMG), an open-source standards organization of 250 companies, to develop formal standard extensions for physics. Goals included increased I/O channels and board size for analogue functions; rear transition modules with managed interfaces to enable hot-swap operation; and precision machine time synchronization and event triggering architectures. At the same time a software working group was launched to work on standardizing application interfaces, architectures and protocols and generic low level drivers for common modules such as ADCs; and to explore industrial high availability auto-failover software techniques for N+1 redundant systems in which a computer node has a backup processor and hub switch for example, or a backup timing network and generator-receiver at the node level.

The two major hardware standards have passed PICMG approval and are in publication, while software efforts continue with a dedicated core group. Exploration for controls is growing at several laboratories led by DESY, SLAC, IHEP and ITER. Several detector groups are exploring xTCA for LHC upgrades and several non-high energy physics machines including XFEL at DESY, LCLS at SLAC and others.

The major challenge today is to mature the new standard sufficiently quickly to meet needs of emerging new machine opportunities, particularly programs such as LCLSII at SLAC, the European Spallation Source in Europe and a number of smaller machines. The remainder of this paper will review progress to date and show examples of lab-industry collaboration to provide core infrastructure and common applications support.

TECHNICAL JUSTIFICATION FOR XTCA FOR PHYSICS

The initial attraction of xTCA for the 20-mile linear collider was based on bandwidth and throughput to cover machine and detector applications for the next 1-2 decades; and on its dual redundant Gbps serial backplane to achieve 0.99999 availability at the crate (shelf) level. The large ATCA card was seen to be most suited to special high throughput processor engines for fast RF feedback and detectors, while smaller more economical MicroTCA platform seemed best suited to Control systems supporting a variety of low and high speed applications in the same crate, e.g. medium speed RF feedback and slow DC magnet or vacuum controls and monitoring. A serially-networked xTCA architecture also easily accommodates so-called *network-attached devices* such as beam monitoring instruments distributed along a large machine at low density communicating only by serial link. A third attraction is the ability to extend IPMI management functions into non-xTCA devices, such as pulsed modulators and magnet power supplies, to bring unprecedented diagnostic information into control rooms and maintenance service centers.

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In summary, xTCA offers the following features:

- ATCA large card platform ideally matched to high bandwidth and throughput DAQ applications
- ATCA accommodates up to eight AMC mezzanine cards
- AMC mezzanine cards adapt easily to MicroTCA platform with similar bandwidth performance if desired
- MicroTCA real estate is cost effective for both very high speed applications as well as a high density of slow speed applications typical of industrial control
- Standards maintained and advanced by large industry consortium
- Consortium now includes laboratory members to advance features for both physics and non-physics applications
- Applications in non-physics areas including telecom potentially increases volume, improves market stability and decreases unit cost

NEW INFRASTRUCTURE STANDARDS FOR PHYSICS

Technical Features

The first standard extension, PICMG3.8, provides a standard hardware IO and management interface to the large ATCA card, which was left unspecified by PICMG. PICMG since has added an IPMI interface but no standard connectors. A new power and management connector was developed by the physics group for the standard. The interface is expected to cover a range of perhaps 80% of all applications. Where justified, the company or physics designer is permitted to choose a different connector which however compromises the physics goal of *interoperability* of designs made by different labs and companies.

The first test application at SLAC of PICMG3.8 is shown in Fig. 1.

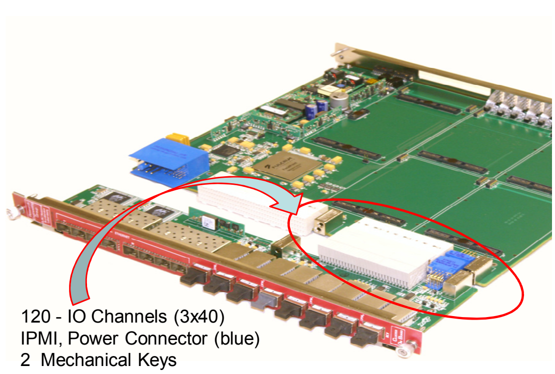

Figure 1: New ATCA RTM Interface PICMG3.8.

