



# ELI Beamlines CS Status

Pavel Bastl, June 21th. 2016, 30<sup>th</sup> annual TANGO meeting, ONERA, Toulouse







## Laser Building

First Floor

### Support Room

Cryogenic systems, power supply cooling, auxiliary systems

### Laser 1

100 mJ 1kHz beamlines

### Laser 2

PW / 20 J / 10 Hz beamline

### Laser 3

PW / 30 J / 10 Hz beamline

### Laser 4

10 PW / 1.5 kJ beamline

Ground Floor

### Experimental Hall 1

Material & biomolecular applications

### Experimental Hall 2

X-ray sources

### Experimental Hall 3

Plasma Physics

### Laser 4c

10 PW pulse compressors

### Experimental Hall 4

Proton acceleration

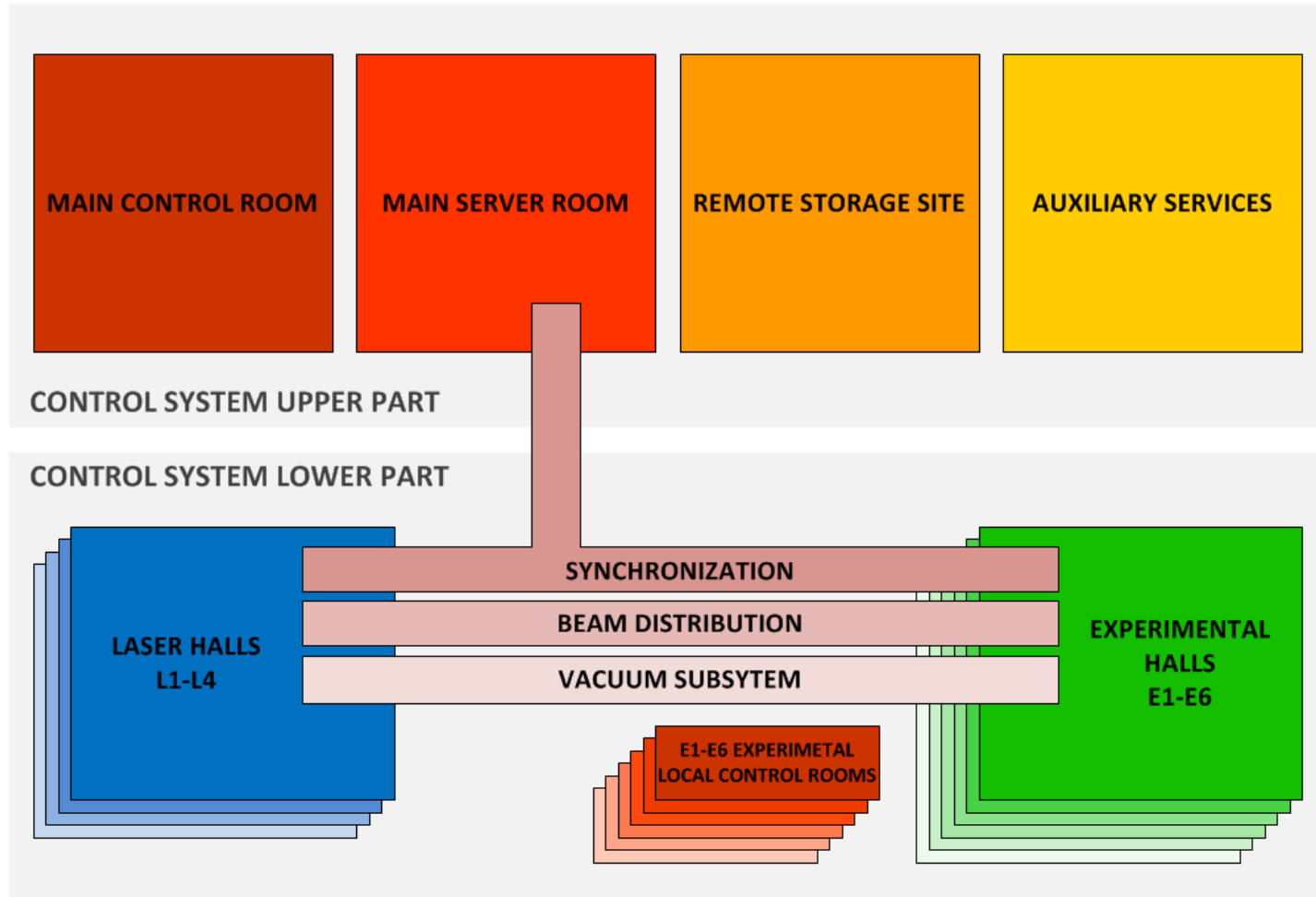
Basement

### Experimental Hall 5

Electron acceleration

### Experimental Hall 6

# Control view and subsystems



## TECHNOLOGY

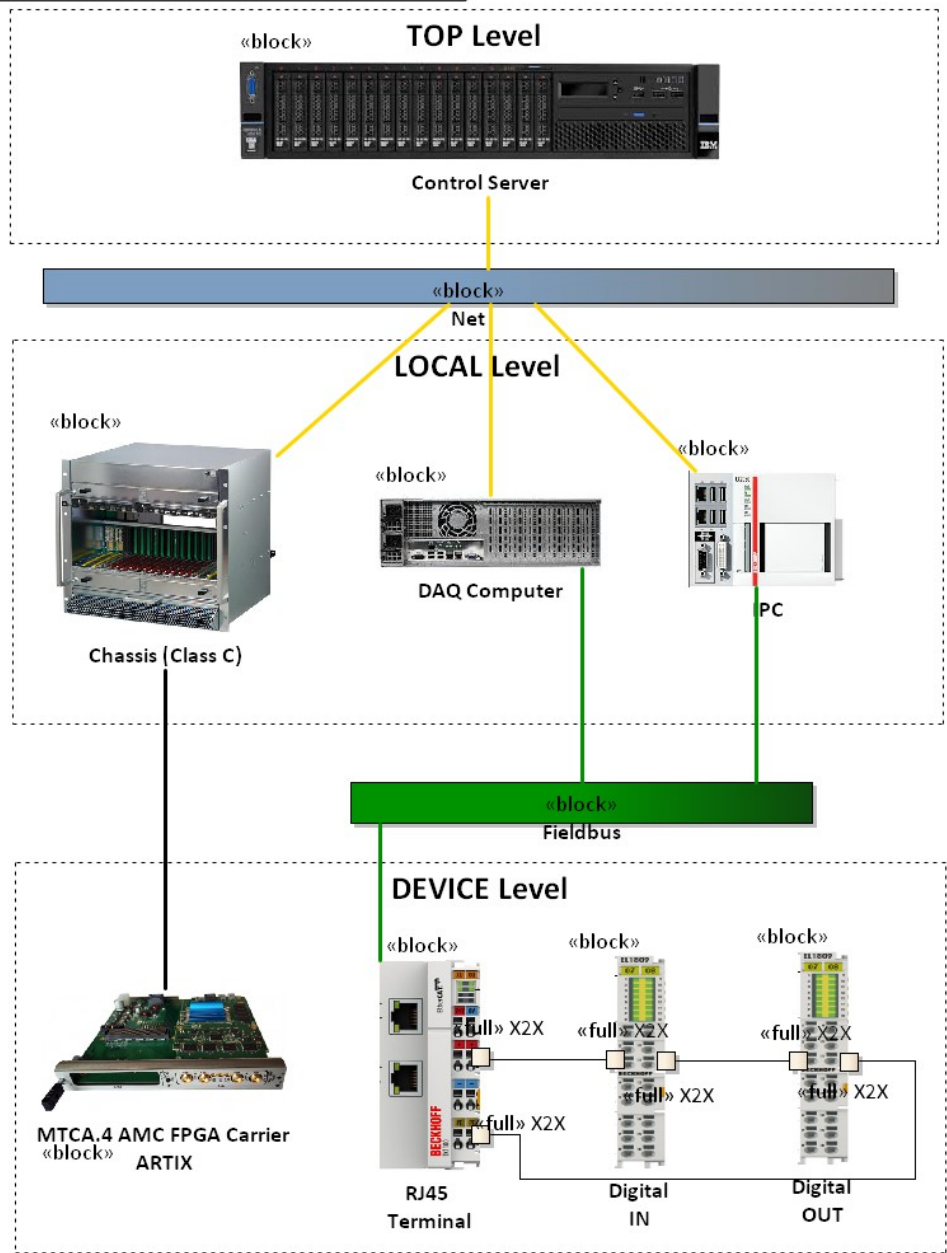
- Vacuum system
- Switch-yard control
- Beam alignment
- Beam diagnostics
- Laser systems interface
- Experiment control
- Instrumentation

## SUPPLEMENTARY SUBSYSTEMS

- Control system network
- Timing system
- Data acquisition
- Safety systems

## CONTROL SYSTEM SERVICES

- Control system Hardware (SysML)
  - HW architecture – done
  - HW design – in progress (Server room, Main control room, Experimental area)
  - HW implementation – in progress (Server room, Main control room, Network, Lab)
- Control system Software (UML)
  - SW Architecture – in progress
  - SW Design – in progress
  - SW Implementation & Testing – in progress
  - SW Deployment – in progress (testbed)



