Instrument Control Software of ESO instruments

TETIS

TEchnologies for Telescopes and Instrument control Software

TETIS Coordination Unit within the INAF UTG1 OptNIR Division

Instrument Control Software

- What is Instrument Control Software
- TETIS teams:
    - **OAPD** Control Software team
    - **OACN** Software and Electronics team
    - **OAAb** Software and Electronics team
    - **OATS** Software and Electronics team
- Projects Overview
    - Examples:
        - MORFEO
        - MAVIS
        - SOXS
        - ANDES
        - VST / VSTPOL

What are we doing

Mainly 2 things:

1. designing/developing/testing/installing/teaching/supporting/maintaining the entire control Software of ground based instruments, mainly for ESO (ELT, VLT, La Silla), but not only (LBT, LSST).

2. collaborating to the development of the Real-Time Computer (RTC) of MORFEO (OAPD)

Instrument Control System Software (ICSS, ICS, ICS-SW, INS…)

- Usually we follow the development of the Control Software since the beginning of the project (conceptual phase) until the acceptance of the instrument (punch list after commissioning and science verification)
- An important characteristic is that the Control Software Work Package is **“transversal” to the instrument**. It means we need to interface with:
  - the system engineer (who decides what to control)
  - the instrument scientist (who defines the instrument operations)
  - the Adaptive Optics (AO) experts, if any
  - the electronics team (selection of compliant electronics)
  - the sub-system engineers (if the instrument is complex)
  - the Acceptance Integration and Test (AIT) team
  - the facilities of the observatory (telescope, observing blocks, preparation tool etc)
  - the Real Time Computer (RTC) team
  - **Data reduction**
  - client instrument(s), if any

The development process

Software is not just writing the code!

- gathering of the SW requirements
- analysis of the SW requirements
- writing of the SW technical specifications
- design of the SW architecture
- design of the graphical interfaces
- identification of the SW interfaces (external: TCS internal: RTC for example)
- identification of the acquisition procedures
- identification of the observational procedures
- identification of the maintenance procedures
- identification of the calibration procedures

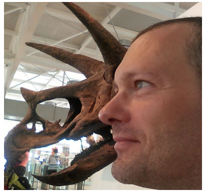
- **actual implementation of the SW**
- implementation of the SW tests (unit tests)
- implementation of the integration tests
- SW support to the sub-system integration
- SW support to the system integration
- SW for the preliminary acceptance tests
- SW support to the system reintegration
- SW support to the commissioning(s)
- SW support to the science verification
- SW support to the final acceptance (punch list)

+ writing the technical documentation

OAPD Control Software team

SPHERE's first light team:
Andrea Baruffolo, Daniela Fantinel, Bernardo Salasnich





Joined for SOXS, SHARK (LBT), MAVIS:
Davide Ricci, Elia Costa


Joined for MORFEO ICSS, SHARK (LBT):
Fulvio Laudisio, Alessandro Lorenzetto


Joined for MORFEO ICSS and RTC:
Chiara Di Prospero, Salvatore Lampitelli, Daphne Diretto



Software Quality Assurance:
Andrea Balestra, Rosanna Sordo


↑ also involved in **Model Based System Engineering** (MORFEO, MAVIS, CUBES, ANDES + PLATO)
→ AstroMBSE (ref. Marcello Scalera)
→ ESA MBSE initiative.

IT support:
Amedeo Petrella, Danilo Selvestrel

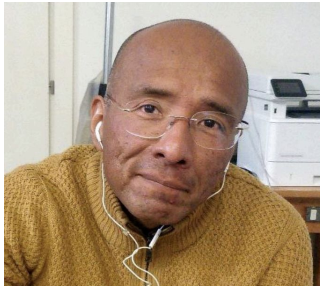

OACN Control Software and Electronics team

Team leader:
Pietro Schipani

Control software development:
Laurent Marty

HW Control Electronics:
Sergio D’Orsi

HW & SW control systems:
Giulio Capasso, Mirko Colapietro, Salvatore Savarese, Ricardo Zanmar Sanchez



OAAb Control Software and Electronics team

Team leader:
Gianluca Di Rico

Control software development:
Benedetta Di Francesco

OATS control/science software and electronics team

Paolo Di Marcantonio

Control software

Giorgio Calderone

Sara Bertocco

Matteo Porru

Roberto Cirami

Veronica Strazzullo (science reqs&verif.)

Control electronics

Igor Coretti

Veronica Baldini

Antonio Sulich

Data Reduction

Guido Cupani

OAPD Projects

MORFEO ICSS @ELT, towards Final Design Review
[Multiconjugate adaptive Optics Relay For ELT Observations]

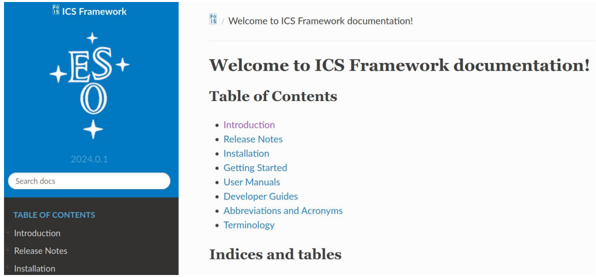
MORFEO RTC @ELT, towards Final Design Review

MAVIS @VLT, towards Final Design Review
[MAVIS - MCAO-Assisted Visible Imager and Spectrograph]

SOXS @NTT, towards Preliminary Acceptance in Europe
[Son Of X-Shooter]

ERIS @VLT, towards Preliminary Acceptance in Chile
[Enhanced Resolution Imager (SPIFFIER) and Spectrograph (NIX), with AO.]

