Advances in Developing Next-Generation Electronics Standards for Physics

IEEE Real Time Conference & xTCA Workshop

Institute of High Energy Physics, IHEP

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Chair, PICMG xTCA for Physics Coordinating Committee

SLAC NATIONAL ACCELERATOR LABORATORY

Outline

- Physics Interest in ATCA & MicroTCA (xTCA)
- xTCA Shortcomings for Physics
- PICMG xTCA for Physics Coordinating Committee
  - Major Goal: Specify Stable Platform Infrastructure
  - Defining Requirements via Survey
  - Progress to Date & Future Plans
  - How to Participate
- Acknowledgment

Physics Interest in xTCA

- PICMG ATCA, AMC standard specifications released June 2004
  - "The most ambitious development ever undertaken by the PICMG Consortium."[1]
  - Unique for Telecom industry to adopt common modular platform:
    - Up front R&D cost savings, quicker time-to-market for new technology products, interoperability gives customer more choices within market segments
- Major attractions for Physics:
  - High Performance BW, throughput, serial multi GbE backplane
  - High Availability design critical to next-generation very large machines
  - Readily adaptable to many data acquisition high speed processing applications
  - RTM solves ugly cable routing problems[2]

- 1. PICMG press release, April 2009. PICMG currently ~400 corporate members worldwide
- 2. First used in FASTBUS, later by VME and others

Physics Developments In Progress

- Growing evaluation projects at major labs
  - DESY, SLAC, IHEP, FNAL, ANL, BNL, KEK, CERN, FZJ, IN2P3, IPFN, JET, …
- Direct interest by funded and future projects
  - XFEL, ILC, ITER, JET, ATLAS Upgrade, Project X, FAIR, AGATA, …
- xTCA interest both accelerators and experiments
- Interest in options: ATCA+RTM, ATCA+AMC+RTM, AMC-µTCA (MTCA) + µRTM[1]
  - [1] New, under discussion by Physics Coordinating Committee

Non-Telecom Areas of Interest

- Medical physics company for new video-rate imaging platform
- µTCA strong interest for non-telecom industrial control, instrumentation markets
- AMC Mezzanine adapters for existing standards such as Industry Pack (IP)
- Analog AMC products beginning to emerge

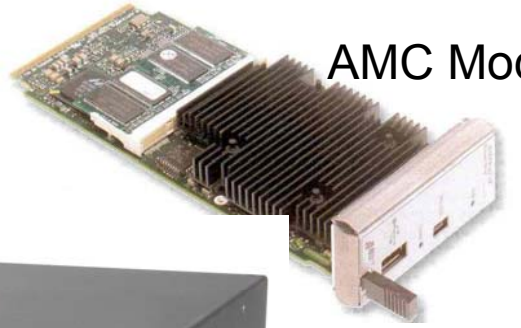
xTCA Components for Evaluation (SLAC)

5-Slot Shelf w/Dual Processors & Hub Switcher

14-Slot Shelf

SLAC DAQ 0.5 TB/s DAQ

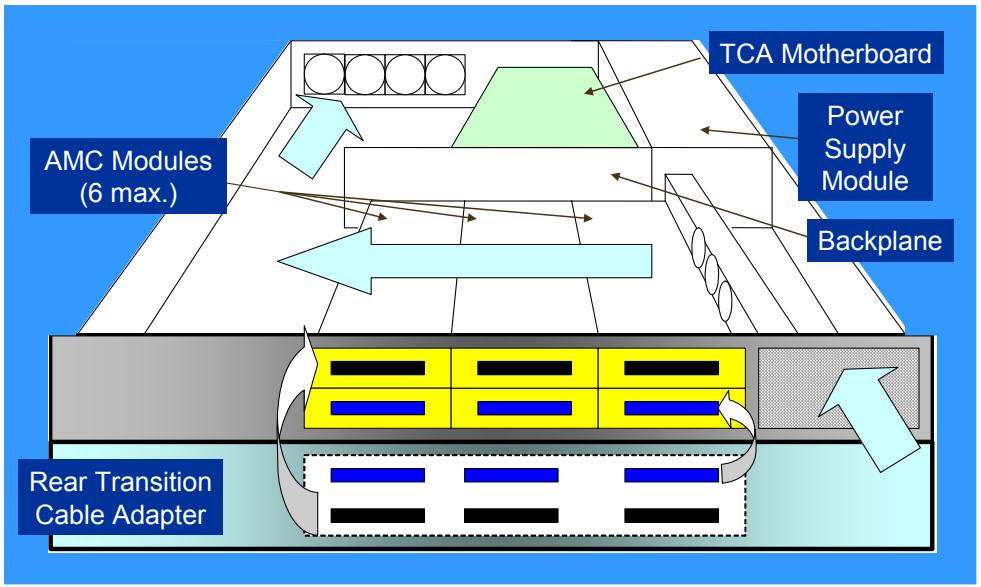
AMC 105 MS/s
14 bit 8 Ch ADC



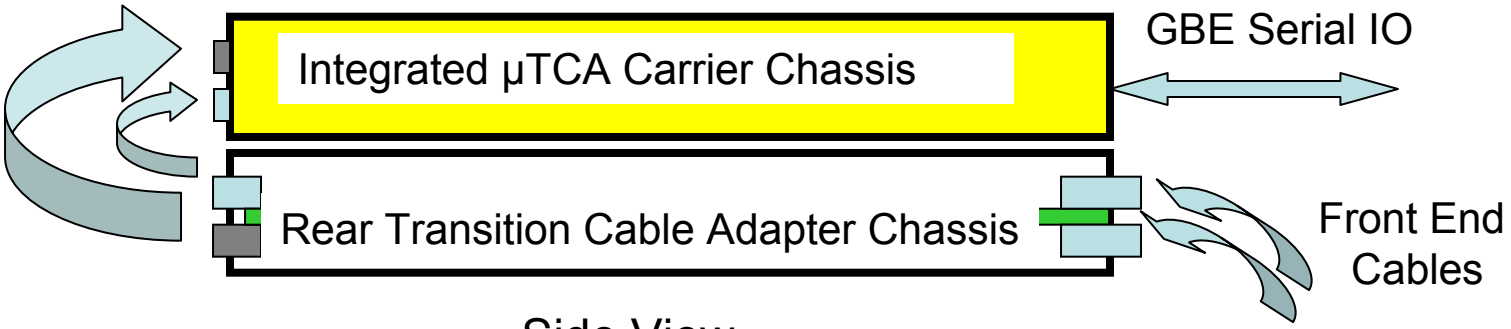
AMC Module

µTCA 6 Slot 1U Shelf

Front Panel Entry Cable Transition Adapter



- Prototype demo for control system major upgrade
- Develop standard rear transition adapter with analog, RF, digital connector options
- Cable entry from rear top or bottom of racks



Side View

xTCA Evaluations 2 (DESY XFEL Interlocks, Kay Rehlich)