The second standard extension on MicroTCA specifies an entirely new 12-slot double-wide crate (shelf) and RTM with power and management controlled from the host AMC. The RTM card is identical in size to the AMC card but flipped vertically to properly align the rear panel with the in-line rear card guides. The IO interface is two 3-row 10 column channels (shielded 100Ω pairs) of which ten pairs are used for power, IPMI and JTAG connections. The concept is shown in Fig. 2 and industry hardware in Figs. 3-5.

Only the AMC connects to the backplane containing all the standard dual star interconnections plus a new layer for triggering and interlock sums. In addition a group of *extended options area* standard lines are specified for point-to-point precision clocks or triggers. The dual star redundant backplane is shown in Fig. 6.

The RTM connects to the host AMC only through its IO connector. Both the AMC and RTM are hot swappable although to swap the RTM all cables must first be disconnected. The RTM is expected to need replacement much less often than the more complex AMC.

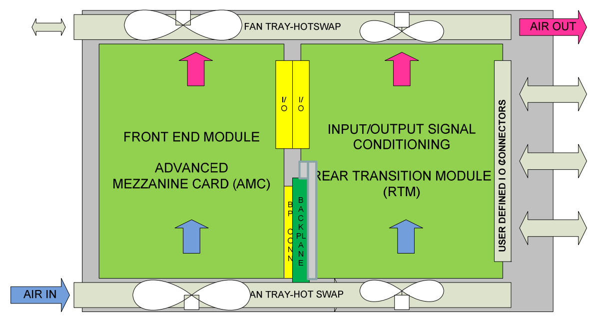

Figure 2: AMC-RTM-Shelf Concept MTCA.4.

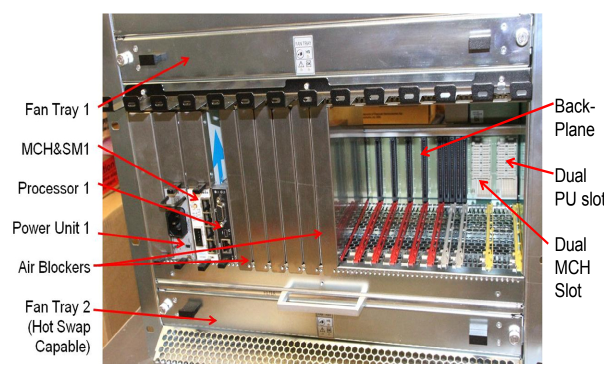

Figure 3: 12-Slot Redundant Shelf MTCA.4.

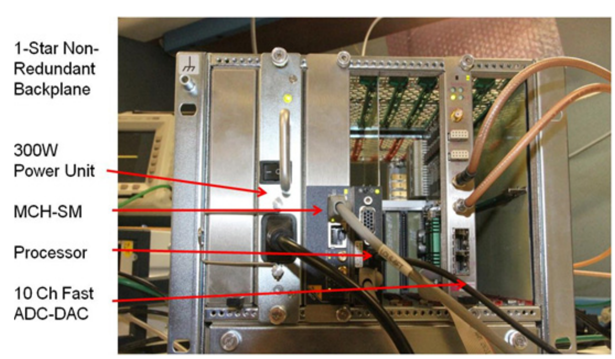

Figure 4: 6-Slot Development Platform MTCA.4.

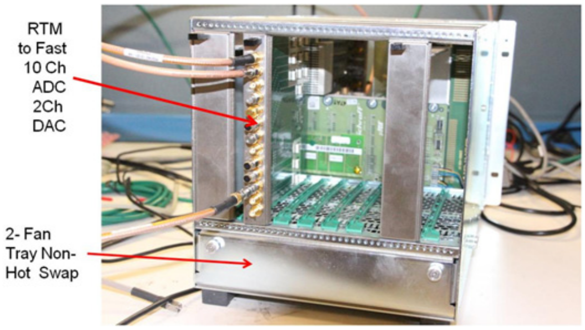

Figure 5: Rear of 6-Slot Shelf with Fast Digitizer RTM.