SHARK-NIR @LBT, currently in early science phase
[Extreme-AO for High Contrast Imaging in the NIR]



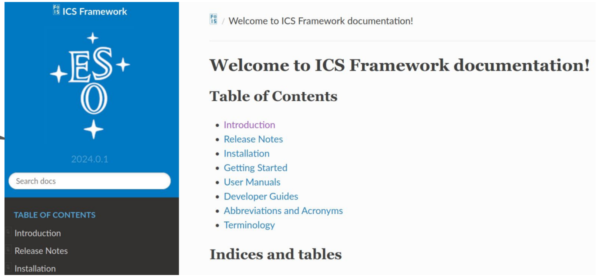
not dependent on ESO frameworks

OACN Projects

MORFEO ICSS @ELT, towards Final Design Review
Multiconjugate adaptive Optics Relay For ELT Observations

MORFEO RTC @ELT, towards Final Design Review

MAVIS @VLT, towards Final Design Review
MAVIS - MCAO-Assisted Visible Imager and Spectrograph



SOXS @NTT, towards Preliminary Acceptance in Europe
Son Of X-Shooter

VSTPOL @VST, system development
Polarimeter for VST

VST, system performance monitoring & analysis
VLT Survey Telescope

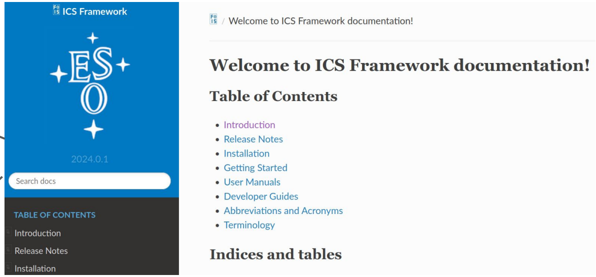
Vera Rubin, novel active optics sensing methodologies
Vera C Rubin Observatory

not dependent on ESO frameworks

OAAb Projects

MORFEO ICSS **@ELT,** towards Final Design Review

Multiconjugate adaptive Optics Relay For ELT Observations



The ultimate spectrograph

SHARP proposal

A near-IR multi-mode spectrograph conceived for the Multi-Conjugate Adaptive Optics module MORFEO@ELT

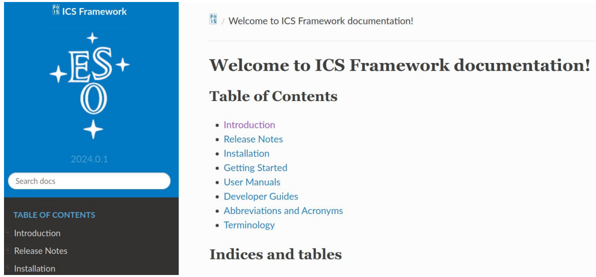
OATS Projects

ANDES@ELT, towards Preliminary Design Review
ArmazoNes high Dispersion Echelle Spectrograph

CUBES@VLT, Final Design Review
Cassegrain U-Band Efficient Spectrograph

FORSUp@VLT, Upgrade
The FORS Upgrade Project

IBIS2.0@Themis, Construction
Interferometric BIdimensional Spectrometer



ASTRI, Construction
Astrofisica con Specchi a Tecnologia replicante Italiana

SKAO, Construction
Square Kilometre Array Observatory

PRISMA, Operational
Prima Rete Italiana per la Sorveglianza sistematica di Meteore e Atmosfera