# Control system structure

## TOP LEVEL CONTROL

- Standard 2U control servers
- Standard 1U management servers

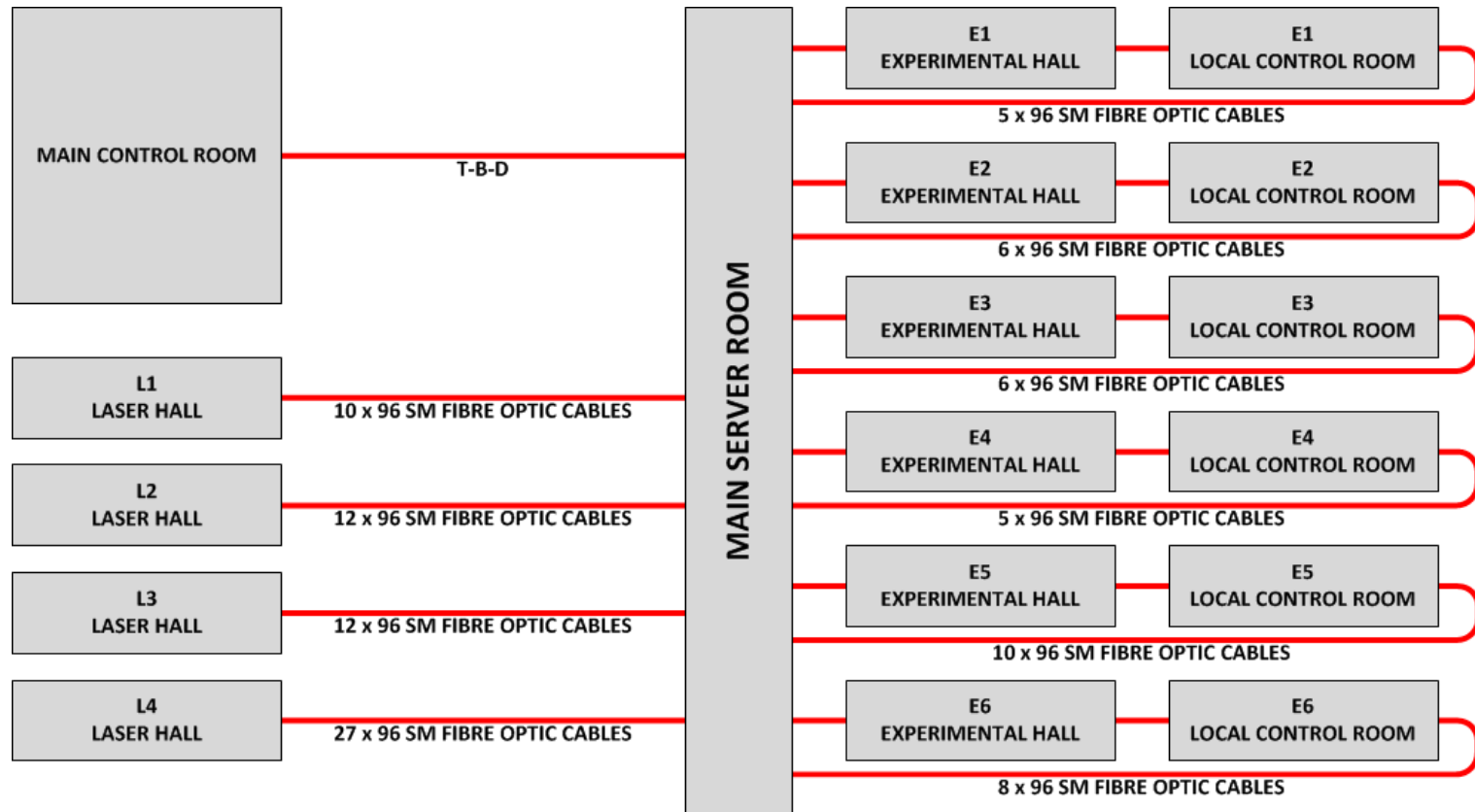
## LOCAL LEVEL CONTROL

- Micro TCA
- IPC

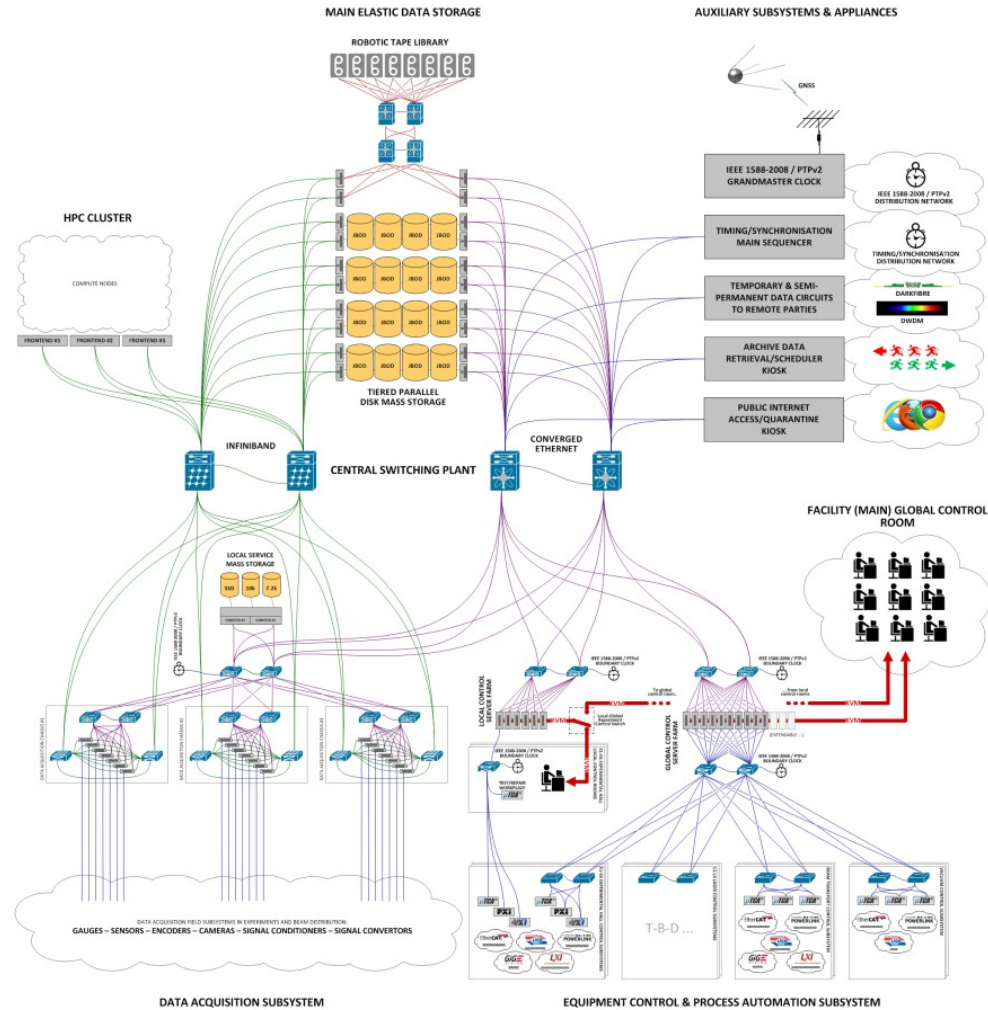
## DEVICE LEVEL

- AMC Cards
- Fieldbus

# Control system network



**15360 OPTICAL FIBRES ARE TO BE TERMINATED IN MAIN SERVER ROOM TOTALY  
30+ KM FIBRE OPTICS CABLES ARE TO BE INSTALLED ACROSS THE BUILDING**



## SCHEMATICS LEGEND





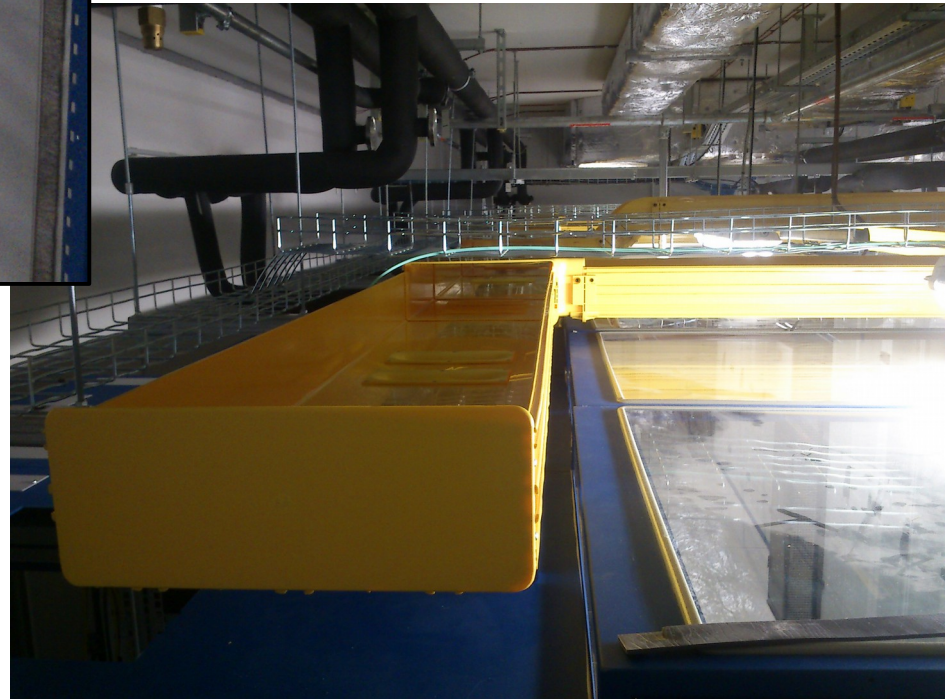


## STRUCTURE

- Core switches
- Top of Rack switches
- Bottom of Rack switches
- Access switches

## CONVERGED ETHERNET

- 10-slots 10/40/100G Datacenter Switch
- 42Tb/s Parallel Forwarding Capacity



## LOCAL CONTROL SWITCHES

Control switch

- 1U 'cheap' switches

Industrial switch

- DIN Rail mount switch



## CONTROL SERVERS

- Standard 2U rack servers
- Top level control
  - Human interface
  - Lenovo x3650 m5 system
  - Accessories have to be purchased



## MANAGEMENT SERVERS

- Standard 1U rack servers
- Control system hardware management and remote control
  - Lenovo x3550 m5 system





## CONTROL SERVERS

Standard 2U rack servers

- Top level control
- Human interface
- Lenovo x3650 m5 system
- Accessories have to be purchased





## LOCAL LEVEL CONTROL

Micro TCA for advanced control

### **HIGH-END**

MTCA.4

2x MCH, 12x AMC

9U Crate



### **COMPACT**

MTCA.4

2x MCH, 6-9x AMC

2U Crate



### **LOW-END**

MTCA.0

1x MCH, 6x AMC

1U Crate



## DEVICE LEVEL

### *AMC for advanced control*

Digitizers, FMC Carriers, etc..

### *FIELDBUS for Industrial control*

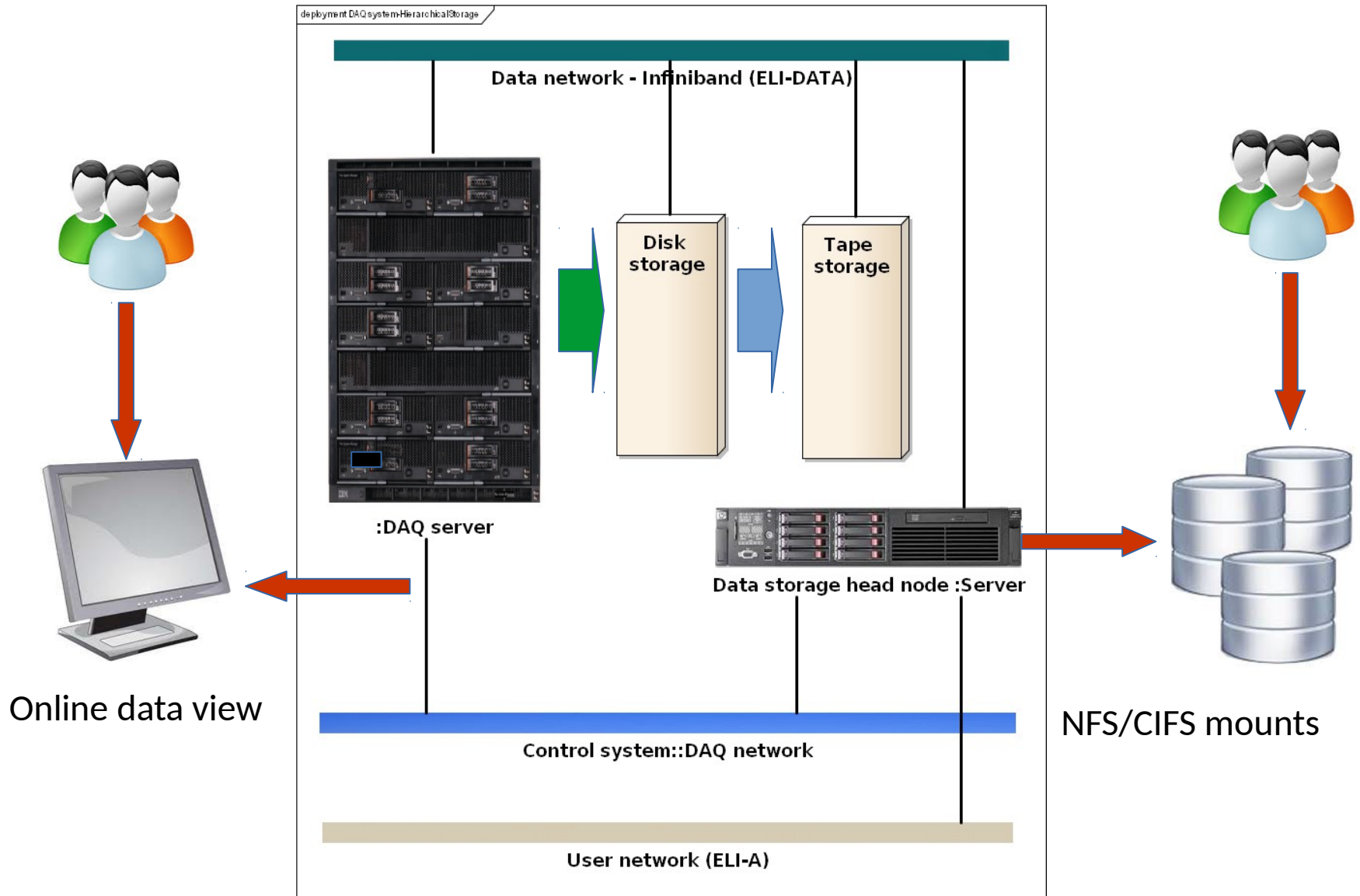
- + Standard Ethernet infrastructure
- + Rich portfolio of IO terminals & Motor control
- + Available with fiber optics for environment with EMC/EMP

