

128 Gbps PCIe Link for Data Acquisition with MTCA.4

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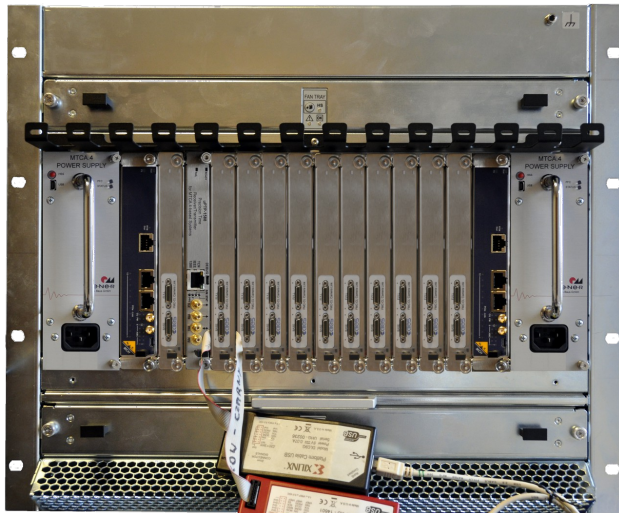
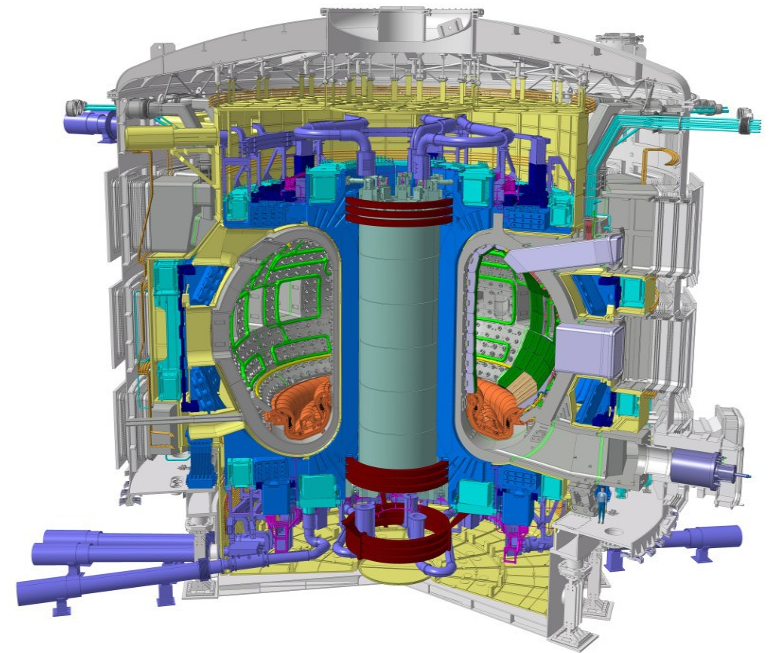
Agenda

- Motivation
- Image Acquisition Systems in MTCA.4
- Example of IAS
- Test Procedure
- Data Throughput Measurements
- Summary

Motivation #1

Challenges in design of imaging systems for plasma diagnostics:

- ◆ ~50 cameras 1 – 8 Mpx @ 50 – 50000 FPS
- ◆ Throughput can exceed 16 Gb/s per device
- ◆ High scalability and reliability
- ◆ 50 ns synchronization accuracy



Micro Telecommunication Computing Architecture:

- ◆ High scalability
- ◆ Extensions for precision timing and synchronization
- ◆ Intelligent Platform Management
- ◆ Good price to performance ratio

Motivation #2

A typical Image Acquisition System (IAS)