not dependent on ESO frameworks

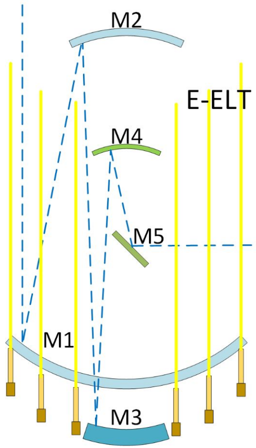
MORFEO ICSS

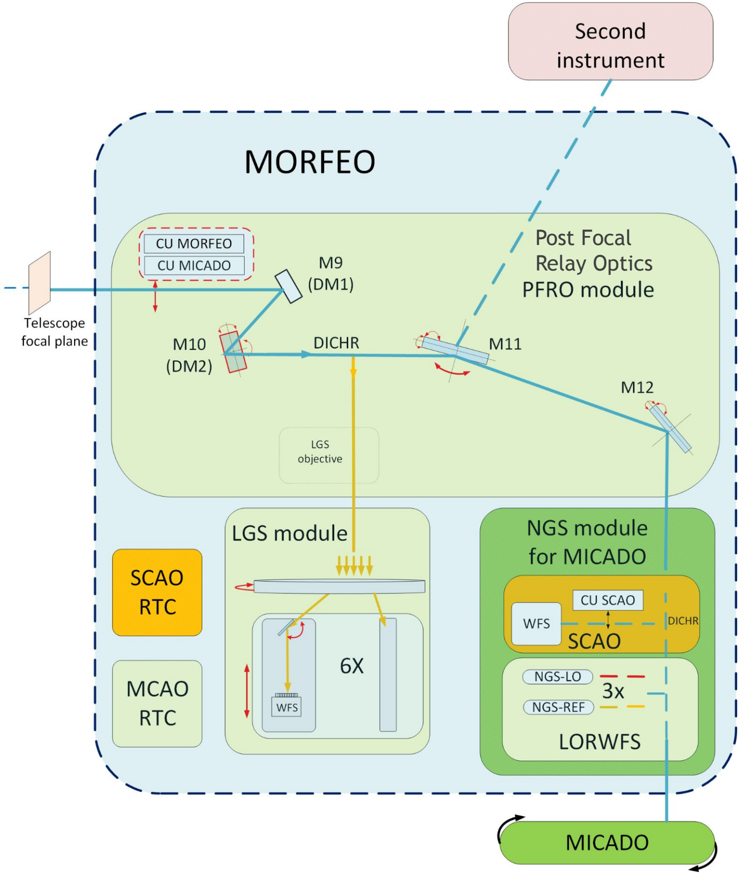
FDR June 2025 First Light >= 2030 (?)

MORFEO Multi-conjugate adaptive Optics Relay For ELT Observatory

Is the "AOM" of MICADO

- ❑ Location: Armazones, Chile, ELT, Nasmyth
- ❑ Post focal adaptive module for E-ELT
- ❑ Master instrument: MICADO
- ❑ Second instrument to be defined
- ❑ MCAO mode
  - ❑ Actuators: ELT M4 and M5 + 2 DMs
  - ❑ Sensors: 12 WFS (6 LGS + 3x2 NGS)
    - ❑ 6 LGS-WFS (Sony Imx425)
    - ❑ 3 NGS-WFS IR (FREDA)
    - ❑ 3 NGS-WFS Visible Truth (ALICE)
- ❑ SCAO mode
  - ❑ Actuators: ELT M4 and M5
  - ❑ Sensors: 1 WFS (NGS)





INS to IF with **RTC** to handle four main control loops:

- ❑ HO: Fast (100-500Hz), ~ 5000 modes. 589 nm
- ❑ LO: Fast (100-500Hz), 5 modes (tip/tilt, ast., focus). band
- ❑ REF: Slow (0.1-100Hz), 55 modes. Visible, truth sens
- ❑ LGSTT: Fast (jitter)

MORFEO RTC

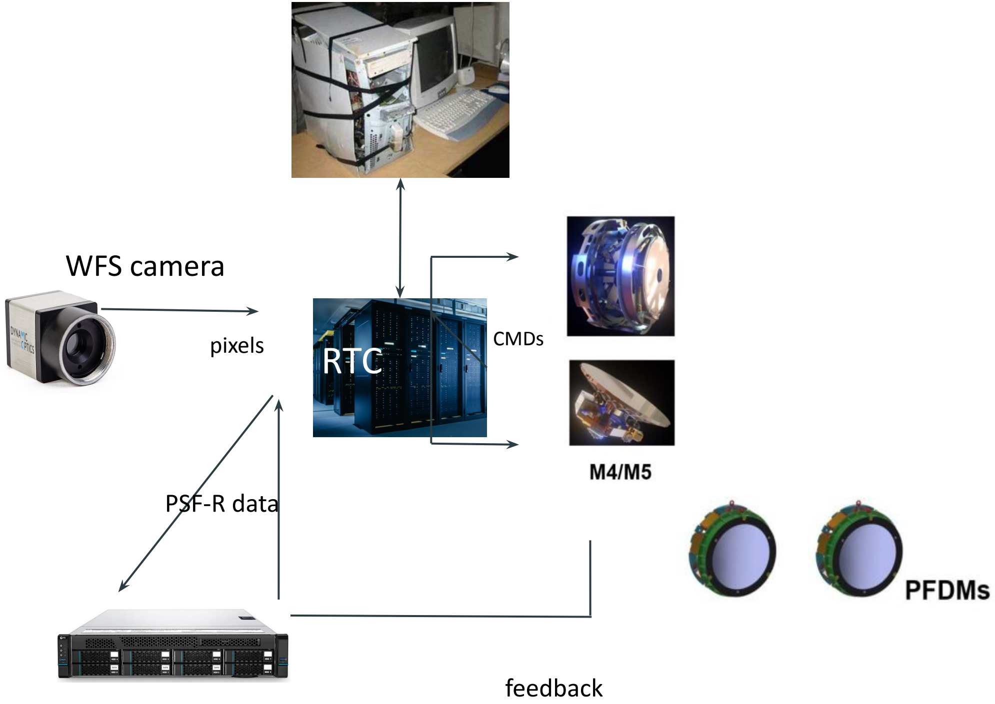
- The heart of MORFEO's adaptive optics system.
- Processes incoming WFS data in real-time.
- Executes complex algorithms to correct atmospheric distortions acting on AO actuators (DM in loop(s) at high frequency
- Enables high-speed adjustments to maintain optimal image quality.

MORFEO’s RTC is split into two subsystems:
Hard **R**eal **T**ime **C**omputer (**HRTC**) and **S**oft **R**eal **T**ime **C**luster (**SRTC**).

