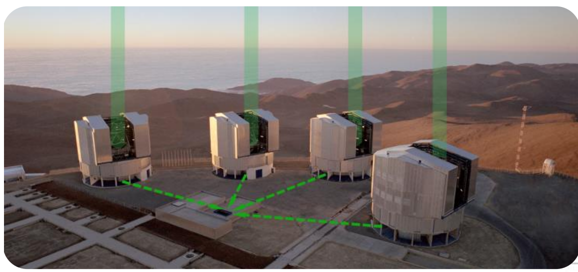
Controlling “large” astronomical instruments: trends, solutions and lesson learned

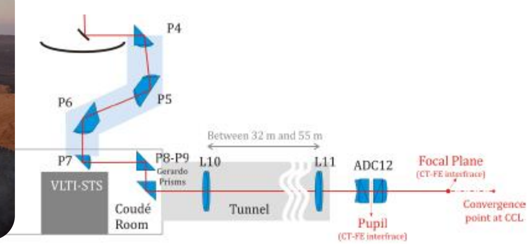
Paolo Di Marcantonio

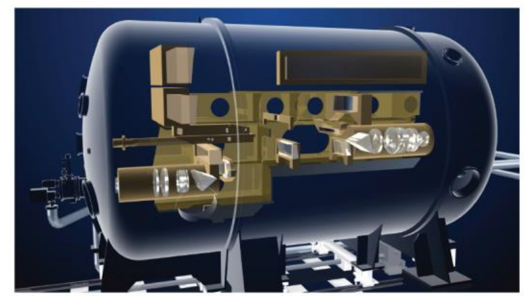
on behalf of INAF-OATs CS team: R. Cirami, I. Coretti, V. Baldini, G. Calderone, P. Santin

Outline of the talk

- Motivations
- Standardized industrial solution choices
- The working example: ESPRESSO (Echelle SPectrograph for Rocky Exoplanets and Stable Spectral Observations)







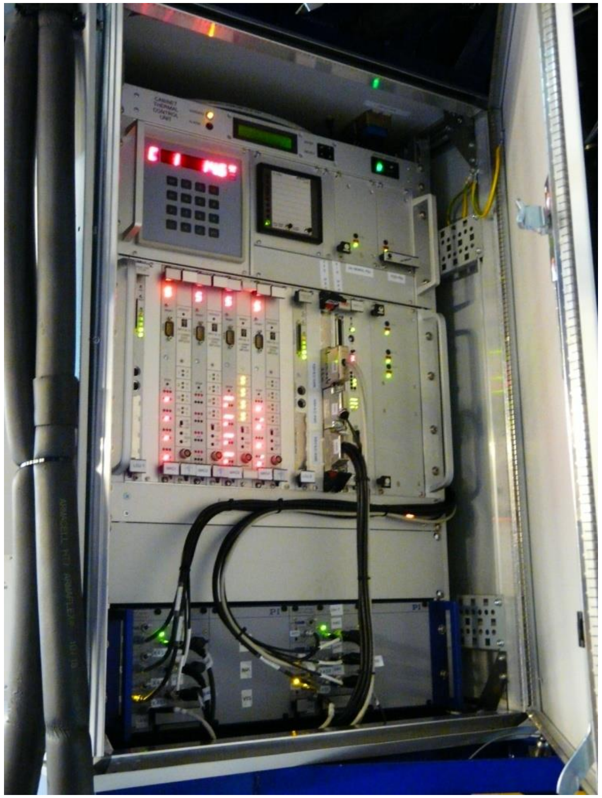
- The future: HiRes for the E-ELT
- Final considerations

Motivations

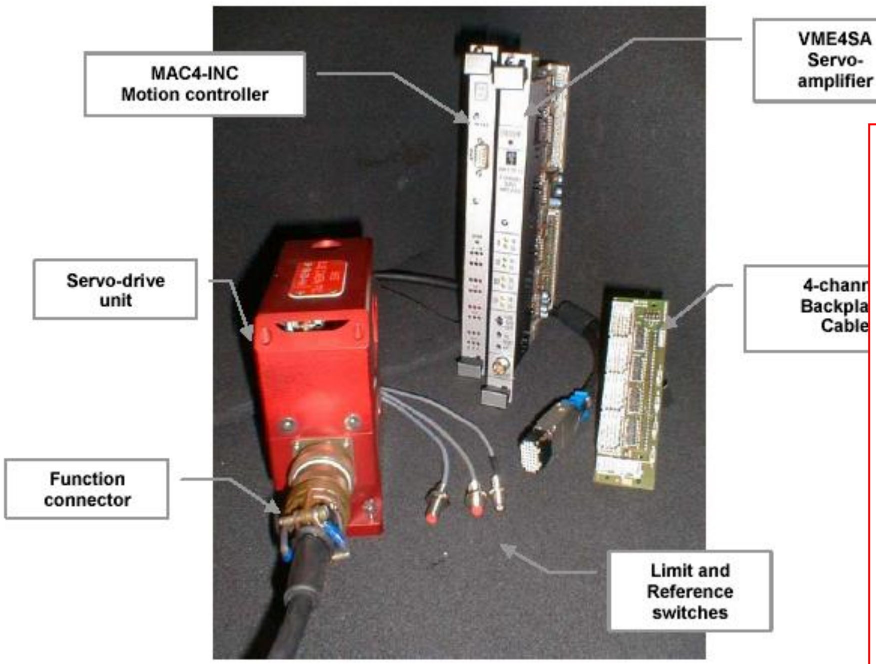
- Obsolescence issue (technology is advancing very fast)
- Custom solutions are expensive both to develop/implement as well as to maintain (especially in the long term)
- Market offers a variety of solution that could be chosen to fit instrumental needs boosting performance, easing integration and lowering the costs
- Moving towards E-ELT (from the VLT) requires the most up-to-date hw/sw solutions to cope with the new Observatory requirements

The VLT case

"Old" VLT standard is heavily based on the concept of *VME-based LCU* (Local Control Unit) dedicated to the control of sub-systems hardware. Even though the VME bus is an international standards there are several limitations in the way it can be used, in particular:



- the strong hw/sw coupling;
- deployment and distribution issues;



- costs !!!

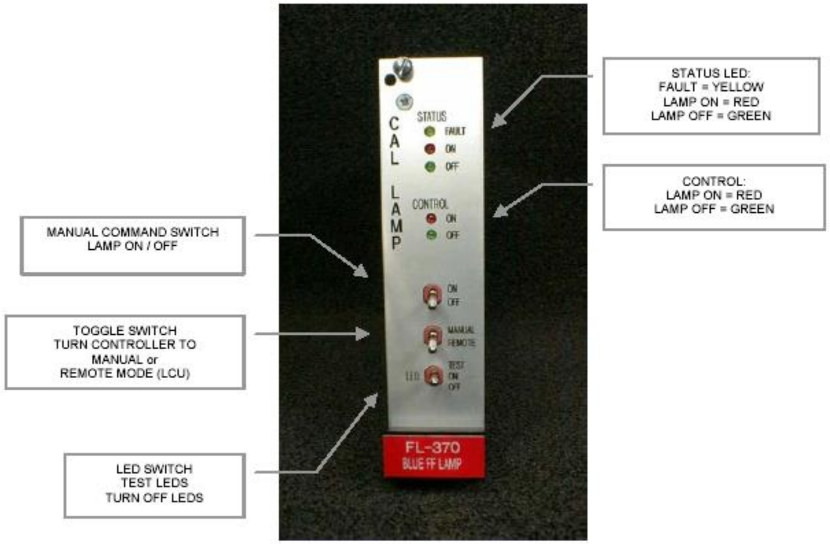


Figure 20- CFC control electronics sub-rack

TCCD@ESO

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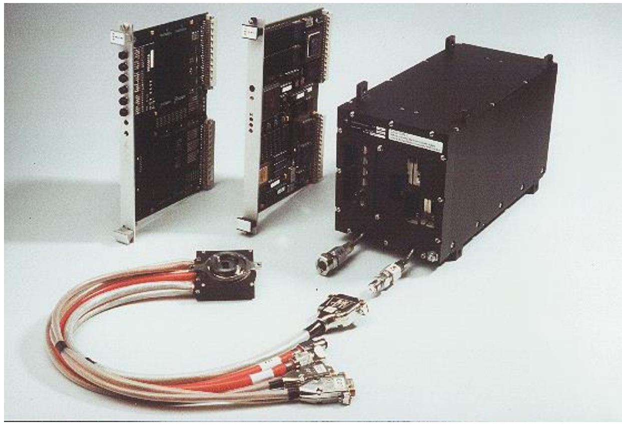