- **Development of an 'universal' AMC module**
  - Hardware design with Virtex5 and 256MB DDR2 SRAM (1GB/s)
  - FPGA code development with PCIe interface and DMA
    - 370 MB/s into user space (128byte payload size)
  - DOOCS server and OS driver with hot-swap
  - IPMI code for 'Module Management Controller' (Atmega-128)
  - Piggyback with 2 ADC and 2 DAC channels, 100MHz

xTCA Shortcomings for Physics

- xTCA designed Telecom-centric, no analog
- Physics needs very high dynamic range, low noise and crosstalk to at least 100-200 MHz
- Virtually no analog products on market except AMC adapters for Industry Pack (IP) slow devices ADC-DAC (~100 KHz)
- New industry 100 MHZ ADC stimulated by DESY not fully tested (but appears very promising from system comparisons at DESY)
- DESY piggy-back board will give more information at 100 MHz; 500 MHz contemplated for next design
- One 500 MHz AMC design advertised but not delivered

Urgent Need for Addressing Analog

- Worries expressed at 051009 Workshop:
  - We don't know we can build good enough designs because of proximity of switching power supply noise
  - There isn't enough room on AMC to get good enough isolation between high BW ADC channels
  - Requirements are being pushed all the time and we can't adopt xTCA without demonstrating real results in our applications

Analog Solutions

- Every new generation of instruments has this "chicken-and-egg" problem
  - Early CAMAC introduction was shunned by some on basis that could not support high performance analog (wrong)
  - VME was criticized for same reasons (wrong)
- Rapid demonstration of xTCA for high performance analog requires a strong lab-industry collaboration
  - Labs must take initiative to define critical requirements
  - Collaborate on joint plans with industry to verify designs, develop industrial suppliers
  - Cannot be accomplished by labs working in isolation from each other and industry

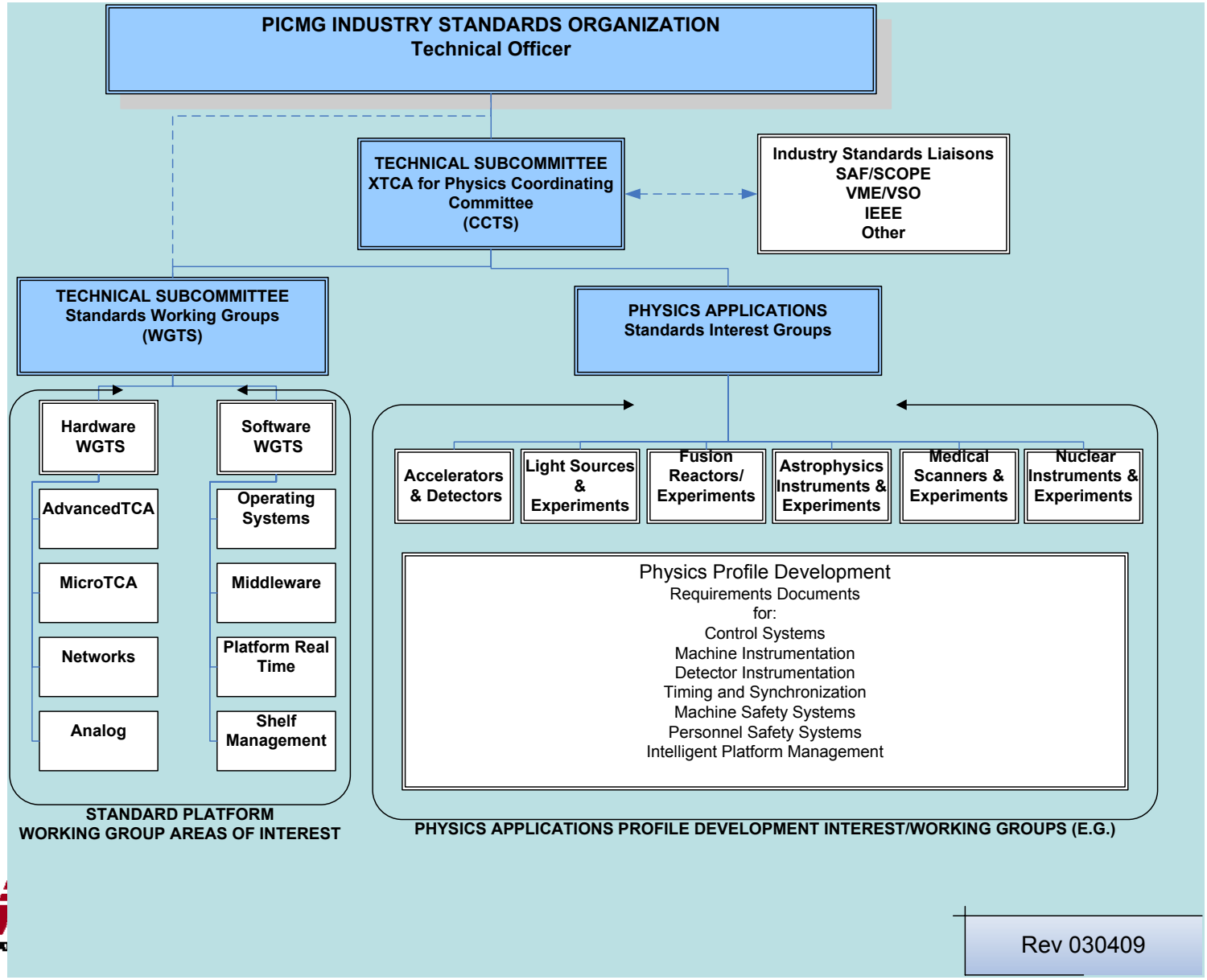
Short Wish-List for Physics

- MicroTCA package for Accelerator, Detector controls with analog space, connectors, rear I/O and RTM options
  - Current MTCA designs at “Wild West” stage
- Design approach for precise timing, synch and trigger distribution
  - Our systems must synch to machine RF, beams down to sub-picoseconds if needed
- Generic analog-digital-processing boards with infrastructure support of high level, real time, IPMI software, development tools that can be made widely available
  - Well defined “user payload design space” on generic AMCs with high quality interconnects, isolation, grounding and shielding for analog-digital applications

xTCA for Physics Coordinating Committee

- Why a Physics Subcommittee of PICMG?
  - Major Goals of a formal specifications, guidelines effort
    - Address expressed needs of current participants, seek out new requirements from broader physics community
    - Save engineering development effort for new designs, both hardware and software; concentrate on unique problems within stable platform
    - Share infrastructure designs, drivers, firmware, system software, IPMI among labs before embarking on major new system detailed applications designs
    - Plan to make all new generic and high volume applications products available through industry. Labs cannot compete with industry in efficient production if volumes are sufficient
    - *Fragmentation of the physics market will destroy chances for best commercial products at lowest cost!*