HRTC implements all the functionalities directly related to the AO control loops. HRTC performs **high frequency**, **low latency** computation aimed to correct for the fast evolving atmospheric distortions. It uses a dedicated **deterministic network**.

SRTC is the only RTC subsystem which interfaces to the Instrument Control System Software (ICSS). Moreover the SRTC performs **auxiliary tasks** necessary to optimize AO corrections such as: **calibration** of AO loop parameters, computation of optimal values for **configuration** parameters, telemetry data storage and so on.
SRTC is built upon **RTC Toolkit** software tools developed by ESO.

SRTC foresees a node to **simulate** the WFS pixel streams.



Some of SRTC Data Tasks

Update of the Control Matrix

By means of the control matrix the **WFS slopes measurements** can be converted into **commands to apply to DMs** to perform wavefront corrections. The update is necessary because of the occurrence of mechanical flexures which change the instrument alignments. This computation must be performed every **6 minutes**.

Measurements of misregistration parameters

The most occurring misregistration error are **rotation** and **x, y shift** of the pupil with respect to WFS sub-apertures and DMs. Misregistration occurs because of **misalignment** between DMs and AO instrument itself. SRTC must monitor the evolution of registration state recomputing the misregistration parameters every **10-20s.**

LIFT algorithm for M4

M4 is segmented into **six independent spatial segments**, and it is necessary to control the **relative pistons positions** between the segments in order to add the new relative positions to the M4 control commands. The algorithm must be run every **0.1s**

MAVIS

New instrument for ESO VLT, UT4. FDR June 2025 First Light → 2030 (?)

Composed of:

- an **imager:** 9kx9k detector to image a 30x30 arcsec field (~MICADO) on a 4k x 4k window
- an **integral field spectrograph:** 2x 9kx9k detectors, 3x3/5x7 arcsec FoV, 6000 to 15000 resol.
- MCAO Assisted = an inner AOM, which includes **two post focal DMs** (~3200 actuators) and **one RTC**
- a **calibration unit**

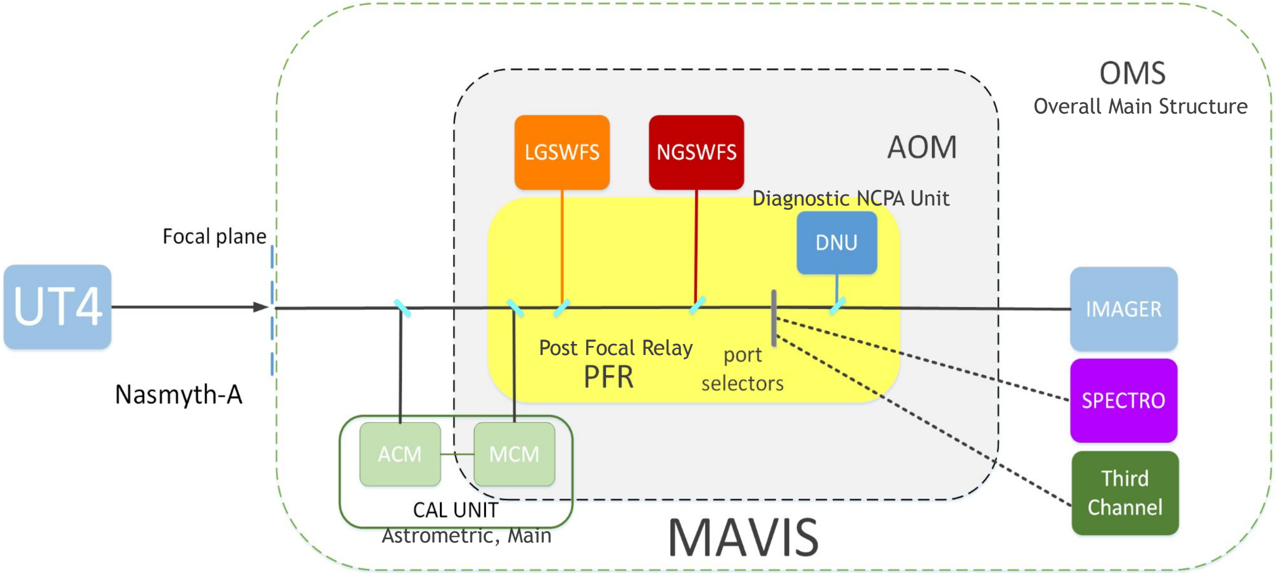
- It will operate in the **visible** band 370 - 1000 nm

AOM Sensors:

- **8** Laser Guide Stars
- **3** Natural Guide Stars
  Non sidereal targets

PI-ship: Australia

- Imager, SPE, CU: Australia
- AOM: INAF
- ICSS: INAF OAPd

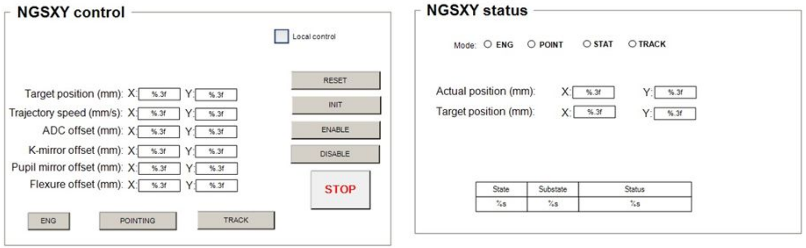


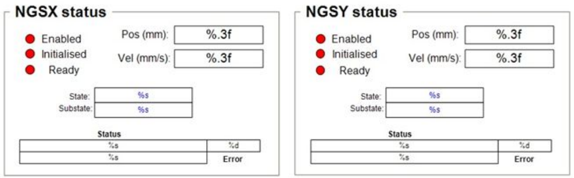
MAVIS

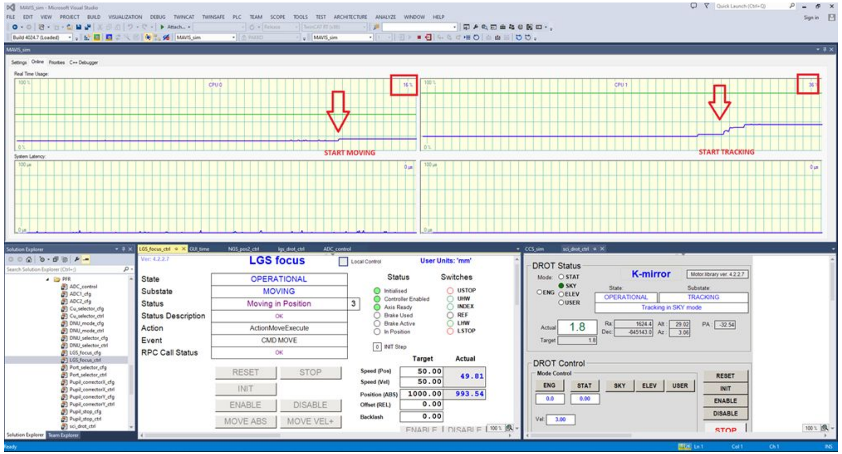
- Instrument control hardware design, assembly and test
    - System electronics
    - AOM control electronics

- Low level control software
    - Beckhoff PLC TwinCAT solution development
        - standard devices
        - PID control parameters tuning
        - Engineering GUIs

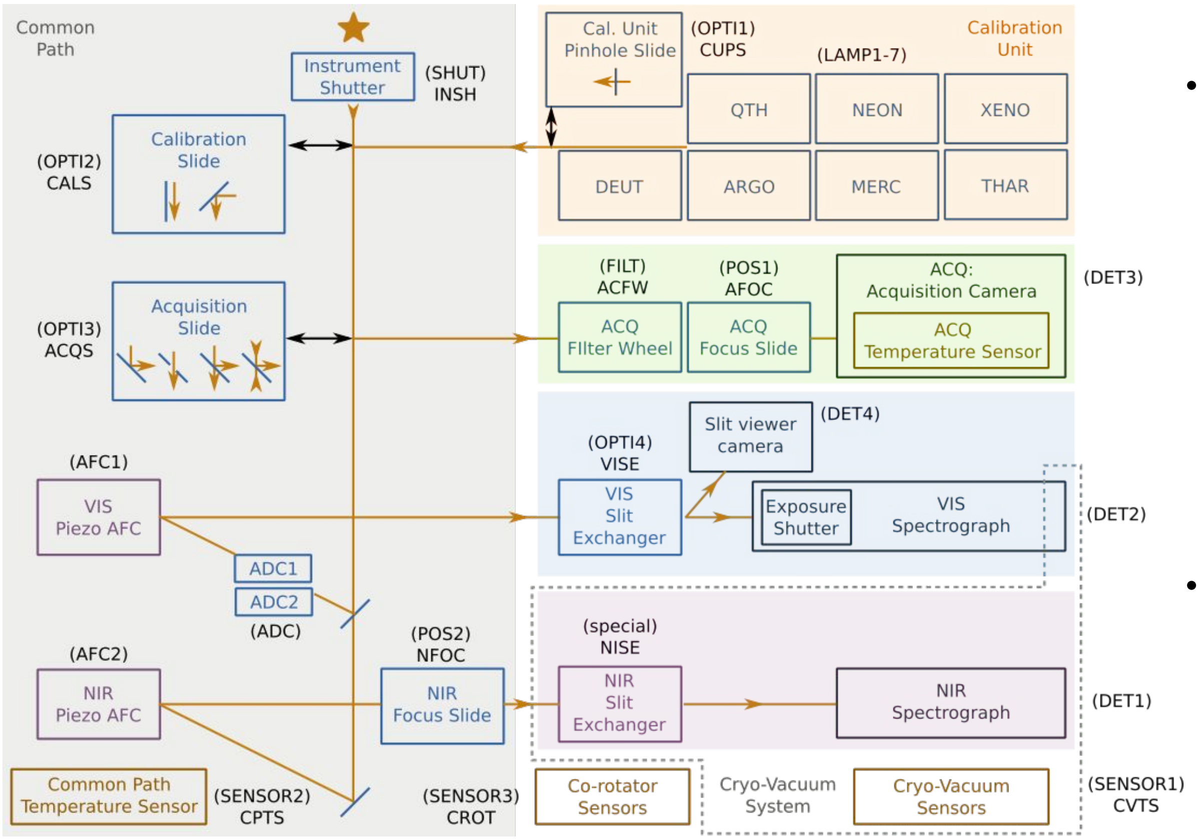
- High level control software, in synergy OAPD-OACN