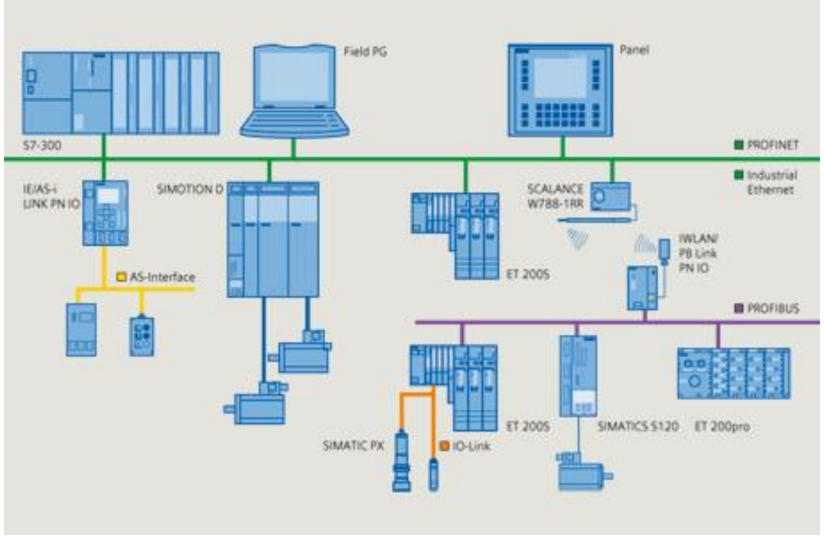
The first generation TCCD in the early 1990's was a joint collaboration between ESO and Dornier Jena Optik: it encompassed ad-hoc VME boards and array control electronics built on INMOS transputers and Russian frame transfer CCD detectors.

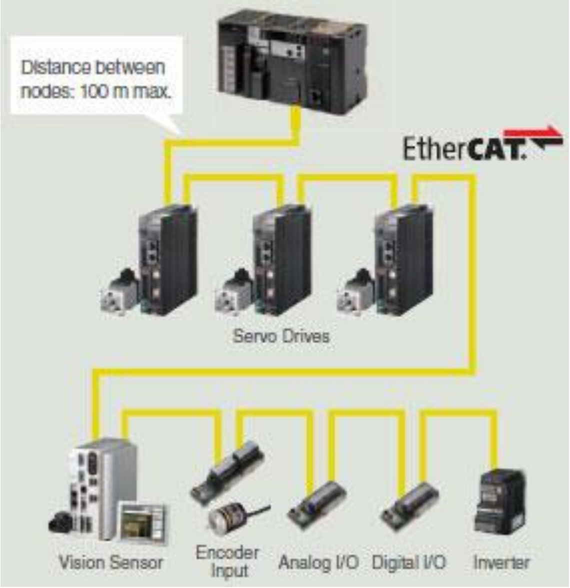
The second generation was introduced in 2005 and was based on the San Diego State University (SDSU) systems deploying DSPs on PCI bus bridged to Motorola PowerPC VME boards and e2v detectors integrated in ESO made camera heads.

⇨ expensive in terms of costs, manufacturing, integration and maintenance

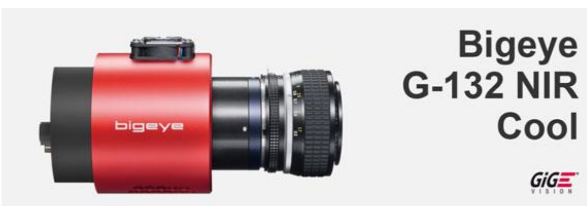
Industrial Ethernet i.e. Ethernet based industrial communication systems with extensions for real-time communications. Aim is to replace several possible open or proprietary protocols such as *Modbus*, *CANopen*, *Profibus* … to made systems more inter-operable and reuse the "ubiquitous" Ethernet infrastructure.

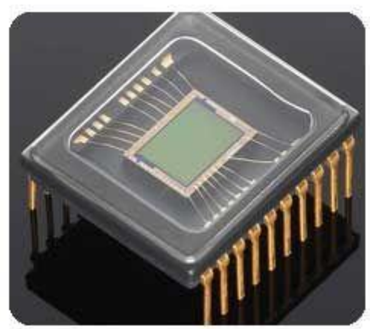
Used @ OATs Profinet (for Siemens systems) and EtherCAT (for Beckhoff systems).





GigE Vision interface industrial standard for high-performance industrial cameras which provides a framework for transmitting high-speed video and related control data over *Ethernet* networks (members: AVT, DALSA, BASLER AG …)





Bigeye	G-132 NIR Cool
Interface	IEEE 802.3 1000baseT
Resolution	1280 x 1024
Sensor	Sony ICX285
Sensor type	CCD Progressive
Sensor size	Type 2/3
Cell size	6.45 µm
Cooling temperature	-20 °C
Dark noise	tdb
Dark current	tbd
Saturation capacity	tbd
Dynamic range	tbd
Lens mount	C-Mount
Max frame rate at full resolution	12.5 fps
A/D	12 bit
On-board FIFO	32 MB
	Output
Bit depth	12 bit
Mono modes	Mono8, Mono12, Mono12Packed
	General purpose inputs/outputs (GPIOs)
TTL I/Os	1/1
Opto-coupled I/Os	3/3
RS-232	2
	Operating conditions/Dimensions
Operating temperature	0 °C ... 35 °C
Power consumption (12 V)	max. <36 W, typ. <18 W
Mass	1270 g
Body Dimensions (L x W x H in mm)	100.8 x 90 x 99 mm incl. connectors, w/o lens
Regulations	CE, RoHS (2002/95/EC)

At higher abstraction level, the GenICam™ standard provides a generic programming interface for all kinds of cameras and devices no matter what interface technology (GigE Vision, USB3 Vision, Camera Link, 1394 DCAM, etc.)

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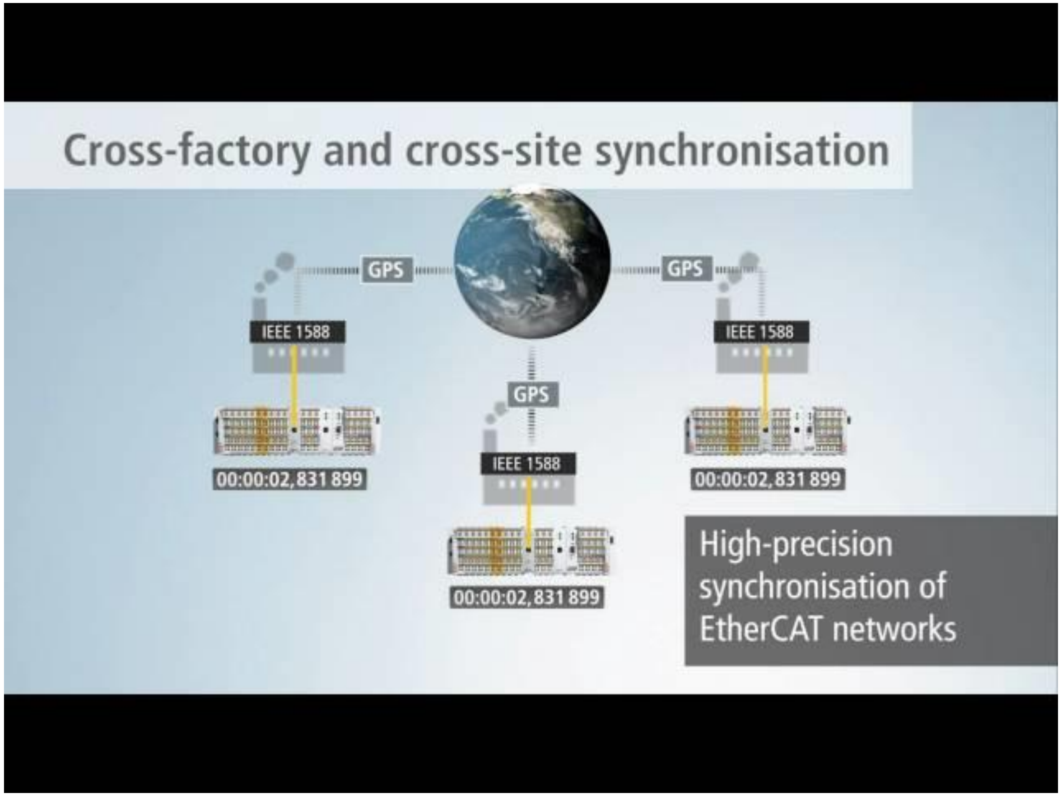
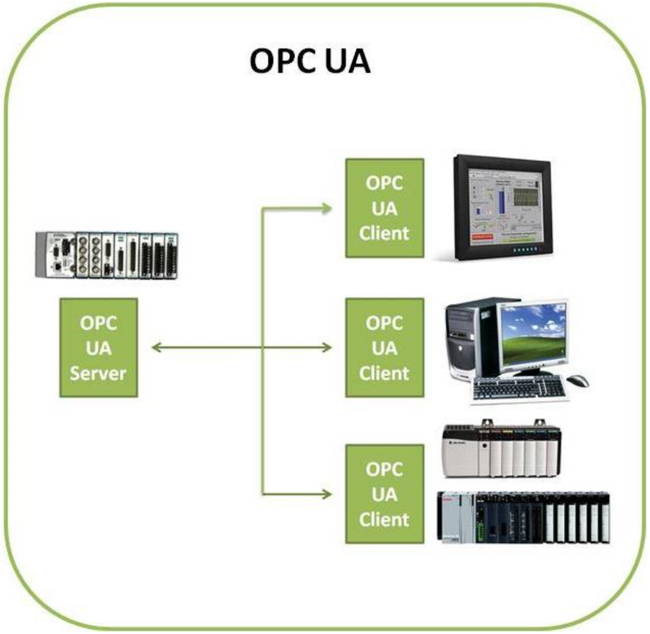
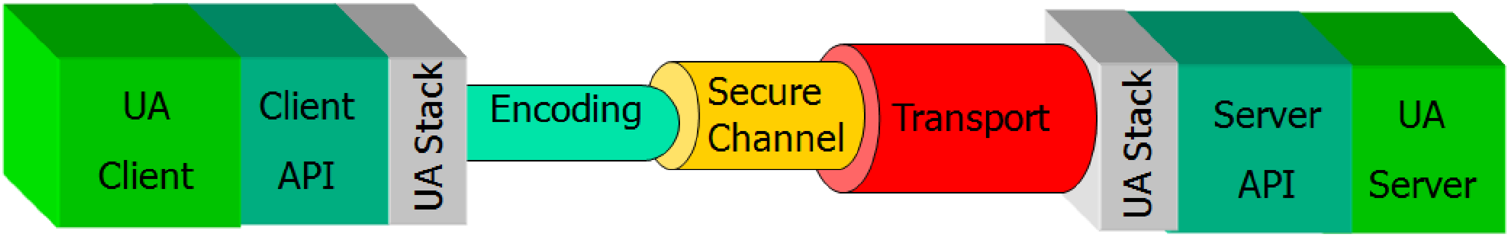
IEEE 1588 is the standard defining the *PTP* (precision time protocol), which is able to achieve sub-microsecond range clock accuracy. Its is the time synchronization system foreseen for the E-ELT.