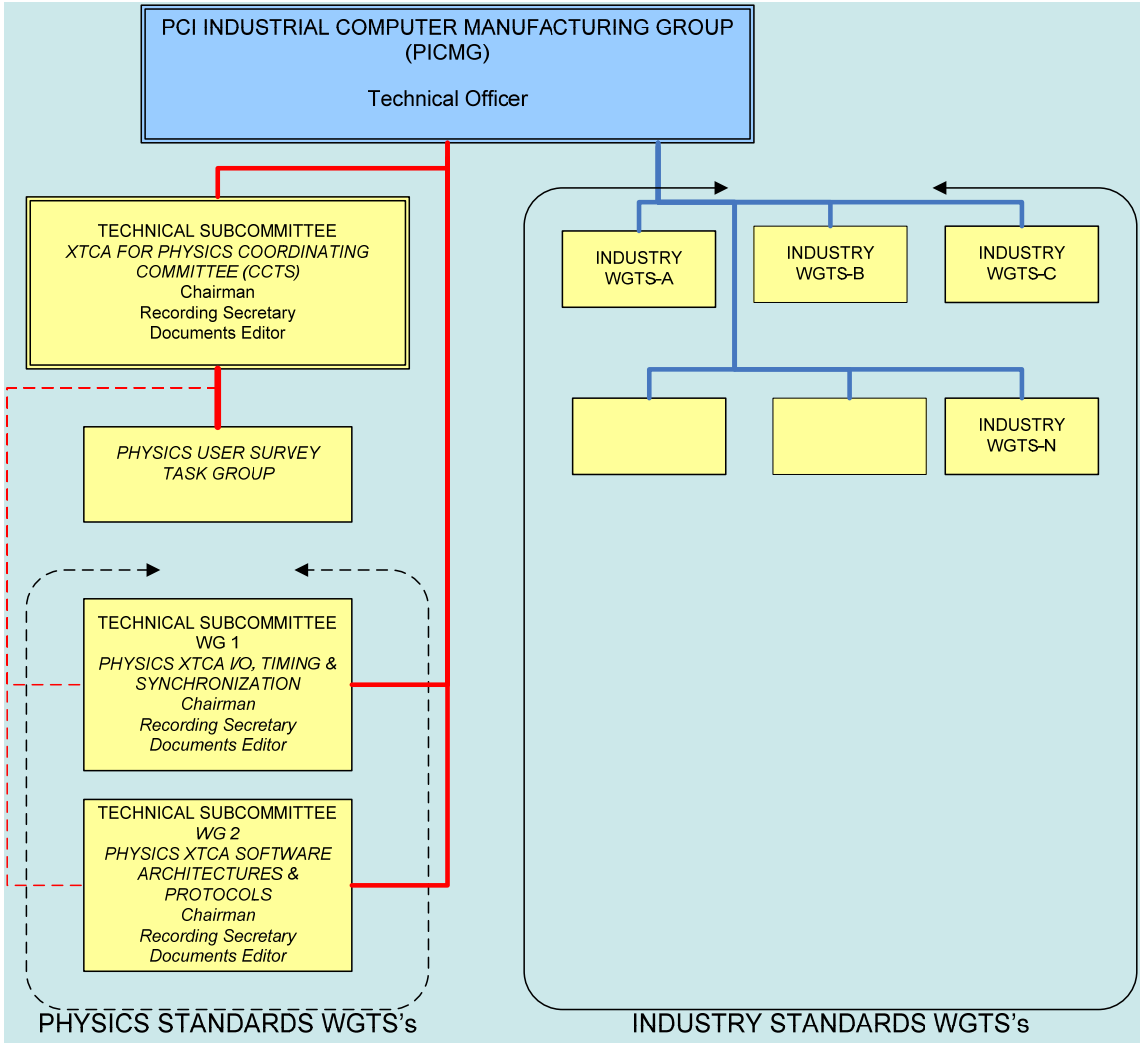
xTCA for Physics Technical Subcommittee Organization & Proposed Scope



PICMG *xTCA for Physics Coordinating Committee* Technical Subcommittee

- PICMG TC for Physics (CCTS)
  - Proposed at 2008 Nuclear Science Symposium, Dresden, in conjunction with 2-day xTCA Workshop
  - Organization of *Coordinating Committee* subsequently sponsored by PICMG Executive Members SLAC, DESY, IHEP and FNAL plus two Executive Member companies, Cypress Point Research & Performance Technologies
  - Approved by PICMG ExCom, organized March 10, 2009
    - Holds weekly web meetings
    - Current membership 44 companies, 5 labs, 65 individual members

Organization xTCA for Physics Technical Subcommittee



- Physics Coordinating Committee (CCTS) proposes WGTS's
- All WGTS's report to PICMG Technical Officer
- All WGTS standards documents reviewed/ approved by CCTS before submittal to PICMG
- Call for Participation (CFP) for WGTS by PICMG standard procedure
- Specifications final approval by full PICMG membership

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New Working Groups

- Two major *Working Groups* approved, about to be formalized with election of officers
- *WG1: Physics xTCA I/O, Timing and Synchronization Working Group*
- *WG2: Physics xTCA Software Architectures and Protocols Working Group*

Future Plans

- Conduct survey of requirements among labs actively engaged or planning on using xTCA
  - Find contact person in labs to help distribute survey
  - Small CCTS team correlates results, distributes report
  - Survey team led by Stefan Simrock, DESY, CCTS Assistant Chair

Future Plans 2

- Establish public web page for Physics on PICMG site
  - Background, goals of group
  - Reports, papers of current interest
  - xTCA Workshop presentations (FNAL ’07, Dresden ’08, IHEP ’09, …)
  - Current organization, information contacts, how to join CCTS and/or WG’s
- Operational before end 05/09

Future Plans 3

- Review WG Work Products
  - Some WG tasks urgent, driven by project needs at DESY, SLAC, etc.
  - Aiming for initial design, MTCA with µRTM by end 09 with prototype efforts underway
  - Down-select preferred *first draft* protocols on same timeframe.
- Further Information
  - www.picmg.com ("coming soon")

Acknowledgments

- The ongoing work described is a collaboration of several labs and industry partners.
- Thanks to the PICMG organization, members and officers for encouragement and generous help, and to the key people at the founding labs.
- Special thanks to PICMG Physics Committee officers Augustus Lowell and Zhen-An Liu; to Assistant Officers Stefan Simrock and Robert Downing ; to Kay Rehlich and Stefan Simrock and their teams for generous sharing of xTCA R&D for the new XFEL accelerator control systems; and again to Robert Downing for leading the Profile for Physics concepts development and documentation and many fruitful discussions.

Backup Slides

xTCA for Physics CC Membership

Corporate Members	Corporation/Institution	Committee Members
1	Adlink	1
2	Advanet	1
3	Alcatel-Lucent	1
4	Arroyo Technology Consultants	1
5	Astek	1
6	BittWare	1
7	Carlo Gavazzi	1
8	Communication Automation	1
9	Cypress Point Research	1
10	DESY	5
11	Diversified Technology	1
12	Elma	3
13	Elma/Bustronic	1
14	Emerson	1
15	FNAL	2
16	Foxconn	1
17	Gage	1
18	GE Fanuc	1
19	Huawei	1
20	Hybricon	1
21	IHEP	2
22	Intel	2
23	Jblade	1
24	Kontron	3
25	Linear Tecxhnology Corp	2
26	Lecroy	1
27	N.A.T.	1
28	National Instruments	1
29	PCI Systems	1
30	Pentair/Schroff	2
31	Performance Technologies	3
32	PICMG Japan	1
33	Pigeon Point Systems	1
34	Pinnacle Data Systems	2
35	RadiSys	2
36	Rittal/Kaparel	2
37	SAIC	1
38	Scan Engineering Telecom	1
39	SLAC National Accelerator Lab	2
40	Triple Ring Technologies	1
41	Yamaichi	1
41	**Totals**	60

Rev. 021209

Technical Challenges 2

- Auto-failover software for HA
- Low latency software & firmware protocols for fast feedback systems
- IPMI subsystem
  - Out-Of-Band vs. In-Band systems, HA implications of choices
  - Extension of IPMI to “non-managed-platform” chassis as currently found throughout accelerator systems

WG1 Preliminary SOW Tasks

- Specify AMC's with Rear I/O (AMC-IO) and an associated µRTM
- Consider potential needs for Mezzanine Cards.
- Specify ATCA carrier for the AMC-IO.
- Specify ATCA RTM module to accommodate AMC-IO along with support features such as power, management, JTAG, etc.

