

Overview of Acquisition and Control Electronics and Concepts for Experiments and Beam Transport at the European XFEL



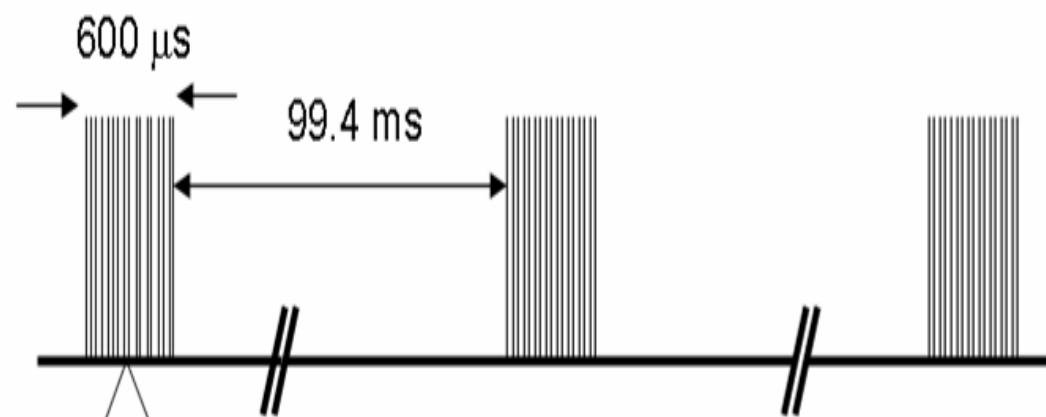
Dr. Patrick Geßler
European XFEL
Head of Electronic and Electrical Engineering

ICALEPCS 2019, New York
October 10th, 2019

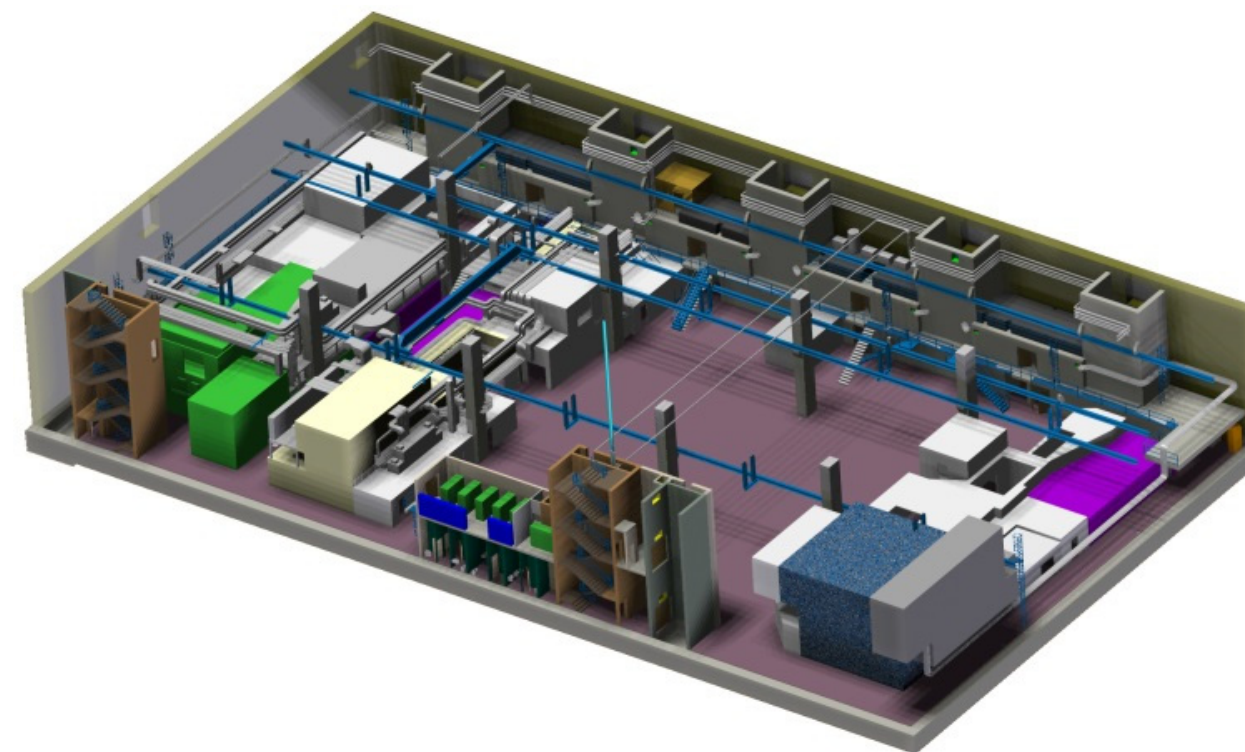
European XFEL — a leading new research facility



Boundary conditions in time and space...