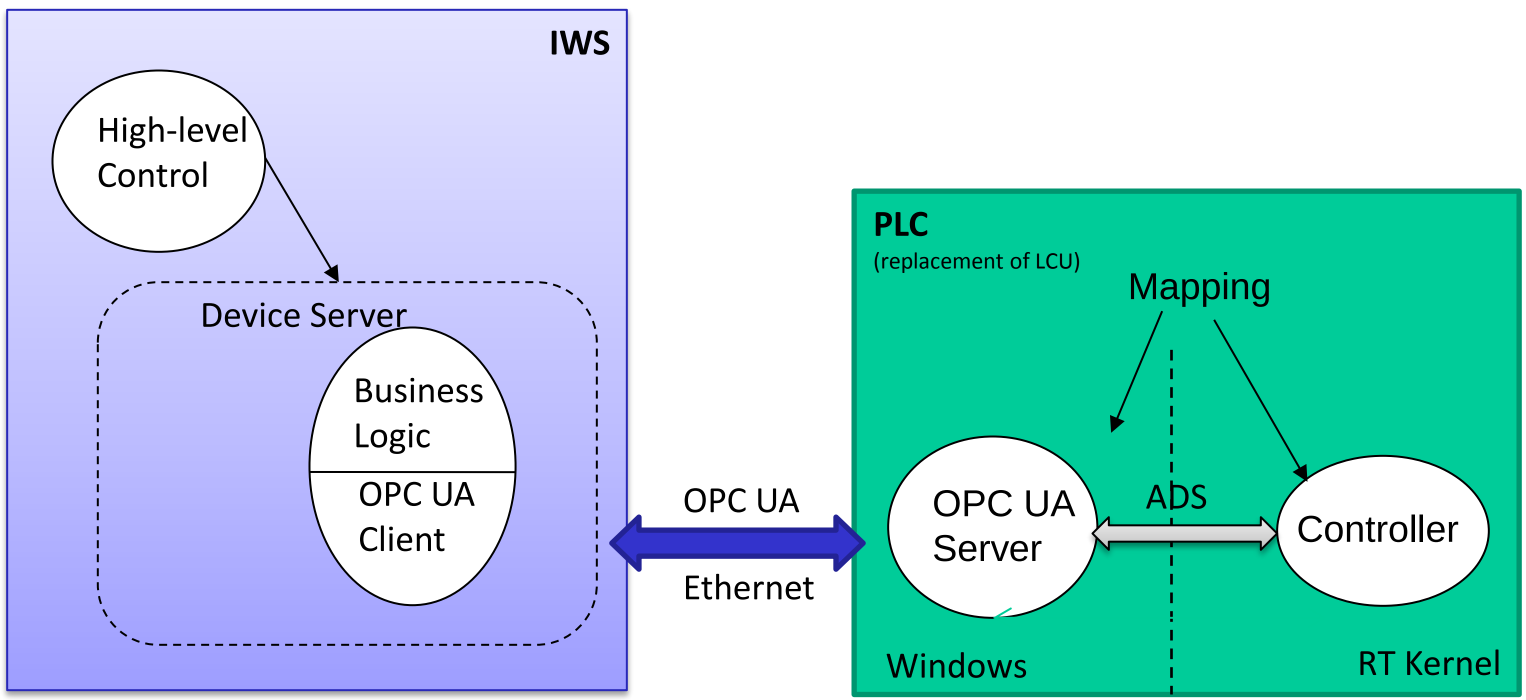


OPC Unified Automation is an industrial communication protocol developed for interoperability by the OPC foundation.





OPC-UA architecture



OPC-UA @ OATs

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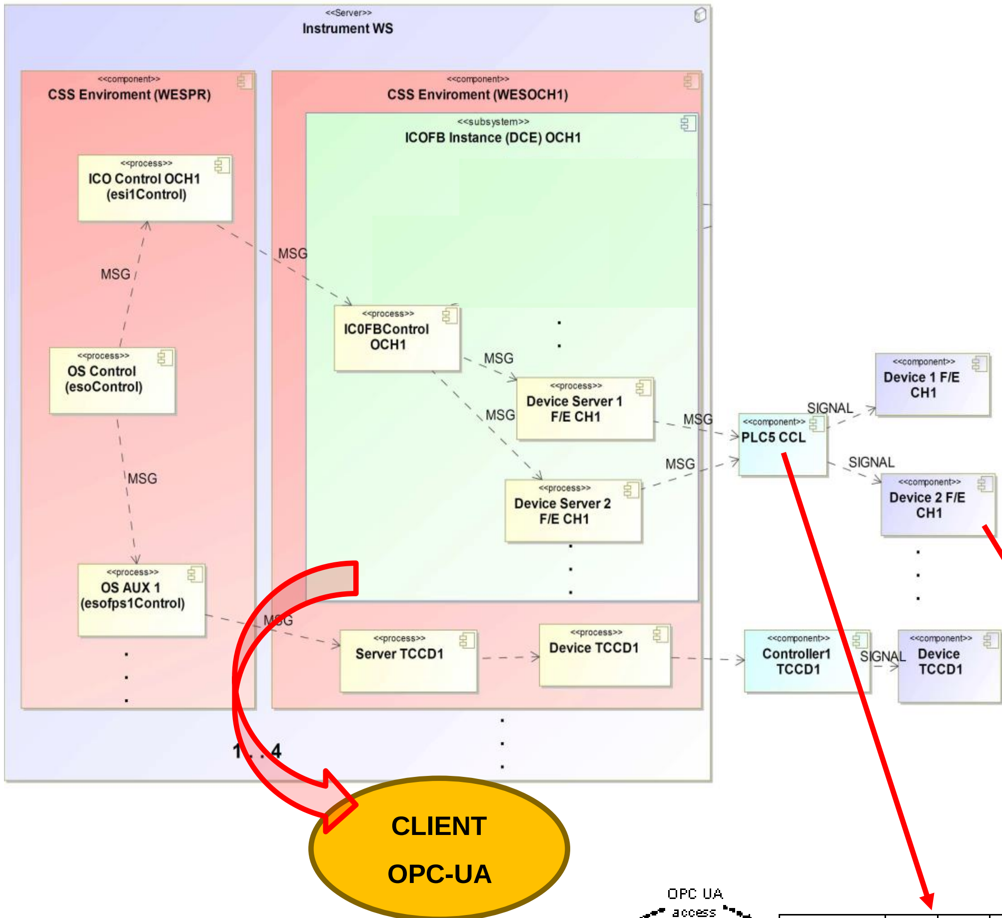
Unified Architecture