WG1 SOW Tasks -2

- Specify e-keying code extensions to the Shelf Management Section to accommodate the additions to the AMC, RTM, µRTM and the µTCA shelf specifications.
- Specify lines, both bussed and radial, that are in both ATCA and µTCA backplanes that could be used for Physics clocks, gates and triggers. If necessary, specify lines that are not in the ATCA and µTCA backplanes but could be added to the RTM and/or µRTM for such use.

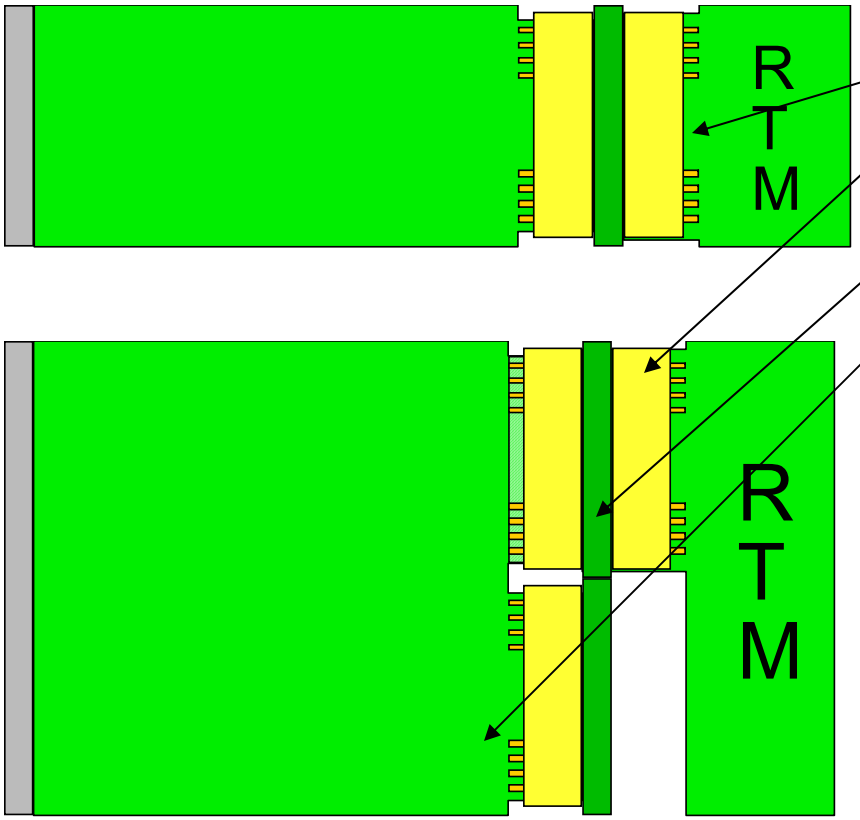
WG2 Preliminary SOW Tasks

- Define protocols and APIs for management and control of real-time data acquisition and machine-control components, to include calibration, synchronization, and triggering mechanisms.
- Define protocols and APIs for high-rate and low-latency distribution of data among the various data acquisition, machine-control, data processing, data storage, and data transmission components, including use of the backplane fabrics within shelves and use of external links between shelves.
- Define the mechanisms and techniques within the ATCA/µTCA infrastructure to manage component-, shelf-, subsystem-, experiment-, and facility-level redundancy and automated failover.

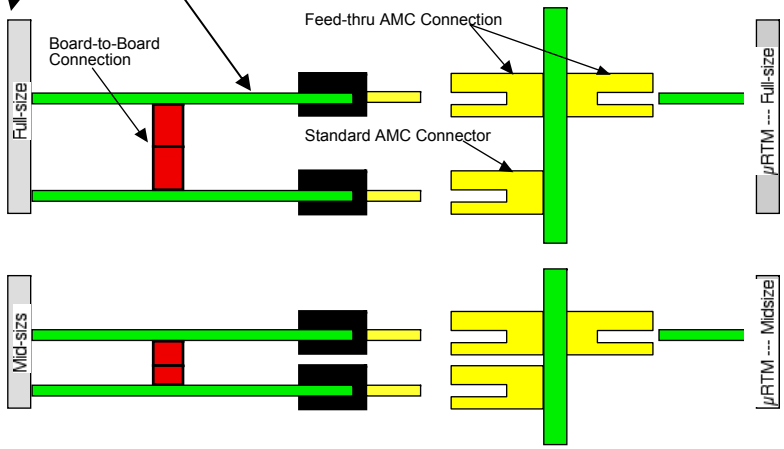
WG2 SOW Tasks -2

- Define protocols and APIs for management of resources within an xTCA network, including identification and allocation of common functional modules among subsystems and experiments, management of active module disposition and status, and auditing of component usage and maintenance.
- Define a common set of APIs and functional blocks at the software and FPGA firmware levels to be provided as a standard development library for xTCA application development, including standard operating system and thread management functions, module identification and data routing functions, standard I/O management functions, and standard data processing blocks.

