

Telescope and Instrument Software and Control Activities at INAF Capodimonte TESTA lab

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+

many others in the previous decades





TElescopi e STRumenti per l'Astronomia

(o almeno *proviamo* a mettercela)

Overview of past and present

Talk about



Control software

Control

Software

Electronics

Project Management

System Engineering

Active Optics

Integrated Modeling

Integration, commissioning

....

Where it all began



TNG - The good old days ('90s)

- Tracking Control Az, Alt, Rot (x2)
- M3 Control
- Software, Servo Control, Electronics, Integration, Commissioning

PDOS Real-time O. S.

VME bus

Servo Control Software still working every night

1994
'desk'



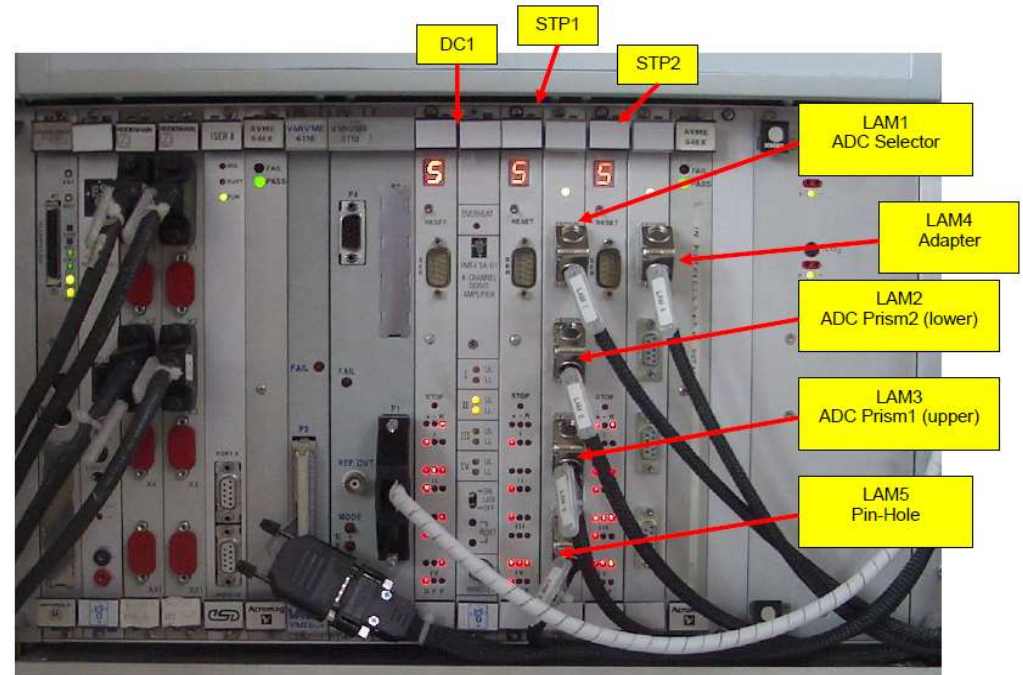
The ESO ecosystem



The (old) ESO standards

- Real-time VxWorks
- VME bus
- HP-UX
- C,C++,TclTk
- CMM version control

- ✓ Software
- ✓ Electronics
- ✓ Integration
- ✓ Commissioning



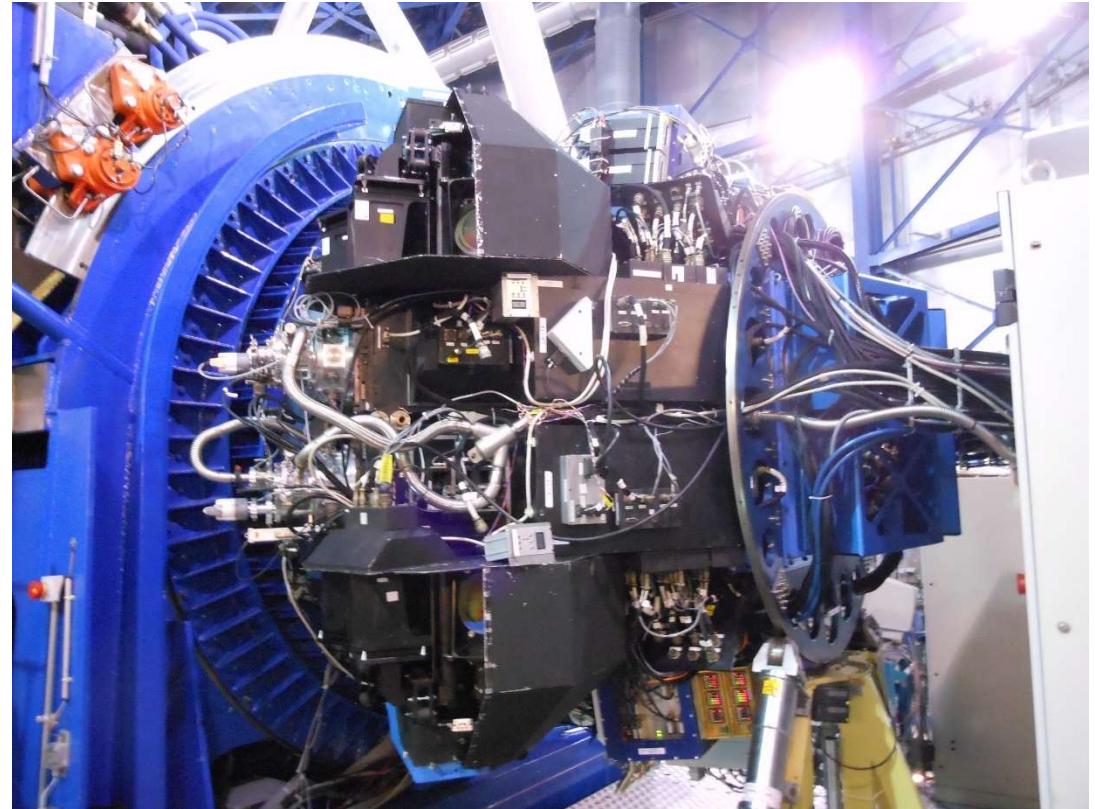
Involvement in ESO projects since 1996



VIMOS @VLT



- ❑ 4 spectrographs
- ❑ 52 motors + lamps, etc.
- ❑ Real-time control sw of hw functions
- ❑ OS
- ❑ Control Electronics



A decade with the VST



- ❑ 8 Local Control Units VxWorks real-time O.S.
- ❑ 1 Scientific Linux WS
- ❑ 60 software modules
- ❑ 10 control cabinets
- ❑ CAN Bus network

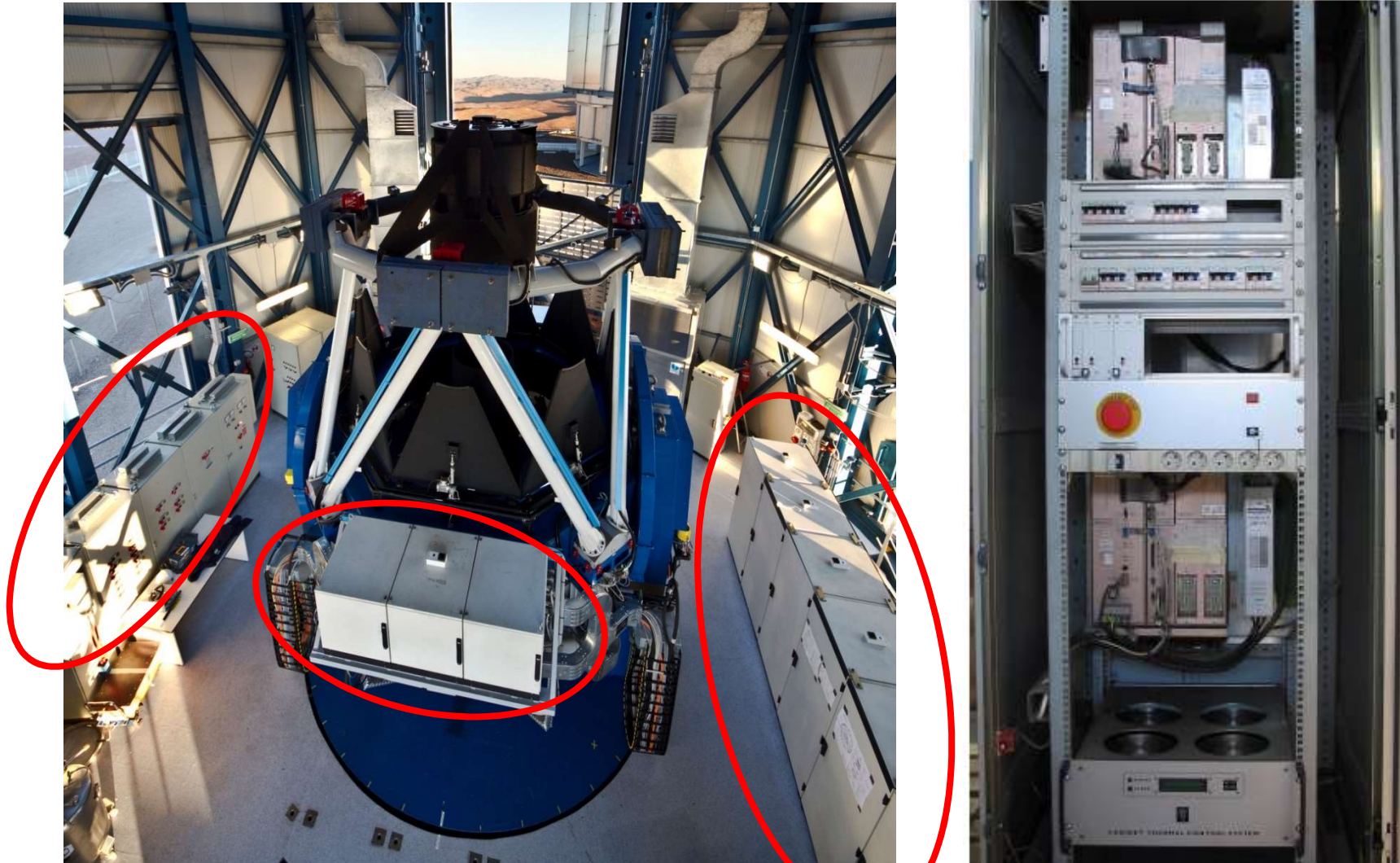
- Point&Track (Az,Alt,Rot,AG) SW
- AO (WFS, M1, M2) SW
- ADC SW
- Probe SW
- Etc.