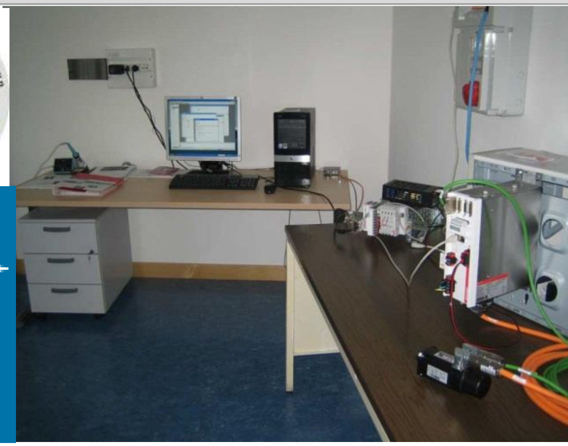
TM Openess Productivity Collaboration

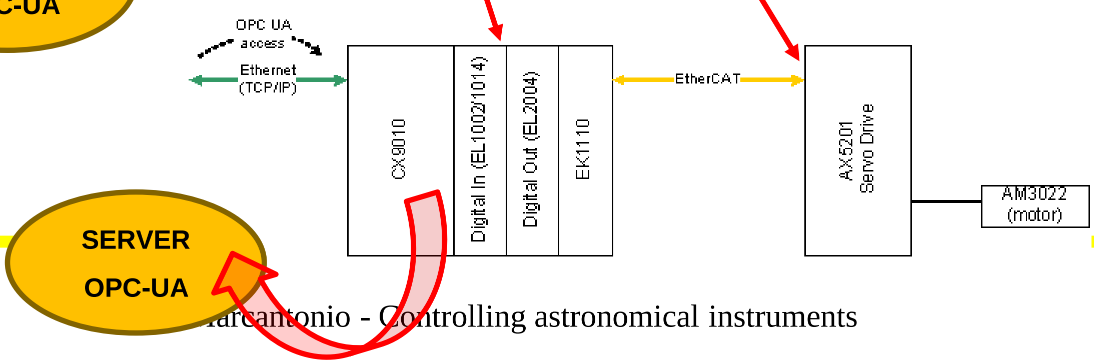


First Laboratory Instrument which uses OPC-UA

Astrophysical Technologies Group
ATG
Trieste
OATs

ESO





PLCs

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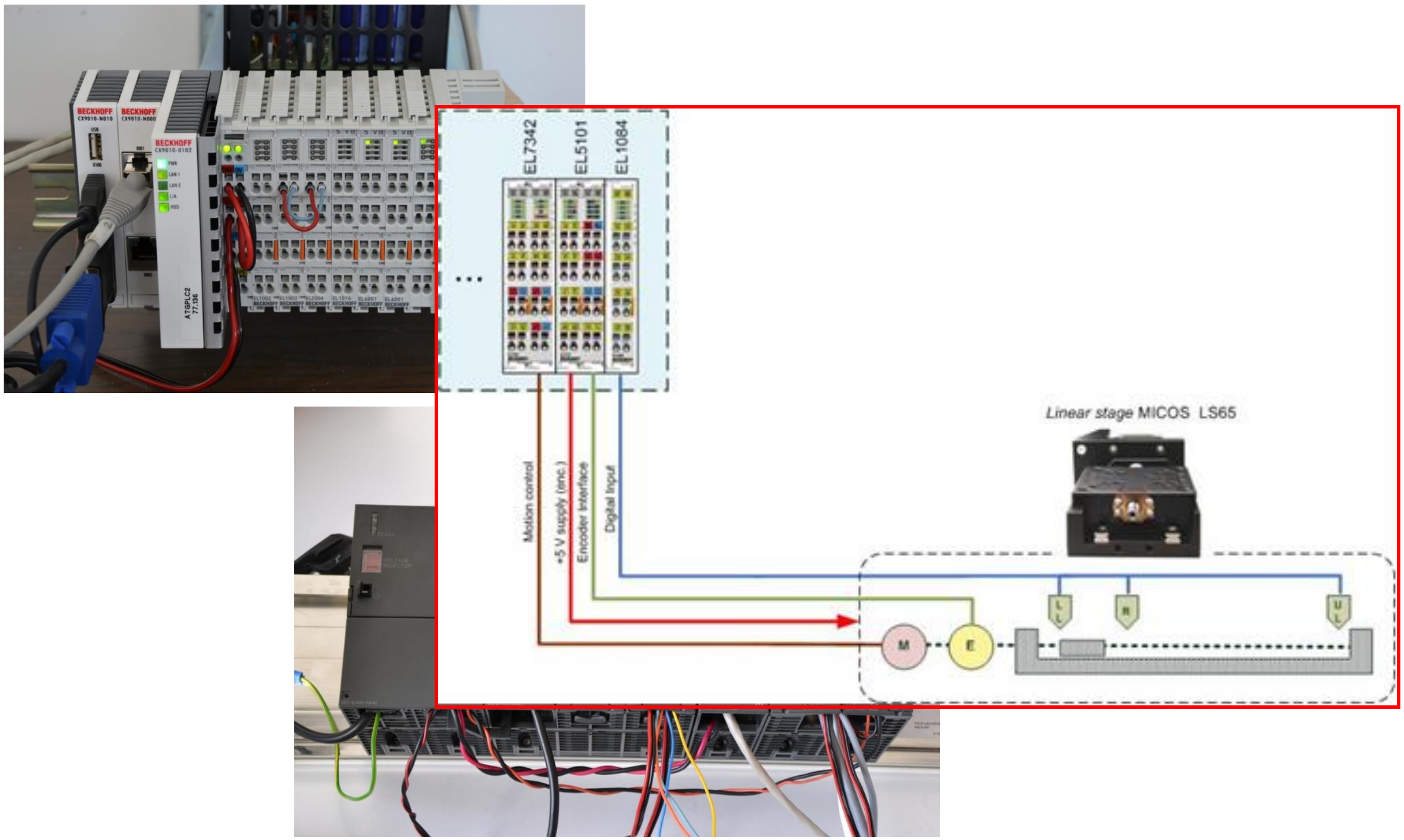
A programmable logic controller, PLC, or programmable controller is a digital computer used for automation of typically industrial processes.

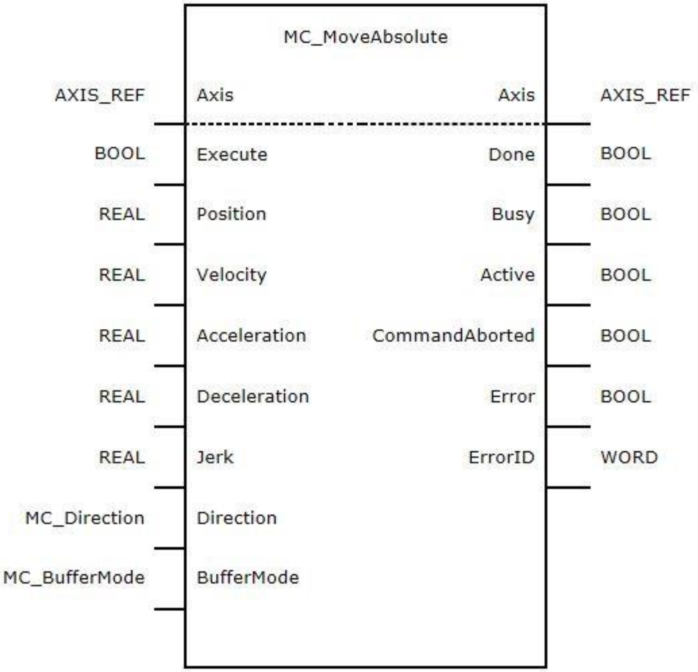


PLC Open MC

PLCopen motion standard provide a way to have standard application libraries that are reusable for multiple hardware platforms. It offers in particular function blocks based on the IEC 61131 languages to create efficient, flexible code that is vendor- and product-independent.