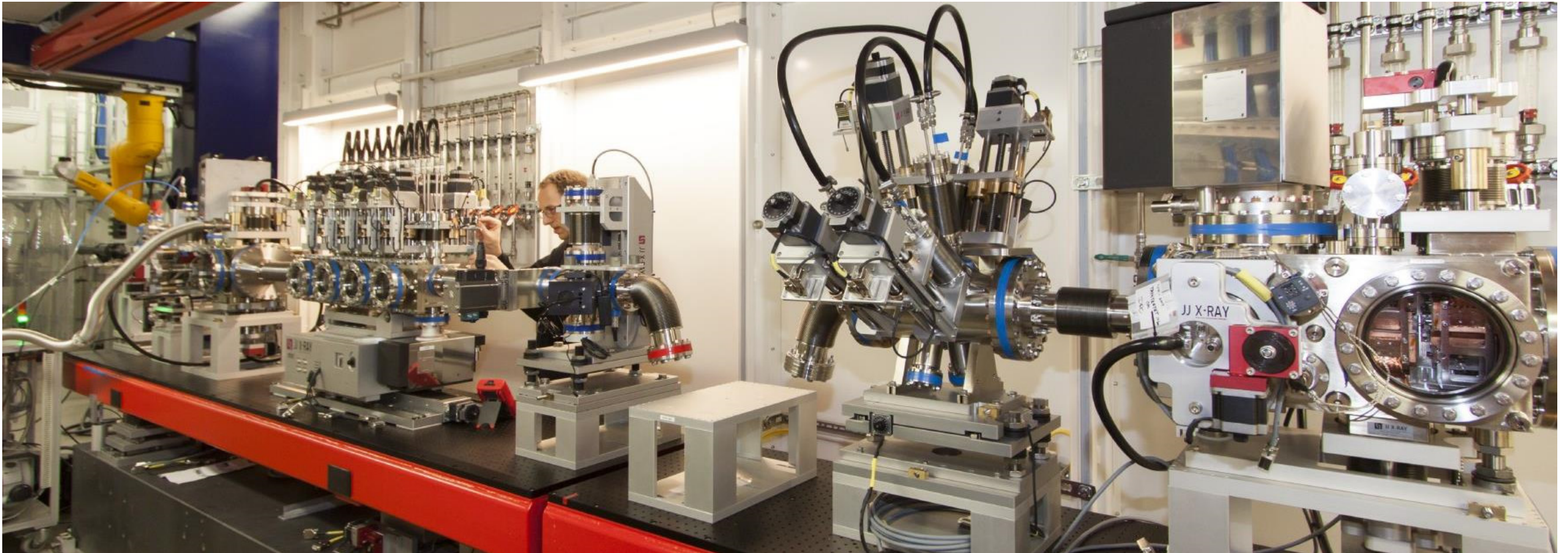


Burst of up to 2700 pulses in 600us every 100ms



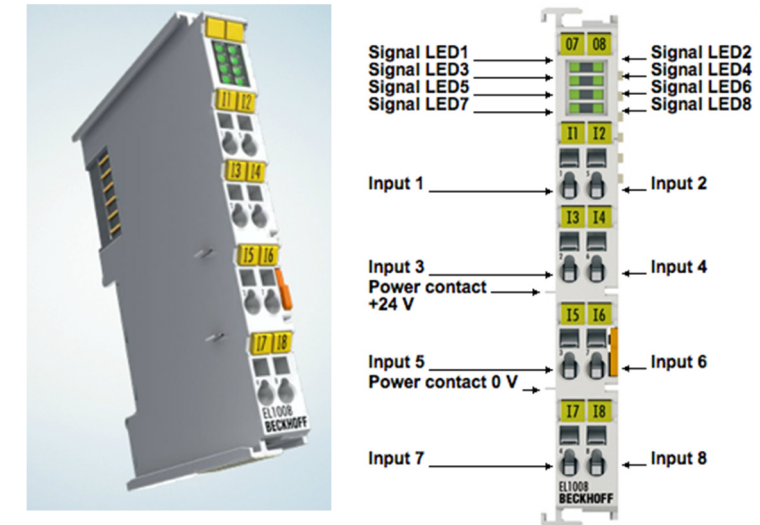
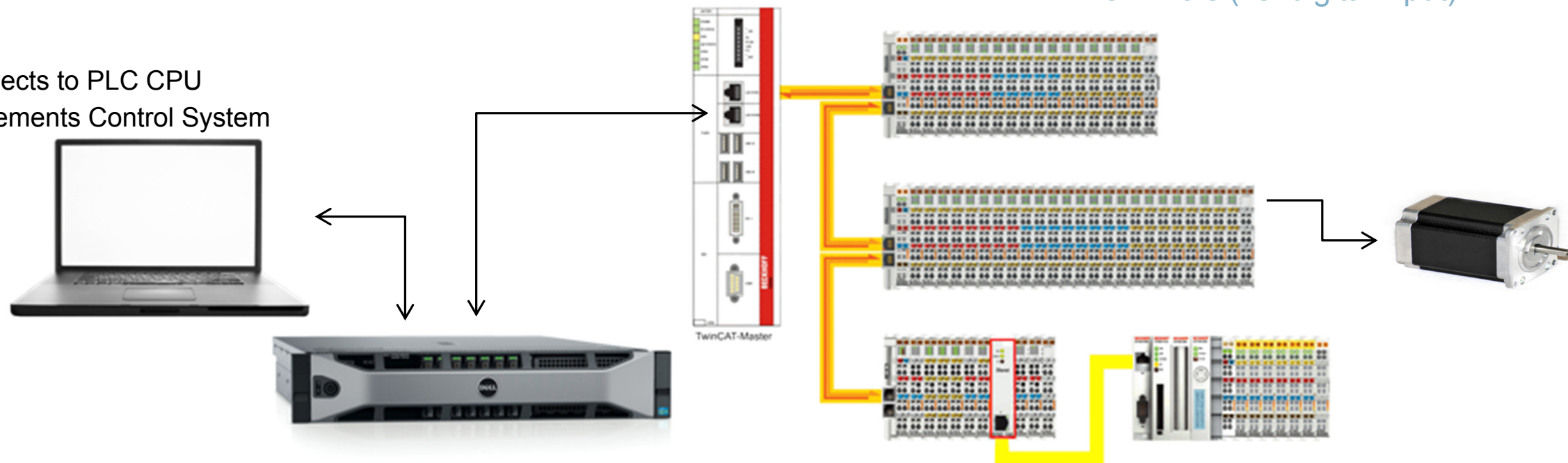
All control electronics should be placed in 19" racks in rack room above the experiment hutches

What has to be controlled: motion, vacuum, temperature, power, protection,...



PLC systems – simplified overview

- Programmable Logic Controller
- Terminals as interface to h/w
- Terminals are connected together
- PLC CPU
 - Connects via cables to Terminals
 - Implements programs for control
- Computer
 - connects to PLC CPU
 - Implements Control System



Terminals (i.e. digital input)

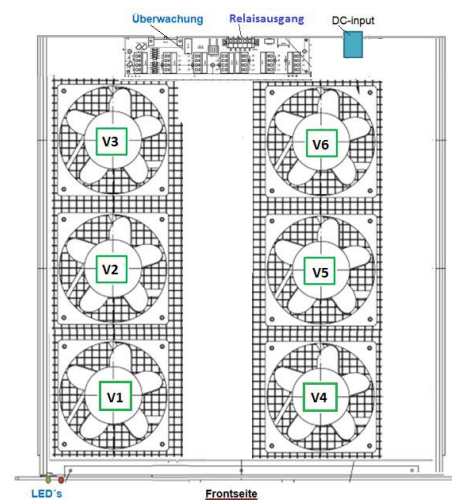
PLC systems – modular and compact structure