Technical Challenges 1
Single & Double Wide on µTCA

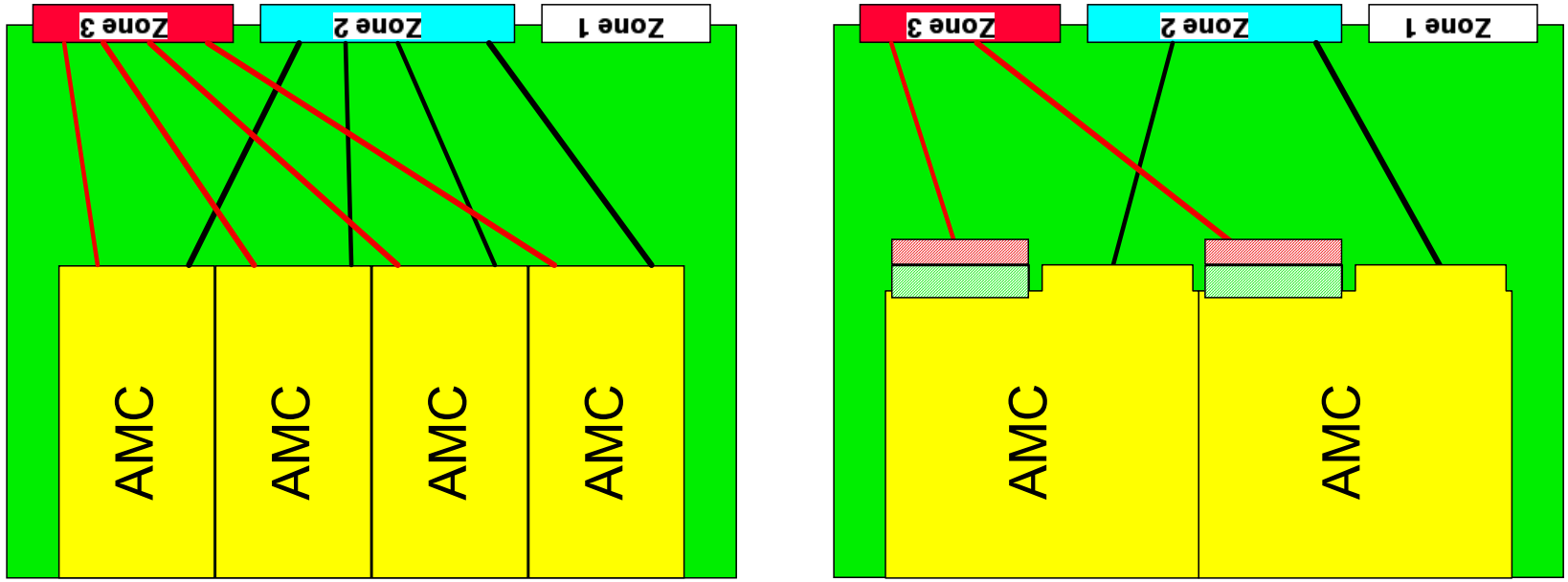


- **Options**
  - **I/O "Stolen lines" vs. separate connectors**
  - **Timing & I/O backplane**
  - **Double wide**
  - **Stacked boards**
  - **Panel width**



Courtesy R. Downing

Single & Double Wide on ATCA Carrier



- All I/O, special timing connections via Zone 3
- All serial data connections via Zone 2
- All Power Zone 1

Courtesy R. Downing

“Stolen Lines” Initial Concept for µRTM

Pin #	Signal	Driven By	Mating	Pin Function on the AMC	Pin #	Signal	Driven By	Mating	Pin Function on the AMC
85	GND	Carrier	First	Ground	86	GND	Carrier	First	Ground
84	PWR	Carrier	First	Power, 12V	87	Rx8-	AMC or Carrier	Third	Port 8 Rcvr -
83	PS0#	Carrier	Last	Presence 0	88	Rx8+		Third	Port 8 Rcvr +
82	GND	Carrier	First	Ground	89	GND	Carrier	First	Ground
81	FCLKA-	FCLKA driver	Third	Fabric Clock A-	90	Tx8-	AMC or Carrier	Third	Port 8 Xmitter -
80	FCLKA+		Third	Fabric Clock A+	91	Tx8+		Third	Port 8 Xmitter +
79	GND	Carrier	First	Ground	92	GND	Carrier	First	Ground
78	TCLKB-	FCLKB driver	Third	Telco Clock B -	93	Rx9-	Carrier	Third	Port 9 Rcvr -
77	TCLKB+		Third	Telco Clock B +	94	Rx9+		Third	Port 9 Rcvr +
76	GND	Carrier	First	Ground	95	GND	Carrier	First	Ground
75	TCLKA-	FCLKC driver	Third	Telco Clock A -	96	Tx9-	AMC	Third	Port 9 Xmitter -
74	TCLKA+		Third	Telco Clock A +	97	Tx9+		Third	Port 9 Xmitter +
73	GND	Carrier	First	Ground	98	GND	Carrier	First	Ground
72	PWR	Carrier	First	Power, 12V	99	Rx10-	Carrier	Third	Port 10 Rcvr -
71	SDA_L	IPMI Agent	Second	IPMB-L Data	100	Rx10+		Third	Port 10 Rcvr +
70	GND	Carrier	First	Ground	101	GND	Carrier	First	Ground
69	Rx7-	Carrier	Third	Port 7 Rcvr -	102	Tx10-	AMC	Third	Port 10 Xmitter -
68	Rx7+		Third	Port 7 Rcvr +	103	Tx10+		Third	Port 10 Xmitter +
67	GND	Carrier	First	Ground	104	GND	Carrier	First	Ground
66	Tx7-	AMC	Third	Port 7 Xmitter -	105	Rx11-	Carrier	Third	Port 11 Rcvr -
65	Tx7+		Third	Port 7 Xmitter +	106	Rx11+		Third	Port 11 Rcvr +
64	GND	Carrier	First	Ground	107	GND	Carrier	First	Ground
63	Rx6-	Carrier	Third	Port 6 Rcvr -	108	Tx11-	AMC	Third	Port 11 Xmitter -
62	Rx6+		Third	Port 6 Rcvr +	109	Tx11+		Third	Port 11 Xmitter +
61	GND	Carrier	First	Ground	110	GND	Carrier	First	Ground
60	Tx6-	AMC	Third	Port 6 Xmitter -	111	I/O 15-	AMC or Carrier	Third	Port 15 I/O -
59	Tx6+		Third	Port 6 Xmitter +	112	I/O 15+		Third	Port 15 I/O +
58	GND	Carrier	First	Ground	113	GND	Carrier	First	Ground
57	PWR	AMC	First	Power, 12V	114	I/O 14-	AMC or Carrier	Third	Port 14 I/O -
56	SCL_L	IPMI Agent	Second	IPMB-L Clock	115	I/O 14+		Third	Port 14 I/O +
55	GND	Carrier	First	Ground	116	GND	Carrier	First	Ground
54	Rx5-	Carrier	Third	Port 5 Rcvr -	117	I/O 13-	AMC or Carrier	Third	Port 13 I/O -
53	Rx5+		Third	Port 5 Rcvr +	118	I/O 13+		Third	Port 13 I/O +
52	GND	Carrier	First	Ground	119	GND	Carrier	First	Ground
51	Tx5-	AMC	Third	Port 5 Xmitter -	120	I/O 12-	AMC or Carrier	Third	Port 12 I/O -
50	Tx5+		Third	Port 5 Xmitter +	121	I/O 12+		Third	Port 12 I/O +
49	GND	Carrier	First	Ground	122	GND	Carrier	First	Ground
48	Rx4-	Carrier	Third	Port 4 Rcvr -	123	I/O 11-	AMC or Carrier	Third	Port 11 I/O -
47	Rx4+		Third	Port 4 Rcvr +	124	I/O 11+		Third	Port 11 I/O +
46	GND	Carrier	First	Ground	125	GND	Carrier	First	Ground
45	Tx4-	AMC	Third	Port 4 Xmitter -	126	I/O 10-	AMC or Carrier	Third	Port 10 I/O -
44	Tx4+		Third	Port 4 Xmitter +	127	I/O 10+		Third	Port 10 I/O +
43	GND	Carrier	First	Ground	128	GND	Carrier	First	Ground
42	PWR	Carrier	First	Power, 12V	129	I/O 9-	AMC or Carrier	Third	Port 9 I/O -
41	ENABLE#	Carrier	Second	AMC Enable	130	I/O 9+		Third	Port 9 I/O +
40	GND	Carrier	First	Ground	131	GND	Carrier	First	Ground
39	Rx3-	Carrier	Third	Port 3 Rcvr -	132	I/O 8-	AMC or Carrier	Third	Port 8 I/O -
38	Rx3+		Third	Port 3 Rcvr +	133	I/O 8+		Third	Port 8 I/O +
37	GND	Carrier	First	Ground	134	GND	Carrier	First	Ground
36	Tx3-	AMC	Third	Port 3 Xmitter -	135	TCLKC-	FCLKC driver	Third	Telco Clock C -
35	Tx3+		Third	Port 3 Xmitter +	136	TCLKC+		Third	Telco Clock C +
34	GND	Carrier	First	Ground	137	GND	Carrier	First	Ground
33	Rx2-	Carrier	Third	Port 2 Rcvr -	138	TCLKD-	FCLKD driver	Third	Telco Clock D -
32	Rx2+		Third	Port 2 Rcvr +	139	TCLKD+		Third	Telco Clock D +
31	GND	Carrier	First	Ground	140	GND	Carrier	First	Ground