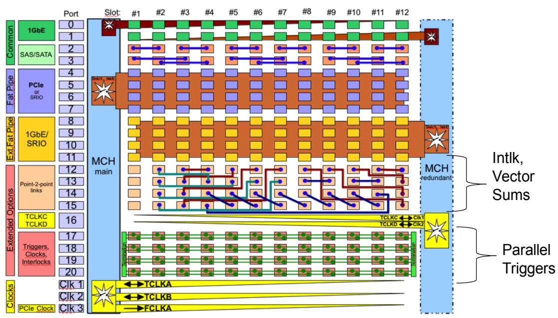

Figure 6: 12 Slot Redundant Backplane MTCA.4.

Progress Toward Infrastructure COTS Availability

One of the important metrics for the viability of any standard unless wholly developed and supported internally is availability of Commercial Off The Shelf products and servicing. Table 1 summarizes progress in the number of vendors supporting key components of the new standard, which officially is just being made public for the first time. Clearly the numbers are small but although no names are mentioned a significant number of major ATCA vendors contributed to the development and are fully engaged in product development.

Table 1: COTS Infrastructure Progress MCTA.4

Infrastructure	Description	COTS Availability
Development Shelf non-redundant	6-payload shelf with PU, integral cooling fans	2 vendors
Station Node Shelf dual star redundant	12-payload slot shelf , hot-swappable fan tray(s)	3 vendors
Modular Power Supplies	12V Power Units (PUs) 300/600/900W	2-4 vendors
Hub Controller (MCH) – full featured for timing needed	MCH Controller w/ integral IPMI shelf manager, hot-swap, access to radial timing option	2 vendors Switches for radial timing lines need development
IO Controller Processor (IOC)	Generic AMC processor running Linux, EPICS	2+ vendors
Timing Module	1 or 2-wide AMC (SLAC needs EVR compatible, needs adaptation)	1st units available (U. Stockholm), need COTS sources (2)

Note that the last item on the list is a timing module for MCTA.4, which has been developed in a collaboration of DESY with University of Stockholm but only recently is completed to where commercialization can be considered. Two versions are in progress, a single wide Tx-Rx unit suitable also for use on an ATCA Carrier board, and a double-wide for MTCA.4 that will allow additional channels to be distributed outside the shelf via the RTM. Small quantities of the first have been delivered and are operational, while the design of the second is in progress for completion in late 2011. Commercial sources are interested and working toward solutions also. The single wide unit and double-wide concept are shown in Figure 5.

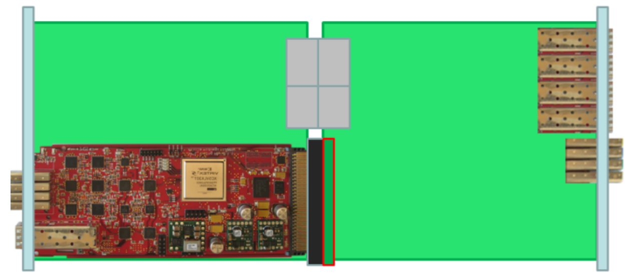

Figure 7: MTCA.4 Tx-Rx Timing Module Prototype (Stockholm University & DESY) and Double Wide Concept (in design, Stockholm).

LAB-INDUSTRY APPLICATIONS DEVELOPMENTS ON MTCA.4

The next important metric is the commercial availability of key generic AMC modules:

- High performance fast digitizers for DAQ and LLRF applications
- FPGA modules to process instrumentation tasks such as interlocks, beam position, beam charge etc.
- AMC Adapter modules for common industry standards e.g. PMC, Industry Pack, FMC etc,

With these three generic modules and customized RTMs developed by either labs or by industry, the bulk of controls and monitoring requirements for an accelerator can be instrumented. Some AMC adapter applications include stepping motor drivers, temperature, beam loss, wire scanners, fast frame grabbers, etc. Examples are shown in Figures 6-13.