+ everything else



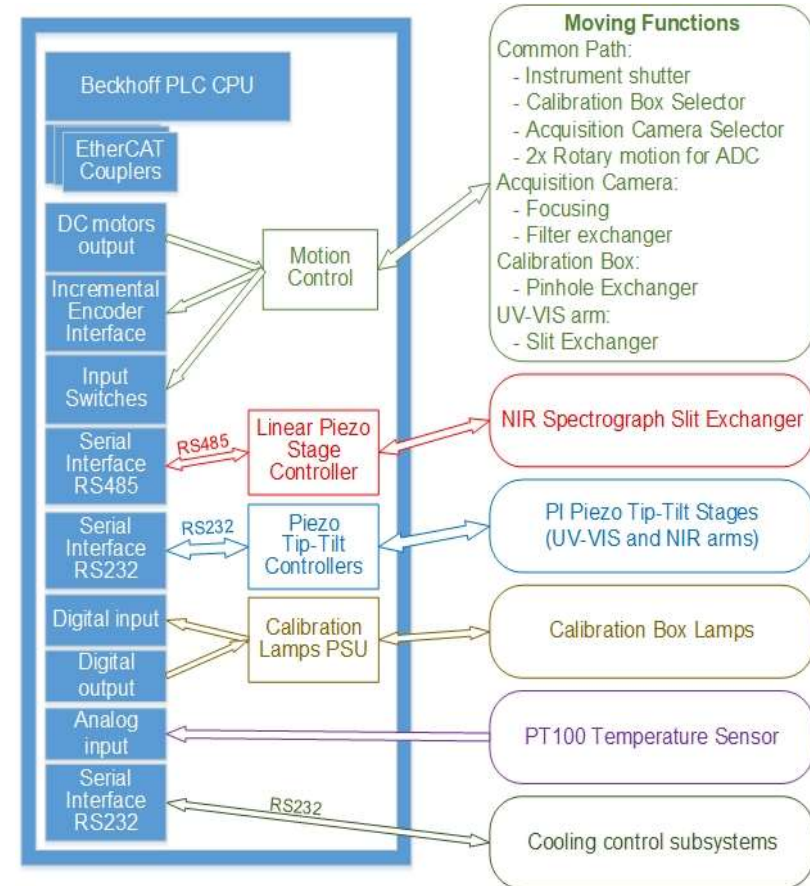
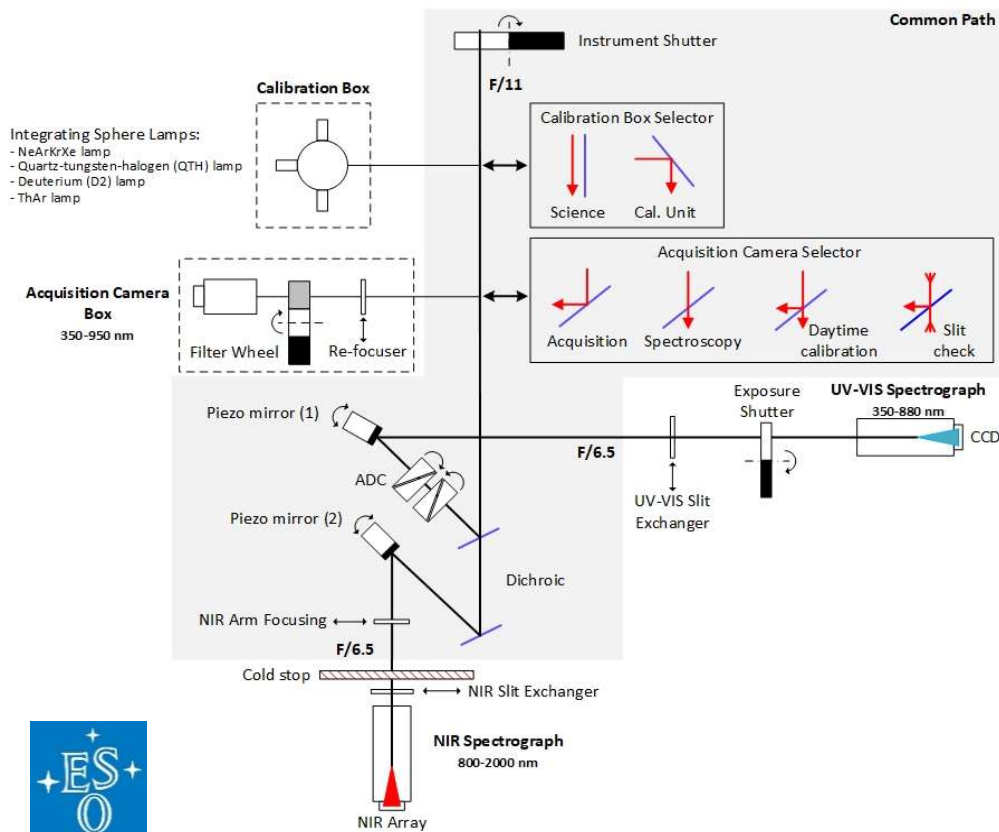
Very big project, very small staff (2-3 for SW)