30	Tx2-	AMC	Third	Port 2 I/O -	141	I/O 7-	AMC or Carrier	Third	Port 7 I/O -
29	Tx2+		Third	Port 2 I/O +	142	I/O 7+		Third	Port 7 I/O +
28	GND	Carrier	First	Ground	143	GND	Carrier	First	Ground
27	PWR	Carrier	First	Power, 12V	144	I/O 6-	AMC or Carrier	Third	Port 6 I/O -
26	GA2	Carrier	Second	Geog. Addr. 2	145	I/O 6+		Third	Port 6 I/O +
25	GND	Carrier	First	Ground	146	GND	Carrier	First	Ground
24	Rx1-	Carrier	Third	Port 1 I/O -	147	I/O 5-	AMC or Carrier	Third	Port 5 I/O -
23	Rx1+		Third	Port 1 I/O +	148	I/O 5+		Third	Port 5 I/O +
22	GND	Carrier	First	Ground	149	GND	Carrier	First	Ground
21	Tx1-	AMC	Third	Port 1 I/O -	150	I/O 4-	AMC or Carrier	Third	Port 4 I/O -
20	Tx1+		Third	Port 1 I/O +	151	I/O 4+		Third	Port 4 I/O +
19	GND	Carrier	First	Ground	152	GND	Carrier	First	Ground
18	PWR	Carrier	First	Power, 12V	153	I/O 3-	AMC or Carrier	Third	Port 3 I/O -
17	GA1	Carrier	Second	Geog. Addr. 1	154	I/O 3+		Third	Port 3 I/O +
16	GND	Carrier	First	Ground	155	GND	Carrier	First	Ground
15	Rx0-	Carrier	Third	Port 0 I/O -	156	I/O 2-	AMC or Carrier	Third	Port 2 I/O -
14	Rx0+		Third	Port 0 I/O +	157	I/O 2+		Third	Port 2 I/O +
13	GND	Carrier	First	Ground	158	GND	Carrier	First	Ground
12	Tx0-	AMC	Third	Port 0 I/O -	159	I/O 1-	AMC or Carrier	Third	Port 1 I/O -
11	Tx0+		Third	Port 0 I/O +	160	I/O 1+		Third	Port 1 I/O +
10	GND	Carrier	First	Ground	161	GND	Carrier	First	Ground
9	PWR	Carrier	First	Power, 12V	162	I/O 0-	AMC or Carrier	Third	Port 0 I/O -
8	RSRVD8		Second	Reserved	163	I/O 0+		Third	Port 0 I/O +
7	GND	Carrier	First	Ground	164	GND	Carrier	First	Ground
6	RSRVD6		Second	Reserved	165	TCK	Carrier	Second	JTAG Clk In
5	GA0	Carrier	Second	Geog. Addr. 0	166	TMS	Carrier	Second	JTAG Mode Sel In
4	MP	Carrier	First	Power, 3.3V	167	TRST#	Carrier	Second	JTAG Rst In
3	PS1#	AMC	Last	Presence 1	168	TDO	AMC	Second	JTAG Data Out
2	PWR	Carrier	First	Power, 12V	169	TDI	Carrier	Second	JTAG Data In
1	GND	Carrier	First	Ground	170	GND	Carrier	First	Ground

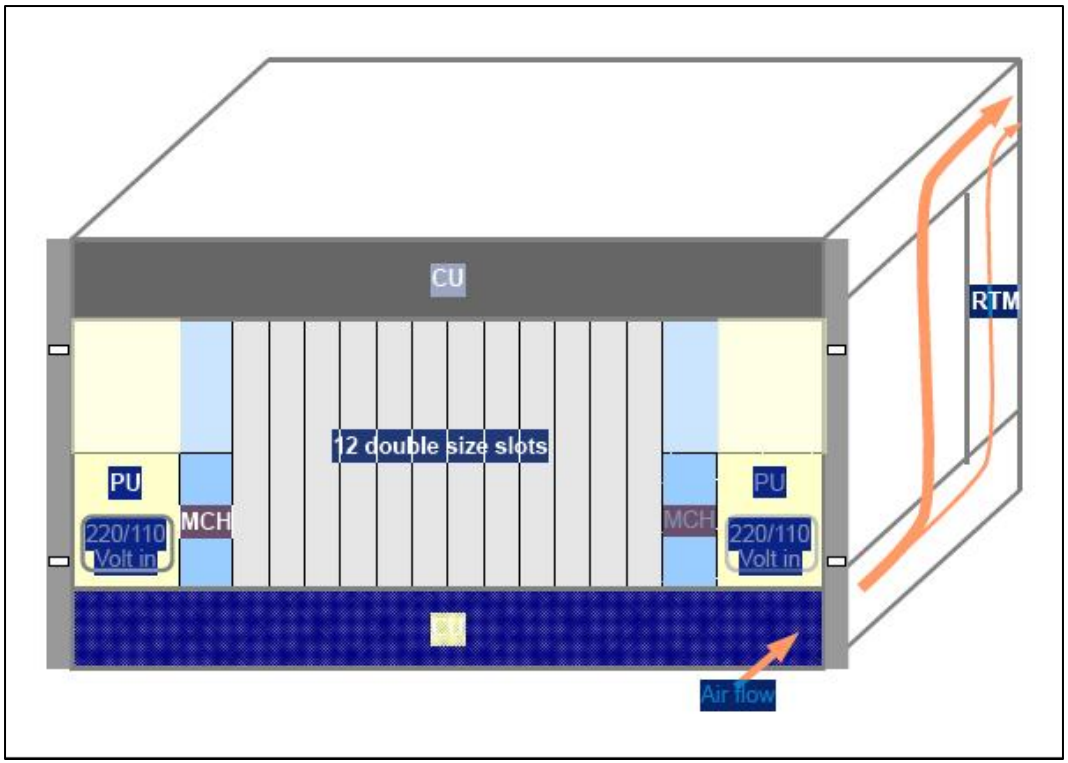
KEY

Color	Function	# Pins	Notes
	Ground	56	
	Power +12 V	8	limited to 80 W for AMC module
	Power +3.3 V	1	power for management
	System Management Interface	13	Mgmt. - 5, GA - 3, JTAG - 5
	Common Options Fabrics	16	reserve 4 channels for fabric connections
	Clocks	10	telco spec'd, useful?
	RTM signals	64	16 channels converted to 32 diff. RTM I/O
	Reserved	2	do not use!
	total	170	