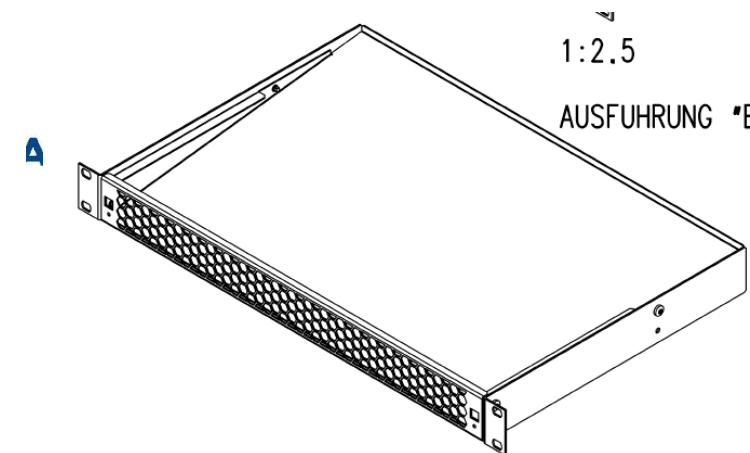
2 PLC modules in one 19" frame



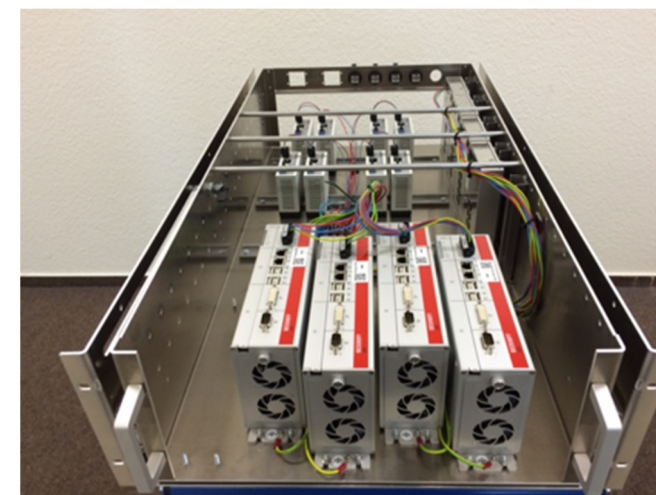
TDK Lambda HFE Supply



FAN unit with alarm output



Air duct to redirect airflow in rack

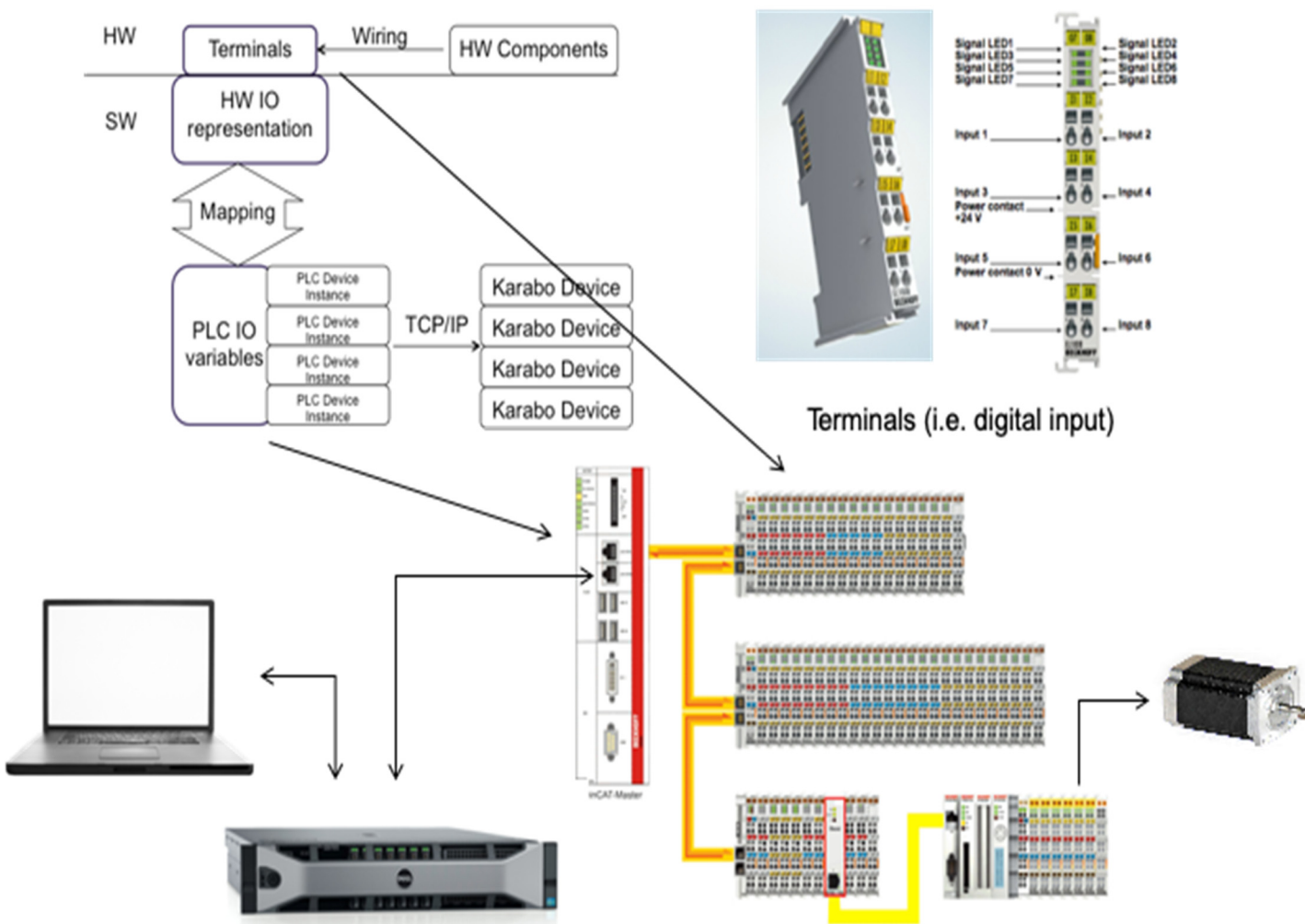


PLC CPU 19" cabinet

Example of installed PLC systems

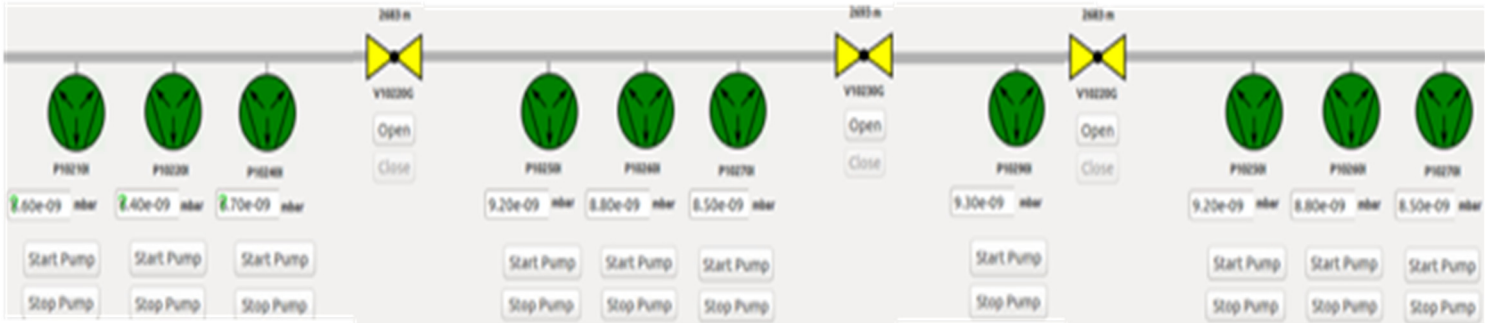


PLC Framework Library and generic interlock functionality



Device Name	SA1_XTD2_VAC/VALVE/V10230G				
Conditions	Signal Source (Device.Parameter)	Operator (optional)	Signal Source (Device.Parameter)(optional)	Operator	Limit
c1	SA1_XTD2_VAC/IPUMP/P10210I._bit IonPumpDI			EQOp	FALSE
c2	SA1_XTD2_VAC/IPUMP/P10220I._bit IonPumpDI			EQOp	FALSE
c3	SA1_XTD2_VAC/IPUMP/P10240I._bit IonPumpDI			EQOp	FALSE
c4	SA1_XTD2_VAC/IPUMP/P10250I._bit IonPumpDI			EQOp	FALSE
c5	SA1_XTD2_VAC/IPUMP/P10260I._bit IonPumpDI			EQOp	FALSE
c6	SA1_XTD2_VAC/IPUMP/P10270I._bit IonPumpDI			EQOp	FALSE
c7	SA1_XTD2_VAC/IPUMP/P10290I._bit IonPumpDI			EQOp	FALSE
c8	SA1_XTD2_VAC/IPUMP/P10300I._bit IonPumpDI			EQOp	FALSE
c9	SA1_XTD2_VAC/IPUMP/P10310I._bit IonPumpDI			EQOp	FALSE
c10	SA1_XTD2_VAC/IPUMP/P10320I._bit IonPumpDI			EQOp	FALSE
c11					

Actions	Logic	Action	Value	Latch	Lock
a1	c1 or c2 or c3 or c4 or c5 or c6 or c7 or c8 or c9 or c10	CClose		no	yes
a2					



Component Requirement Document (CRD) – the starting point

European XFEL

COMPONENT REQUIREMENT DOCUMENT

DAQ and Control Systems

Equipment overview

This form must be used to define all requirements relevant for DAQ & Controls. It typically occurs in an EPLAN drawing.

Summary

Component (short)

LHEAT

Component (long)

Laser Heating

Component Group

IA2

Component Group (long)

Interaction Area 2

Instrument/Group

HED

Beamline

SASE2

Patch panel (optional)

WCB#23

Hutch / Room¹

A12

Rack (optional)

A22

Floor (optional)

First Floor

Equipment ID

Filled in by DAQ and Controls experts

Equipment ID

Filled in by DAQ and Controls experts

Creation date

12.03.18

Requester WP

HED / WP82

Short description

Requester contacts

Andreas Berghäuser

Email and phone if non-XFEL

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Phone: 6793

Revisions

Version	Date	Author	Comment
1	28.03.19	AB	added monitor signals added interface specifications
2	28.03.2019	NC	Terminals and loop assignments
3	23.05.2019	NC /JR	Added Typical Information, corrected wrong WCB number
4			

Equipment Type	Quantity	# IP-Addresses needed
Stepper Motor	2	no
Cameras	3	yes
Pneumatic Drive	9	no
Analog Output	4	no
Digital Output	25	no
Digital Input	16	no