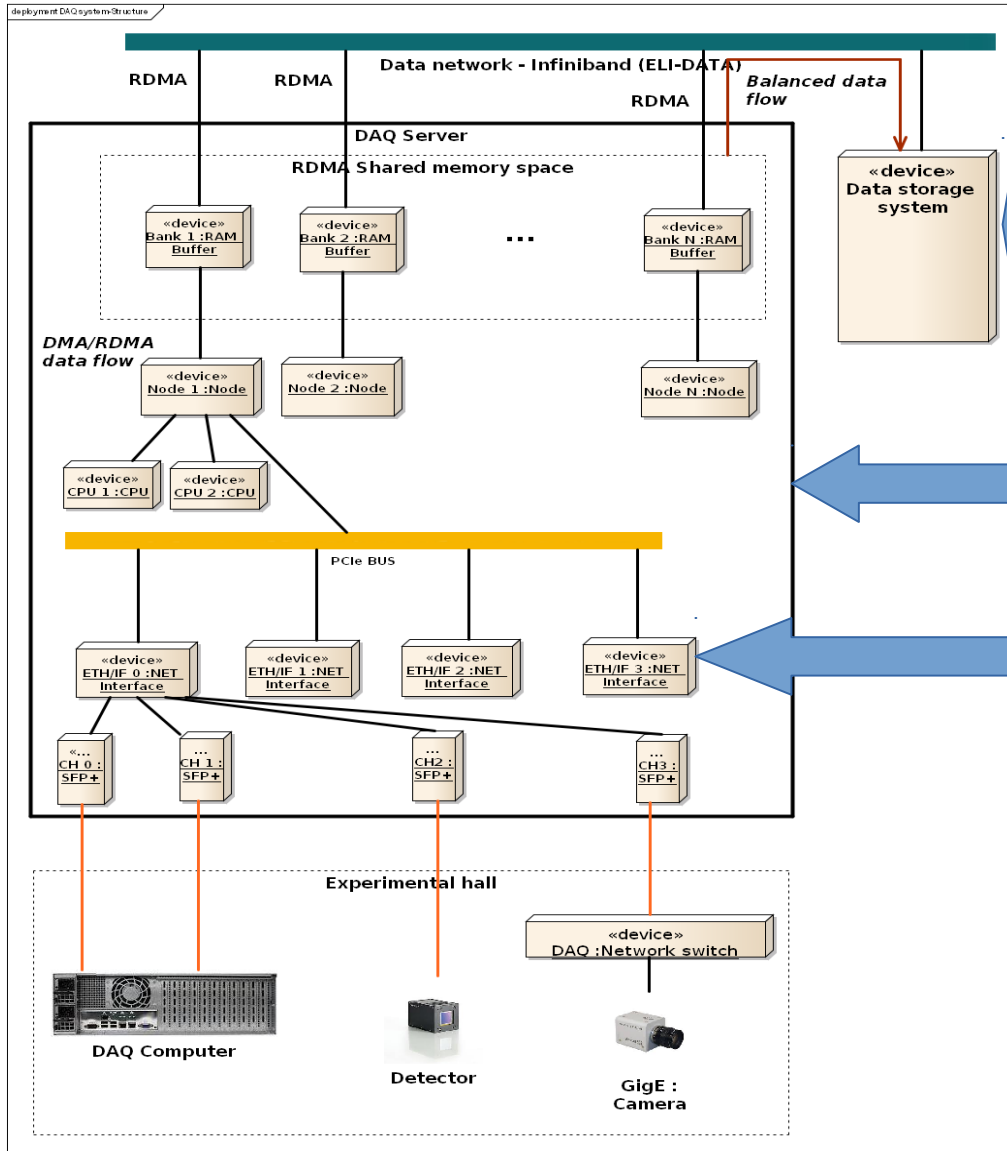
ETHERNET   
**POWERLINK**

Ether**CAT** 



# Data acquisition system





## HIERAR

- High speed disks - Tier 1
- Low speed disks - Tier 2
- Tape library - Tier 3

Multinode DAQ server

- Shared DRAM - Tier0

Network interface

- At minimum 4xSFP+ 40Gb interface



## DATA ACQUISITION SERVERS

Blade rack servers

- Infiniband switch
- Converged ethernet switch



## DATA STORAGE

Central multi tier data storage

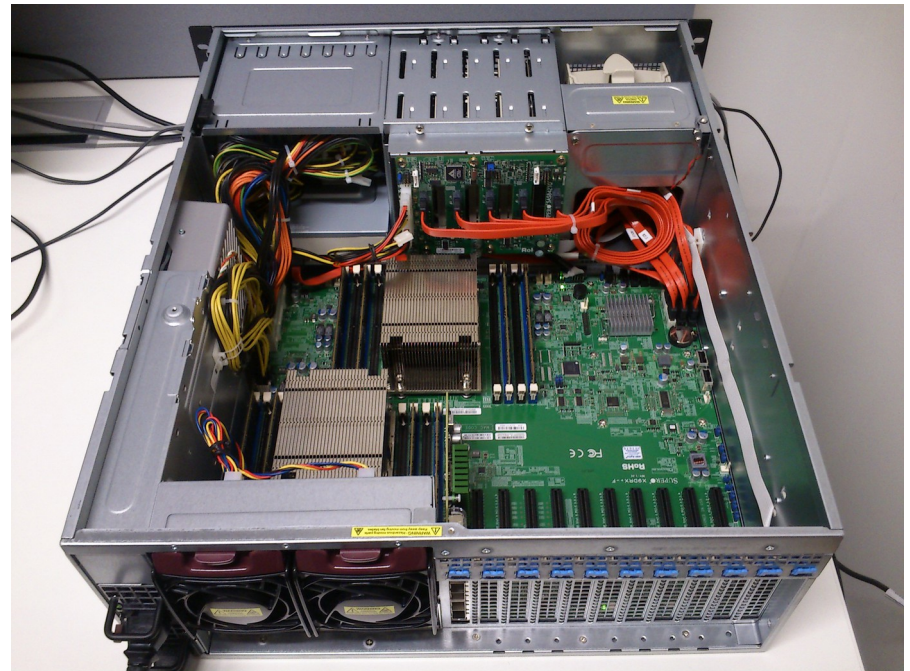
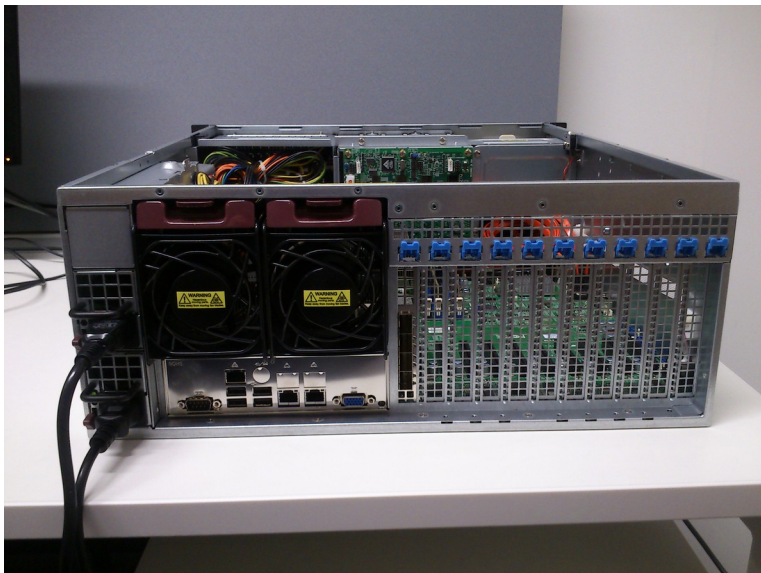
- Data acquisition
- SSD/HDD/TAPE Tier
- Tier0 – Blade server RAM memory
- Extensible solution



## DATA ACQUISITION COMPUTERS

### 4U rack servers

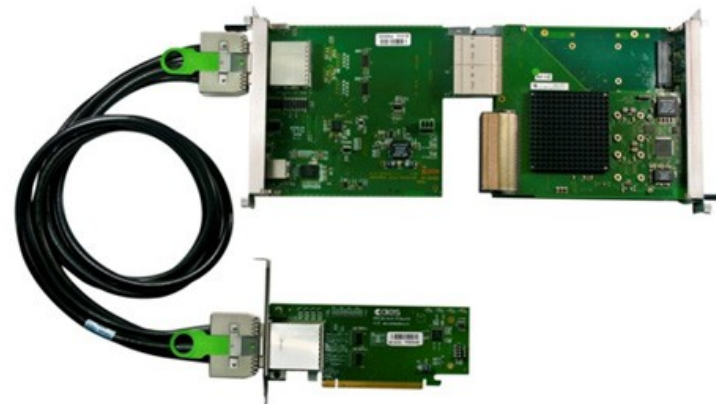
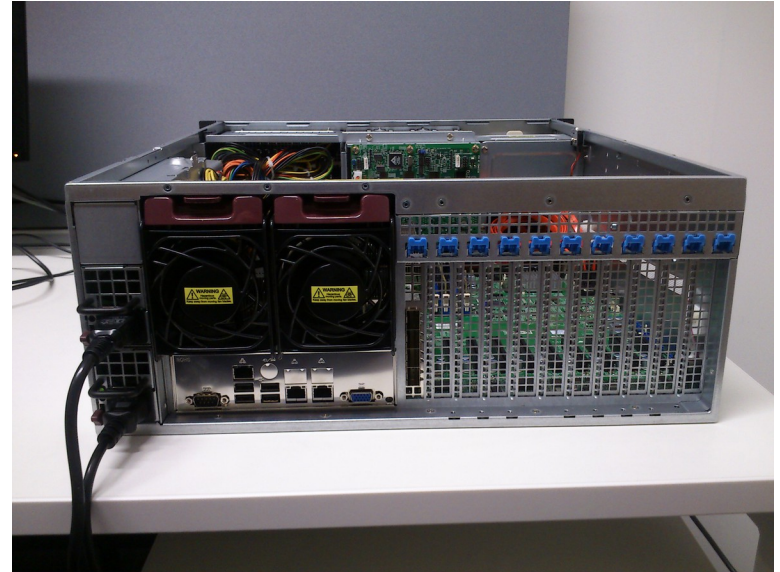
- Local data acquisition
- 11x PCIe x8 slots
- 4x 10Gb Ethernet, RDMA