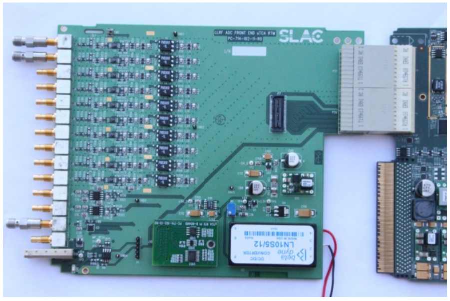

Figure 8: 25 MHz IF RTM (SLAC) for 10 Ch 16 bit 125 MSps COTS Digitizer (Struck).

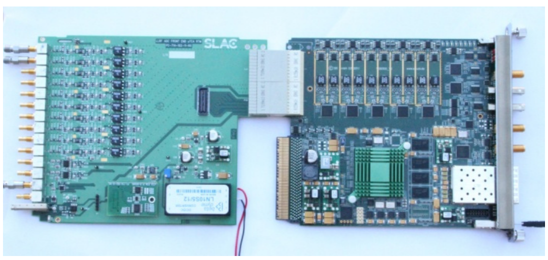

Figure 9: RTM passes signals at 25 MHz from 2.856 GHz down-converter in external RF Front End chassis.

Figure 10: Fast/Slow ADC RTM (SLAC) mates to COTS Generic FPGA AMC (TEWS 651) for Klystron Interlocks Processing.

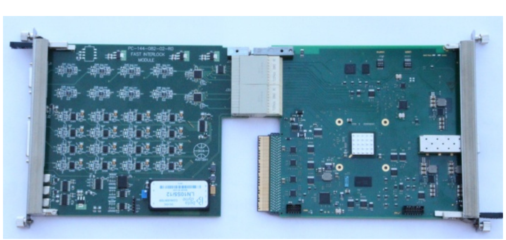

Figure 11: Mated Pair handles 8 Channels 60 MSps and 16 Channels 2 KSps Interlock Input Channels.

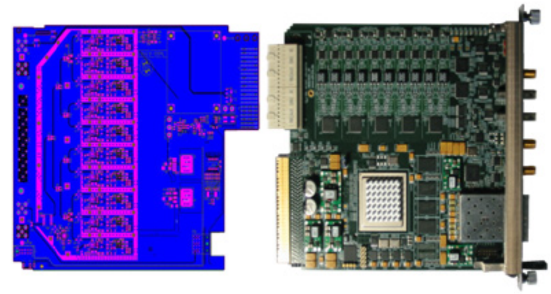

Figure 12: IF Down-Converter RTM to Struck ADC-DAC (DESY).

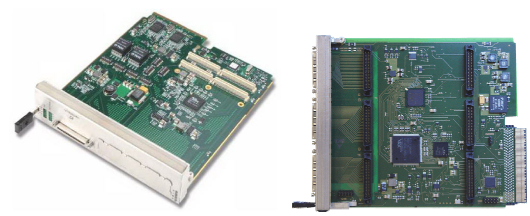

Figure 13: PMC Double Wide AMC Adapter (Vadatech) and 3-IP AMC Adapter (TEWS)*
*Now available on MTCA.4 version with RTM.

Progress Toward Generic Applications COS Availability

Table 2 summarizes progress toward development of COTS suppliers for generic AMC modules. There are 1-2 vendors in existence or in development for the items shown. It is the goal of the PICMG program to develop at least two commercial suppliers for critical products so the Physics Technical Committee has chosen to apply this to both basic infrastructure and basic generic products.

The right hand column is a partial list of the instrumentation applications that can be served by this limited list of generic products. In other words, a small number of complex AMC products is highly leveraged to a number of applications which significantly reduces development costs and speeds time to project-readiness (or to market for vendors).