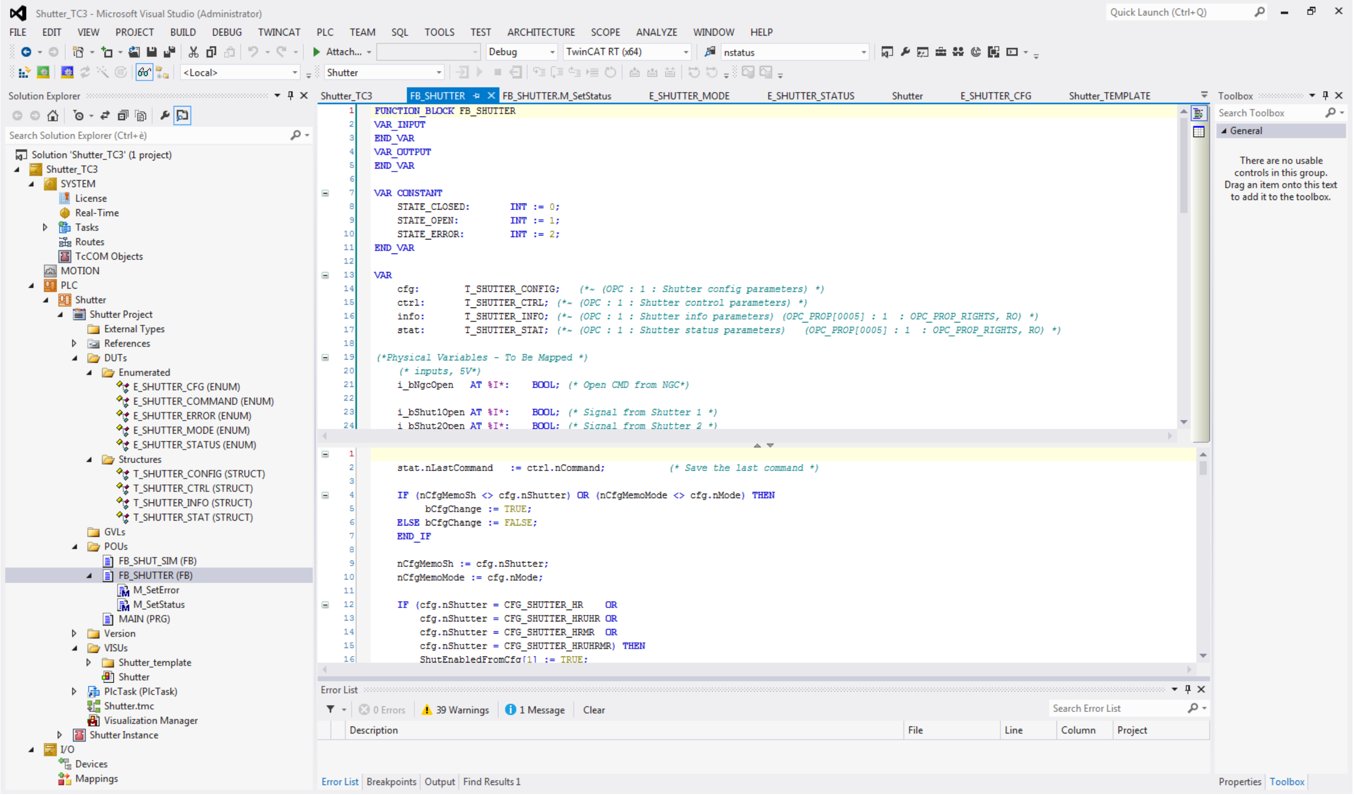
FB-Name	**MC_MoveAbsolute**
This function block commands a controlled motion at a specified absolute position.	

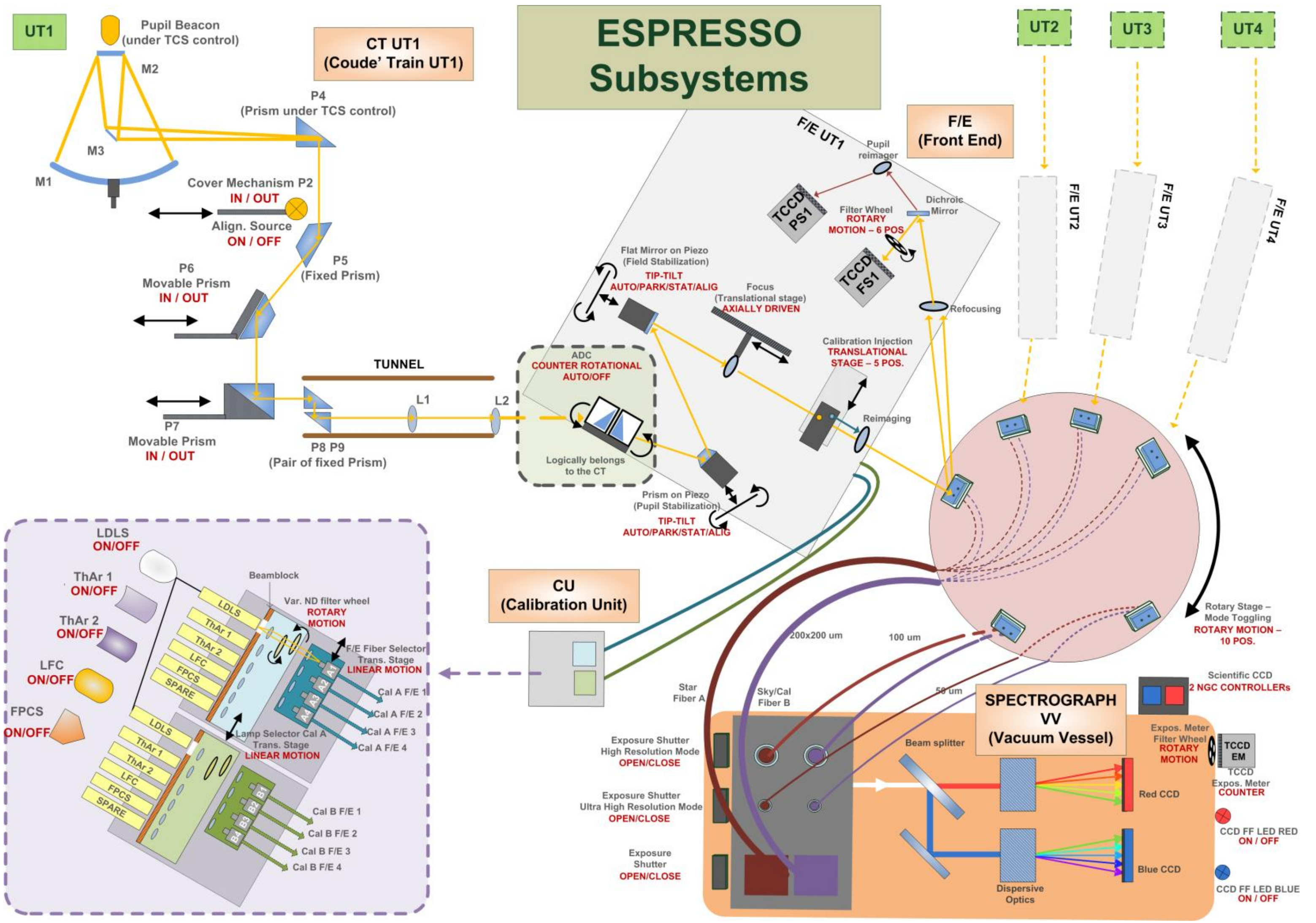
Graphical representation:



IEC 61131-3 deals with PLC programming languages and defines two graphical and two textual PLC programming language standards (among others):

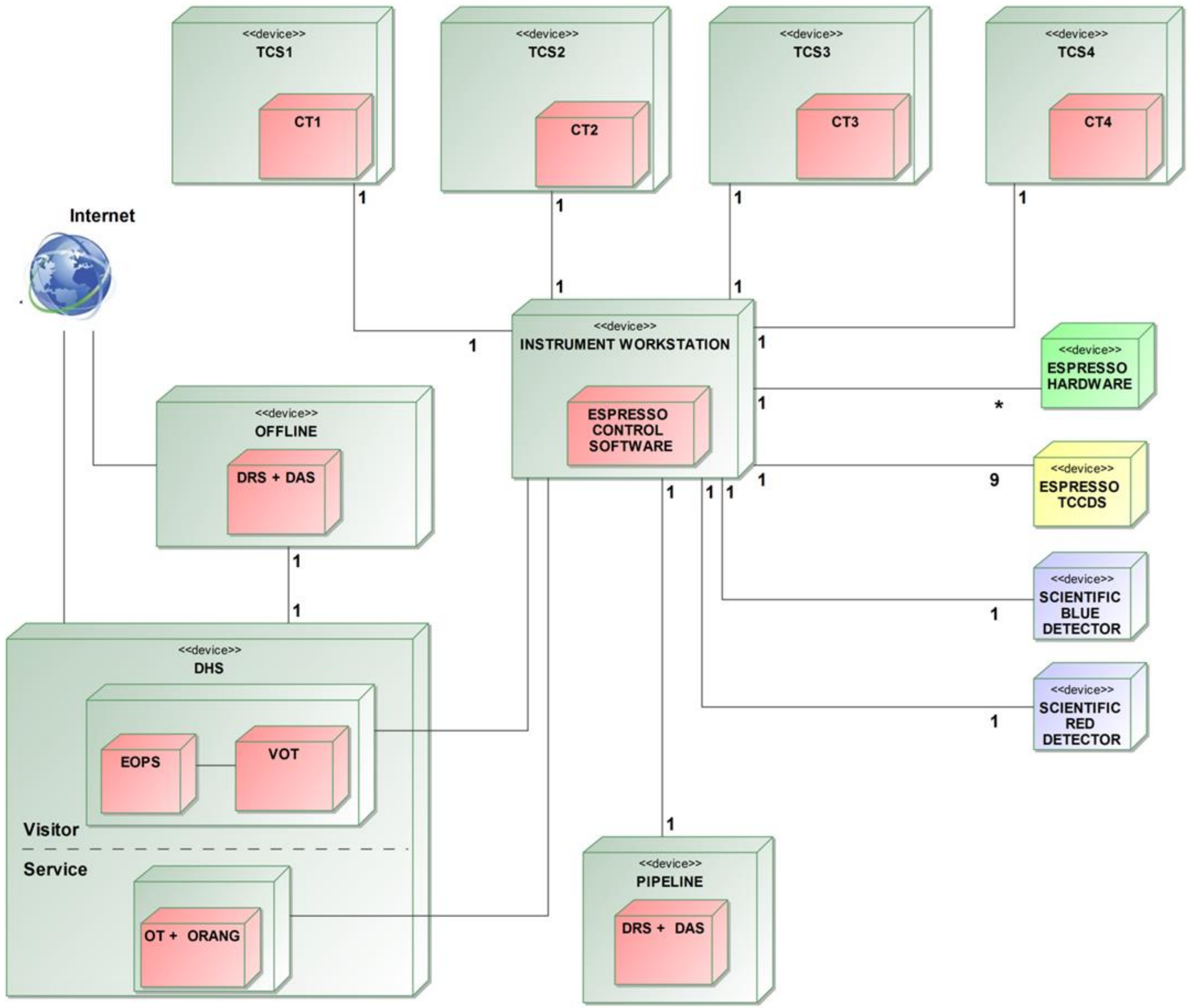
- Ladder programming;
- Functional Block Diagram;
- Structured Text;
- Instruction List.