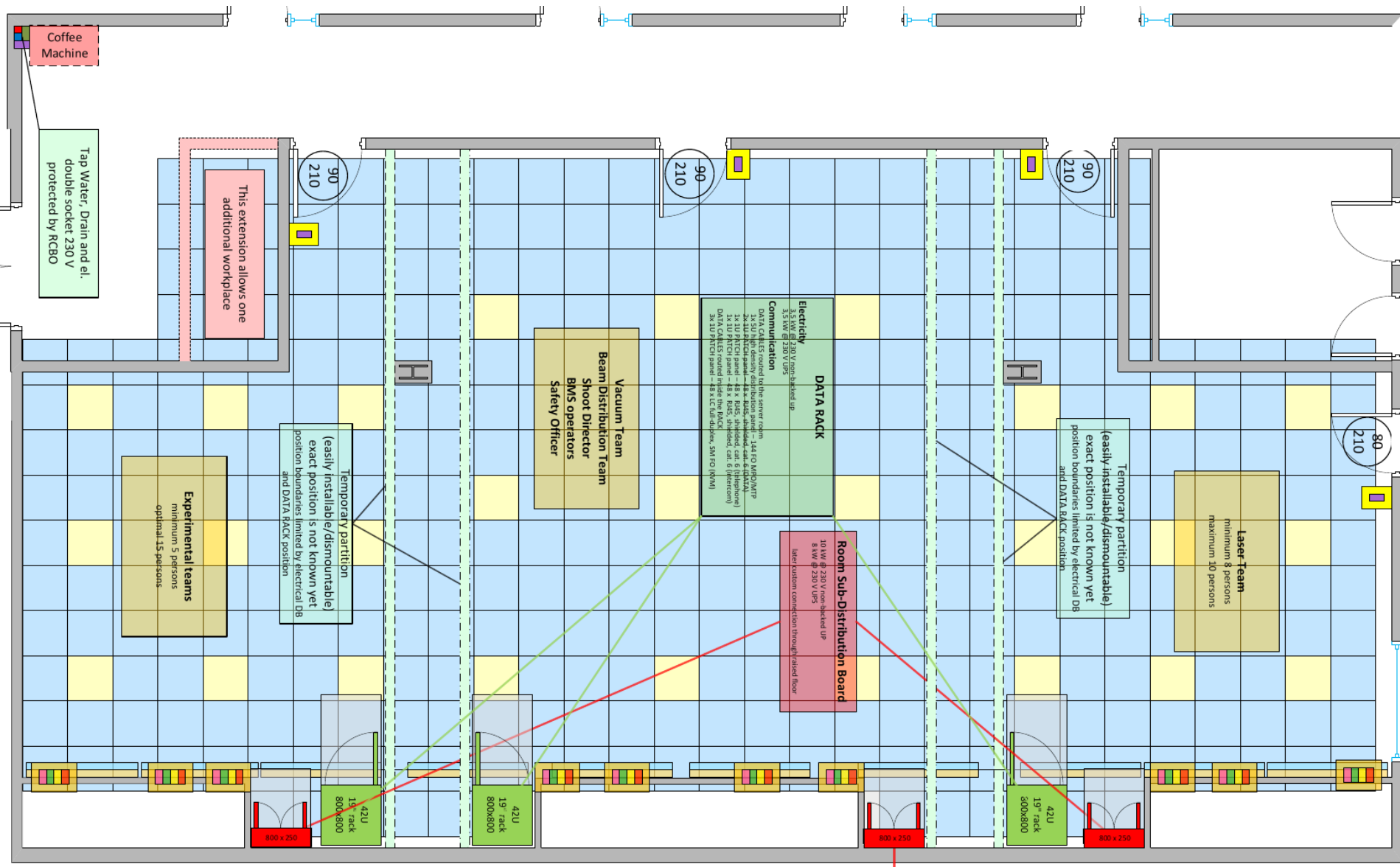
## DATA ACQUISITION COMPUTERS

### uTCA Chassis

- 12 AMC
  - PCIe x8 interface to DAQ Computer
- Computer









## REQUIREMENTS

Experimental team

- Opt. 10 operators seats

Laser team

- Min. 8 operators seats

Control systems & Beam transport

- Opt. 8 operators seat (includes shot director)

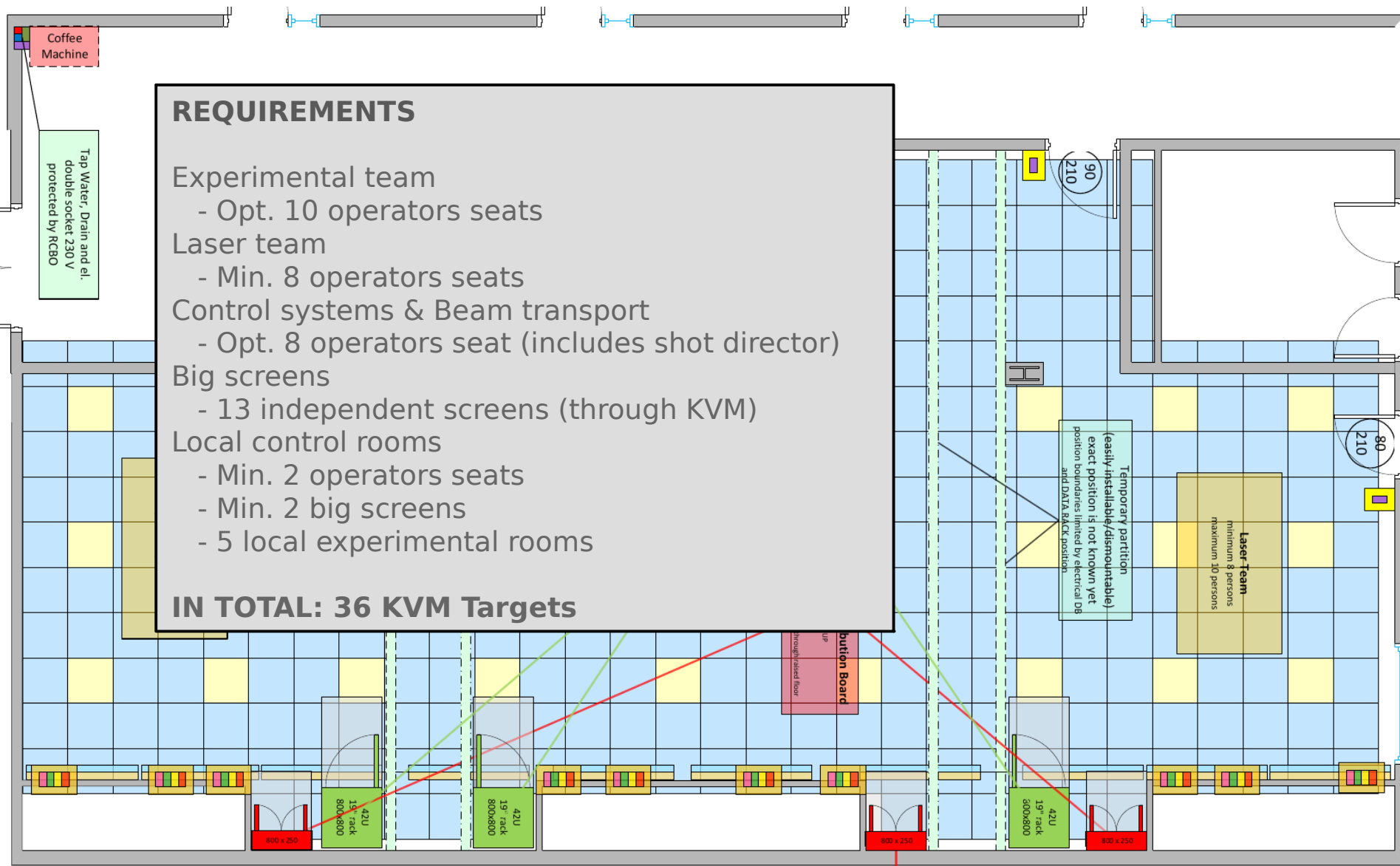
Big screens

- 13 independent screens (through KVM)

Local control rooms

- Min. 2 operators seats
- Min. 2 big screens
- 5 local experimental rooms

**IN TOTAL: 36 KVM Targets**



## Remote desktops & KVM

- Quiet solution
- Simple solution for remote displays (data available in local control rooms)
- Safety (simple safety approach to internet by users)
- **Simple switching of any information to everywhere without any added SW development effort**