SOXS



- VLTSW→ Standard management of standard components;
- Internal interfaces:
  - **Instrument HW control software:**
    - Mainly VLTSW standard devices;
    - NIR Slit Exchanger, AFCs: special device;
  - **Detector Control Software:**
    - NGC-Opt; NGC-IR;
    - TDCS for the Acquisition Camera;
  - **Cryo-Vacuum System;**
- External interfaces:
  - **Observation preparation Software:**
    - Observation and Maintenance templates;
  - **Telescope Control Software;**
  - **Archive.**

SOXS

- Instrument control hardware design, assembly and test

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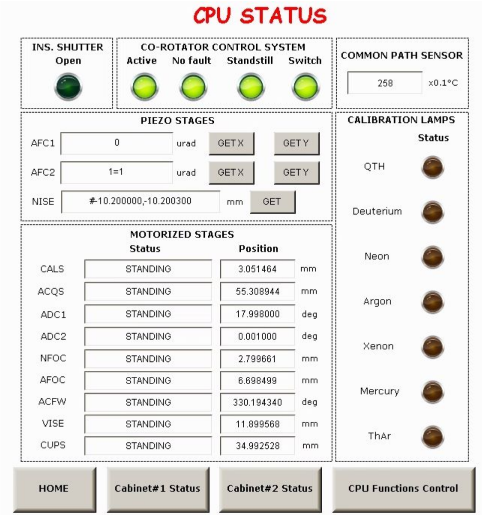
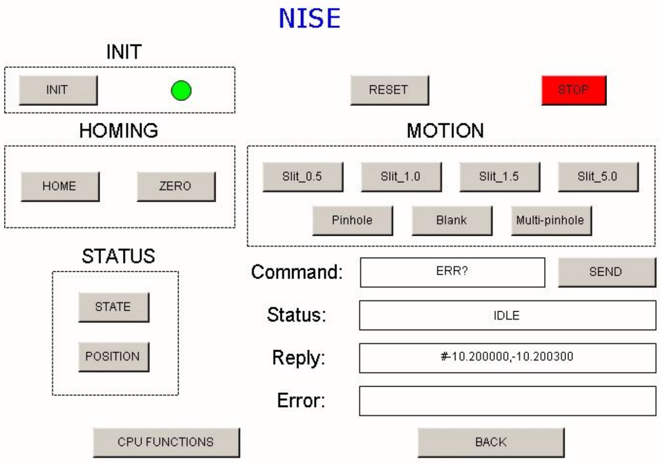
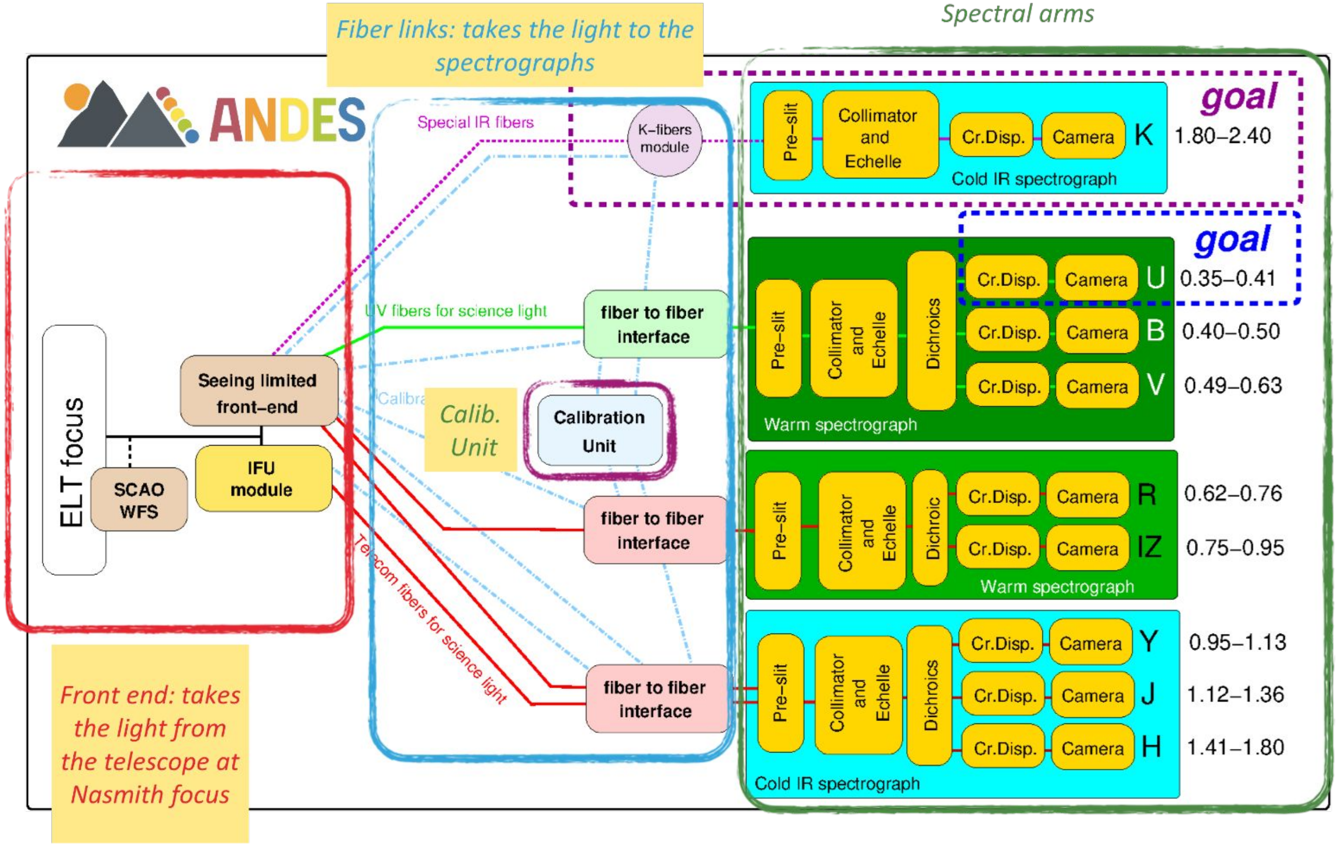