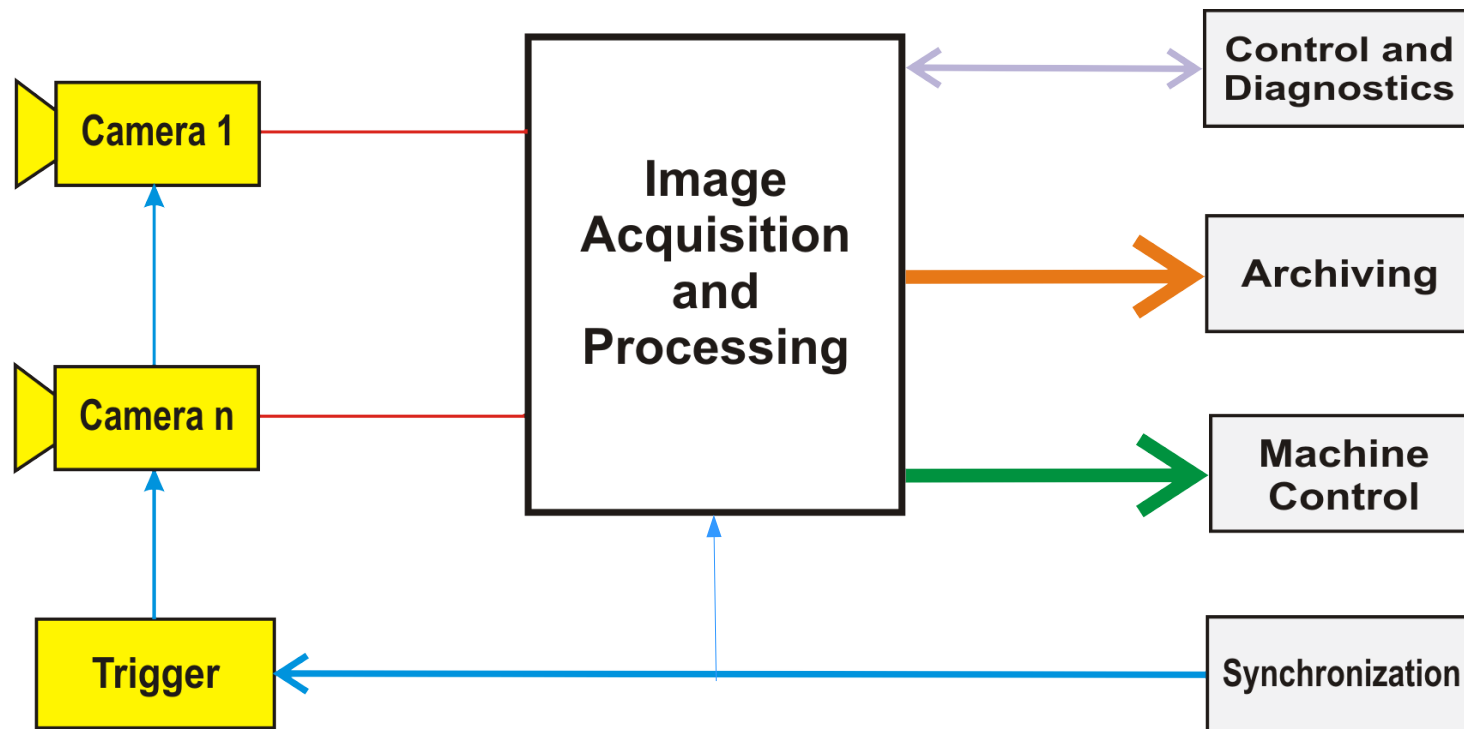


Image Acquisition Systems in MTCA.4

MTCA.4 Chassis