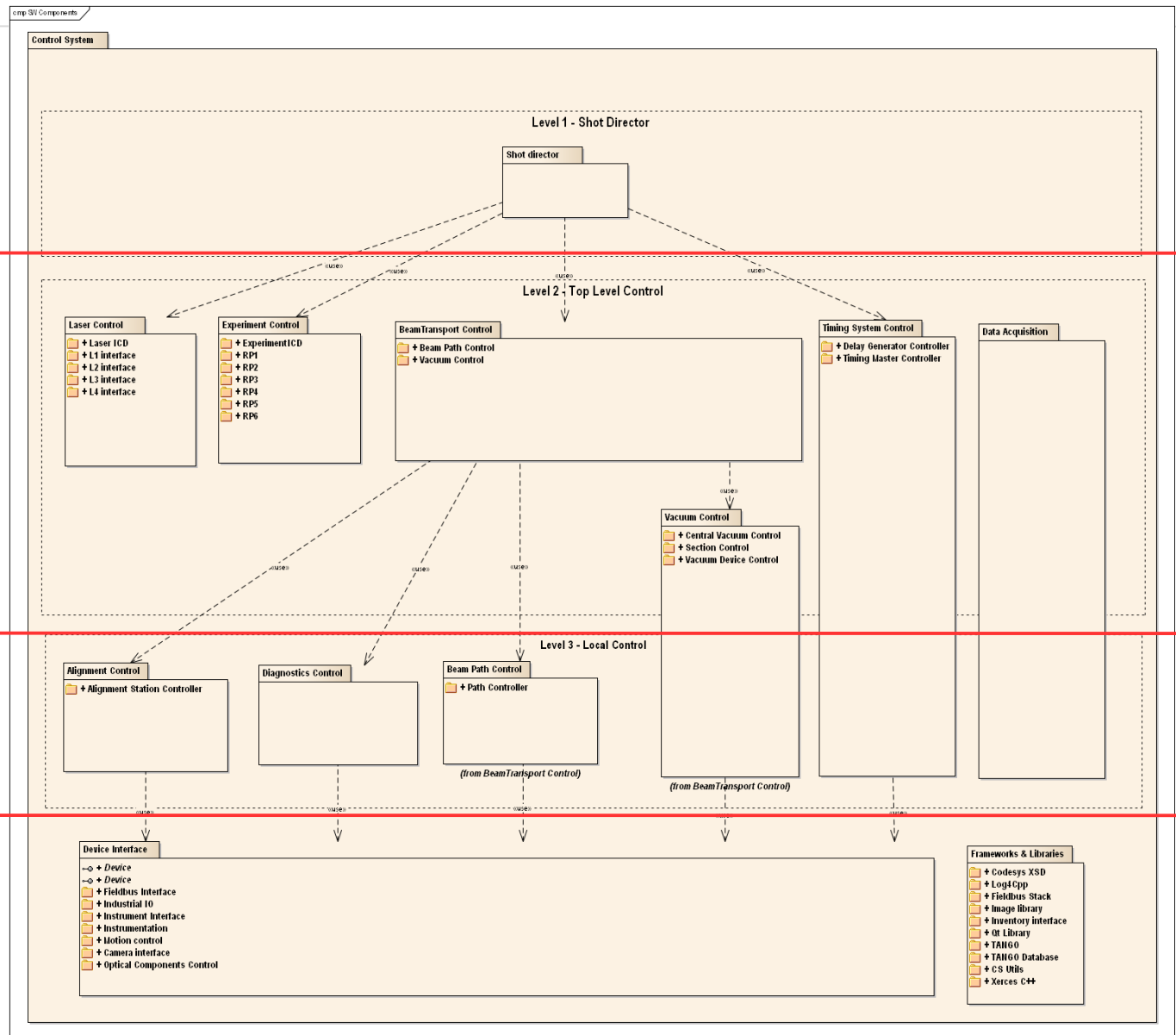


## Shot Director

## Integration Level

## Local Level

## Device Interface



## CONTROL SYSTEM SOFTWARE DEVELOPMENT STRATEGIES

### Abstract API

- Based on user requirements

### Component model

- C++/Python interface

- TANGO interface

- Matlab (Octave)&Labview&Scilab interface

- Component complex configuration by XML

### Plugin interface

- Device level – lot of devices available on the market

- Even more devices will come later

### Software generation

- Fieldbus software support

- Instrumentation

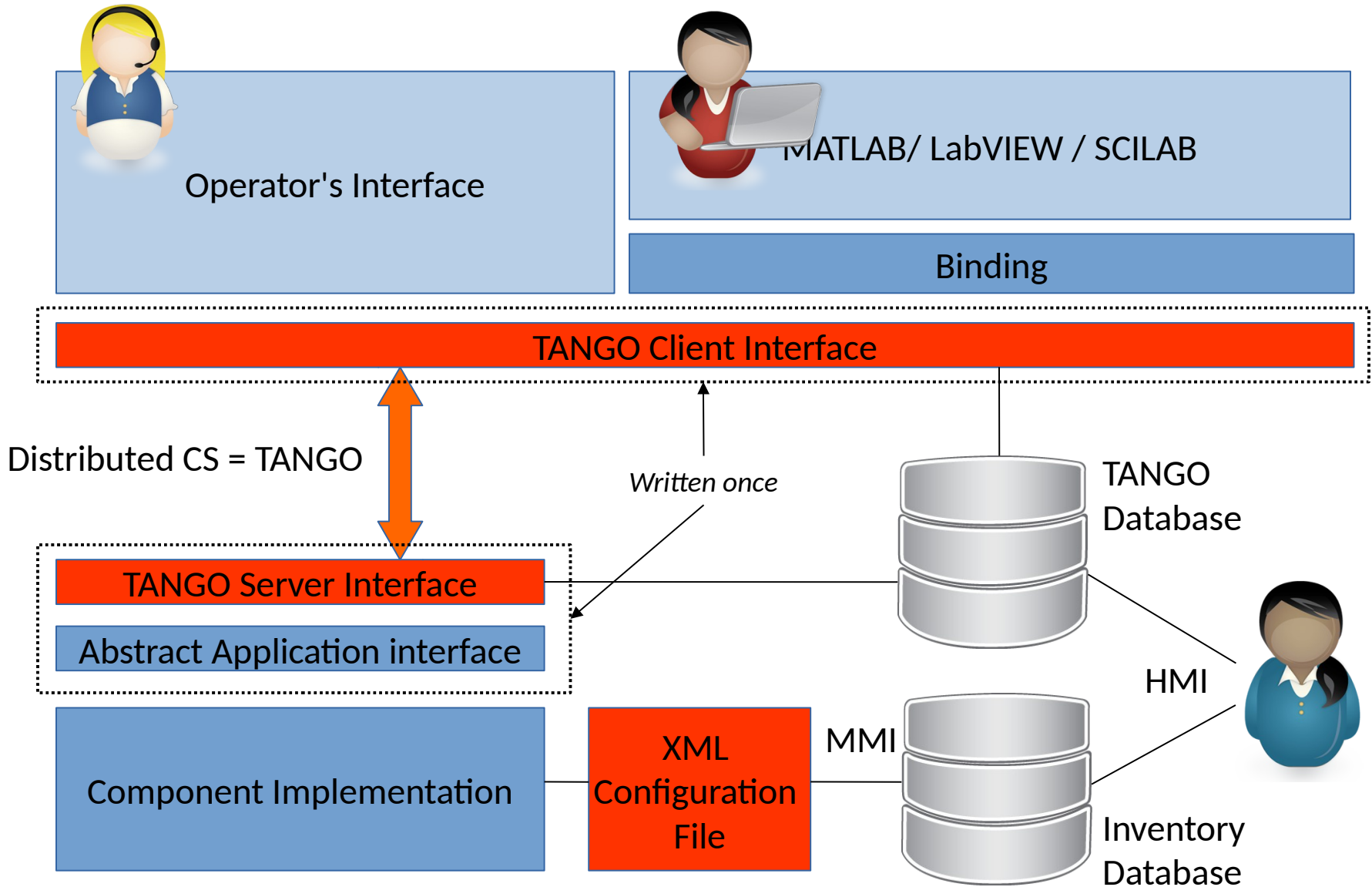
### Generic GUI interface

- Complex GUI creation without compilation

- Automatic software generation support

- 3D system model support

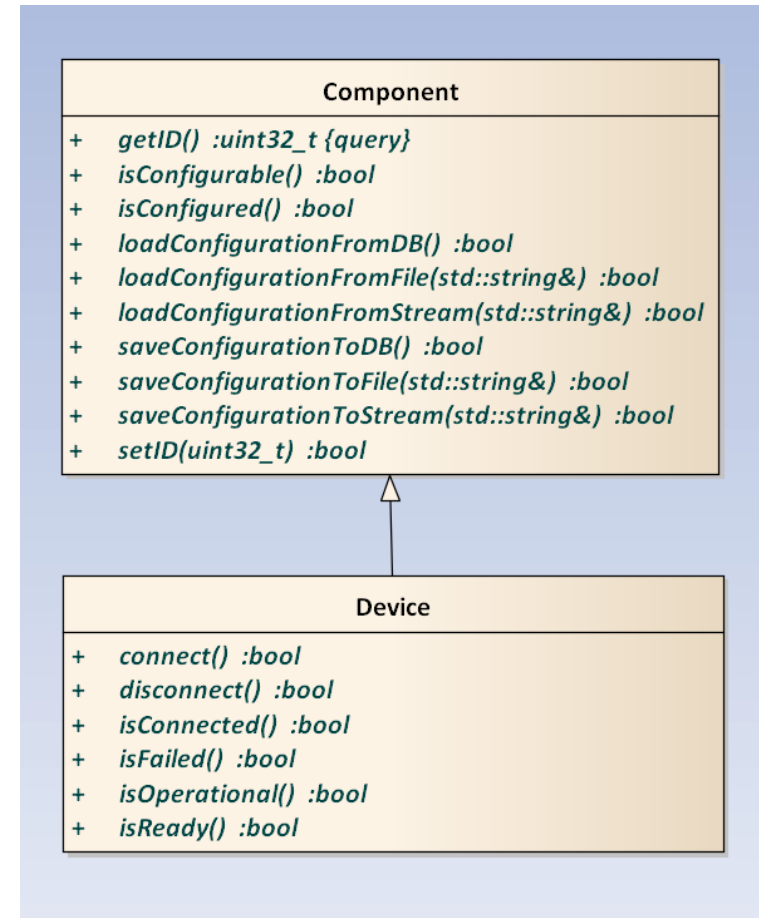
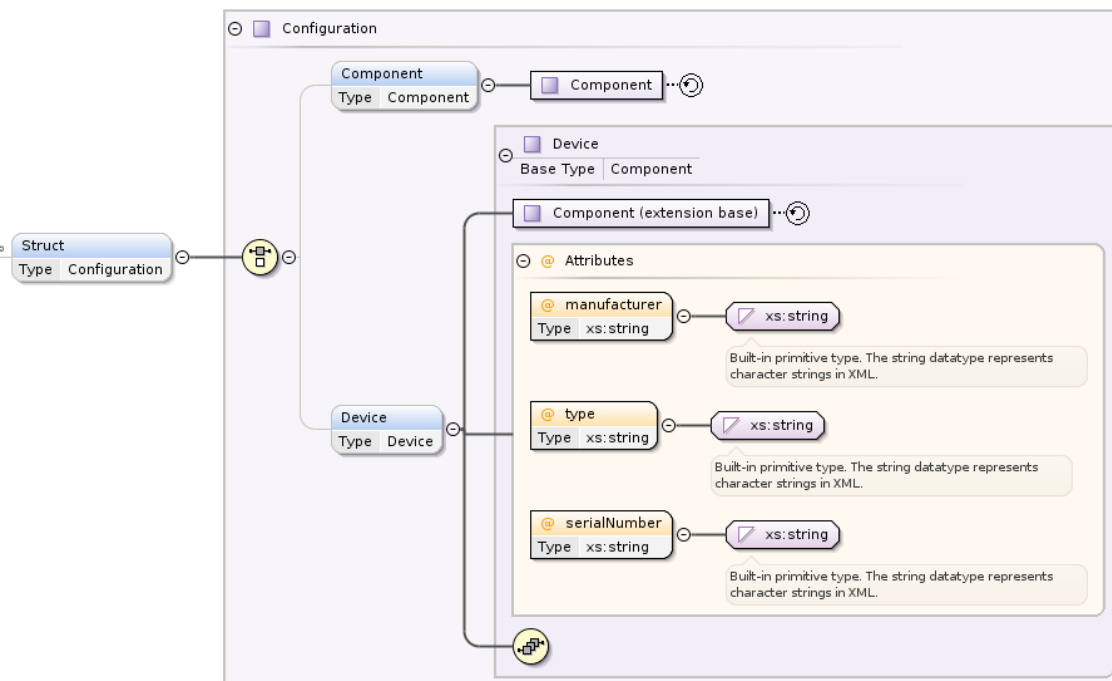
# Control system Component design structure – TANGO deployment



## COMPONENT CONFIGURATION

### Reconfigurable components

- Solution for specific parametrization
- Based on XML ser/des technique
  - May be edited by user from XML editor
- May be send/receive through data stream
- May be saved in local file
- May be saved in Database





## PLUGINS

### Plugin

- Reused API
- User component does not have to be even recompiled
- New components or devices which supports well defined API may be added simply

### Extremely simple API

- Supports version control (automatically taken from plugin source code)
- Supports type checking

```
template<typename T> class Plugin
{
public:

    Plugin();

    ~Plugin();

    void attach(const std::string path);
    void detach(void);

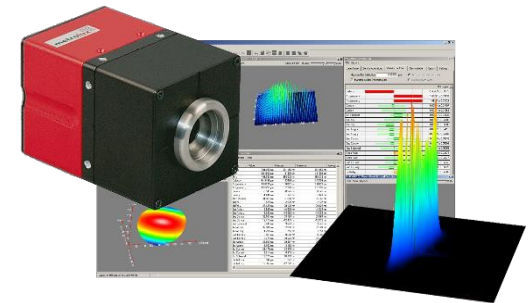
    T* operator->(void) const throw(csexception::CSRuntimeError);

    uint32_t majorVersion(void);
    uint32_t minorVersion(void);
    uint32_t patchVersion(void);
}
```

## STANDARD API DETECTORS

- Abstract API
- Implementation based on GigE Vision, naturally supported wide range of modern cameras including Wave front sensors
- GigE, GigE2.0, USB 3.0
- CoaxPRESS in development
- Plugin concept gives us the opportunity to work even with obsolete interfaces (USB 2.0) but only in case of specialized detectors