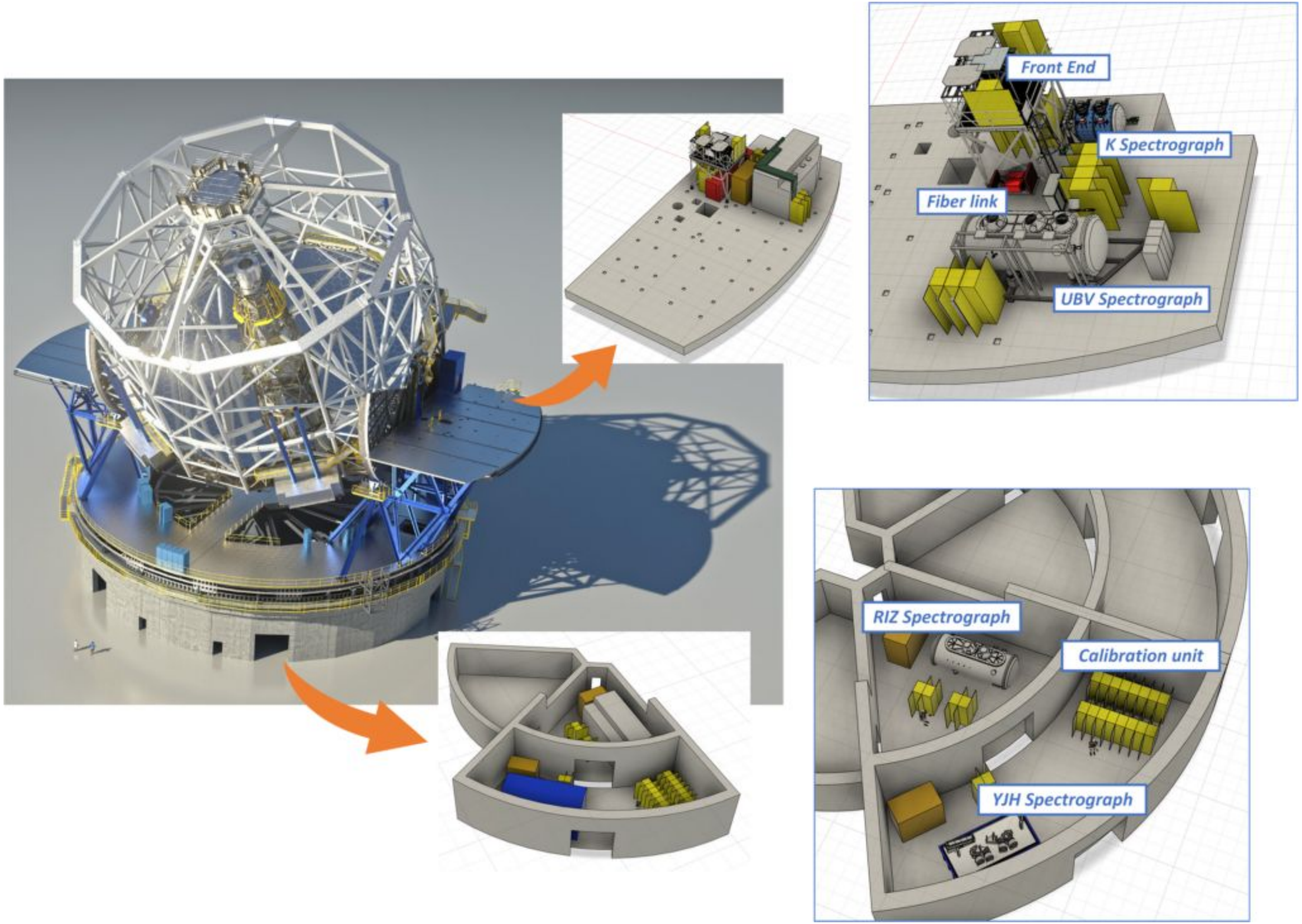
ANDES

A High Dispersion Echelle Spectrograph 4 ELT



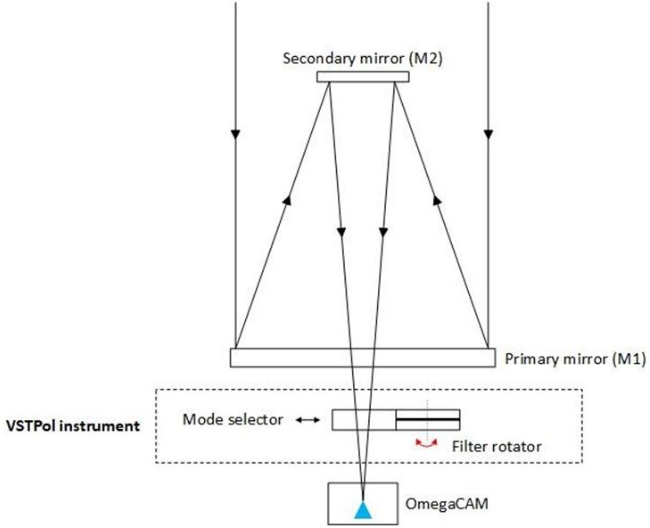
- Modular fibre-fed cross dispersed Echelle spectrograph
- Simultaneous range 0.4-1.8 μm (ultra-stable BV+RIZ+YJH)
  Goal 0.37-2.4 μm (with U and K); Resolution ~100,000
- Several interchangeable, observing modes: Seeing limited & SCAO+IFU

ANDES

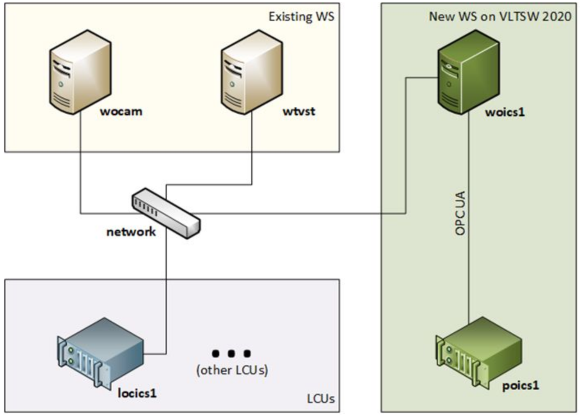

Front End
K Spectrograph
Fiber link
UBV Spectrograph
RIZ Spectrograph
Calibration unit
YJH Spectrograph

VSTPOL

VST upgrade with a new polarimetric mode



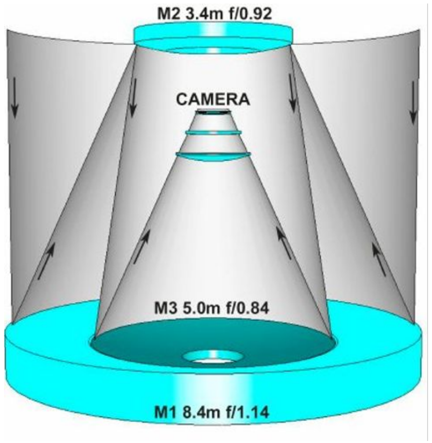
- Instrument control hardware design and test
- Low & High level control SW development
- Integration of the Beckhoff PLC technology into a system based on the ESO VLT2010 framework, which was based on LCUs.



Vera C. Rubin (LSST) - INAF in kind contribution S22

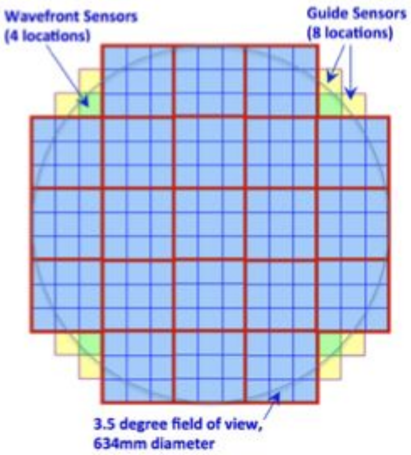
Simonyi Survey Telescope @ Vera Rubin Observatory
(formerly known as LSST)

- Located in Cerro Pachón, Chile
- Fast (f/1.23) 8m three mirror anastigmat
- 3.5° FoV
- Curvature AOS controlling several degrees of freedom:
  - M1M3 + M2 mirror figures (176 + 78 actuators)