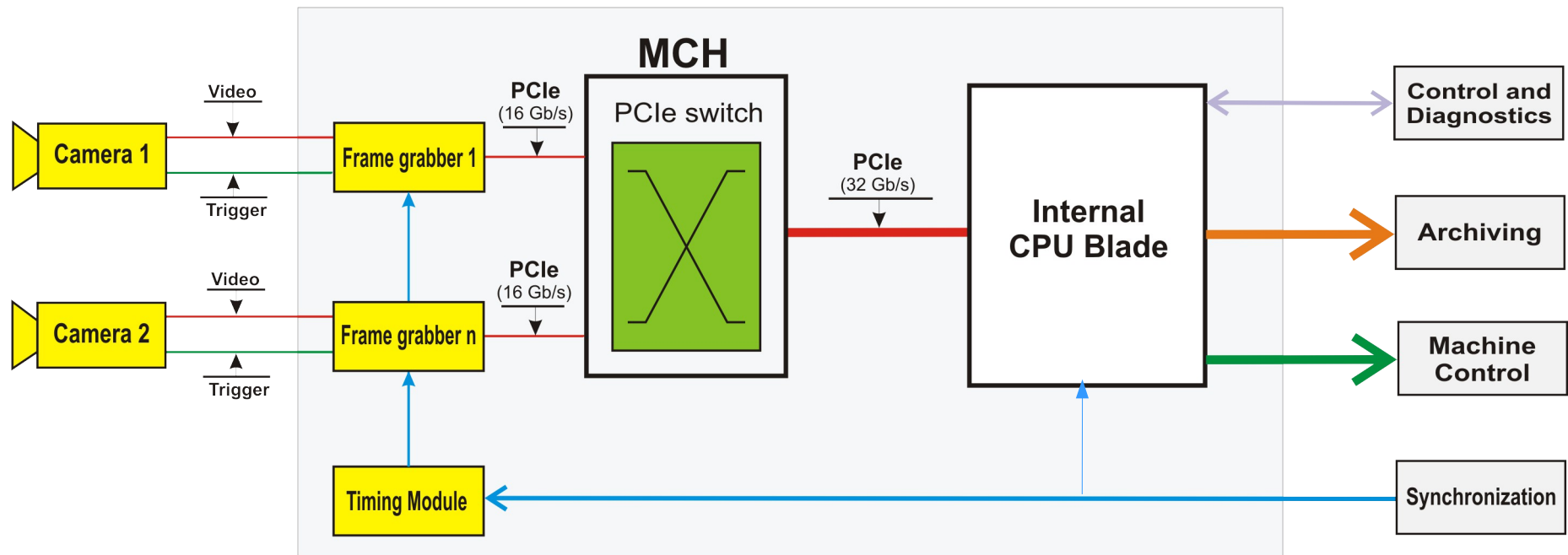
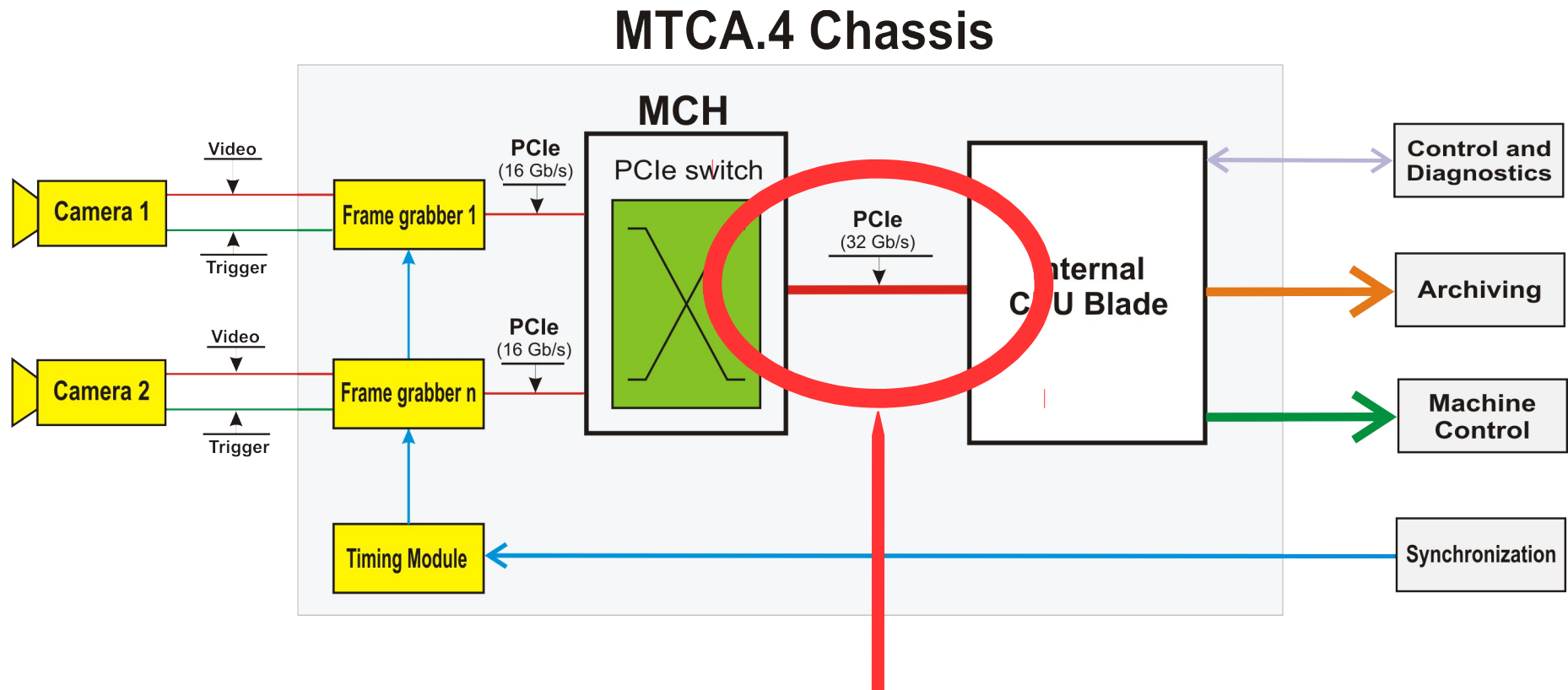
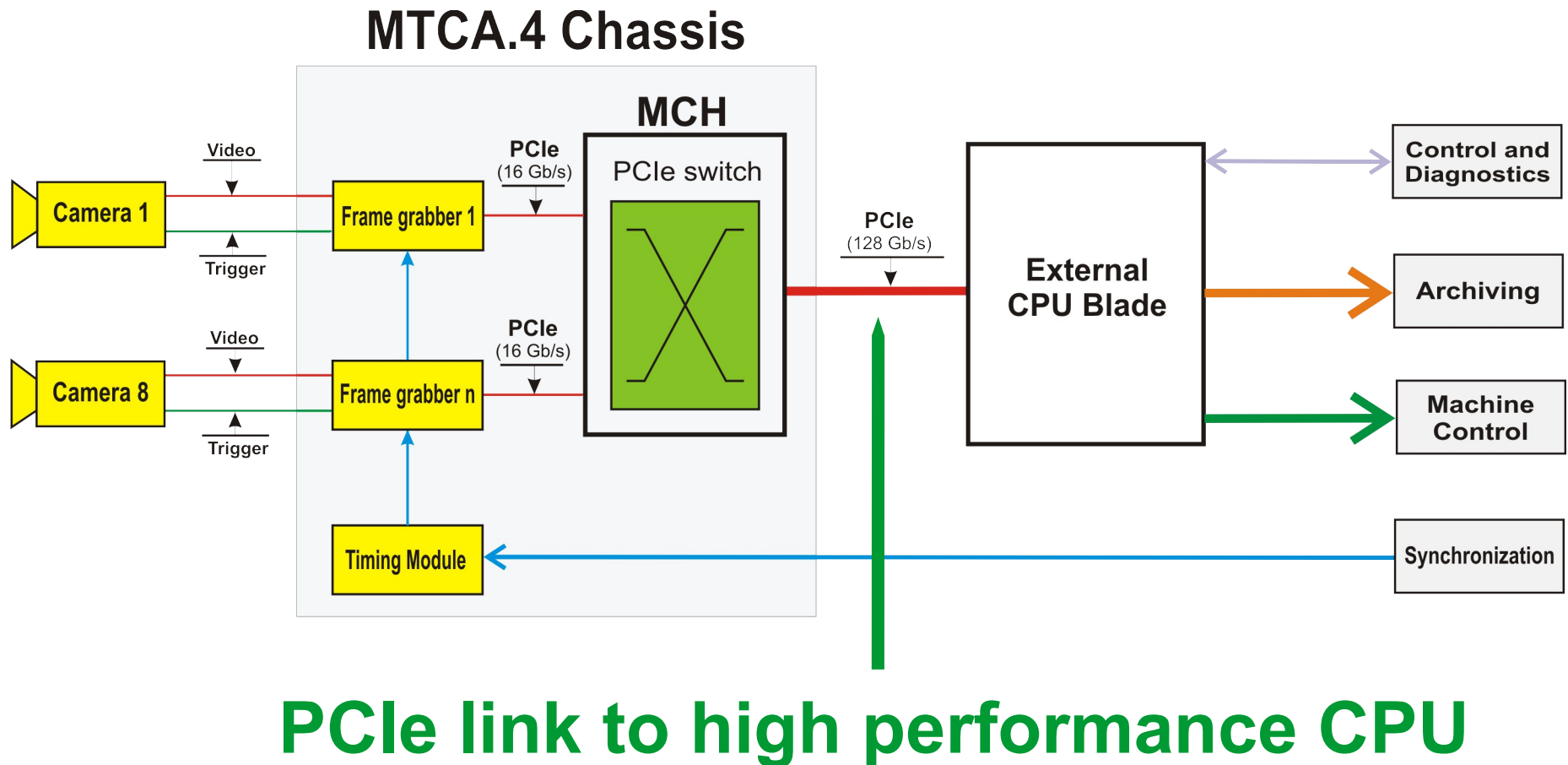


