ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-MOPHA029

FORS-UP: AN UPGRADE OF THE FORS2 INSTRUMENT @ ESO VLT

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Abstract

The FORS Upgrade project (FORS-Up), financed by the European Southern Observatory (ESO), aims at upgrading the FORS2 instrument currently installed on the UT1 telescope of the ESO Very Large Telescope in Chile. FORS2 is an optical instrument that can be operated in different modes (imaging, polarimetry, long-slit and multi-object spectroscopy). Due to its versatility, the ESO Scientific Technical Committee has identified FORS2 as a highly demanded workhorse among the VLT instruments that shall remain operative for the next 15 years. The main goals of the FORS-Up project are the replacement of the FORS2 scientific detector and the upgrade of the instrument control software and electronics. The project is conceived as "fast track" so that FORS2 is upgraded to the VLT for 2022. This paper focuses on the outcomes of the FORS-Up Phase A, ended in February 2019, and carried out as a collaboration between ESO and INAF – Astronomical Observatory of Trieste (INAF – OATs), this latter in charge of the feasibility study of the upgrade of the control software and electronics with the latest VLT standard technologies (among them the use of the PLCs and of the latest features of the VLT Control Software).

INTRODUCTION AND UPGRADE MOTIVATION

FORS2, acronym for FOcal Reducer/low dispersion Spectrograph, is a multimode (imaging, polarimetry, long slit and multi-object spectroscopy) optical instrument mounted on the Antu Unit Telescope (UT) Cassegrain focus of ESO Very Large Telescope (VLT) located on Cerro Paranal in the Atacama desert in Chile. Originally, two twin instruments have been built and installed, named FORS1 and FORS2, but FORS1, after roughly ten years of successful operations, has been decommissioned to make way for the second generation of VLT instrumentation.

FORS2 entered regular science operations on April 2000 and has been observing ever since without significant interruptions. It is one of the most successful instruments in Paranal and led, with its twin FORS1 now decommissioned, to more than 2600 refereed publications (as of 01.09.2019), of which almost 1600 are from FORS2 alone. As a multi-mode instrument it has contributed to a broad range of science topics like spectroscopic study of the GOODS-South field and the Chandra Deep Field-South, Ly-alpha emitters in the early universe, spectro-polarimetry of massive stars, photometry studies of young stellar regions, astrometric studies of brown dwarfs and transmission spectroscopy of exoplanets and many others [1].

FORS2 covers a wide wavelength range spanning from 330 nm to 1100 nm, with a very great sensitivity: the transmission is above 60% over 360-1100 nm and reaches almost 80% around 440 nm. It is equipped with a mosaic of two blue-optimized 2k x 4k detectors, which can be exchanged with a red-optimized detector mosaic. Due to its versatility, the ESO Scientific Technical Committee has identified FORS2 as a highly demanded workhorse among the VLT instruments that shall remain operative for the next 15 years. However, the current science done with FORS2 differs from what was initially foreseen. Many current observing programmes, photon-noise limited, use relatively short exposure times, and therefore, beside efficiency, the read-out noise of the CCD become an issue. The VLT Instrument Operation Team, since years, is requesting therefore the upgrade of FORS2 with a 4k x 4k broad band detector that shall improve the operations of the instrument, eliminating also the need for the exchange of the red or blue detector systems on the instrument (currently only one can be installed at a time).

Moreover, both software and electronics controlling the instrument have been developed at the end of the '90s and several control parts are obsolete, not supported anymore by vendors and not "VLTSW compliant", i.e. they do not follow the standards imposed by ESO for the instruments currently installed at the ESO VLT.

These considerations led to the FORS-Up project, financed by the European Southern Observatory. The main goals of the project, beside the upgrade of the FORS2 scientific detector (and of some instrument optics), is the upgrade of the instrument control software and electronics [2], which is the main topic of this paper.

INSTRUMENT DESCRIPTION

FORS2 Subsystems

FORS2 physically consists of four parts: a top section (which includes the two internal calibration units), a collimator section, a filter/camera section and the external calibration unit.