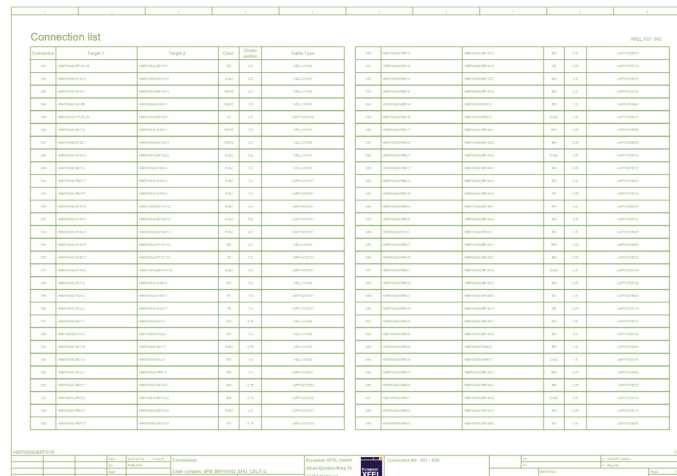
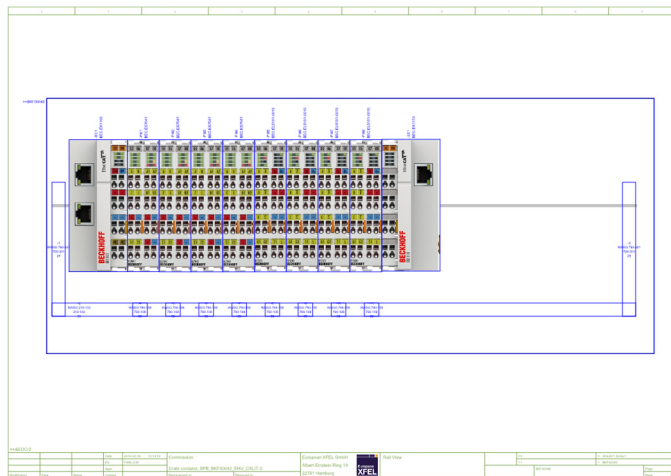
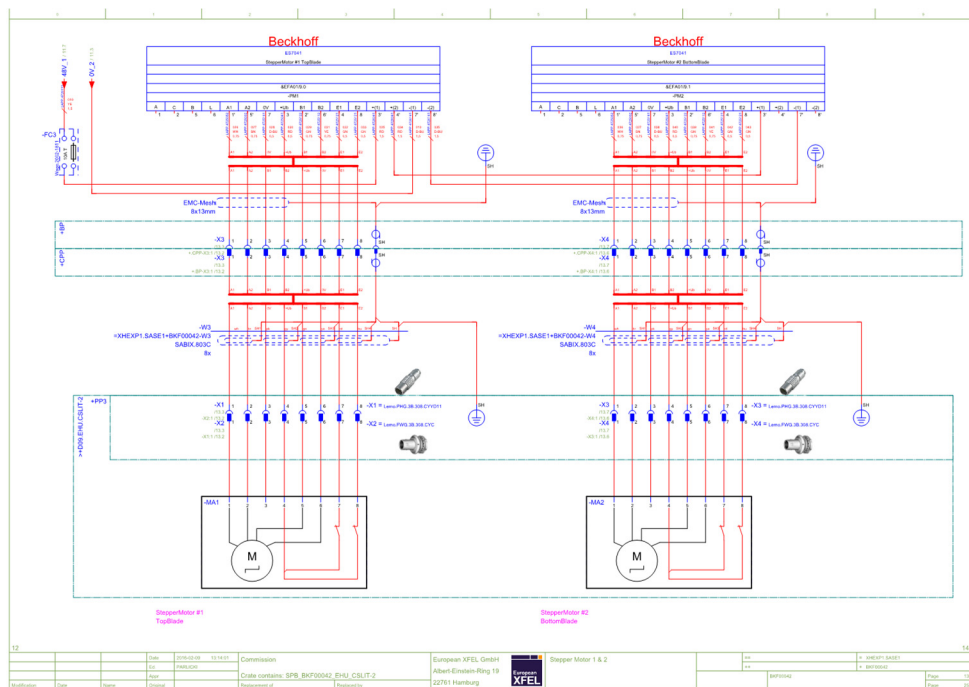
#	Equipment Type	Name	Manufacturer	Model	Data Sheet	Connector Type, Pin Assignment	Comment	Standard	Control Interface Hardware	Driver class (I/O, v/w)
1	Stepper Motor	ROTATOR_1	Newport	NSR-1	Appendix 1	Via WCB 24 WT-215 C_260	Filter rotator	YES	ES7031	SD_MC2MOTOR
2	Stepper Motor	ROTATOR_2	Newport	NSR-1	Appendix 1	Via WCB 24 WT-215 C_260	Filter rotator	YES	ES7031	SD_MC2MOTOR
2	Camera	BASLER_1	Basler	ACA1600-20gm	basler-1600-datasheet	Data: GigE PoE via switch in A22 Trigger: XFEL trigger	Integration in Karabo For EET: no ES2624 terminal is needed			

¹ For tunnels, please provide room number (if known) and absolute position in meters.

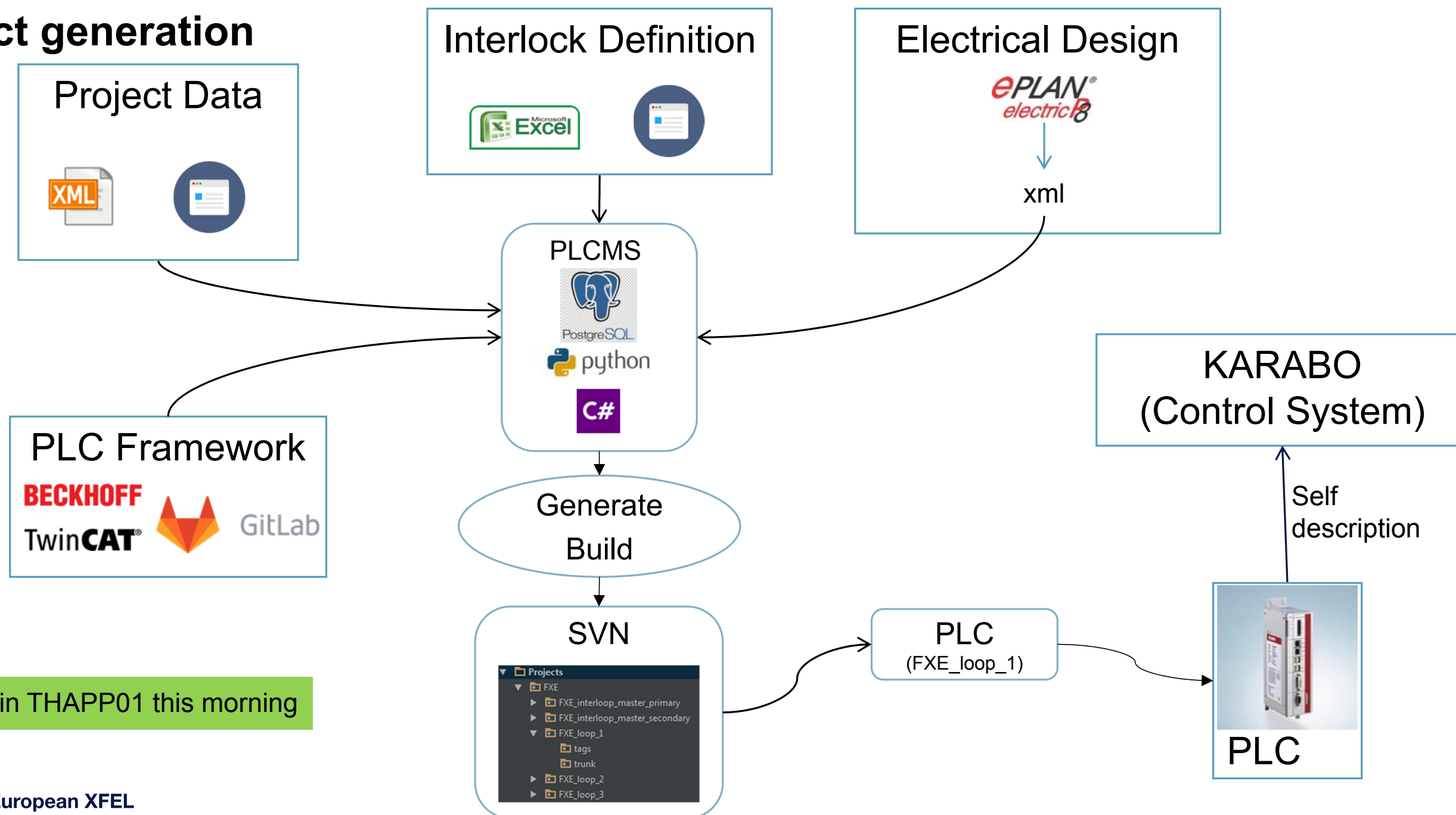
DAQ and Control Systems Component Requirement Document (v1) 1 of 21