Image Acquisition Systems in MTCA.4



Limits performance and scalability of IAS

MTCA.4 - High Performance Solution



Parameters of Tested Visible Light Camera

Camera features:

- ◆ 3 Mpx high speed CMOS sensor
- ◆ High resolution: 1696 x 1710 pixel
- ◆ 256 levels of grey (8 bit resolution)
- ◆ Up to 285 frames/s at full resolution
- ◆ Up to 180 000 (275 000) frames/s with reduced resolution
- ◆ Extended-Full Camera Link Interface
- ◆ ITER requirements
 - ◆ 1 Mpx @ 1000 fps
 - ◆ Data throughput 8 Gbps



Image Acquisition System for ITER Tokamak Use Case

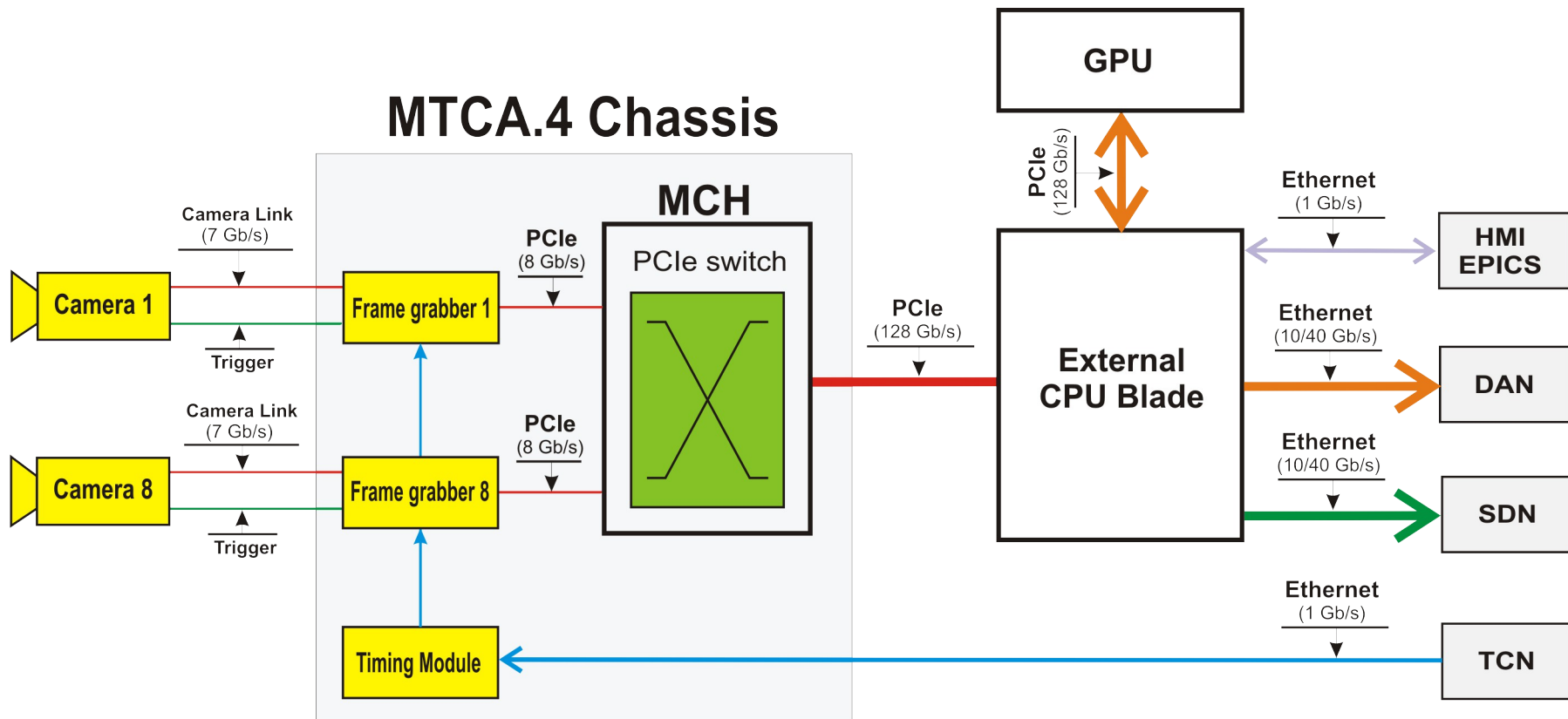
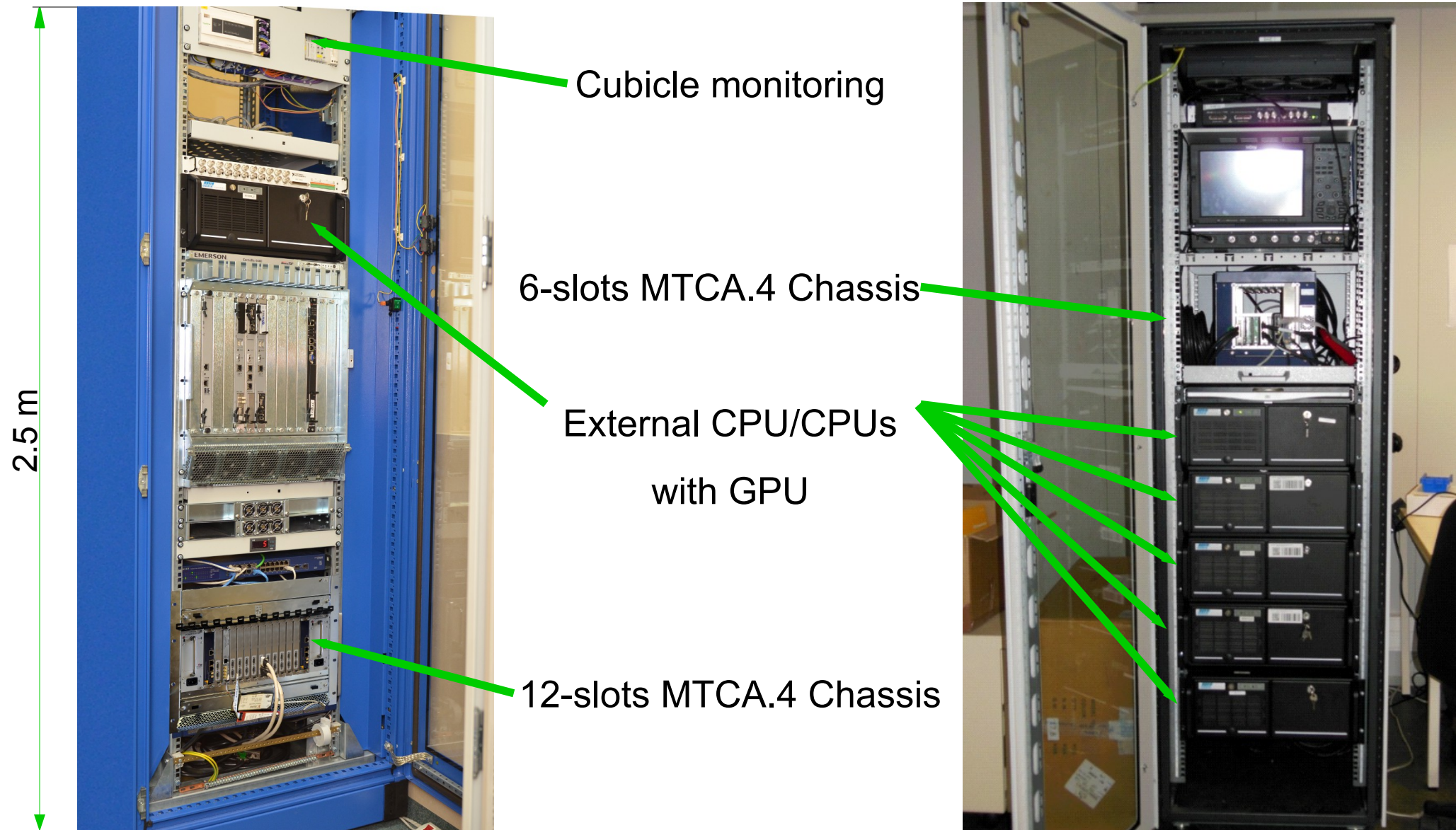
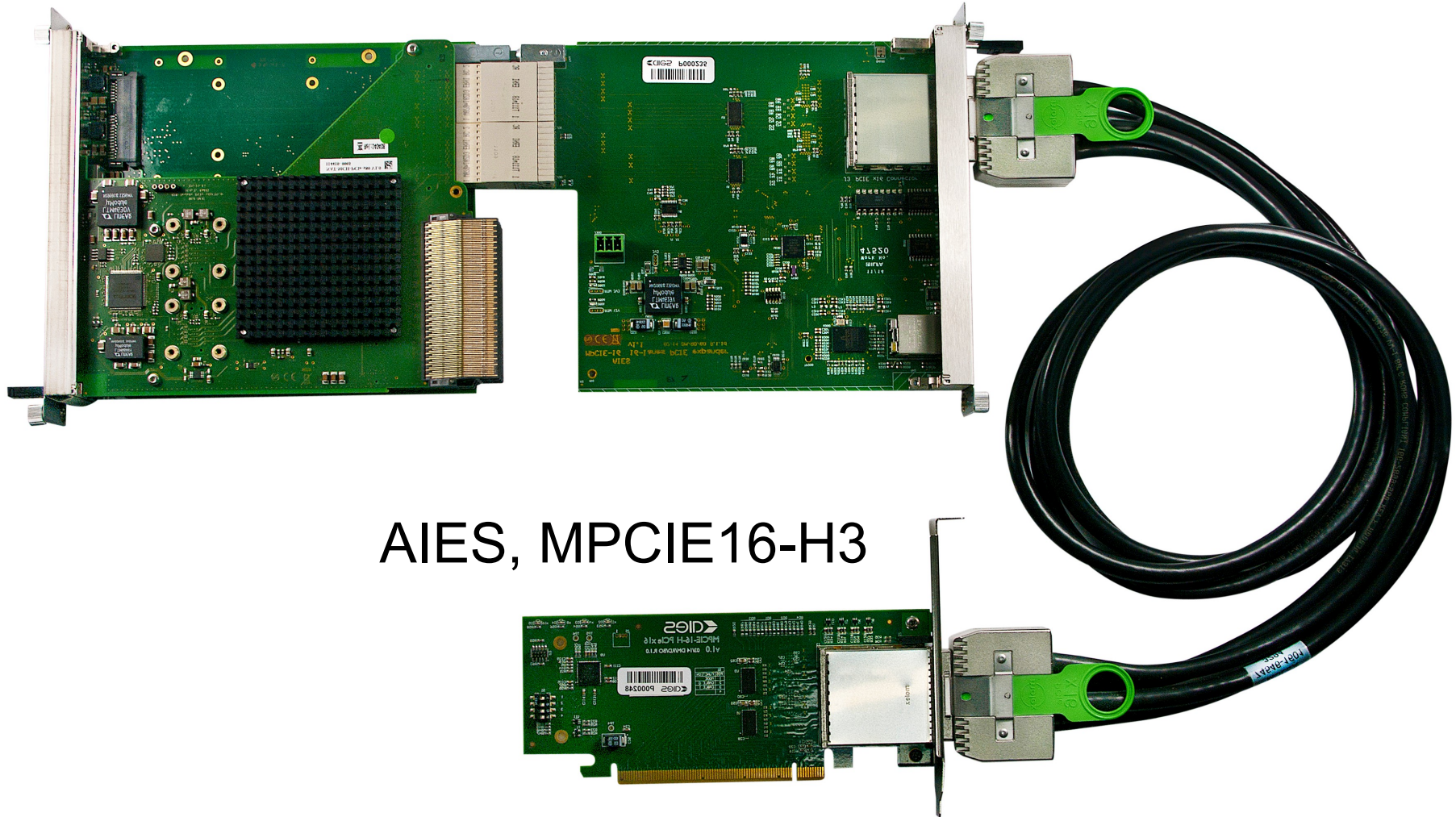