- Top section. It contains the focal plane equipment. The motorized functions are an entrance shutter, a MOS (Multi-Object Spectroscopy) unit with 19 movable slits each composed by two blades that can be moved individually and simultaneously, a longslit mask unit with 9 slits and a mask exchange unit for MOS spectroscopy (MXU) consisting of a storage magazine holding up to 10 masks.
- Internal calibration units. They are equipped with the following arc lamps: Ne (2x), Ar (2x), He (1x) and HgCd (1x).

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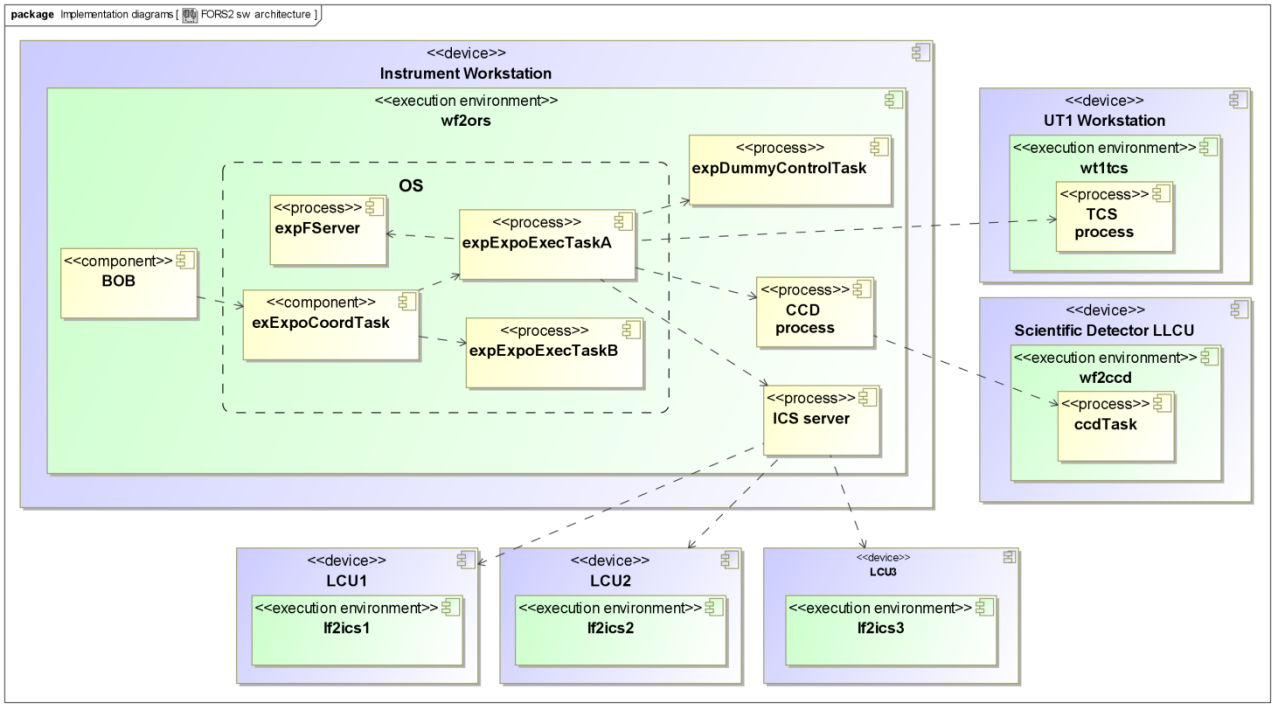

Figure 1: FORS-Up current control architecture.

- Collimator section. It contains the two collimators (Standard Resolution and High Resolution) and the electronic cabinets.
- Filter/camera section. It contains the retarder plate mosaics swing arm with the linear and circular retarder plate mosaics (used for polarimetry and spectro-polarimetry), the camera focusing stage, the exposure shutter, five filter wheels containing the Wollaston prism, the grisms and the broadband and interference filters and the scientific detector.
- External calibration unit. It is located in the UT Cassegrain tower and consists of three flat field lamps (blue 1x and red 2x) which are linked to the Cassegrain tower with a fiber bundle.

Beside the motorized functions reported above, several sensors are used to monitor the instrument status.

