AN OPC-UA BASED ARCHITECTURE FOR THE CONTROL OF THE ESPRESSO SPECTROGRAPH @ VLT

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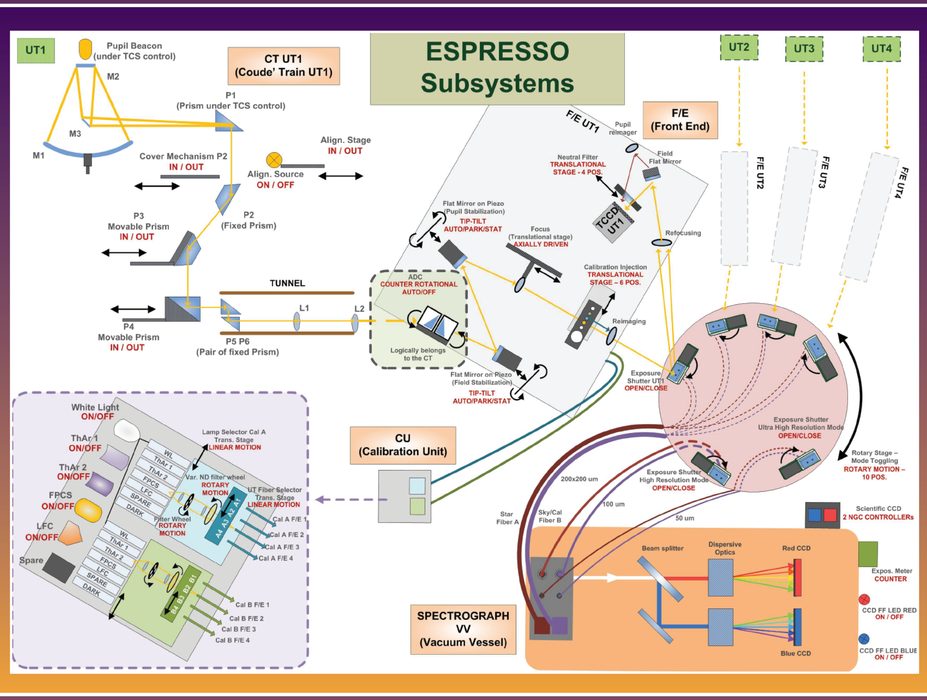
ESPRESSO is a fiber-fed, cross-dispersed, high-resolution echelle spectrograph for the ESO Very Large Telescope (VLT). The instrument is designed to combine incoherently the light coming from up to 4 VLT Unit Telescopes. To ensure maximum stability the spectrograph is placed in a thermal enclosure and a vacuum vessel. Abandoning the VME-based technologies previously adopted for the ESO VLT instruments, the ESPRESSO control electronics has been developed around a new concept based on industrial COTS PLCs. This choice ensures a number of benefits like lower costs and less space and power consumption requirement. Moreover it makes possible to structure the whole control electronics in a distributed way using building blocks available commercially off-the-shelf and minimizing in this way the need for custom solutions. The main adopted PLC brand is Beckhoff, whose product lineup satisfies the requirements set by the instrument control functions. OPC-UA is the chosen communication protocol between the PLCs and the instrument control software, which is based on the VLT Control Software.

ESPRESSO subsystems

The telescope light is conveyed to the Coudé Combined Laboratory via a Coudé Train optical system (one for each telescope). Inside the Coudé Combined Laboratory a Front-End unit, after performing the filed and pupil stabilization via a set of piezo tip-tilt stages, combines the light coming from the telescope(s) and feeds it into the spectrograph fibers. Two fibers feed the spectrograph simultaneously: the target fiber and the sky/calibration fiber. The ESPRESSO calibration unit is composed by the traditional flat-field and spectral calibration sources. Moreover, the use of a Laser Frequency Comb is foreseen as calibration source. The two-arm (red and blue) echelle spectrograph has a fixed optical layout, with no moving parts foreseen in order to maximize the stability and repeatability of the instrument performances. The instrument has two scientific detectors, one for the red arm and one for the blue one. The instrument will cover the whole visible wavelength range (380-780 nm) and its radial velocity precision will reach the 10 cm s^{-1} level.



ESPRESSO control system

The ESPRESSO control software architecture is compliant with the ESO/VLT standards and is based on the VLT Control Software. Its main subsystems are the Observation Software (which coordinates an exposure), the Instrument Control Software (control of the instrument devices) and the Detector Control Software (control of the scientific detectors).
The instrument control electronics is based on industrial PLCs. The choice of "Commercial-Off-The-Shelf" (COTS) components offers a number of advantages: besides the lower costs, it leaves the maintenance of the boards and driver code to the vendor and requires less space and less power consumption. The PLC supplier chosen for ESPRESSO is Beckhoff, one of the ESO hardware suppliers, whose line-up of products covers all the ESPRESSO control system requirements.