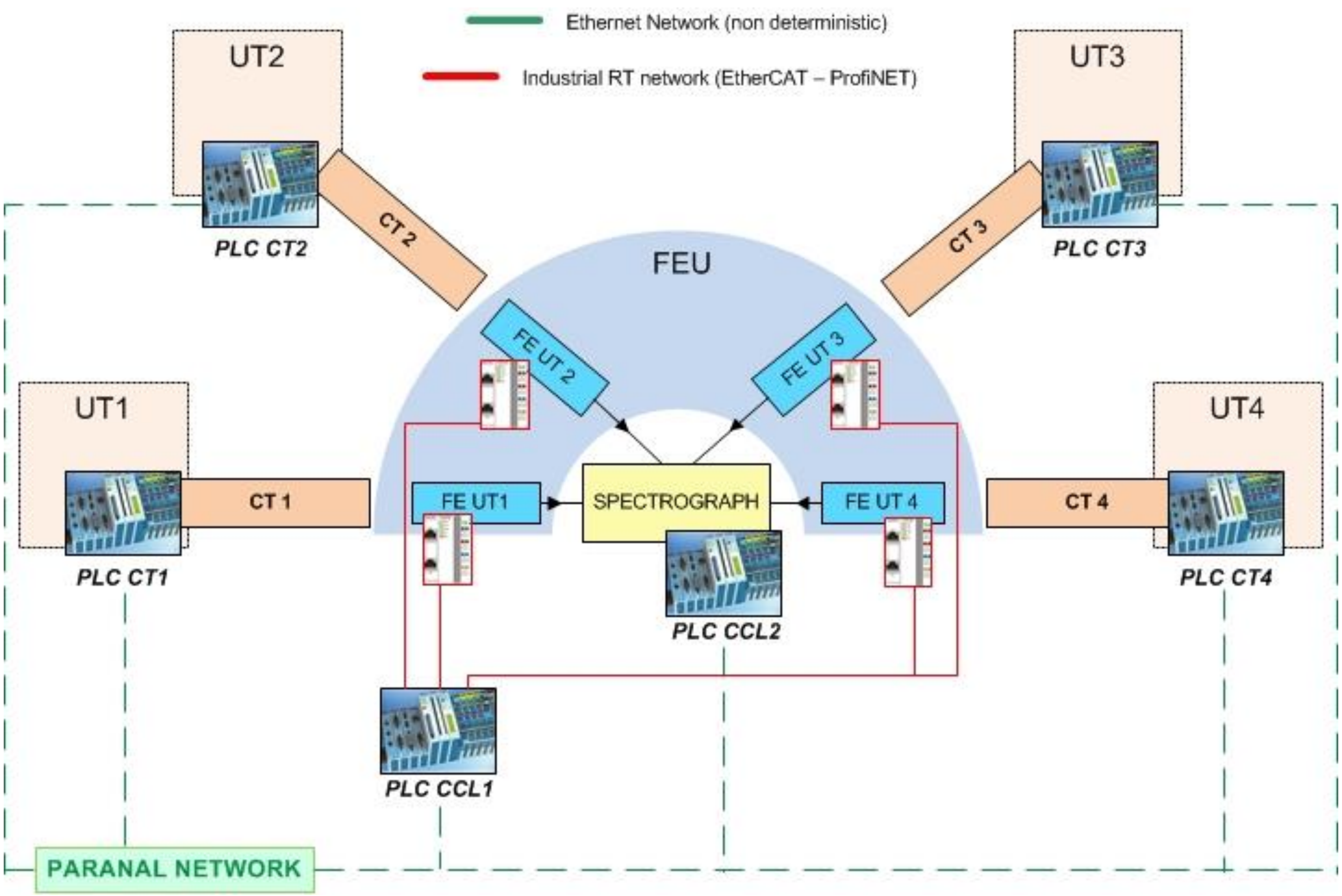


ESPRESSO Subsystems
UT1
Pupil Beacon (under TCS control)
M2
M3
M1
CT UT1 (Coude' Train UT1)
P4 (Prism under TCS control)
Cover Mechanism P2 IN / OUT
Align. Source ON / OFF
P5 (Fixed Prism)
P6 Movable Prism IN / OUT
TUNNEL
L1
L2
P7 Movable Prism IN / OUT
P8 P9 (Pair of fixed Prism)
ADC COUNTER ROTATIONAL AUTO/OFF
Logically belongs to the CT
F/E UT1
F/E (Front End)
Pupil reimager
TCCD PS1
Filter Wheel ROTARY MOTION – 6 POS
Dichroic Mirror
TCCD FS1
Refocusing
Flat Mirror on Piezo (Field Stabilization) TIP-TILT AUTO/PARK/STAT/ALIG
Focus (Translational stage) AXIALLY DRIVEN
Calibration Injection TRANSLATIONAL STAGE – 5 POS.
Reimaging
Prism on Piezo (Pupil Stabilization) TIP-TILT AUTO/PARK/STAT/ALIG
UT2
UT3
UT4
F/E UT2
F/E UT3
F/E UT4
Rotary Stage – Mode Toggling ROTARY MOTION – 10 POS.
LDLS ON/OFF
ThAr 1 ON/OFF
ThAr 2 ON/OFF
LFC ON/OFF
FPCS ON/OFF
Beamblock
Var. ND filter wheel ROTARY MOTION
F/E Fiber Selector Trans. Stage LINEAR MOTION
Cal A F/E 1
Cal A F/E 2
Cal A F/E 3
Cal A F/E 4
Lamp Selector Cal A Trans. Stage LINEAR MOTION
Cal B F/E 1
Cal B F/E 2
Cal B F/E 3
Cal B F/E 4
CU (Calibration Unit)
200x200 um
100 um
50 um
Star Fiber A
Sky/Cal Fiber B
Exposure Shutter High Resolution Mode OPEN/CLOSE
Exposure Shutter Ultra High Resolution Mode OPEN/CLOSE
Exposure Shutter OPEN/CLOSE
SPECTROGRAPH VV (Vacuum Vessel)
Beam splitter
Dispersive Optics
Red CCD
Blue CCD
Scientific CCD 2 NGC CONTROLLERs
Expos. Meter Filter Wheel ROTARY MOTION
TCCD EM
TCCD Expos. Meter COUNTER
CCD FF LED RED ON / OFF
CCD FF LED BLUE ON / OFF