Image Acquisition System in Cubicle



Hardware – PCIe x16 Link for MTCA.4

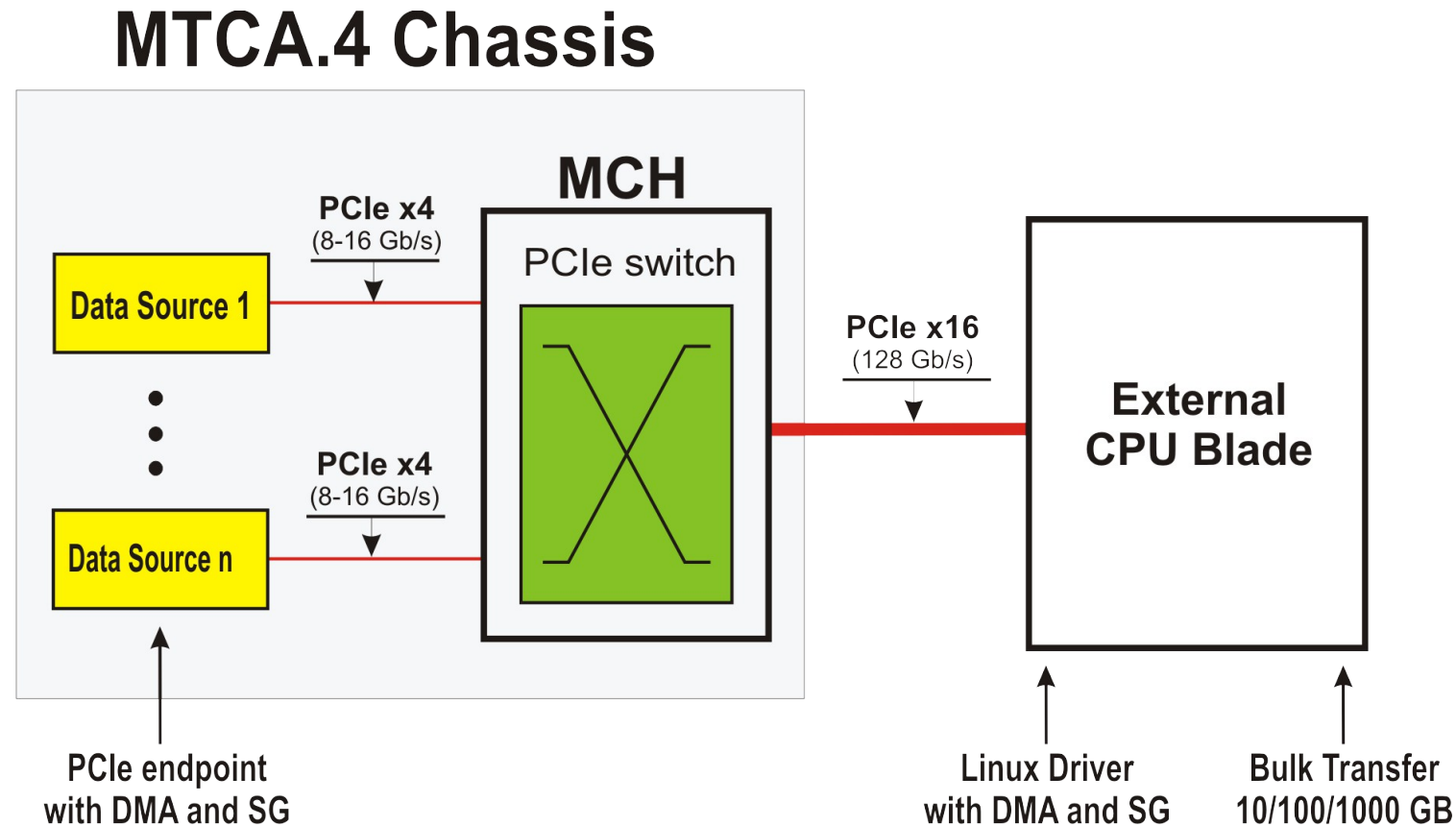
NAT, MCH-PHYS80 AIES, MPCIE16-T3



AIES, MPCIE16-H3

PCIe Link Test Procedure

- ▶ AMC modules with PCIe endpoints produce data
- ▶ Data are sent using PCIe SG-DMA
- ▶ Camera is not used
- ▶ Correctness of PCIe transfers verified with Advanced Error Reporting

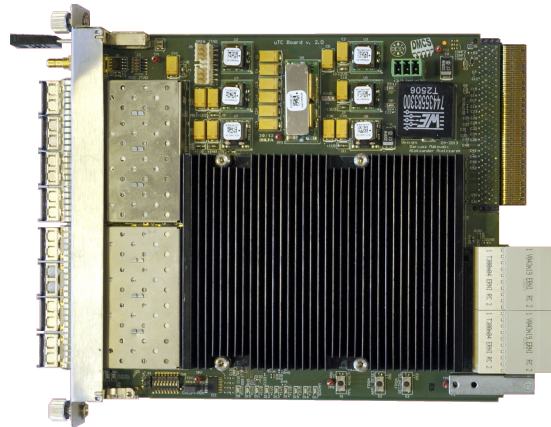


```
dd if=/dev/dmcs4 of=/dev/null bs=1000 count=1000
```