OPC - Unified Architecture (OPC-UA)

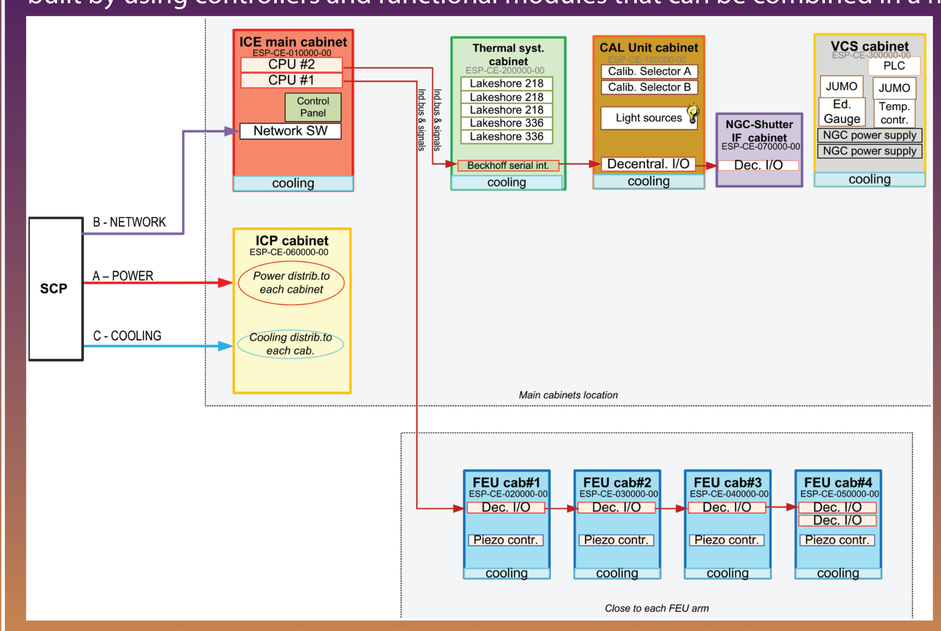
The OPC-UA is a platform-independent standard through which various kinds of systems and devices can communicate by sending messages between clients and servers over TCP networks. A typical OPC-UA application is composed by two entities: a "server" and a "client". The "server" is usually supplied by the hardware manufacturer and represent the interface between proprietary protocols and OPC-UA standard. It is usually a thread on the process controller which exposes process data and methods and communicates with the hardware with proprietary protocols. The "client" implements the OPC-UA communication stack by means of APIs and allows the user application to access the data and methods exposed by the "server". Both client and server can be implemented on any platform and can be supplied by different suppliers and still guarantee the inter-operability, as defined by the standard.

ESPRESSO control software and OPC-UA - client side

The Instrument Control Software is the software responsible for controlling the instrument hardware (excluded the detectors). The VLT Control Software architecture to interface and control devices connected via field-buses is named ICS Field-Bus Extension (ICSFB); it allows controlling devices not only via field-buses like Profibus/Profinet, EtherCAT or CANbus, but also via Ethernet. It can be seen as a SDK used to implement device drivers and also provides the run-time environment for deploying device drivers and control processes.
In order to communicate with the device hardware, ICSFB makes use of the ICSFB Communication Interface which supports different protocols. For ESPRESSO, the adopted communication protocol is OPC-UA. A distinguishing feature of this protocol is to ensure hardware independence, allowing to choose among any hardware supplier that supports it. In this architecture, the ESPRESSO ICSFB Device Drivers play the role of OPC-UA "clients".

ESPRESSO control electronics and OPC-UA - server side

The ESPRESSO control electronics is distributed in several subsystems physically located in the Coudé Combined Laboratory. The instrument functions are managed by the control software via PLCs located in proximity of the spectrograph. The system is built by using controllers and functional modules that can be combined in a modular way to obtain the required functionality.



The PLC CPUs (two to balance the workload) belong to the CX2000 series, with TwinCAT 3 runtime installed. The EK1100 module provides the possibility to decentralize the functional modules away from the CPUs via EtherCAT. All the ESPRESSO motorized stages were chosen from the MICOS supplier. The motion control concept is based on the Beckhoff TwinCAT NC software layer that operates between the hardware modules and PLC software runtime. Its purpose is to offer a standard software interface to the PLC software on one side (PLCopen MC compliant), and a flexible and heavily configurable software-controlled axis positioning system on the other side.
The task of the PLC is to implement the low level code for managing the devices. The PLC code is kept as simple as possible (relatively to the device complexity) and generally implements just the tasks that require a real time response. Every device driver exposes, by means of the OPC-UA server, a set of process variables that are accessible by the higher levels of the control software. The simplest drivers are just wrappers between I/O port variables and the OPC-UA exposed variables. This structure reduces the maintenance of the PLC code, as the major part of the task is implemented by the control software.

References
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