  - M2 and Camera tip-tilt + decenter (2 hexapods)



study of a Novel Active Optics Control

based on in-focus science images



							“junior”				SQA		IT	
	Andrea Baruffolo	Daniela Fantinel	Bernardo Salasnich	Davide Ricci	Elia Costa	Fulvio Laudisio	Alessandro Lorenzetto	Salvatore Lampitelli	Chiara Di Prospero	Daphne Diretto	Andrea Balestra	Rosanna Sordo	Amedeo Petrella	Danilo Selvestrel
ICSS	■	■	■		■	■				■	■	■		
RTC	■							■	■		■	■	■	■
MAVIS	■	■	■		■						■	■		
	■		■	■										
ERIS	■	■	■											
	■			■		■	■							

abstract

INAF is leader in the Instrument Control Software development of telescope instruments at large, in particular ESO ones.

Within the framework of the TETIS (TEchnologies for Telescopes and Instrument control Software) Coordination Unit, we present the members of OAPD, OATS and OACN and the projects in which they are involved.

Then, we briefly state the several common tasks faced by the teams, and the development process of a typical Control Software of an ESO instrument.

Finally, we give a short description of the main projects managed by the OAPD (MORFEO, MAVIS, SOXS), by the OATS (ANDES) and OACN (SOXS, VSTPOL) teams.