API IS NOW ADOPTED TO X-Ray cameras just by simple inheritance

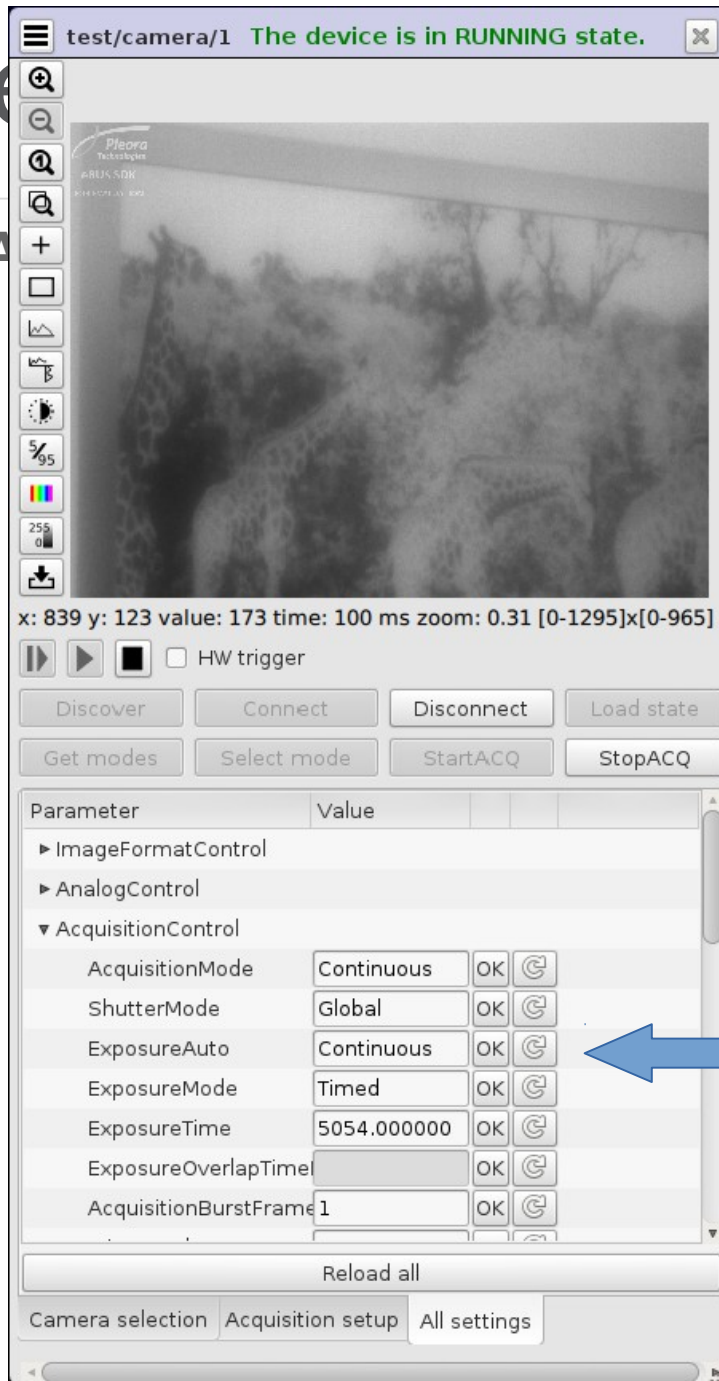


# Control system Software - Example Cameras

STA

- 
- 
- 
- 
- 
- 

API

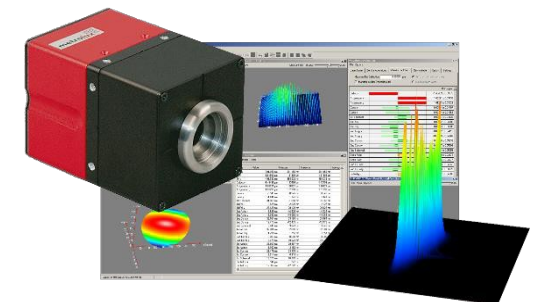


E Vision,  
ge of modern  
sensors

portunity  
terfaces  
specialized

camera

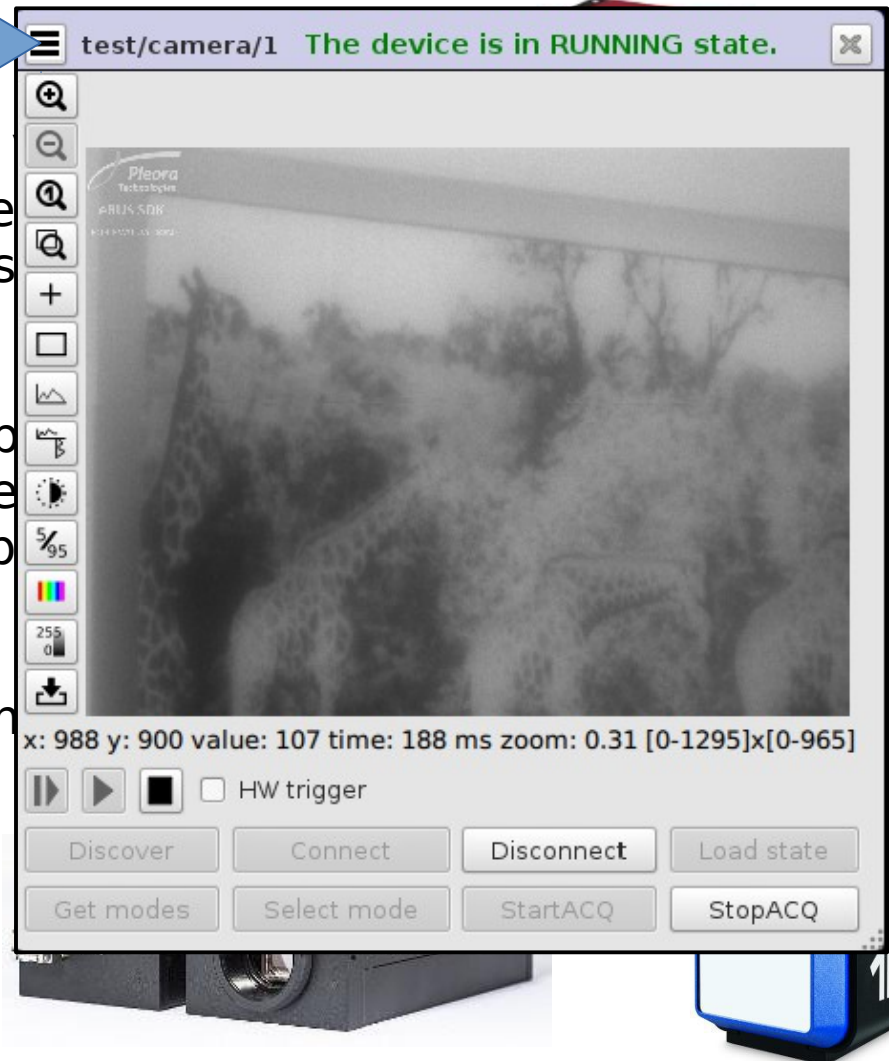
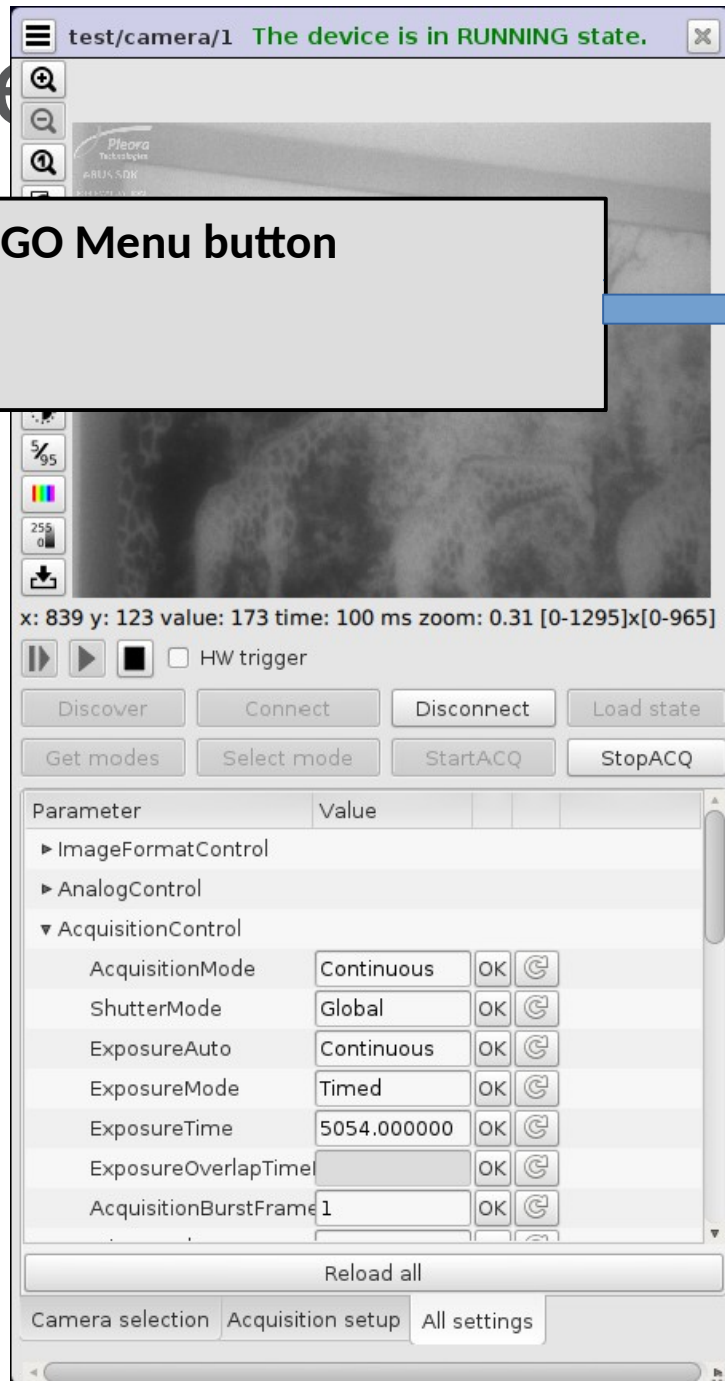
XML device configuration