European XFEL

Electrical CAD design (EPLAN P8)



PLC Project generation



Presented in THAPP01 this morning

General MicroTCA Infrastructure



MicroTCA Crates

Large 12 slot 9U and
small 6 slot 2U
(including MCH, Power
Supply and CPU)



X2Timer

XFEL Timing System
module for
synchronization (clocks
and triggers) and pulse
parameters from NAT



DAMC2

Required for Clock & Control
system for fast 2D detectors,
VETO System, Machine
Protection System and
photon beam loss monitors
from DESY



SIS8300

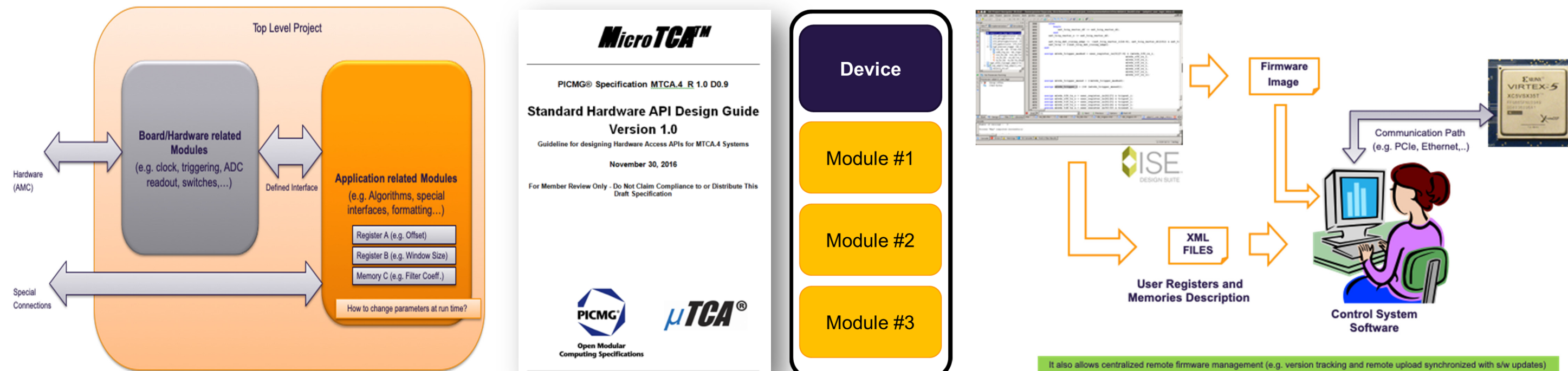
Fast 125MSPS ADC
with 10 channels and
16bit resolution for
diagnostics and
detectors from Struck
Innovative Systeme



ADQ412/ADQ14/ADQ7

High-speed digitizers
from 1.8GSPS to
10GSPS with 12 to 14
bit resolution from
Teledyne SP Devices

Overview of general FPGA design concepts



Providing Structure: Start-Up Projects separation in board and application

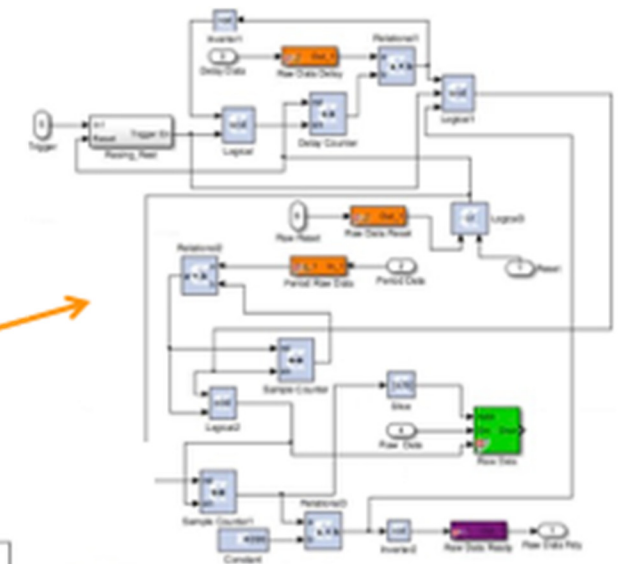
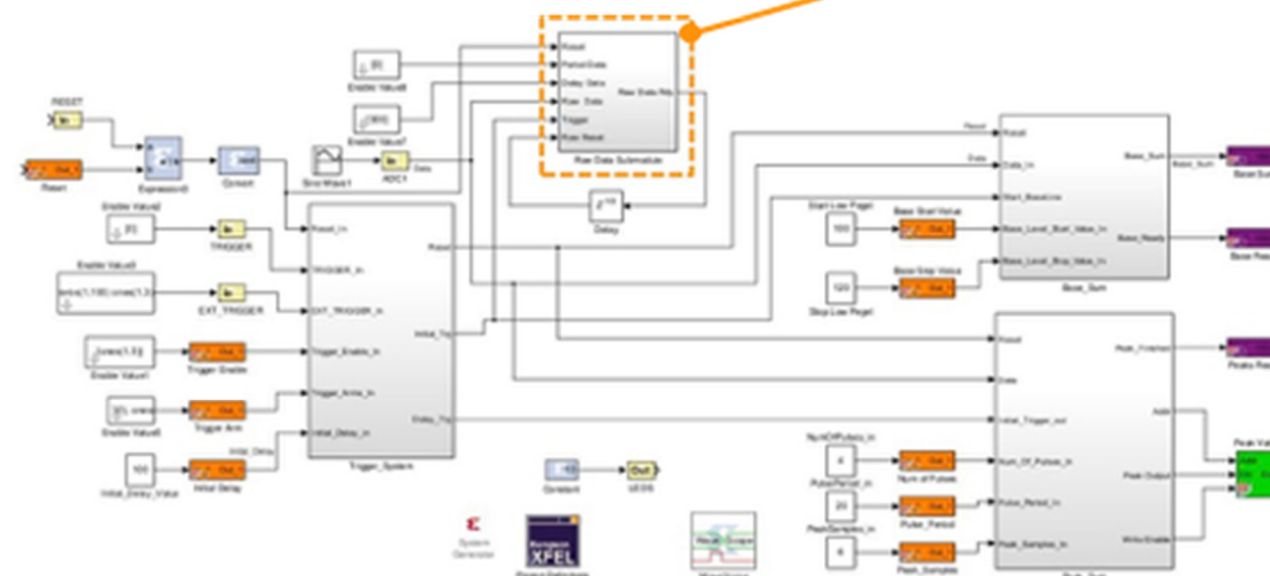
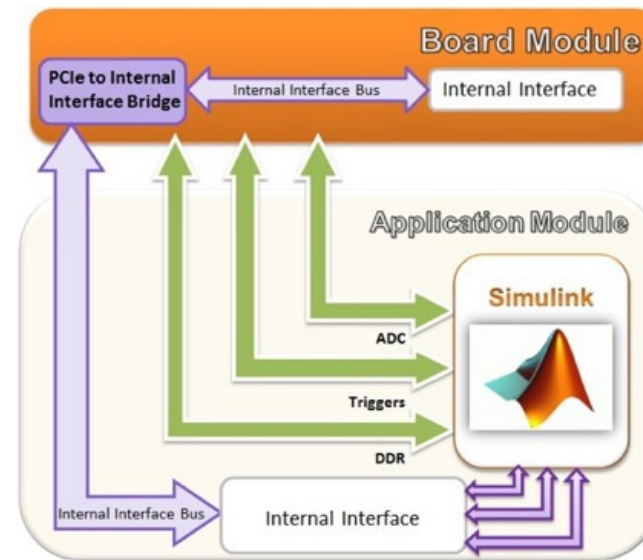
Self-descriptive register set to auto detect and check for compatibility