- Appropriated unused Telco Lines for Physics I/O, clocks-sync-triggers
- Note: Precision clocks best on star configuration, not bussed
- Could use extraneous 10GbE lanes

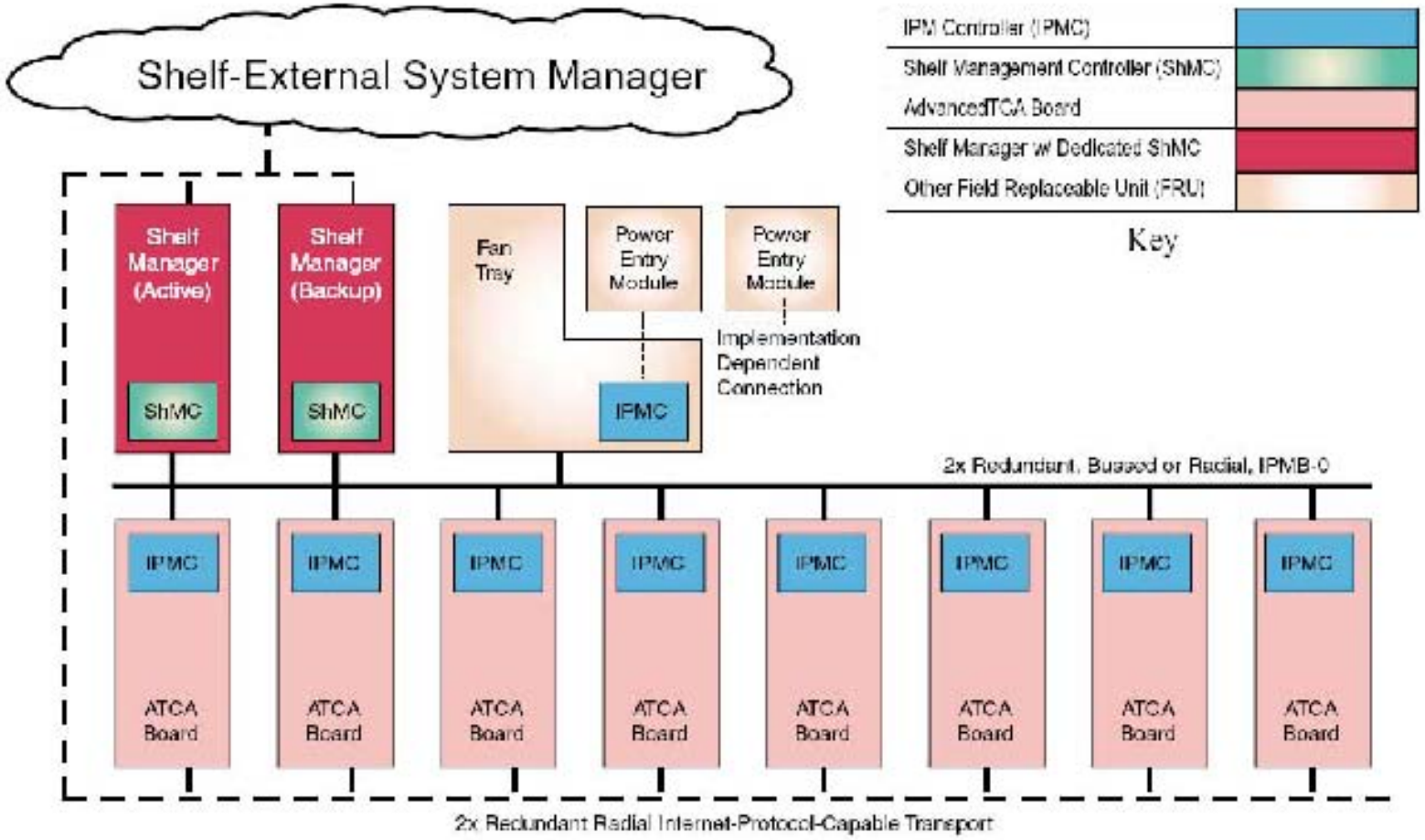
Pin #	Signal	Driven By	Mating	Pin Function on AMC	Physics definition of Function on AMC
81	FCLKA-	FCLKA driver	Third	Fabric Clock A-	Used for PCIe in Physics
82	FCLKA-		Third	Fabric Clock A+	Used for PCIe in Physics
78	TCLKB-	TCLKB driver	Third	Telco Clock B-	Physics Clock B-
77	TCLKB+		Third	Telco Clock B+	Physics Clock B+
75	TCLKA-	TCLKA driver	Third	Telco Clock A-	Physics Clock A-
74	TCLKA-		Third	Telco Clock A+	Physics Clock A+
135	TCLKC-	TCLKC driver	Third	Telco Clock C-	Physics Clock C-
136	TCLKC+		Third	Telco Clock C+	Physics Clock C+
138	TCLKD-	TCLKD driver	Third	Telco Clock D-	Physics Clock D-
139	TCLKD+		Third	Telco Clock D+	Physics Clock D+

MicroTCA Shelf Concept (Kay Rehlich, DESY)



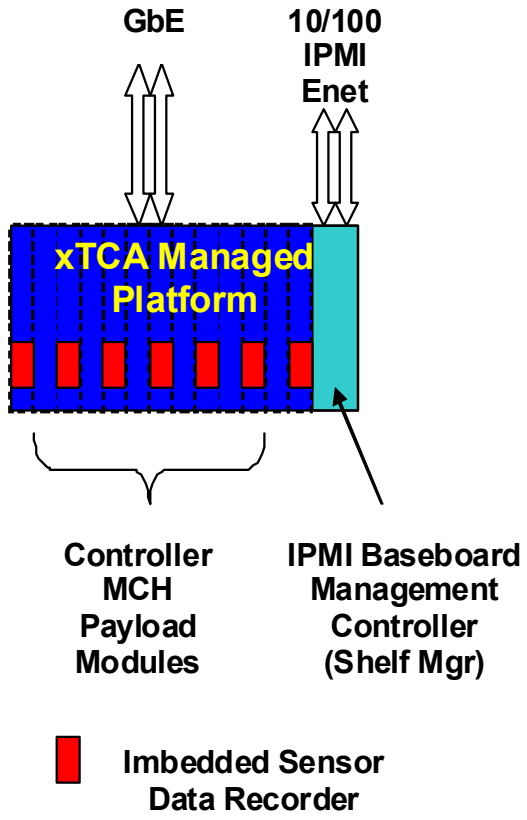
- *Features*
  - *12-Double high payload slots*
  - *RTM powered*
  - *Dual bulk power*
  - *Dual MCH-Shelf Manager*
  - *Accommodates standard AMC's in half height*
  - *Scalable number of payloads*
  - *Scalable redundancy*

IPMI in ATCA (Chris Engels, 2008 Tutorial)