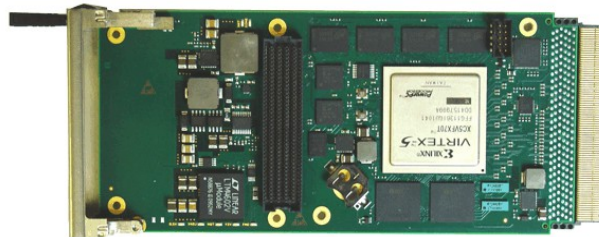
1048576000000 bytes (1.0 TB) copied, 665.112 s, 1.6 GB/s

Data Source – Frame Grabber Card

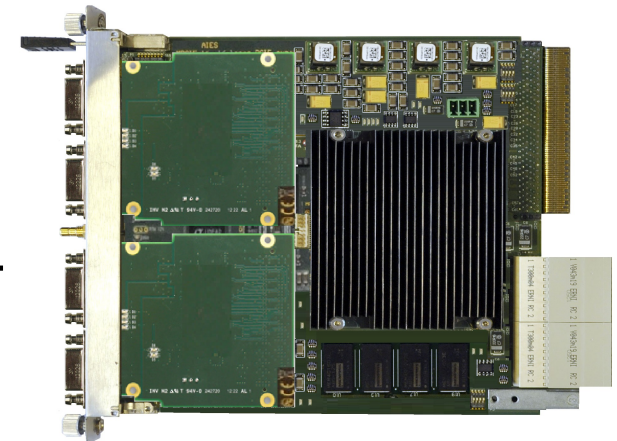
- Three types of AMC modules applied as data sources
 - ♦ AIES, MFG4 – Dual Frame Grabber card
 - ♦ TEWS, TAMC 641 – Single Frame Grabber card
 - ♦ Vadatech/Desy, CM045/TCK7 – Data Processing Module (LLRF)



DESY TCK7/
VADATECH
CM045



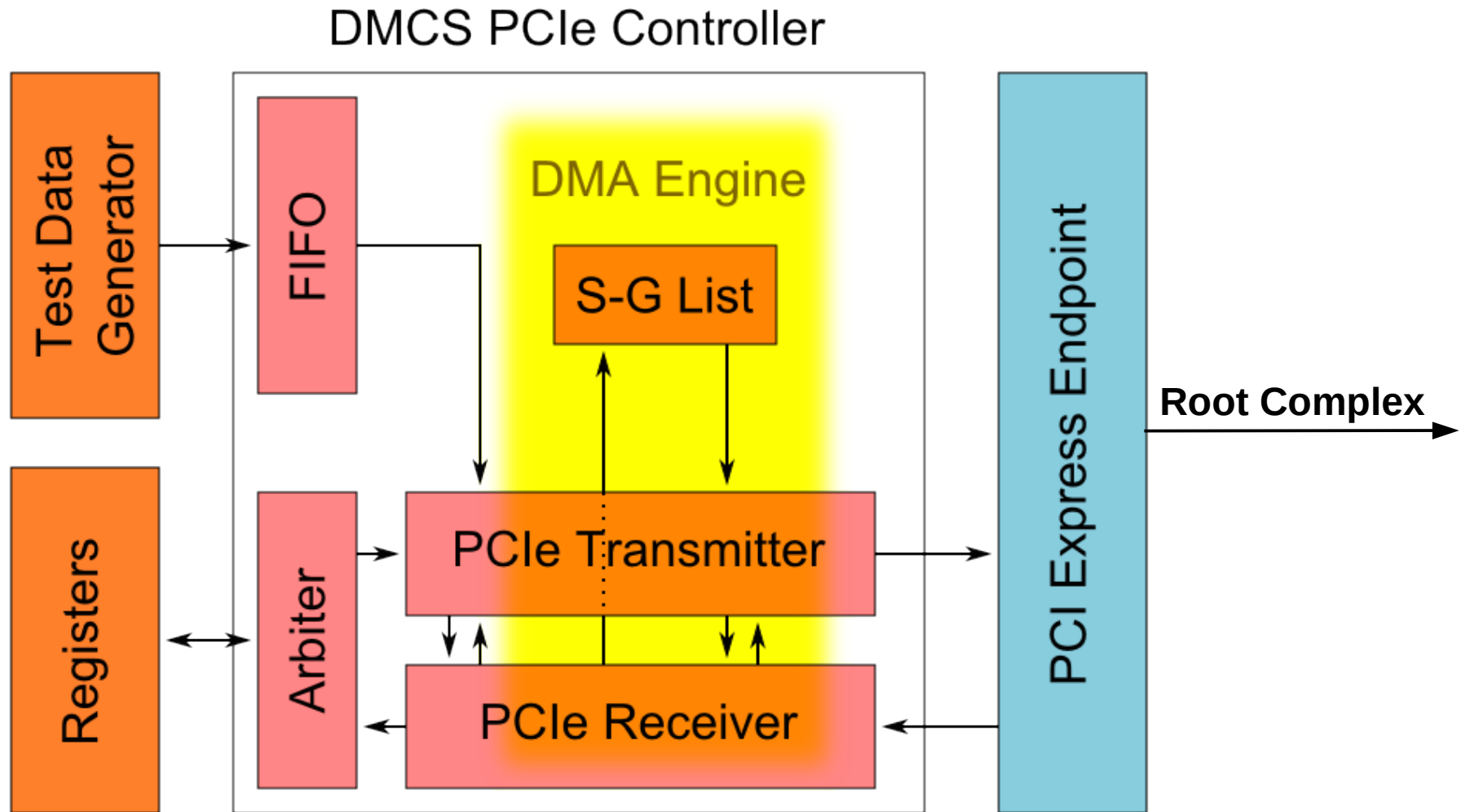
TEWS,
TAMC 641



AIES,
MFG4

Module	Manufacturer	Type	Function	FPGA	Throughput
MFG4	AIES	Dual FMC carrier	Dual Frame Grabber card	Artix 7	16 Gbps
TAMC641	TEWS	Single FMC carrier	Single Frame Grabber card	Virtex 5	8 Gbps
CM045/TCK7	DESY/Vadatech	Data processing module	Dual AMC	Kintex 7	16 Gbps