From VME Control





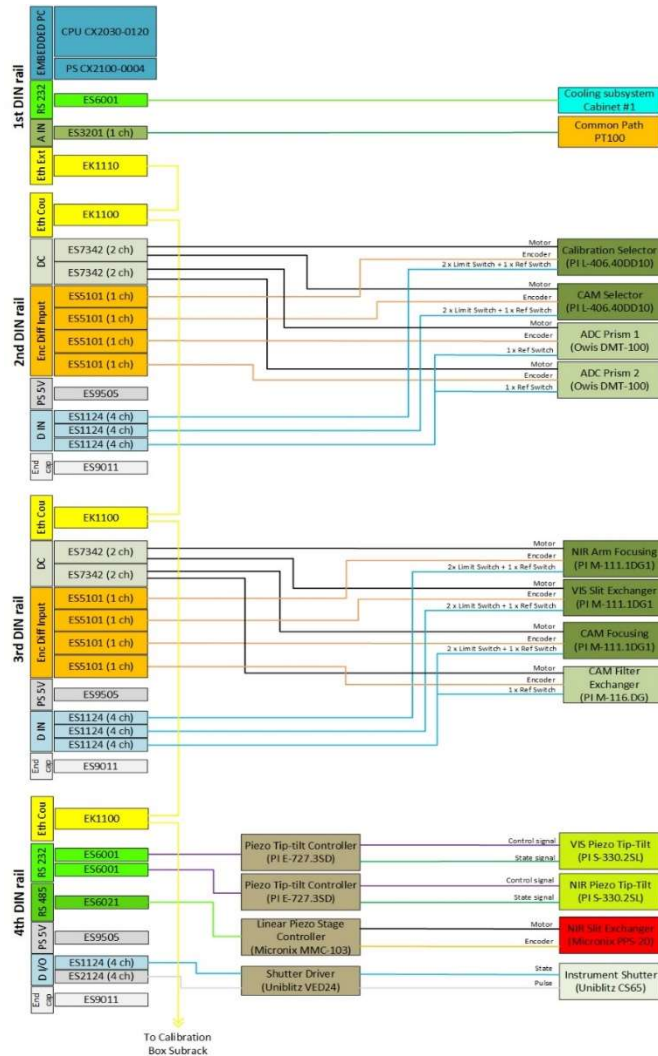
SOXS (Son Of X-Shooter)



To Beckhoff PLCs



SOXS (Son Of X-Shooter)



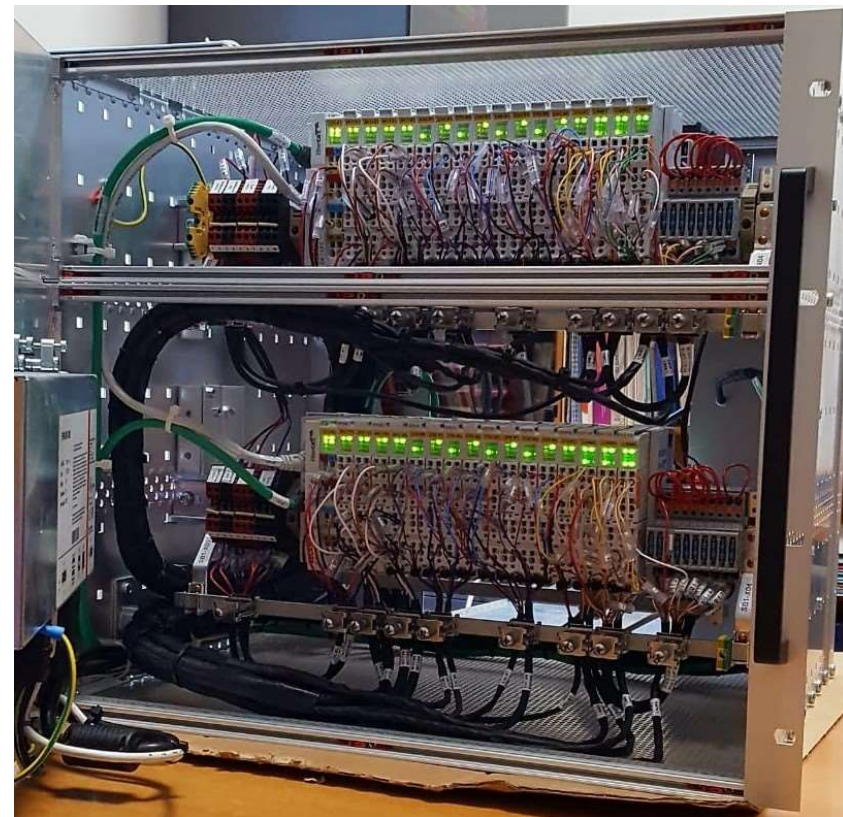
- CPU - CX2030 series (CX2030-0120)
- Power Supply module - CX2100-0004
- Software - TwinCAT 3.1