RISK FACTORS AND RISK REDUCTION

General Observations

Most if not all new accelerator projects, by the time they have spent years in development and battling for approvals, are highly averse to potential time and cost risks associated with a new standard. The decision by a single large project or a number of projects to adopt a new controls and instrumentation platform, an event that occurs approximately every two Sun-Spot Cycles in physics and industry, must be solidly based on enough prior work to demonstrate the technology, especially the

Table 2: COTS Generic Applications Progress

Generic AMC	COTS Availability	RTM Adapters
10/2 Ch ADC/DAC 16 bit 125 MSPS	1 vendor available 2nd vendor due end FY11	• RF-IF down-mixers • BPM adapter • Photodiodes
4 Ch ADC AMC 14-16 Bit 125 -500 MSPS	1-2 vendors in development	• BPM single bunch • BPM multi-bunch • Beam intensity Toroid • Beam Length
FPGA Virtex/Spartan, FMC optional	1 vendor in development	• Interlocks ADCs12 bits, 8 ch @60 MSps, 16ch@2KSps • Wire scanner interface
AMC Industry Pack Adapter (2-3 IPs)	2 vendors in development	• Stepping motor control • Vacuum control-monitoring • Temp control-monitoring
AMC PMC Adapters	2 vendors	• Timing Rx adapter • Frame grabber adapter

software, and the hardware-software costs by achieving basic COTS availability.

ATCA is actually a decade old and it is in mid-ramp in Telecom which now is claiming in excess of $1B per year of product in a $10B per year market. A small part of this is in MicroTCA which developed as a standalone in a second phase of development so is much less mature. Therefore one has to admit that establishing any new platform takes time and investment and involves risk.

On the other hand, technologies advance rapidly, obsolescence is inevitable, and at some point all platforms have to be replaced. Laboratories must plan the inevitable changes to minimize risks to ongoing and emerging products when they do occur. Otherwise, as many laboratories have learned, a failure to modernize adiabatically during the long life of huge accelerators can cause insurmountable barriers of time and cost when they become truly unavoidable.

Lab Industry Collaborations a Tool for Risk Reduction

New platform development is a large costly undertaking and requires a dedicated community of champions to achieve. The PIMCG consortium is such a community which has had large success for many years. The xTCA for Physics standards efforts are only two years old but have already saved large development time and cost by the collaboration. Coordinated joint development of basic industry support for both infrastructure and generic applications is already paying dividends. There is major work ahead for any lab adopting the standards, but a great deal is already done and being made available to the entire community.

NEXT STEPS: SOFTWARE EXTENSIONS

The xTCA for Physics collaboration has achieved its initial goals and now must bring the same enthusiasm to developing streamlined software modules, tools and supports. The major goal is to standardize modules to address imbedded FPGA based systems and to simplify development of new applications by such standards or best practices guidelines. The objective as in hardware is to make products built in both labs and industry more compatible and *interoperable* as has been achieved through the IPMI management system for the hardware platforms.

CONCLUSION

The xTCA for Physics Lab-Industry collaboration has achieved the launching of a new hardware and software architecture for physics. Its ultimate success depends on many factors and will vary across many applications, but it is now available as new system that is already being explored and adopted at several labs. The next major effort must be to extend software compatibility at low levels of hardware, which has never been achieved satisfactorily in any present standard.

The same approaches that underlie the xTCA architectures are also extendable to non-xTCA devices such as Megawatt class power supplies and pulsed modulators for RF systems, AC and DC high availability systems etc. A judicious use of extra dual or N+1 redundancy can enable us to visualize in future “machines that never break.” Of course they will break, but the high availability architectures of xTCA applied broadly (which linacs have inherently) can make render breakages of little or no impact in keeping the machine running.

Similarly Intelligent Platform Management diagnostic extensions beyond basic control and instrument modules into all major power systems and remote instruments will have a major impact on machine uptime and reduce the time, effort and number of people required for servicing.

ACKNOWLEDGMENTS

This paper represents the work of an entire community far too many to name.

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Enormous credit is due to key contributors from both labs and industry, including Schroff, ELMA, Positronix, TE Systems, Pentair-Schroff, Performance Technologies and others from among over 40 industry members

The DESY XFEL teams headed by Kay Rehlich and Stefan Simrock (now with ITER) made ground-breaking technical contributions in ATCA and MTCA.4 early applications and design.

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