Data Source PCIe Endpoint with PCIe DMA and SG List



Hardware – Root Complex

- ♦ Desktop CPU with PCIe gen. 3 (8 GT), x16 link (128 Gbps)
 - ♦ Intel i5 CPU @ 3.2 GHz
 - ♦ Ubuntu 14.04, Kernel 3.13.0
- ♦ Industrial CPU with PCIe gen. 2 (5 GT), x8 link (64 Gbps)
 - ♦ Intel Xeon CPU @ 2.53 GHz
 - ♦ Red Hat Enterprise 6.3, Kernel 2.6.32
- ♦ Various PCIe cables (only copper connection was tested): 1 m, 3 m, 7 m

Example Results from Data Throughput Tests

```
dmcs@dmcs-All-Series:~/dm$ ps -aux | grep dd
```

```
dmcs    2629  6.4 12.7 1031236 1024536 pts/0 S   23:56   0:00 dd if=/dev/dmcs3 of=/dev/null bs=1000M count=1000
dmcs    2630  8.8 12.7 1031236 1024476 pts/0 S   23:56   0:00 dd if=/dev/dmcs4 of=/dev/null bs=1000M count=1000
dmcs    2631  7.8 12.7 1031236 1024536 pts/0 S   23:56   0:00 dd if=/dev/dmcs5 of=/dev/null bs=1000M count=500
dmcs    2632  8.4 12.7 1031236 1024532 pts/0 S   23:56   0:00 dd if=/dev/dmcs6 of=/dev/null bs=1000M count=1000
dmcs    2633  9.4 12.7 1031236 1024436 pts/0 S   23:56   0:00 dd if=/dev/dmcs7 of=/dev/null bs=1000M count=1000
```

```
dmcs@dmcs-All-Series:~/dm$
```

524288000000 bytes (524 GB) copied, 667.076 s, 786 MB/s

1048576000000 bytes (1.0 TB) copied, 748.096 s, 1.4 GB/s

1048576000000 bytes (1.0 TB) copied, 748.788 s, 1.4 GB/s

1048576000000 bytes (1.0 TB) copied, 815.423 s, 1.3 GB/s

1024458752000 bytes (1.0 TB) copied, 838.478 s, 1.2 GB/s

Example Results from Data Throughput Tests #1

Single module			
Module	Size	Throughput	
AM045/TCK7	10 GB	1,4	GB/s
AM045/TCK7	10 GB	1,3	GB/s
MFG4	10 GB	1,4	GB/s
MFG4	10 GB	1,3	GB/s
TAMC641	10 GB	0,75	GB/s

Single module			
Module	Size	Throughput	
AM045/TCK7	100 GB	1,5	GB/s
AM045/TCK7	100 GB	1,5	GB/s
MFG4	100 GB	1,5	GB/s
MFG4	100 GB	1,5	GB/s
TAMC641	100 GB	0,77	GB/s

Single module			
Module	Size	Throughput	
AM045/TCK7	1000 GB	1,6	GB/s
AM045/TCK7	1000 GB	1,5	GB/s
MFG4	1000 GB	1,5	GB/s
MFG4	1000 GB	1,6	GB/s
TAMC641	1000 GB	0,77	GB/s

Example Results from Data Throughput Tests #2

Two modules			
Module	Size	Throughput	
AM045/TCK7	1000 GB	1,5	GB/s
AM045/TCK7	1000 GB	1,5	GB/s

Three modules			
Module	Size	Throughput	
AM045/TCK7	1000 GB	1,5	GB/s
AM045/TCK7	1000 GB	1,5	GB/s
MFG4	1000 GB	1,5	GB/s

Four modules			
Module	Size	Throughput	
AM045/TCK7	1000 GB	1,5	GB/s
AM045/TCK7	1000 GB	1,5	GB/s
MFG4	1000 GB	1,5	GB/s
TAMC641	524 GB	0,76	GB/s
Total		5,26	GB/s
		42,07	Gb/s

Five modules			
Module	Size	Throughput	
AM045/TCK7	105 GB	1,4	GB/s
AM045/TCK7	105 GB	1,3	GB/s
MFG4	105 GB	1,2	GB/s
MFG4	105 GB	1,4	GB/s
TAMC641	52 GB	0,77	GB/s
Total		6,07	GB/s
		48,56	Gb/s

Five modules			
Module	Size	Throughput	
AM045/TCK7	1000 GB	1,4	GB/s
AM045/TCK7	1000 GB	1,4	GB/s
MFG4	1000 GB	1,2	GB/s
MFG4	1000 GB	1,3	GB/s
TAMC641	524 GB	0,78	GB/s
Total		6,08	GB/s
		48,64	Gb/s

Summary

- ♦ PCIe x16 copper link, dedicated for MTCA.4 systems was successfully tested
- ♦ The PCIe link to external CPU allows to overcome the limitations of MTCA.4
- ♦ The maximum data throughput for PCIe x4, gen. 2 endpoint (Xilinx Artix and Kintex FPGAs) was 1.6 GBps
- ♦ Single MTCA.4 chassis could acquire data from up to 6-12 cameras
- ♦ More tests are planned for the full image processing path (GPU, DAN, SDN)

Thank you for your attention