ESPRESSO heritage

To Beckhoff PLCs



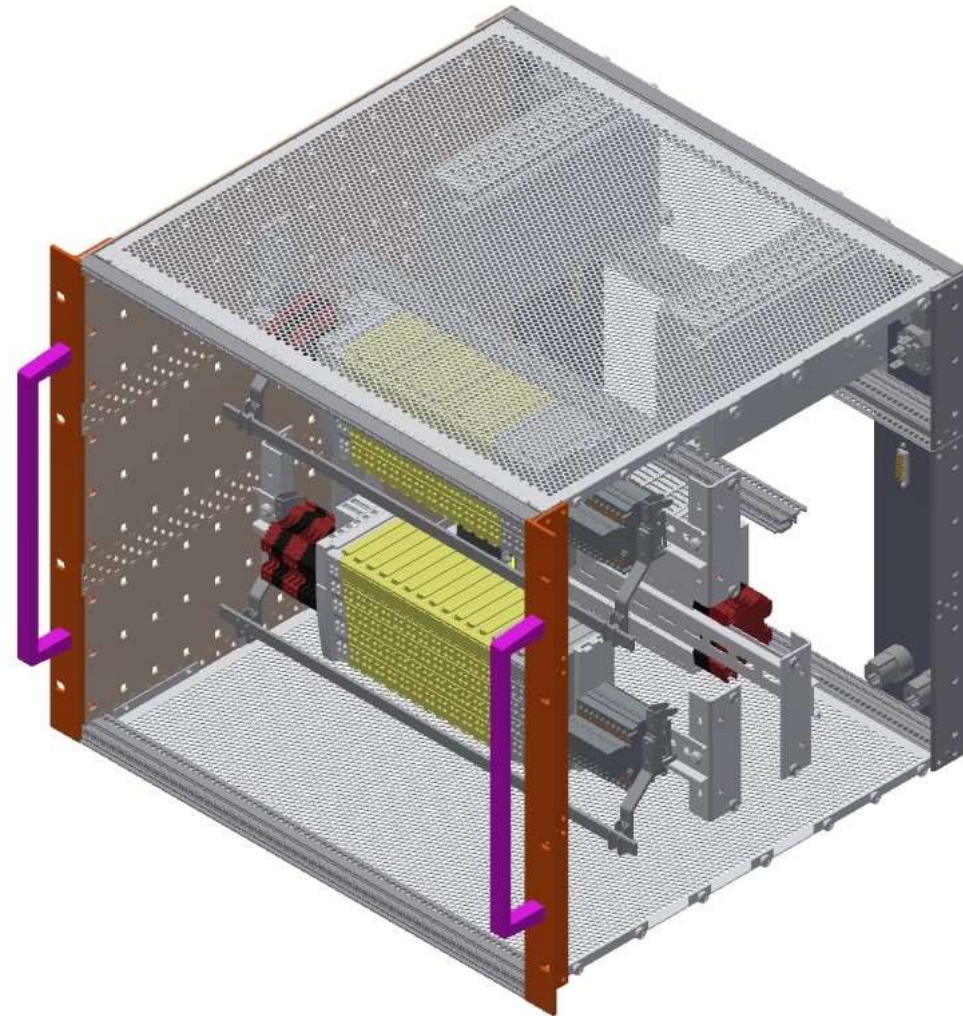
SOXS (Son Of X-Shooter)



To Beckhoff PLCs



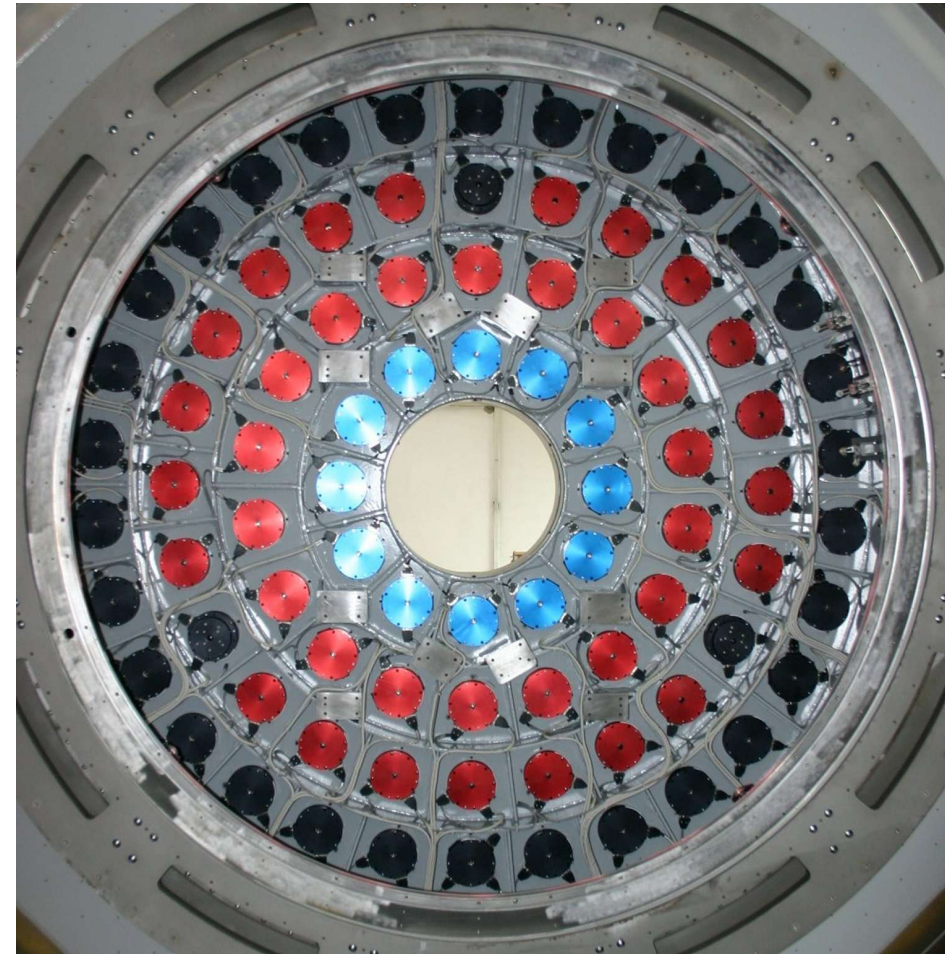
MCAO Assisted Visible Imager and Spectrograph





Active Optics

- CAN Bus Network
- PIC Microcontrollers





ExoMARS DREAMS

- CANOpen protocol
- CANoe
- CAPL programming language



The screenshot shows the DREAMS_IF software interface. Key components highlighted by red circles are:

- 1: ID 1
- 2: REDUNDANCY STATE: BUS M active, BUS R active
- 3: Real Bus Mode checkbox
- 4: CRUISE mode selection
- 5: Switch bus button
- 6: Set Operational button
- 7: Test button
- 8: Control tabs (TEM, WIND, SIS, P, H, MARES)
- 9: TEST SCRIPT Start button
- 10: STD OPERATIONS buttons (Check Out, MTL Update, Battery On)
- 11: Delay(s) input field
- 12: TM RECEIVED (Hex) display showing TM_EVT_GET_STATUS
- 13: SCET 6000 Bytes 0-5 display
- 14: BSO 6001 BufferStatus and SDOContent display
- 15: DREAMS POWER status (TEM, WIND, SIS, PH, UARES, BATTSW, CAINO, CPU, ADC)
- 16: SDO HEADER table with columns: Time(s), H0, H1, Counter, Type, Aux, CRC
- 17: Log file name and log content area

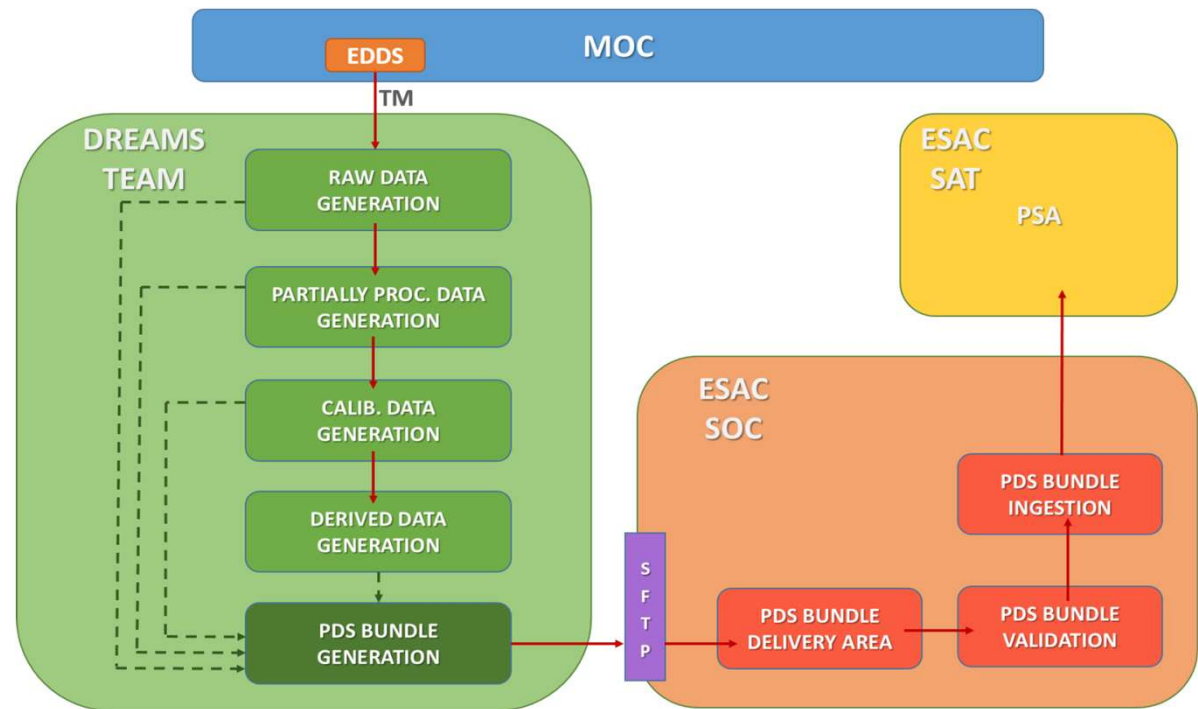
| Time(s) | H0 | H1 | Counter | Type | Aux | CRC |
|----------|-------|-------|---------|-------------------------|-------|-----|
| 4.419000 | 44.52 | 00.01 | 20.00 | 00.01.02.03.e8.07.d0.00 | 95.17 | |
| 4.619000 | 44.52 | 00.02 | 20.00 | 00.02.02.03.e8.07.d0.00 | 55.52 | |
| 5.940530 | 44.52 | 00.00 | 10.00 | 01.01.02.03.e8.07.d0.00 | 96.3b | |
| 7.100170 | 44.52 | 00.00 | 10.00 | 01.02.02.03.e8.07.d0.00 | 96.3f | |
| 8.319000 | 44.52 | 00.01 | 20.00 | 03.01.05.03.e8.13.88.00 | 96.db | |
| 8.519000 | 44.52 | 00.02 | 20.00 | 03.02.05.03.e8.13.88.00 | 88.3f | |
| 8.720000 | 44.52 | 00.03 | 20.00 | 03.03.05.03.e8.13.88.00 | 00.00 | |
| 8.920000 | 44.52 | 00.04 | 20.00 | 03.04.05.03.e8.13.88.00 | 00.00 | |
| 9.120000 | 44.52 | 00.05 | 20.00 | 03.05.05.03.e8.13.88.00 | 00.00 | |



ExoMARS DREAMS

☐ PDS4

☐ Java + Eclipse





- Example:
- Active Optics Software**
 - SW Prototyping
 - Control simulations
 - Integrated modeling (Ansys-Zemax-Matlab)
 - Data analysis (e.g. tracking, active optics)