# Control system Software - Example Cameras

TANGO Menu button

API



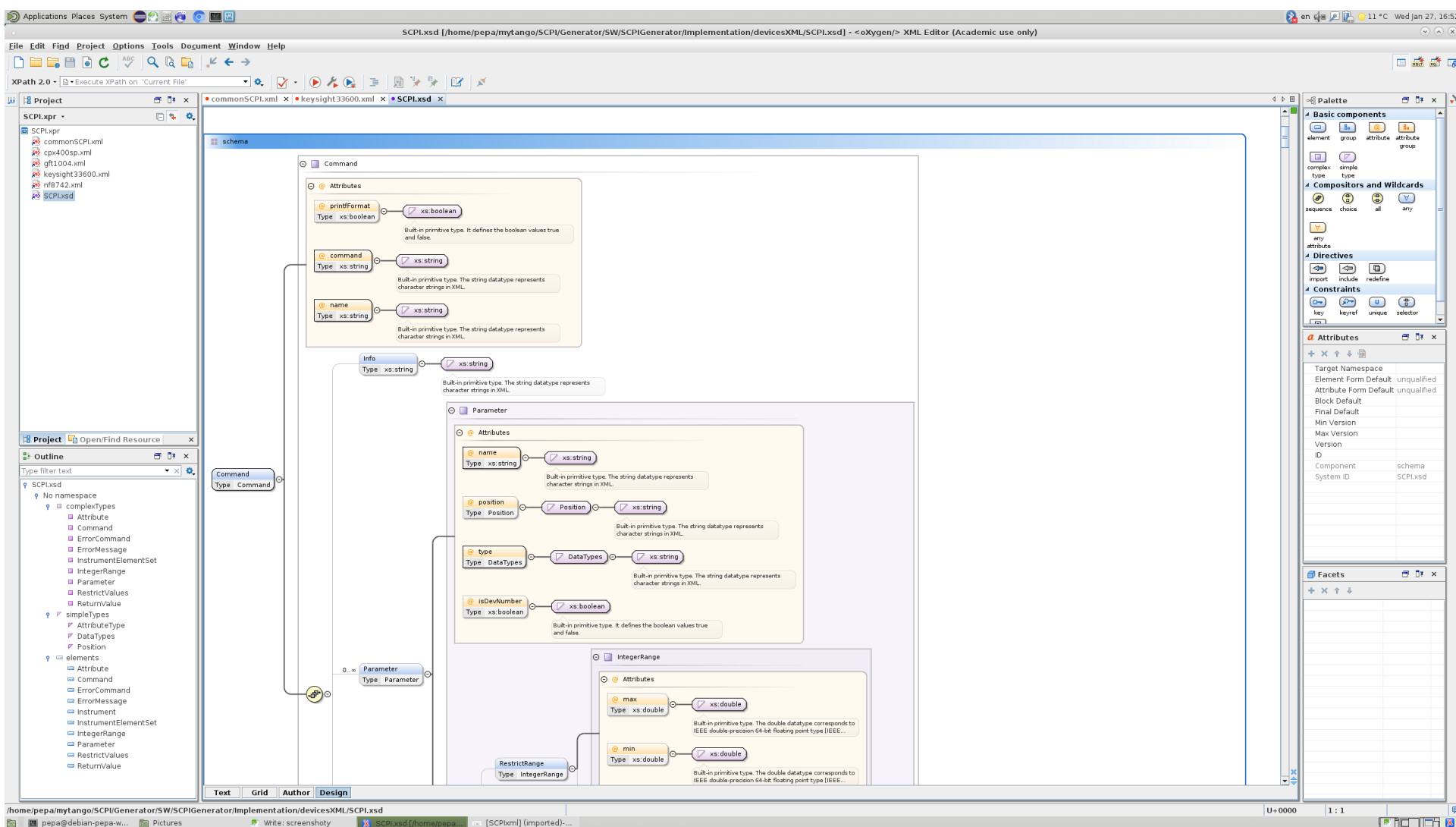


## AUTOMATIC SOFTWARE GENERATION

SCPI Based devices are good example

- Motivation → piezo actuator
- Also other devices are support
  - Agilent wave generator
  - Agilent oscilloscopes
  - TTI controlled power sour





ELI-BL-4400-PRE-00000000-A

Applications Places System

File Edit Find Project Options Tools Document Window Help

XPath 2.0 - Execute XPath on 'Current File'

Project

SCPLxpr

- commonSCPL.xml
- cpv400sp.xml
- gpl1004.xml
- keylight33600.xml
- nf8742.xml
- SCPLxsd

Project Open/Find Resource

Outline

Type filter text

- SCPLxsd
  - No namespace
    - complexType
      - Attribute
      - Command
      - ErrorCommand
      - ErrorMessage
      - InstrumentElementSet
      - IntegerRange
      - Parameter
      - RestrictValues
      - ReturnValues
    - simpleTypes
      - AttributeType
      - DataTypes
      - Position
    - elements
      - Attribute
      - Command
      - ErrorCommand
      - ErrorMessage
      - Instrument
      - InstrumentElementSet
      - IntegerRange
      - Parameter
      - RestrictValues
      - ReturnValues

Command

Type Command

Text Grid Author Design

/home/pepa/mytango/SCPL/Generator/SW/SCPLGenerator/Implementation/devicesXML/SCPLxsd

pepa@debian-pepa-w... Pictures Write: screenshot SCPLxsd [home:pepa... SCPLxml] (imported)...

### Command

#### @ Attributes

**@ printfFormat**  
Type xs:boolean

Built-in primitive type. It defines the boolean values true and false.

**@ command**  
Type xs:string

Built-in primitive type. The string datatype represents character strings in XML.

**@ name**  
Type xs:string

Built-in primitive type. The string datatype represents character strings in XML.

**isDevNumber**  
Type xs:boolean

Built-in primitive type. It defines the boolean values true and false.

**IntegerRange**

**@ max**  
Type xs:double

Built-in primitive type. The double datatype corresponds to IEEE double-precision 64-bit floating point type IEEE...

**@ min**  
Type xs:double

Built-in primitive type. The double datatype corresponds to IEEE double-precision 64-bit floating point type IEEE...

RestrictRange  
Type IntegerRange

Facets

U+ 0000 1 : 1

Applications Places System en 11 °C Wed Jan 27, 16:51

keyightsight33600.xml [/home/pepa/mytango/SCPIGenerator/SW/SCPIGenerator/Implementation/devicesXML/keyightsight33600/keyightsight33600.xml] - <Xygen/> XML Editor (Academic use only)

File Edit Find Project Options Tools Document Window Help

XPath 2.0 • [Execute XPath on 'Current File']

Project

SCPIxpr

- commonSCPI.xml
- cpw400sp.xml
- gh1004.xml
- keyightsight33600.xml
- nf8742.xml
- SCPIxsd

Instrument

Waveform generator Keysight 33600

attributes

- @name: keyightsight33600
- @filename: keyightsight33600
- @classname: keyightsight33600
- @timeout: 30000
- @commandTerm: \n

Subdevice...

- @min: 1
- @max: 2

Info

Library for controlling the Keysight 33600 Waveform generator.

ErrorCommand

- @command: SYST:ERR?
- @returnType: string
- @OKString: +0,6quot;No error6quot;
- @href: ../commonSCPI.xml
- @xmlns:xi: http://www.w3.org/2001/XMLSchema
- xi:fallback: para emphasis FIXME: MISSING XINCLUDE CONTENT

Start of device-specific commands

Attribute (14 rows)	@name	@type	@commandRead	@commandWrite	@printfFormat	@unit	Info	InfoRead	InfoWrite	Parameter	InfoRead	InfoWrite	ParameterWrite	Return	Value
1	AMDepth	ReadWrite	SOUR:AM:DEPT?	SOUR:AM:DEPT %f	true		Internal modulation depth ('percent modulation') in percent.			Parameter	@name: channel @type: integer @isDevNumber: true		Parameter...	@name: depth @type: real	Return
2	AMModeDSSC	ReadWrite	SOUR:AM:DSSC?	SOUR:AM:DSSC %d	true		Amplitude Modulation mode - Double Sideband Suppressed Carrier (1) or AM modulated carrier with sidebands (0).			Parameter	@name: channel @type: integer @isDevNumber: true		Parameter...	@name: mode @type: integer	Return
3	DisplayStatus	ReadWrite	DISP?	DISP			Enables or disables the front panel display. Disabling the display improves command execution speed from the remote interface and provides basic security.	@return 1 when on, 0 when off	@param state 1 to turn on, 0 to turn off			Parameter...	@name: state @type: integer	Return	Value
4	DisplayText	ReadWrite	DISP:TEXT?	DISP:TEXT			Displays a text message on the front panel display.		@param text Quoted string of up to 40 standard keyboard characters, e.g. DisplayTextSet ("Hello, world!\").			Parameter...	@name: text @type: string	Return	Value
5	AMFrequency	ReadWrite	SOUR:AM:INT:FREQ?	SOUR:AM:INT:FREQ %f	true		Frequency of the Amplitude modulation			Parameter	@name: channel @type: integer @isDevNumber: true		Parameter...	@name: frequency @type: real	Return
6	AMFunction	ReadWrite	SOUR:AM:INT:FUNC?	SOUR:AM:INT:FUNC %s	true		Shape of the modulating function.	@param function One of Sine, Square, Ramp, NRamp.		Parameter	@name: channel @type: integer @isDevNumber: true		Parameter...	@name: function @type: string	Return

Text Grid Author

/home/pepa/mytango/SCPIGenerator/SW/SCPIGenerator/Implementation/devicesXML/keyightsight33600/keyightsight33600.xml

U+0000 1:1

pepa@debian-pepa-w... Pictures Write: screenshot keyightsight33600.xml [h...

ELI-BL-4400-PRE-00000000-A



Applications Places System

File Edit Find Project Options Tools Document Window

XPath 2.0 • @ - Execute XPath on 'Current File'

Project

SCPLxpr

commonSCPLxml  
cp4000p.xml  
gh1004.xml  
keysight33600.xml  
nf9742.xml  
SCPLxsd

Instrument

Text Grid Author

/home/pepa/mytango/SCPIGenerator/SW/SCPIGenerator/Implementation/devicesXML/keysight33600/keysight33600.xml

pepa@debian-pepa-w... Pictures Write: screenshoty keysight33600.xml [h...

U+0000 1:1

x1: fallback para emphasis

FIXME: MISSING XINCLUDE CONTENT

Start of device-specific commands

tribute rows)	@name	@type	@commandRead	@commandWrite	@printfFormat	@unit	Info	In
1	AMDepth	ReadWrite	SOUR%d:AM:DEPT?	SOUR%d:AM:DEPT %f	true		Internal modulation depth ("percent modulation") in percent.	
2	AMModeDSSC	ReadWrite	SOUR%d:AM:DSSC?	SOUR%d:AM:DSSC %d	true		Amplitude Modulation mode - Double Sideband Suppressed Carrier (1) or AM modulated carrier with sidebands (0).	
3	DisplayStatus	ReadWrite	DISP?	DISP			Enables or disables the front panel display. Disabling the display improves command execution speed from the remote interface and provides basic security.	
6	AMFunction	ReadWrite	SOURd:AM:INT:FUNC?	SOURd:AM:INT:FUNC %s	true		Shape of the modulating function.	

Parameter

@name @type @isDevNumber

channel integer true

Parameter...