Automatic register and documentation generation based on VHDL table

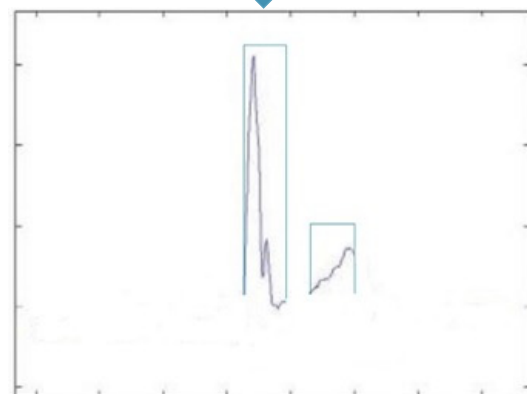
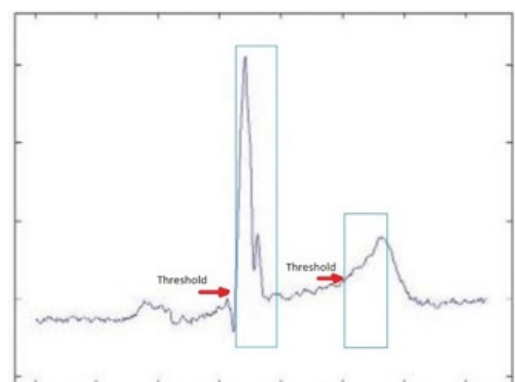
High-level FPGA algorithm development and simulation based on Simulink

The FPGA should bend time and space according to

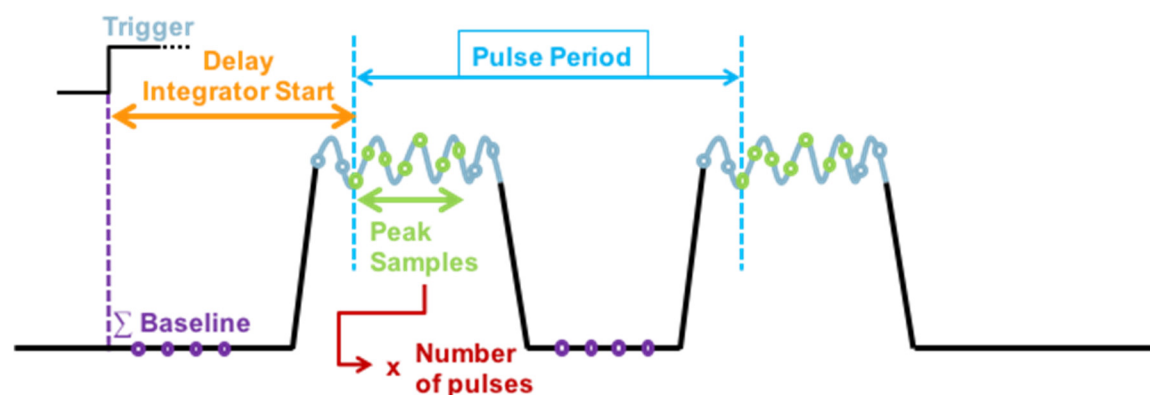
$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$



FPGA processing algorithms and interfacing standards – Signal processing

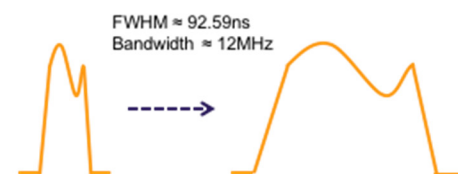


Zero Suppression

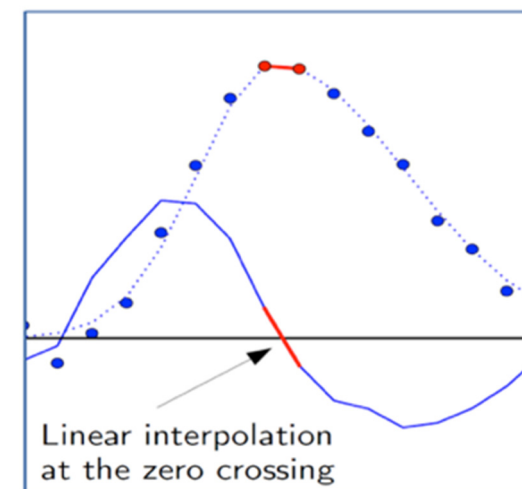
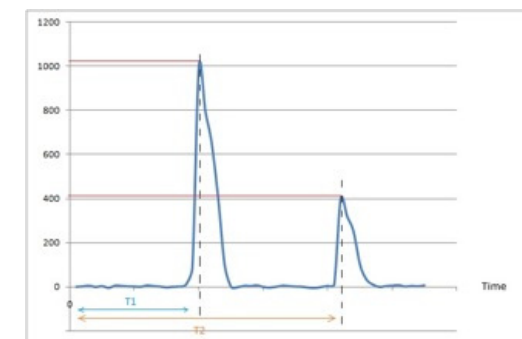


Pulse Stretcher RTM

- 10 SMA Connectors
- 2 Direct channels
- 8 Stretched channels
- Configurable DC Output
- Open/+1.2V/-1.2V