Many thanks to INAF-ICT for procuring Matlab & Simulink



hexgui

| Input | Abs Pos (FK) | Leg Lengths | Leg Error (FK) |
|---------------|--------------|-------------|----------------|
| x [mm] | 1.9209 | L1 [mm] | 3.2969e-012 |
| y [mm] | -0.63916 | L2 [mm] | 3.4106e-012 |
| z [mm] | -0.0060312 | L3 [mm] | 3.89351 |
| psi [x] [°] | 37.8433 | L4 [mm] | 3.903298 |
| theta [y] [°] | 103.9736 | L5 [mm] | 3.900998 |
| phi [z] [°] | 0.009538 | L6 [mm] | 3.893015 |

| | x | y | z |
|----------|-----------|-----------|----------|
| Pm1 [mm] | -80.2387 | 278.5029 | 0.086609 |
| Pm2 [mm] | -280.9549 | -69.1479 | 0.124 |
| Pm3 [mm] | -198.7952 | -211.4526 | 0.056479 |
| Pm4 [mm] | 202.6371 | -211.4526 | -0.14587 |
| Pm5 [mm] | 284.7968 | -69.1478 | -0.16118 |
| Pm6 [mm] | 84.0806 | 278.5029 | 0.003779 |

Active Optics

Defocus Coma AO Priority

Modulus [nm] 10000 DZ [mm] 0

Angle [deg] 70 Delta [°] 37.8433

Epsilon [°] 103.9736

ENOLA GAY

Standard Zernike

| | |
|----------|-----------|
| Piston | -421.8362 |
| Ti | 0 |
| Defocus | -448.2075 |
| Sph3 | 94.6776 |
| Sph5 | -3.2757 |
| Coma | 0.17897 |
| Coma5 | 0 |
| Ast3 | 0.23897 |
| Ast5 | 0 |
| Trefoil | 0 |
| Quad Ast | 0 |

MI Axial Forces

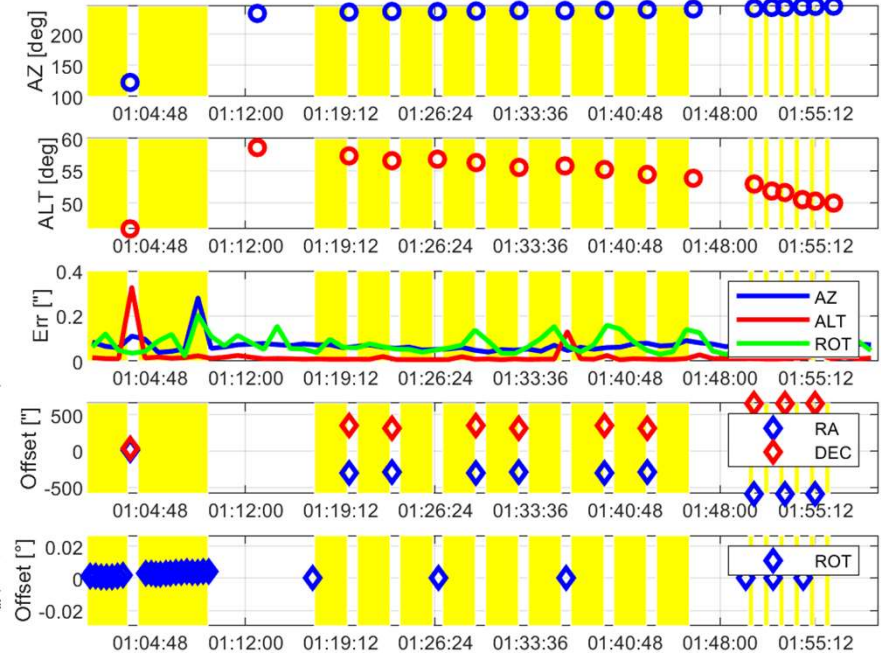
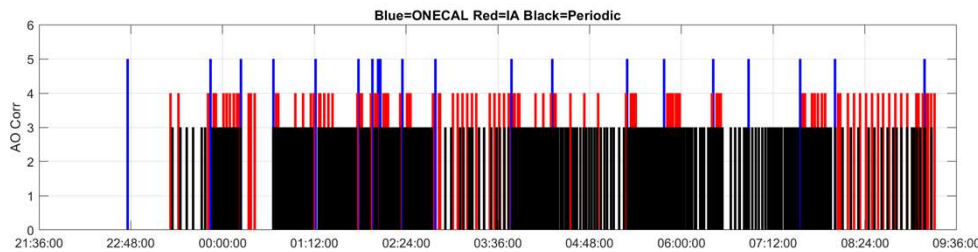
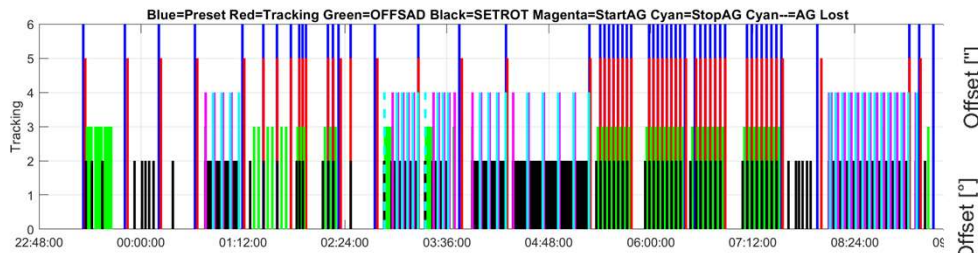
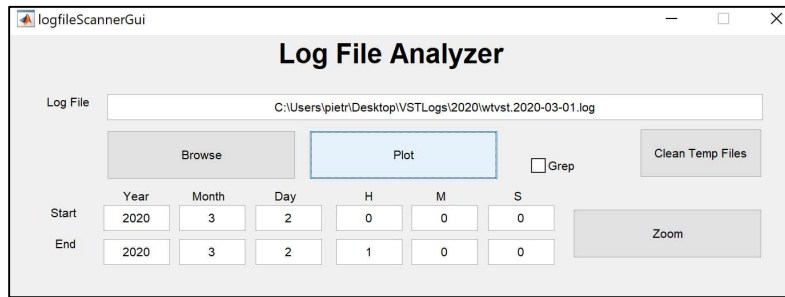
| Field1 | Field2 | Field3 | Field4 | Field5 | Average |
|--------|------------|-----------|-----------|--------|-----------|
| dBO | 27.2 | 23.6 | 25.6 | 27.2 | 29.2 |
| rRMS | 9.3475 | 8.4653 | 8.9711 | 9.6156 | 10.3457 |
| Xc | -0.001681 | -0.001661 | -0.001667 | 130.7 | -0.001678 |
| Yc | 1.609e-005 | 88.81 | 130.7 | 130.7 | 184.7 |