CURRENT CONTROL ARCHITECTURE

Control Software

The current FORS2 control architecture is based on the VLT Software (VLTSW), a distributed system connecting a set of workstations, dedicated to high level operations, and Local Control Units (LCUs), dedicated to the control of sub-systems hardware. The chosen programming language for the workstation applications (running Linux operating system) is mainly C++, except for the Graphical User Interfaces, as well as High-Level Operations Software (e.g. BOB, the Broker for Observation Blocks and the instrument templates), which are based on Tcl/Tk.

The VLTSW are released by ESO on periodical basis (the official release at the time of writing is VLTSW 2018). In the latest releases, the support of PLCs for the hardware control has replaced and substituted the old VME VxWorks-based LCUs

The VLTSW offers the following packages, termed "standard", needed to operate an astronomical instrument:

- Detector Control Software (DCS): it controls the detector system.
- Instrument Control Software (ICS): it is responsible for the control of all the vital, low-level functionalities of the instrument.
- Observation Software (OS): it is responsible for the coordination of activities of the DCS, ICS and the Telescope Control Software (TCS). It also interfaces with the VLT data flow, in particular with BOB, which delivers the next observation blocks (observation recipe) to be executed, and the Archive, which saves the results at the end of each observation.
- Maintenance Software (MS): it provides tools to maintain the configuration of the instrument and to check its health.

Several parts of the FORS2 control software, currently based on the VLTSW 2006 and being ported on VLTSW 2010, present obsolescence or are not more supported by the latest releases of the VLTSW. Among them:

- OS is not based on boss (the standard package that implements the main functionalities of the VLTSW OS), but instead is a "custom" OS.
- The detector controller is obsolete, not more supported by the VLTSW and not supporting the new foreseen upgraded CCD.

Several algorithms implemented in OS (especially those dedicated to the optical alignments) are based on ESO-MIDAS, a system which provides general tools for

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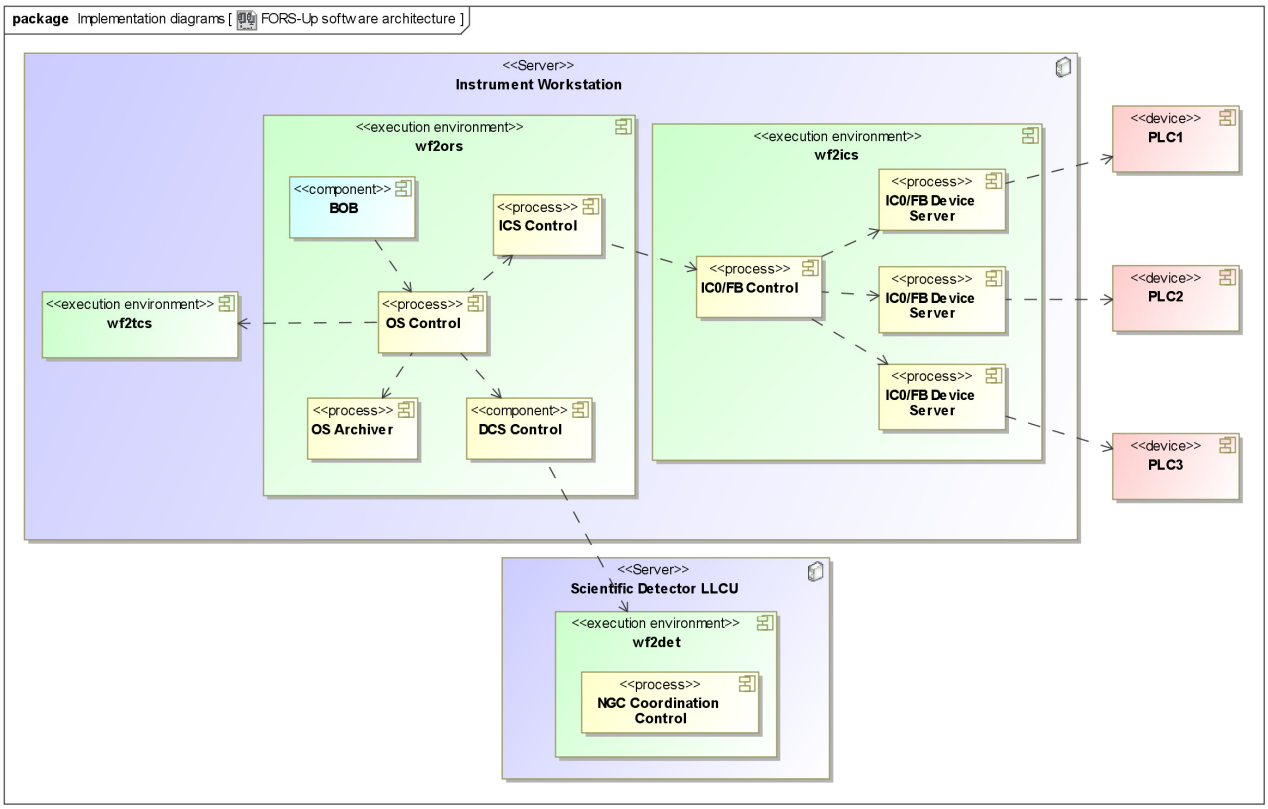