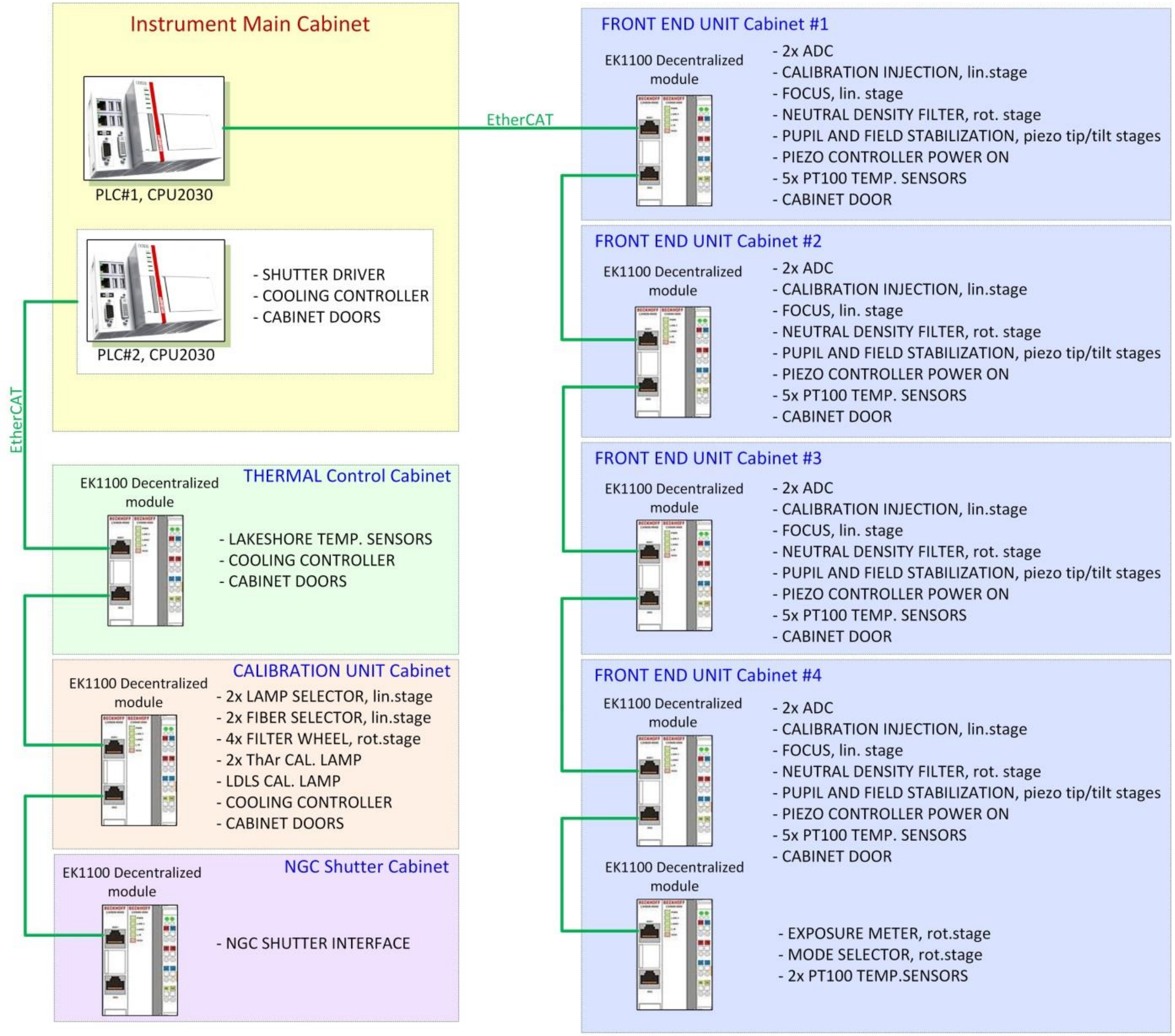
ESPRESSO overall sw infrastructure



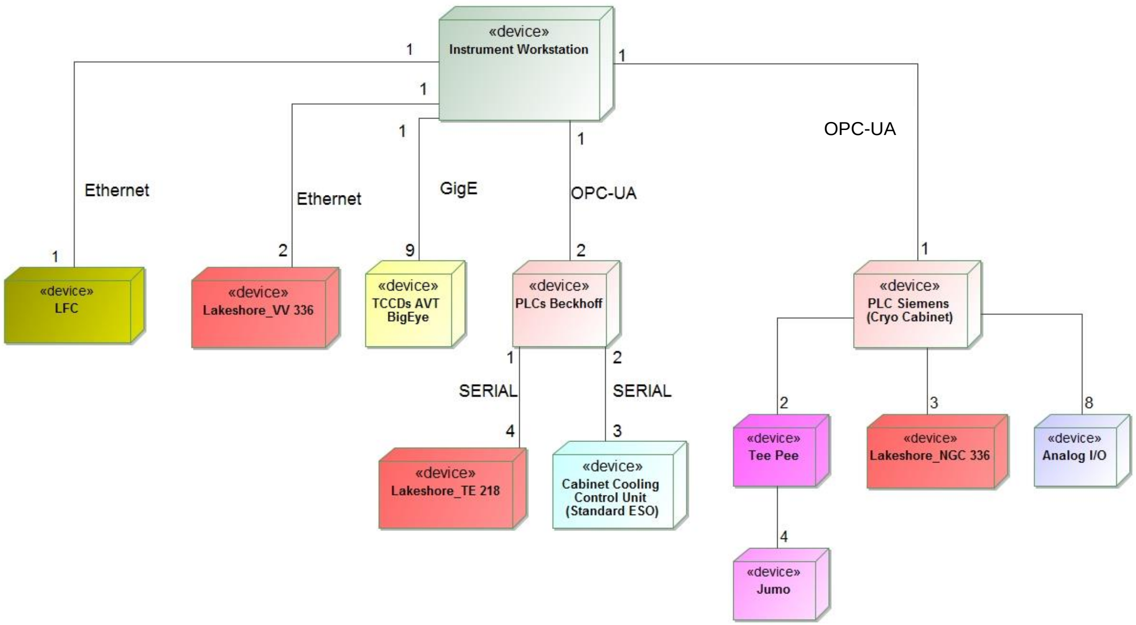
ESPRESSO deployment



ESPRESSO device distribution



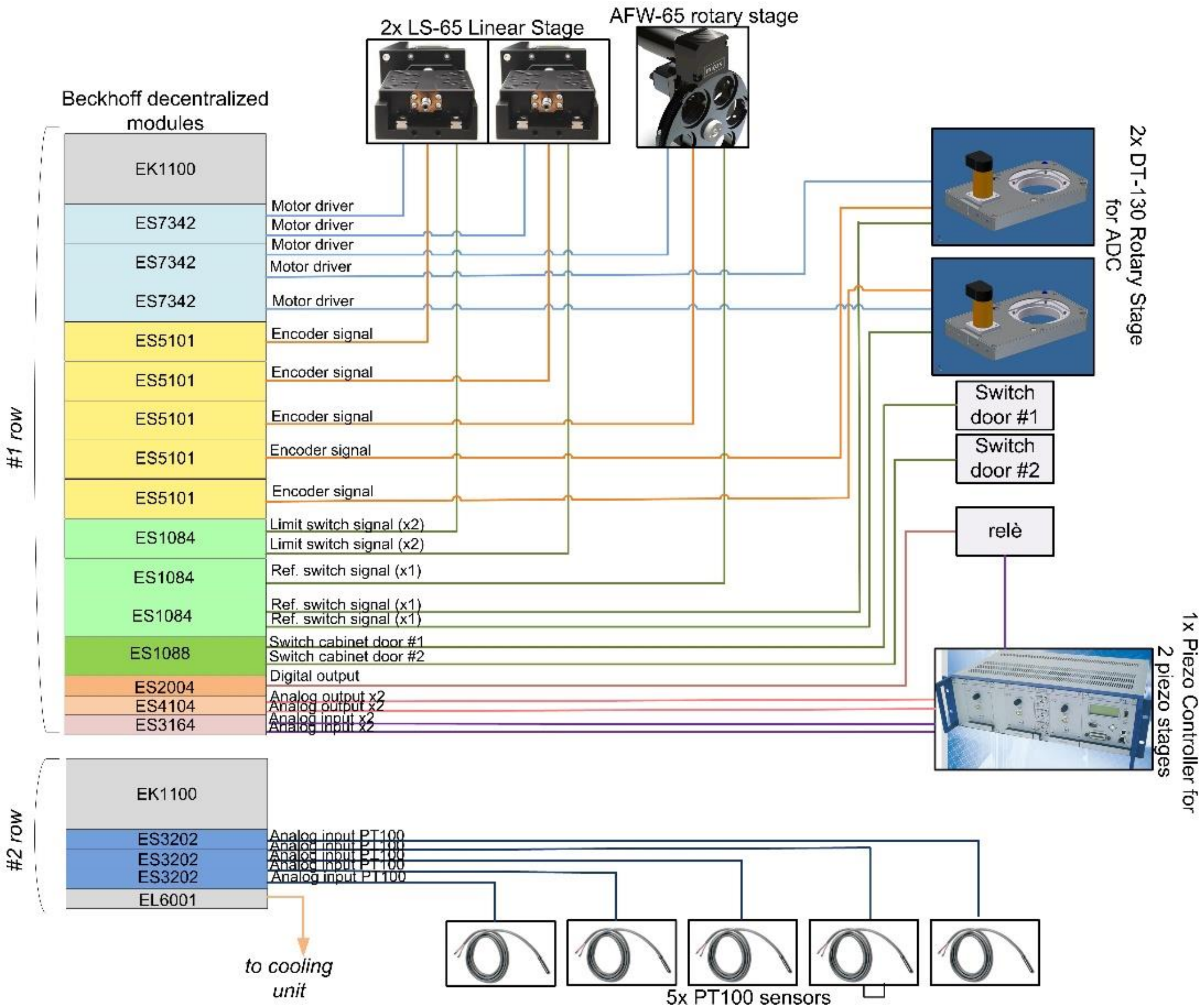
ESPRESSO SW protocols



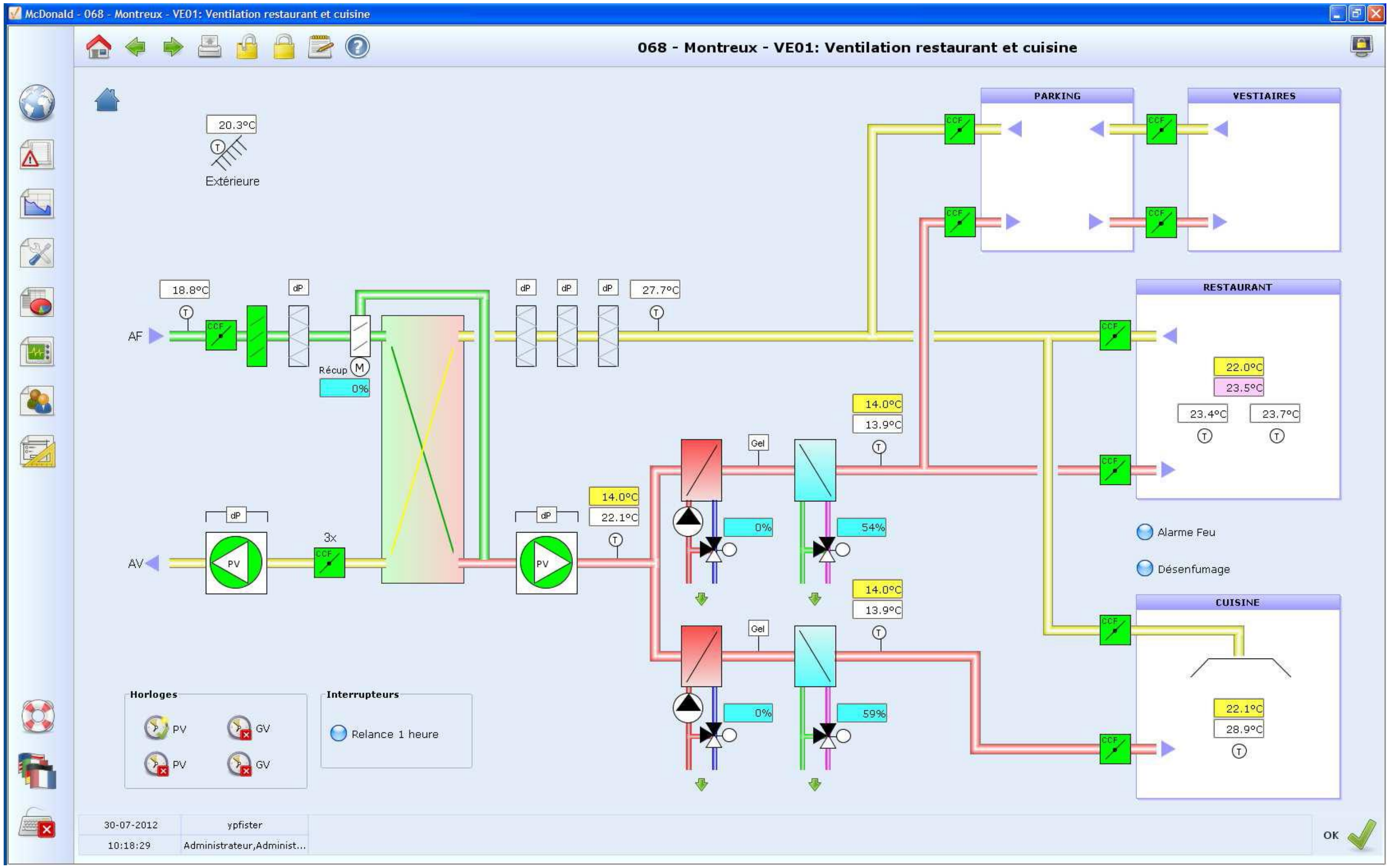
Motor	Type	N.
Linear Stage	MICOS LS-65	**8**
Linear Stage	VT-80	**4**
Rotary Stage	AFW - 65	**9**
Rotary Stage	DT-130	**8**
Rotary Stage	PRS - 200	**1**
Piezo Tip-Tilt	PI – E500	**8**
TOT		**38**

Device	Type	N.
Digital/ Analog Sensors	• Lakeshores 218, 336 • Sensor for Vacuum and Cryo system • PT100 Temp. sensors • Cabinet door sensors • Power piezo controller	**~100**
ThAr Lamp		**2**
LDLS lamp		**2**
Laser Frequency Comb	OPC UA	**1**

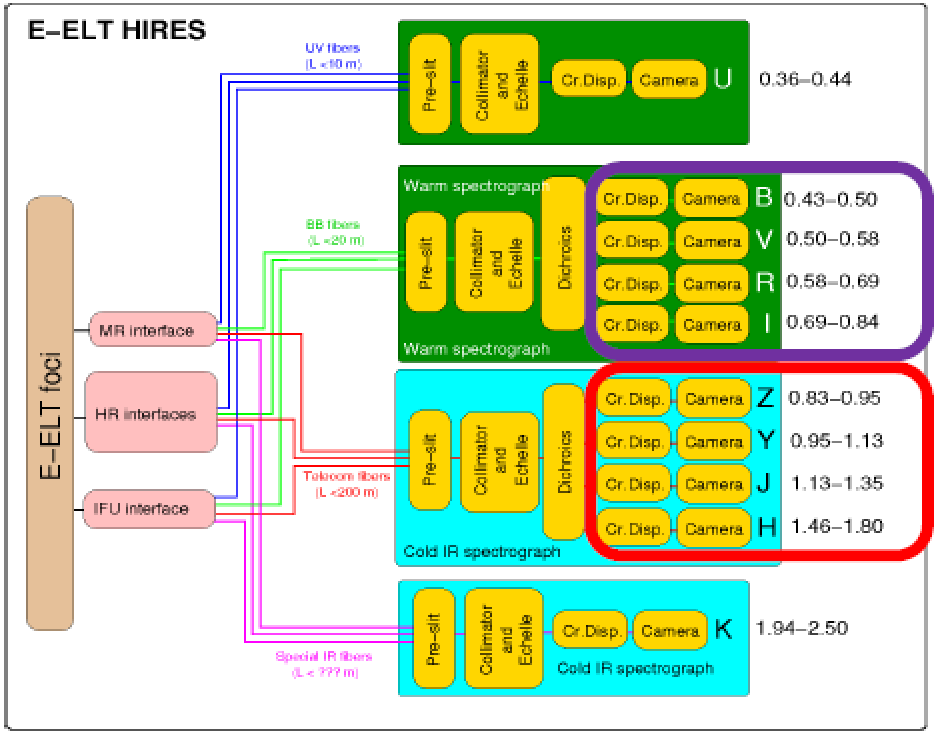
ESPRESSO Device control



ESPRESSO Device control II



HiRes for E-ELT



E-ELT standards

The code delivered for each language shall be compliant with one of the following:

- VHDL according to AD01.
- Function Block Diagram (FBD) and Structured Text (ST) according to AD02.
- C++, (coding standards per AD03).
- Java Standard Edition (SE), (coding standards per AD03).
- Python, (coding standards per AD03).
- LabVIEW G, (coding standards per AD03).
- Matlab, (coding standards per AD03).

The runtime platform shall be one of the following:

- SIMATIC S7
- TwinCAT,
- LabVIEW RT.

The software development environment for control unit software shall be comprised to:

- LabVIEW IDE,
- MS Visual Studio IDE, restricted to C/C++ programming languages,
- Eclipse IDE, restricted to Java and Python,
- Matlab,
- Siemens TIA Portal,
- Beckhoff TwinCAT,
- Subversion (SVN) client.

Conclusions

Although the industrial market is evolving fast the adoption of COTS industrial standard solution seems a possible way to overcome obsolescence issues. However periodic market surveys is also necessary to keep up to date with the latest developments in the various fields (control, image vision etc.).

The adoption of the high level communication protocol (e.g. GigE Vision and possibly its abstraction e.g. GenICam^{TM}) is considered as the correct path to minimize the development and maintenance costs.

The choice of industrial standards separating the business logic from the device specificity (e.g. OPC UA) will allow the integration of new products at almost no cost and reduce the maintenance effort.

The ESPRESSO case study will hopefully serve as a test bed for future E-ELT instruments.