@name @type

function string

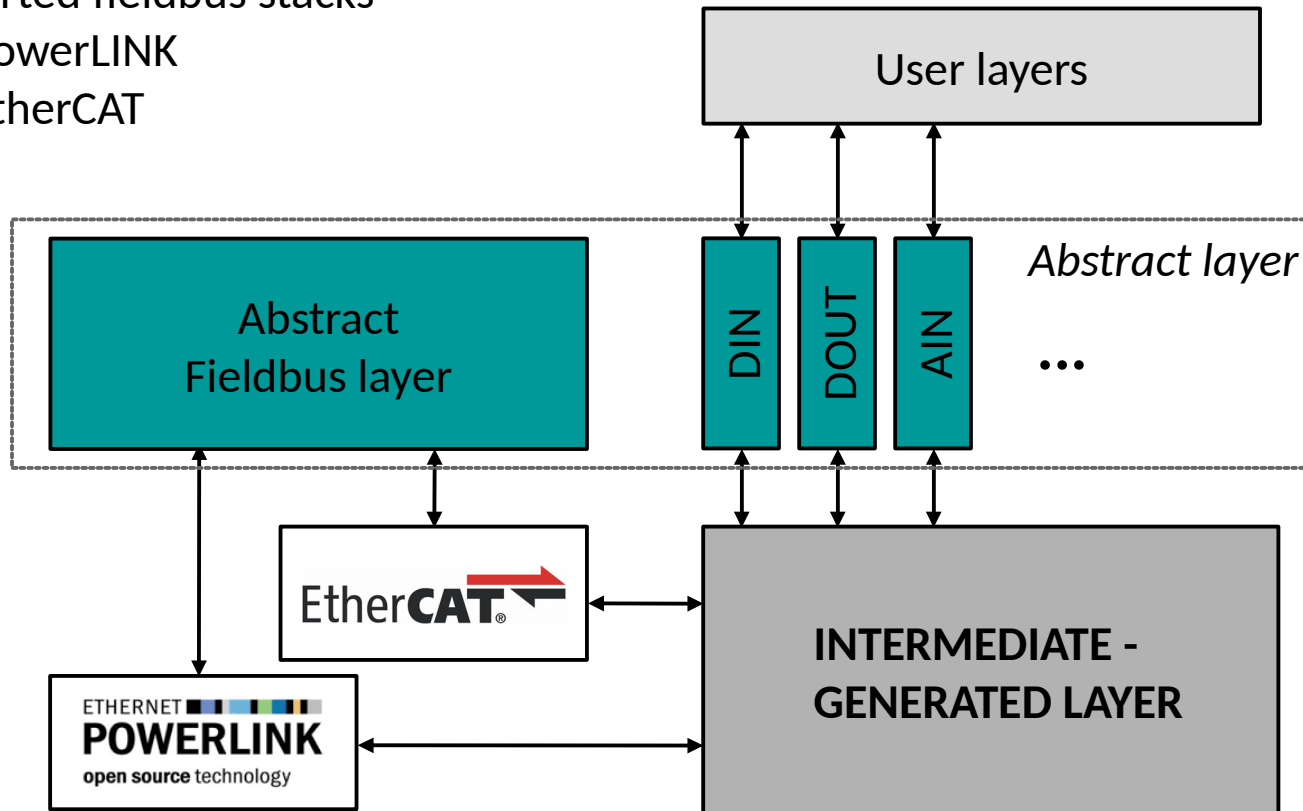
ReturnValue

@type

## SOFTWARE GENERATION

Supported fieldbus stacks

- PowerLINK
- EtherCAT



## SOFTWARE GENERATION

### Software generation chain

- Abstract API upon fieldbus implementation
  - Create configuration in supplier provided tool (almost kind of XML file)
  - Use abstract API (Industrial IO → iio)
  - Generate intermediate C++ code
  - Generate GUI components
- Supported fieldbus stacks
- PowerLINK (B&R Automation)
  - EtheCAT (Beckhoff)

C:\projects\ELI\_GENERIC001\ELI\_GENERIC001.apj\ELI\_GENERIC001 - Automation Studio FieldbusDESIGNER 3.0.80.41 #1 535153

File Edit View Insert Open Project Tools Window Help

Physical View

Model no.	Slot	Description
GENERIC001		
POWERLINK!	GEN	Generic POWERLINK MN (Master)
X20BC0083	GEN	X20 Bus Controller POWERLINK
X20PS9400	GEN	24 VDC power supply module for BC, in
X20AI2622	GEN	2 Inputs $\pm 10$ V / 0 to 20 mA
X20DI9371	GEN	12 Digital Inputs 24 VDC, Sink, IEC 61
X20DO9322	GEN	12 Outputs 24 VDC / 0.5 A

GENERIC001.CPU [POWERLINK] | GENERIC001.CPU.IF1.ST1 [X2X Link] | GENERIC001.CPU.IF1.ST1.IF1.ST2 [I/O Configuration] X

Name	Value	Description
IF1.ST1.IF1.ST2		X20AI2622
Function model	default	Module's operating mode
General		
Module supervised	on	Service mode if there is no hardware module
Module information	off	Additional module information
Input filter	off	Definition of filter level
	32767	Specifies the upper measurement limit
	-32767	Specifies the lower measurement limit
	$\pm 10$ V	Voltage $\pm 10$ V / current 0 to 20 mA / current 4 to 20 mA
	$\pm 10$ V	Voltage $\pm 10$ V / current 0 to 20 mA / current 4 to 20 mA

About Automation Studio

## Automation Studio

FieldbusDESIGNER

Automation Studio  
Version FieldbusDESIGNER 3.0.80.41 (2014.11.20.1)

Copyright © Bernecker + Rainer 2014  
Bernecker + Rainer Industrie-Elektronik Ges.m.b.H.  
www.br-automation.com

This product is licensed to:  
Fyzikální ústav AV ČR, v.v.i.  
Harfa Office Park  
Českomoravská 2420/15  
190 93 Praha 9

Relicense...

Installed Products	Licence Information
Automation Studio Desktop	AS3.0.80.38.SP06
Hardware configuration	AS3.0.80.38.SP06
GNU C Compiler	V 2.95.3
GNU C Compiler	V 4.1.1

Warning: This computer program is protected by copyright law and international treaties. Unauthorized reproduction or distribution of this program, or any portion of it, may result in severe civil and criminal penalties, and will be prosecuted to the maximum extent possible under the law.

Upgrades...

OK



# Control system Software – Example Fieldbus

Physical View

Model no. Slot

TB\_MOTION001.CPU.IF1.ST1 [X2X Link] x TB\_MOTION001.CPU [POWERLINK] TB\_MOTION001.CPU.IF1.ST1.IF1.ST2 [I/O Configuration]

Slave Module	Slave Backplane	Connection	Description
--------------	-----------------	------------	-------------

## Generated files

xap.xml  
xap.h }

GNU C Compiler V 4.1.1

Warning: This computer program is protected by copyright law and international treaties. Unauthorized reproduction or distribution of this program, or any portion of it, may result in severe civil and criminal penalties, and will be prosecuted to the maximum extent possible under the law.

Upgrades... OK

# Control system Software – Example Fieldbus

Physical View

Model no. Slot

TB\_MOTION001.CPU.IF1.ST1 [X2X Link] x TB\_MOTION001.CPU [POWERLINK] TB\_MOTION001.CPU.IF1.ST1.IF1.ST2 [I/O Configuration]

Slave Module	Slave Backplane	Connection	Description										
<div> <div> <p><b>Generated files</b></p> <p>xap.xml xap.h</p> </div> <div> <p><b>Generated TANGO API &amp; QML GUI</b></p> <table border="1"> <thead> <tr> <th>X20BC0083</th> <th>X20PS9400</th> <th>X20AI2622</th> <th>X20DI9371</th> <th>X20DO9322</th> </tr> </thead> <tbody> <tr> <td>Status: <b>Connected</b></td> <td>Status: <b>Ok</b> Voltage: <b>23.89 V</b></td> <td>Ch 1: <b>0.31 V</b> Ch 2: <b>0.01 V</b></td> <td> <input type="radio"/> Bit 01  <input checked="" type="radio"/> Bit 02  <input type="radio"/> Bit 03  <input type="radio"/> Bit 04  <input type="radio"/> Bit 05  <input type="radio"/> Bit 06  <input type="radio"/> Bit 07  <input type="radio"/> Bit 08 </td> <td> <input type="radio"/> Bit 01  <input type="radio"/> Bit 02  <input type="radio"/> Bit 03  <input type="radio"/> Bit 04  <input type="radio"/> Bit 05  <input type="radio"/> Bit 06  <input type="radio"/> Bit 07  <input type="radio"/> Bit 08 </td> </tr> </tbody> </table> </div> </div>				X20BC0083	X20PS9400	X20AI2622	X20DI9371	X20DO9322	Status: <b>Connected</b>	Status: <b>Ok</b> Voltage: <b>23.89 V</b>	Ch 1: <b>0.31 V</b> Ch 2: <b>0.01 V</b>	<input type="radio"/> Bit 01 <input checked="" type="radio"/> Bit 02 <input type="radio"/> Bit 03 <input type="radio"/> Bit 04 <input type="radio"/> Bit 05 <input type="radio"/> Bit 06 <input type="radio"/> Bit 07 <input type="radio"/> Bit 08	<input type="radio"/> Bit 01 <input type="radio"/> Bit 02 <input type="radio"/> Bit 03 <input type="radio"/> Bit 04 <input type="radio"/> Bit 05 <input type="radio"/> Bit 06 <input type="radio"/> Bit 07 <input type="radio"/> Bit 08
X20BC0083	X20PS9400	X20AI2622	X20DI9371	X20DO9322									
Status: <b>Connected</b>	Status: <b>Ok</b> Voltage: <b>23.89 V</b>	Ch 1: <b>0.31 V</b> Ch 2: <b>0.01 V</b>	<input type="radio"/> Bit 01 <input checked="" type="radio"/> Bit 02 <input type="radio"/> Bit 03 <input type="radio"/> Bit 04 <input type="radio"/> Bit 05 <input type="radio"/> Bit 06 <input type="radio"/> Bit 07 <input type="radio"/> Bit 08	<input type="radio"/> Bit 01 <input type="radio"/> Bit 02 <input type="radio"/> Bit 03 <input type="radio"/> Bit 04 <input type="radio"/> Bit 05 <input type="radio"/> Bit 06 <input type="radio"/> Bit 07 <input type="radio"/> Bit 08									

GNU C Compiler V 4.1.1

Warning: This computer program is protected by copyright law and international treaties. Unauthorized reproduction or distribution of this program, or any portion of it, may result in severe civil and criminal penalties, and will be prosecuted to the maximum extent possible under the law.

Upgrades... OK

# Control system Software – Example Fieldbus

Physical View

Model no. Slot

TB\_MOTION001.CPU.IF1.ST1 [X2X Link] x TB\_MOTION001.CPU [POWERLINK] TB\_MOTION001.CPU.IF1.ST1.IF1.ST2 [I/O Configuration]

Slave Module Slave Backplane Connection Description

**Generated files**

xap.xml  
xap.h

**Generated TANGO API & QML GUI**

X20BC0083	X20PS9400	X20AI2622	X20DI9371	X20DO9322
Status: <b>Connected</b>	Status: <b>Ok</b> Voltage: <b>23.89 V</b>	Ch 1: <b>0.31 V</b> Ch 2: <b>0.01 V</b>	<input type="radio"/> Bit 01 <input checked="" type="radio"/> Bit 02 <input type="radio"/> Bit 03 <input type="radio"/> Bit 04 <input type="radio"/> Bit 05 <input type="radio"/> Bit 06 <input type="radio"/> Bit 07 <input type="radio"/> Bit 08	<input type="radio"/> Bit 01 <input type="radio"/> Bit 02 <input type="radio"/> Bit 03 <input type="radio"/> Bit 04 <input type="radio"/> Bit 05 <input type="radio"/> Bit 06 <input type="radio"/> Bit 07 <input type="radio"/> Bit 08

**Real system**

GNU C Compiler V 4.1.1

Warning: This computer program is protected by copyright law and international treaties. Unauthorized reproduction or distribution of this program, or any portion of it, may result in severe civil and criminal penalties, and will be prosecuted to the maximum extent possible under the law.

Upgrades... OK

## STANDARD FRAMEWORKS SUPPORT

Every Component from the lowest layers support frameworks used in research

- Using TANGO → natural support for remote control
- In some cases using standard C++ API for local control when necessary

Supported frameworks

- MATLAB
- LabVIEW → LabVIEW – TANGO interface is an issue, automatic bridge is under development

All components are supported

- Cameras
- Motion control
- Fieldbus
- ... and more



## WE ARE OPEN FOR COOPERATION

- Sharing ready to use components, strategies, ideas etc.
- Co-development for higher efficiency
- HW and SW support

COME TO SEE!



Institute of Physics ASCR, v. v. i.  
Na Slovance 2  
182 21 Prague 8  
Czech Republic  
[eli-cz@fzu.cz](mailto:eli-cz@fzu.cz)  
[www.eli-beams.eu](http://www.eli-beams.eu)