Pulse Integration



Peak Time Detection

Other tools and solutions not mentioned yet

Host State Breakdowns:				
Host	% Time Up	% Time Down	% Time Unreachable	% Time Undetermined
exf-b-fenice	54.435% (87.034%)	7.681% (12.366%)	0.000% (0.000%)	37.883%
exf-b-scs-df1	33.486% (53.899%)	28.641% (48.101%)	0.000% (0.000%)	37.873%
exfpo25915	55.941% (99.579%)	0.236% (0.421%)	0.000% (0.000%)	43.823%
exfpr5740	53.158% (99.857%)	0.091% (0.143%)	0.000% (0.000%)	36.751%
exfuto627	53.012% (99.504%)	0.314% (0.496%)	0.000% (0.000%)	36.875%
exfuto101	53.235% (99.978%)	0.014% (0.022%)	0.000% (0.000%)	36.752%
exfuto101-moh	40.102% (99.987%)	0.005% (0.013%)	0.000% (0.000%)	59.892%
exfuto103	56.168% (99.995%)	0.008% (0.015%)	0.000% (0.000%)	43.823%
exfuto103-moh	40.106% (99.995%)	0.002% (0.005%)	0.000% (0.000%)	59.892%
exfuto104	56.164% (99.956%)	0.025% (0.044%)	0.000% (0.000%)	43.811%
exfuto104-moh	40.102% (99.987%)	0.005% (0.013%)	0.000% (0.000%)	59.892%
exfuto105	52.892% (99.389%)	0.389% (0.611%)	0.000% (0.000%)	36.752%
exfuto105-moh	39.801% (99.235%)	0.307% (0.765%)	0.000% (0.000%)	59.892%
exfuto106	52.858% (99.383%)	0.390% (0.617%)	0.000% (0.000%)	36.751%
exfuto106-moh	39.800% (99.233%)	0.307% (0.767%)	0.000% (0.000%)	59.892%
exfuto107	52.889% (99.431%)	0.360% (0.569%)	0.000% (0.000%)	36.752%
exfuto107-moh	39.801% (99.235%)	0.307% (0.764%)	0.000% (0.000%)	59.892%
exfuto108	52.885% (99.425%)	0.364% (0.575%)	0.000% (0.000%)	36.751%
exfuto108-moh	39.804% (99.243%)	0.304% (0.757%)	0.000% (0.000%)	59.892%
exfuto110	55.185% (99.981%)	0.011% (0.019%)	0.000% (0.000%)	43.824%
exfuto110-moh	40.054% (99.895%)	0.054% (0.134%)	0.000% (0.000%)	59.892%
exfuto111	55.364% (97.964%)	1.151% (2.038%)	0.000% (0.000%)	43.485%
exfuto111-moh	40.106% (99.995%)	0.002% (0.005%)	0.000% (0.000%)	59.892%
exfuto301	58.149% (91.918%)	5.113% (8.082%)	0.000% (0.000%)	36.738%
exfuto301-moh	40.102% (99.987%)	0.005% (0.013%)	0.000% (0.000%)	59.892%
exfuto302	56.391% (88.967%)	6.993% (11.033%)	0.000% (0.000%)	36.615%
exfuto302-moh	39.001% (99.902%)	5.267% (13.085%)	0.000% (0.000%)	59.733%
exfuto304	52.613% (99.164%)	4.528% (0.835%)	0.000% (0.000%)	36.865%
exfuto304-moh	39.578% (98.679%)	5.530% (1.321%)	0.000% (0.000%)	59.892%
exfuto305	52.374% (98.493%)	9.954% (1.507%)	0.000% (0.000%)	36.672%
exfuto305-moh	39.580% (98.685%)	5.527% (1.315%)	0.000% (0.000%)	59.892%
exfutoa1	53.202% (99.745%)	0.149% (0.235%)	0.000% (0.000%)	36.649%
exfutoa3	53.111% (99.441%)	0.354% (0.559%)	0.000% (0.000%)	36.534%
exfutoa4	53.285% (99.847%)	0.097% (0.153%)	0.000% (0.000%)	36.615%
exfutoa6	47.595% (78.287%)	15.505% (24.743%)	0.000% (0.000%)	36.751%
exfutoadev	53.269% (99.193%)	0.115% (0.181%)	0.000% (0.000%)	36.616%
exfutoafae	18.948% (29.955%)	44.302% (70.045%)	0.000% (0.000%)	36.752%
exfutoapw78	51.849% (81.558%)	11.724% (18.442%)	0.000% (0.000%)	36.426%
fxe-int-ma-pri	56.152% (99.954%)	0.020% (0.040%)	0.000% (0.000%)	43.822%
fxe-int-ma-sec	56.106% (99.963%)	0.010% (0.017%)	0.000% (0.000%)	43.884%
fxe-loop-01	56.105% (99.983%)	0.009% (0.017%)	0.000% (0.000%)	43.884%
fxe-loop-02	56.105% (99.983%)	0.009% (0.017%)	0.000% (0.000%)	43.884%
fxe-loop-03	56.089% (99.953%)	0.027% (0.047%)	0.000% (0.000%)	43.884%
fxe-loop-04	56.105% (99.982%)	0.010% (0.018%)	0.000% (0.000%)	43.884%
fxe-loop-05	56.108% (99.988%)	0.008% (0.014%)	0.000% (0.000%)	43.884%
fxe-loop-06	56.105% (99.981%)	0.010% (0.019%)	0.000% (0.000%)	43.884%
fxe-loop-07	56.109% (99.982%)	0.010% (0.018%)	0.000% (0.000%)	43.821%
fxe-loop-08	56.170% (99.984%)	0.009% (0.016%)	0.000% (0.000%)	43.821%
sa1-plc-eps	56.173% (99.994%)	0.003% (0.005%)	0.000% (0.000%)	43.824%
sa1-plc-eps2	56.175% (99.985%)	0.008% (0.015%)	0.000% (0.000%)	43.818%
sa1-plc-free2	56.172% (99.993%)	0.004% (0.007%)	0.000% (0.000%)	43.824%
sa1-plc-mov	56.171% (99.991%)	0.005% (0.009%)	0.000% (0.000%)	43.824%
sa1-plc-mov2	56.171% (99.991%)	0.005% (0.009%)	0.000% (0.000%)	43.824%
sa1-plc-spb	56.173% (99.994%)	0.003% (0.005%)	0.000% (0.000%)	43.824%
sa1-plc-vac	56.172% (99.993%)	0.004% (0.007%)	0.000% (0.000%)	43.824%
sa1-plc-vac2	56.173% (99.994%)	0.003% (0.005%)	0.000% (0.000%)	43.824%
sa3-plc-eps	27.307% (99.992%)	0.002% (0.005%)	0.000% (0.000%)	72.691%
sa3-plc-master	27.308% (99.996%)	0.001% (0.004%)	0.000% (0.000%)	72.691%
sa3-plc-mov1	51.678% (99.998%)	0.002% (0.032%)	0.000% (0.000%)	93.420%
sa3-plc-mov2	27.307% (99.992%)	0.002% (0.008%)	0.000% (0.000%)	72.691%
sa3-plc-scs	27.307% (99.992%)	0.002% (0.008%)	0.000% (0.000%)	72.691%
sa3-plc-sqs	27.307% (99.992%)	0.002% (0.008%)	0.000% (0.000%)	72.691%
sa3-plc-vac	27.118% (99.302%)	0.191% (0.696%)	0.000% (0.000%)	72.691%
sa3-plc-ngm	27.307% (99.994%)	0.002% (0.005%)	0.000% (0.000%)	72.691%
spb-int-ma-pri	51.418% (91.456%)	4.798% (8.534%)	0.000% (0.000%)	43.783%
spb-int-ma-sec	51.418% (91.454%)	4.799% (8.535%)	0.000% (0.000%)	43.783%
spb-loop-1	50.948% (99.953%)	0.024% (0.047%)	0.000% (0.000%)	49.029%
spb-loop-10	51.048% (90.680%)	5.247% (9.320%)	0.000% (0.000%)	43.705%
spb-loop-11	51.427% (91.495%)	4.798% (8.534%)	0.000% (0.000%)	43.775%
spb-loop-12	51.429% (91.488%)	4.797% (8.532%)	0.000% (0.000%)	43.774%
spb-loop-13	50.891% (99.685%)	5.227% (9.314%)	0.000% (0.000%)	43.882%
spb-loop-2	50.947% (99.955%)	0.023% (0.045%)	0.000% (0.000%)	49.030%
spb-loop-3	50.947% (99.954%)	0.023% (0.045%)	0.000% (0.000%)	49.030%
spb-loop-4	50.948% (99.954%)	0.023% (0.045%)	0.000% (0.000%)	49.030%
spb-loop-5	50.948% (99.957%)	0.022% (0.043%)	0.000% (0.000%)	49.030%
spb-loop-6	50.948% (99.957%)	0.022% (0.043%)	0.000% (0.000%)	49.030%
spb-loop-7	50.949% (99.959%)	0.021% (0.041%)	0.000% (0.000%)	49.030%
spb-loop-8	50.731% (99.532%)	0.238% (0.468%)	0.000% (0.000%)	49.030%
spb-loop-9	50.957% (99.953%)	0.024% (0.047%)	0.000% (0.000%)	49.019%
Average	49.491% (96.538%)	2.073% (3.452%)	0.000% (0.000%)	48.498%

Service Overview For All Host Groups

Beckhoff CPUs HERA-SOUTH (beckhoff-cpus-hera-south)

Host	Status	Services	Actions
exf-b-fenice	UP	No matching services	
exf-b-scs-df1	DOWN	No matching services	

PLC CPUs in FXE (plc-fxe)

Host	Status	Services	Actions
fxe-int-ma-pri	UP	9 OK	
fxe-int-ma-sec	UP	9 OK	
fxe-loop-01	UP	9 OK	
fxe-loop-02	UP	9 OK	
fxe-loop-03	UP	9 OK	
fxe-loop-04	UP	9 OK	
fxe-loop-05	UP	9 OK	
fxe-loop-06	UP	9 OK	
fxe-loop-07	UP	9 OK	
fxe-loop-08	UP	9 OK	