Figure 2: FORS-Up proposed control architecture.

image processing and data reduction which is also not maintained by ESO anymore [3].

Figure 1 shows the current FORS2 control architecture. The control software, running on the instrument workstation, communicates with the software that controls the telescope and the scientific detector and with the three LCUs controlling the instrument hardware.

Control Electronics

The control electronics of FORS2 is based on the VME-based Local Control Units (LCUs), since this was the standard for the control electronics of ESO instruments at the time of the FORS2 building, following a similar trend in other big scientific experiments. The crates are equipped with specialized I/O and motion control boards, some of them being custom made. This architecture has now started to be difficult to support and maintain and a replacement is needed. PLC and COTS based control electronics building blocks has superseded the old VME based systems in the new designs. The FORS2 control hardware is split into three parts, each one mounted in a 19" system cabinet, plus a fourth cabinet for the scientific detector system.

UPGRADE FEASIBILITY STUDY

In the framework of the FORS-Up project, INAF – OATs is currently in charge of the feasibility study of the upgrade of the instrument control electronics and software of FORS2. The goal of the Phase A, which ended in February 2019, was the identification of the crucial points for porting the current FORS2 control software and electronics to the latest VLTSW standard (VLTSW 2018), together with the realization of the software and electronics design [4][5]. Recently, an upgrade to the Phase A has been signed, termed Phase A+, with the aim to perform an amendment study to see whether it is possible to adopt for FORS2 even newer instrument standards developed by ESO in the framework of the ELT (Extremely Large Telescope) programme.

In the following sections the main outcomes of the Phase A work will be described. Phase A+ tasks will also be shortly introduced.

Control Software

The FORS-Up control software will be based on the latest VLTSW release (VLTSW 2018 at the time of writing). From the hardware point of view, the most notable modification is the adoption of Beckhoff PLCs, which replace the VMEs. As a consequence, at ICS level, the ESO standard IC0/FB framework will be used to control the instrument devices. With IC0/FB the high-level ICS software runs on the instrument workstation, where the IC0/FB device servers communicate with the PLCs through the OPC-UA communication interface. In the FORS-Up ICS design, almost all the devices will be driven by standard IC0/FB device servers, which are provided by ESO in the framework of the IC0/FB architecture. The only non-standard devices, which will require a dedicated design and implementation, are the MOS slits (due to the fact that their movement must be synchronized) and the

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exposure shutter (in operation it has to be controlled by the DCS NGC, see below, running on a dedicated machine, and in maintenance by the IC0/FB device server running on the instrument workstation).

FORS2 is a versatile instrument that can be operated in several observing modes:

- direct imaging
- longslit spectroscopy
- MOS spectroscopy (with MOS slits or with the use of the MXU)
- imaging polarimetry
- MOS spectropolarimetry

The package responsible to manage them is the OS. In the new upgrade, the OS will be based on the standard VLT boss package. It will implement all the functionalities of the "custom" FORS2 OS. Also, the ESO-MIDAS routines used by the OS alignment algorithms will be replaced by the equivalent CLIP methods thus eliminating completely the need of MIDAS. CLIP (Common Library for Image Processing) is a standard tool for on-line image processing and is part of the latest VLTSW distributions.

Eventually, the old FORS2 scientific DCS controller, FIERA, not anymore supported, will be replaced by the New General detector Controller (NGC) package.