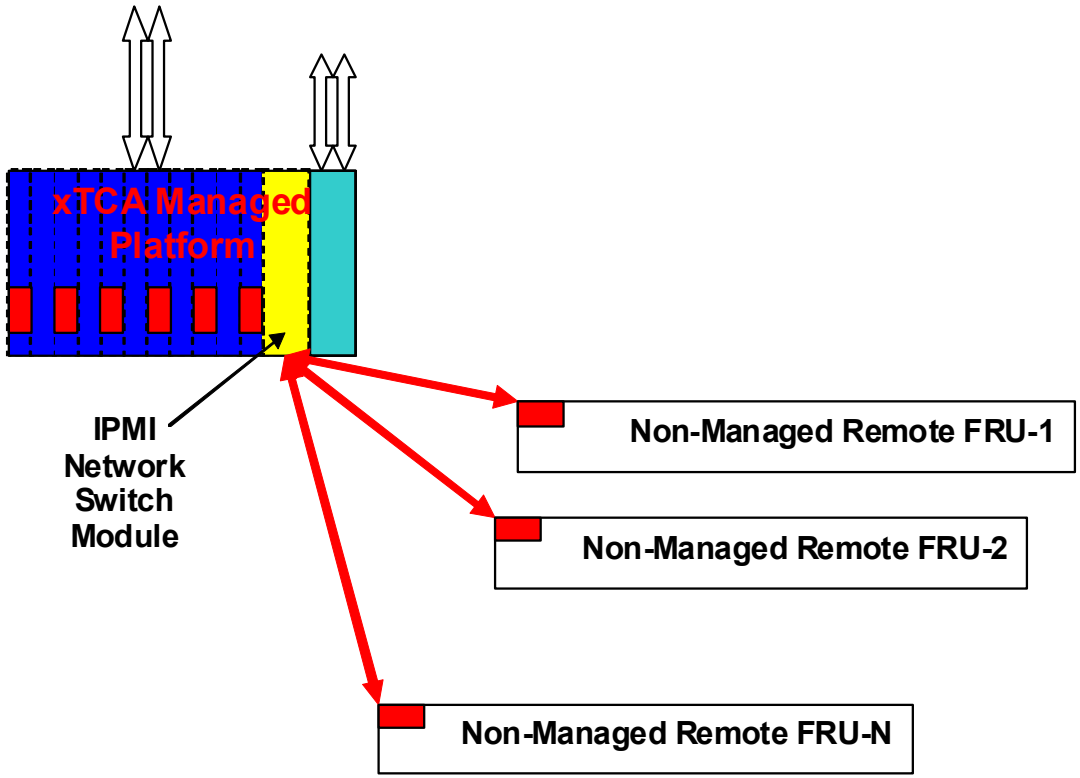


IPMI is the main Protocol of System Management

IPMI Concepts for Managed, Non-Managed Platform Extensions

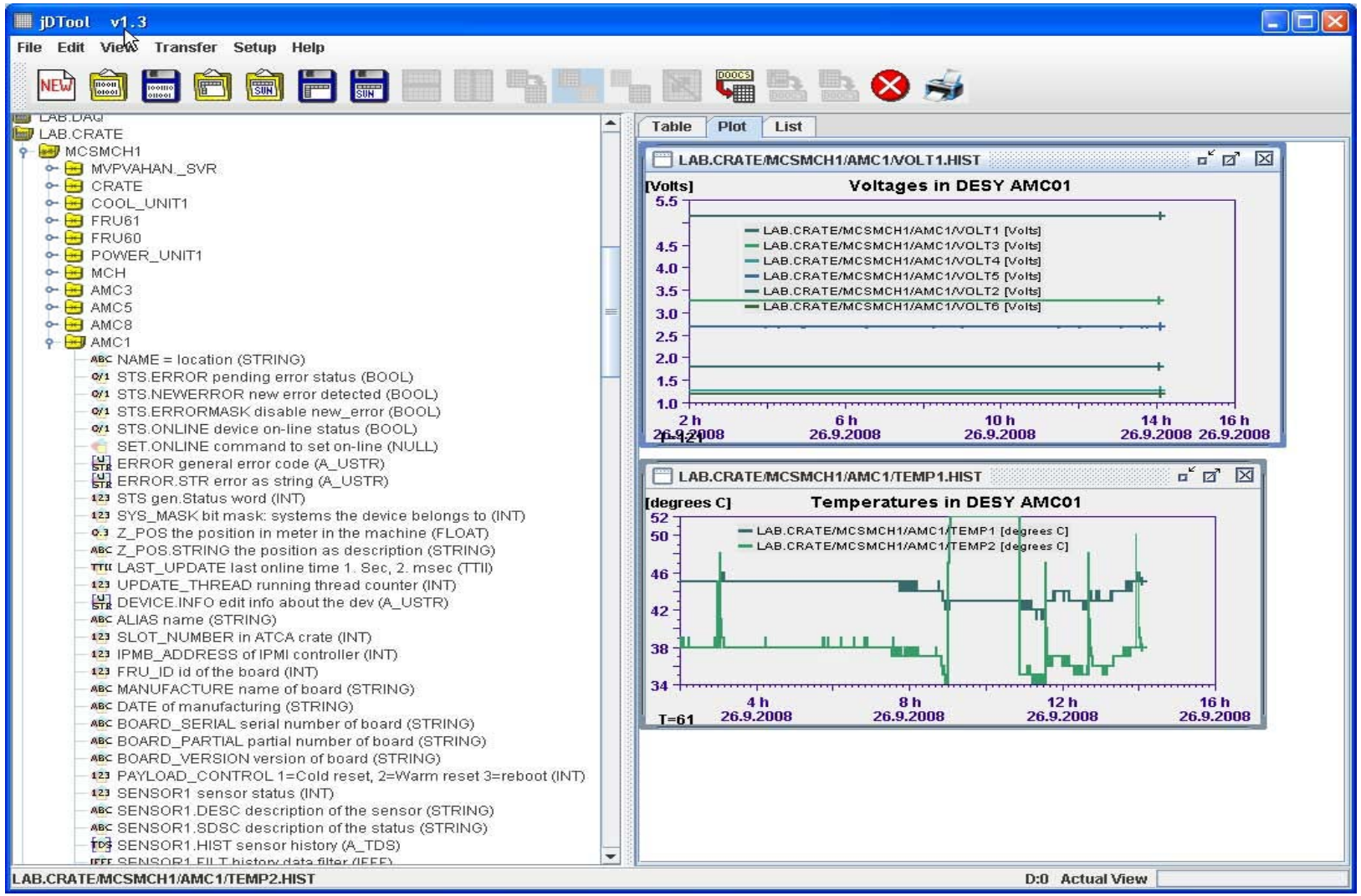


A. Managed System with Shelf IPMI



B. Managed System with Shelf IPMI Extended to Remote FRUs

IPMI Example – DESY (Kay Rehlich)



IPMI Developments – DESY (Kay Rehlich)

- **IMPI code on Atmel-128**
  - Implements version 1.5 functions
  - FPGA code loading in preparation
- **IPMI control system integration**
  - Control System server for ATCA, µTCA and computers
  - IPMI communication via Ethernet to the crates
  - Extracts from IPMI the available information
  - Creates a dynamic list of AMC modules
  - Creates a dynamic list of sensors
  - Archives values and provides reset/boot commands to FPGAs or CPUs
  - Required configuration: one entry per crate (IP name)