PLC CPUs in FXE LASER (plc-laser-fxe)

Host	Status	Services	Actions
exfpo25915	UP	9 OK	

PLC CPUs in SA1 (plc-sa1)

Host	Status	Services	Actions
sa1-plc-eps	UP	9 OK	
sa1-plc-eps2	UP	No matching services	
sa1-plc-free2	UP	No matching services	
sa1-plc-mov	UP	9 OK	
sa1-plc-mov2	UP	No matching services	
sa1-plc-spb	UP	7 UNKNOWN 2 PENDING	
sa1-plc-vac	UP	9 OK	
sa1-plc-vac2	UP	No matching services	

PLC CPUs in SA3 (plc-sa3)

Host	Status	Services	Actions
sa3-plc-eps	UP	1 CRITICAL 8 PENDING	
sa3-plc-master	UP	1 CRITICAL 8 PENDING	
sa3-plc-mov1	UP	9 OK	
sa3-plc-mov2	UP	1 CRITICAL 8 PENDING	
sa3-plc-scs	UP	1 CRITICAL 8 PENDING	
sa3-plc-sqs	UP	1 CRITICAL 8 PENDING	
sa3-plc-vac	UP	9 OK	
sa3-plc-ngm	UP	9 OK	

PLC CPUs in SPB (plc-spb)

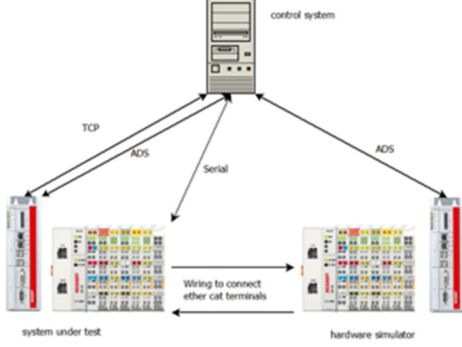
Host	Status	Services	Actions
spb-int-ma-pri	UP	9 OK	
spb-int-ma-sec	UP	9 OK	
spb-loop-1	UP	9 OK	
spb-loop-10	UP	9 OK	
spb-loop-11	UP	9 OK	
spb-loop-12	UP	9 OK	
spb-loop-13	UP	9 OK	
spb-loop-2	UP	9 OK	
spb-loop-3	UP	9 OK	
spb-loop-4	UP	9 OK	
spb-loop-5	UP	9 OK	
spb-loop-6	UP	9 OK	
spb-loop-7	UP	9 OK	
spb-loop-8	UP	9 OK	
spb-loop-9	UP	9 OK	



For automated OS install and config



For OS monitoring



control system

TCP

ADS

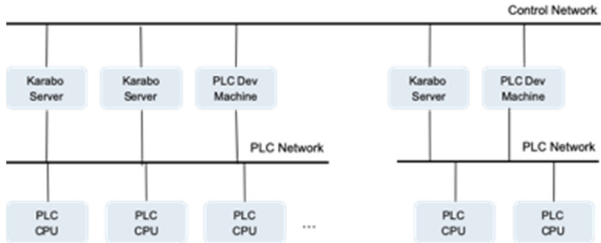
Serial

ADS

system under test

hardware simulator

Wiring to connect ether cat terminals



Control Network

PLC Network

Karabo Server

PLC Dev Machine

PLC CPU

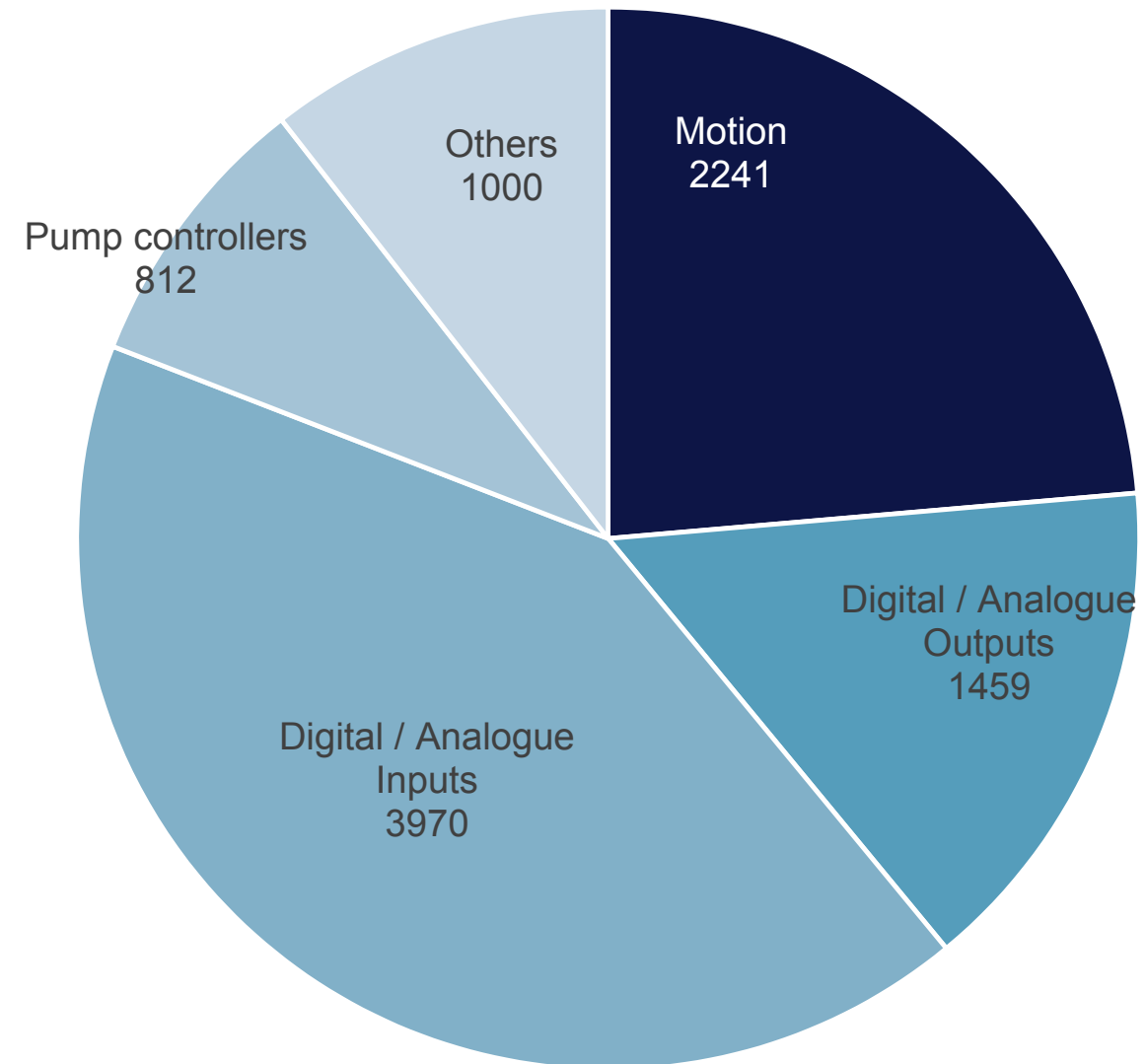
PLC Framework regression test system

PLC security via isolated networks

Status (9/2019): Integration in Numbers

- Softdevices: 9.482
- PLC Loops / CPUs: 120
- Number of Terminals: 8.452
- PLC Modules / crates: >500
- MicroTCA Systems: 35
- Digitizer channels: >280

Distribution of softdevices



What is next...

- Integration of general automation functionality into PLC systems (beyond interlocks)
- Integration of safety PLC systems for cases where a machine is a risk for health
- Development and evaluation of high-speed FPGA based image processing platform

Thank You for Your Attention