Figure 2 shows the control architecture foreseen for FORS-Up. In the new architecture the control software, running on the instrument workstation, communicates with the PLCs through IC0/FB.

Control Electronics

Following the recommendations for the design of new instruments, the proposed control electronics hardware is based on a Beckhoff PLC platform. The original design topology has been kept, where in each of the three cabinets a PLC control unit finds its place. The I/O modules are either connected on the CPU itself or decoupled using EherCAT bus and couplers (see Fig. 3). To keep the instrument downtime at minimum, the proposed baseline design does not foresee changes in the electromechanical architecture, keeping the motor assemblies as they are and refurbishing the parts where necessary. An analogue tachometer is mounted on the motor for the speed control loop feedback, thus the motion control modules identified as the best choice for the baseline are the Elmo Gold Whistle series. These are one of the few to still support this control scheme and offers at the same time EtherCAT connection and compatibility with Beckhoff software.

NEXT PROJECT PHASES

VLTSW development path foresees three years after STC (Scientific Technical Committee) approval and financial committee authorization. However, in the last years, ESO is working in developing new software and electronics control standards for the forthcoming ELT telescope that will supersede VLT standards named CII (Core Integration Infrastructure). The aim is to develop a full-fledged control system able to efficiently fight hardware obsolescence, offer modern software tools, lower costs, integration and maintenance efforts and easy installation. To this purpose and amendment of the Phase A, Phase A+, has been signed by INAF - OATs with the purpose to evaluate functional compliance, feasibility, potential hazards and approximate cost in adopting also for FORS2 the ELT Instrument framework and ELT electronics standards. The Phase A+ will last six months and one of its tasks, beside feasibility and design based on the new standards, is to eventually provide schedule and recommendation for a possible development plan.

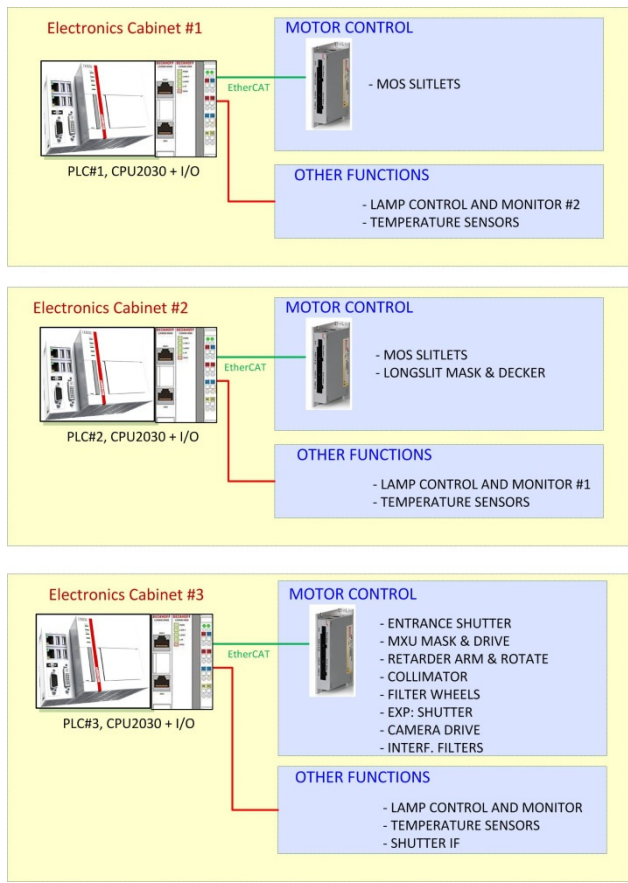

Figure 3: FORS-Up proposed hardware architecture.

CONCLUSIONS

The FORS-Up project aims to upgrade the FORS2 instrument installed at the ESO VLT. The Phase A of the project, ended in February 2019, was carried out as a collaboration between ESO and INAF – OATs, this latter in charge of the feasibility study of the upgrade of the control software and electronics with the latest software and hardware technologies used on the VLT instruments. An amendment of the Phase A (named Phase A+) has been signed by INAF-OATs for evaluating the feasibility and efforts needed to upgrade the FORS2 instrument with the new software and electronics standards developed by ESO for the forthcoming ELT telescope.

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