MI2 Displacements

| | |
|-------|---|
| Dx | 0 |
| Dy | 0 |
| Dz | 0 |
| psi | 0 |
| theta | 0 |



Telescope & Instrument Control Monitoring (VST+ΩCAM)



Post-instrument delivery

- Operations
- Maintenance
- System Improvements



OB Scheduler

Led by M. Landoni
(INAF Brera)

- Control of the telescope operations
- Remote Scheduling

Due for:

- NTT-SOXS
- VST (TBD)



SOXS (Son Of X-Shooter)

The screenshot shows the SOXS SCHEDULER web interface. The main content is a table titled 'List of OBs' with the following columns: AID, OB Type, Target Name, Ra., Dec., Magnitude, Exp. Time, and Actions. The table contains 14 rows of observation data. A sidebar on the left includes navigation options like 'Switch to Night', 'New OB', 'New Urgent OB', 'Refresh', and 'Show Logs'. The top right corner shows 'Items by page 30' and 'Jack From Science Team'.

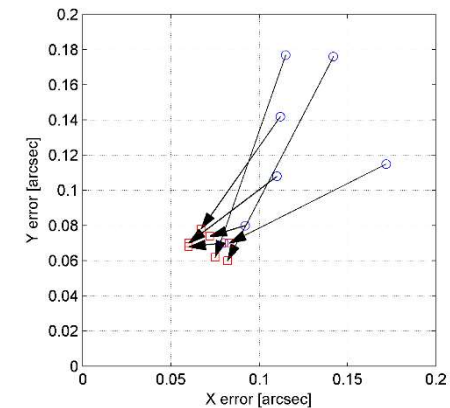
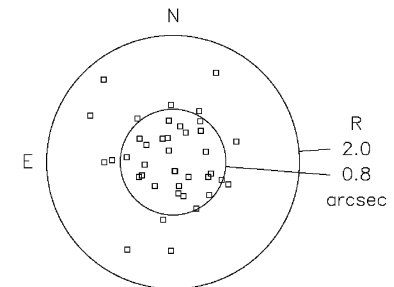
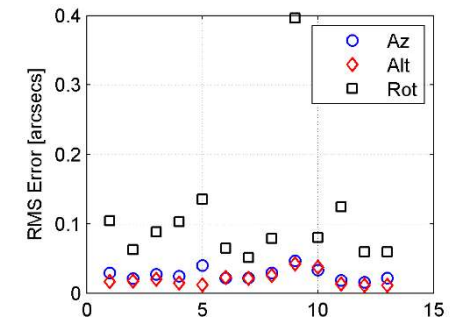
| AID | OB Type | Target Name | Ra. | Dec. | Magnitude | Exp. Time | Actions |
|-----|----------------|------------------|---------------|----------------|-----------|-----------|-----------|
| 1 | Undefined | PKS 1553+113tris | 08h40m00s | +10d00m00s | 11.5 | 3 | [Actions] |
| 4 | Classification | AT2018fsj | 17h51m49.68s | +15d18m28.44s | 18.4 | 2070 | [Actions] |
| 5 | Proposal ESO | AT2018ftn | 01h25m17.88s | +09d39m00.072s | 17.3 | 752 | [Actions] |
| 6 | Classification | AT2018ftv | 19h08m06s | -15d22m09.12s | 18.8 | 2994 | [Actions] |
| 7 | Follow up | AT2018ftx | 01h44m34.56s | -00d28m05.52s | 18.4 | 2070 | [Actions] |
| 8 | Follow up | SN2018fty | 02h26m47.304s | -09d04m02.316s | 18.1 | 1570 | [Actions] |
| 10 | Follow up | AT2018fuc | 04h49m54.48s | -41d56m18.24s | 17.4 | 824 | [Actions] |
| 11 | Undefined | SN2018fuk | 05h45m08.16s | -79d23m47.4s | 17 | 570 | [Actions] |
| 12 | Classification | SN2018fuu | 23h24m56.64s | +09d25m52.68s | 17.8 | 1192 | [Actions] |
| 13 | Classification | AT2018fuw | 19h28m47.04s | +34d50m17.52s | 18.97 | 3501 | [Actions] |
| 14 | Classification | AT2018fux | 17h36m34.72s | 54d01m50.16s | 15.0 | 188 | [Actions] |

Tracking Control

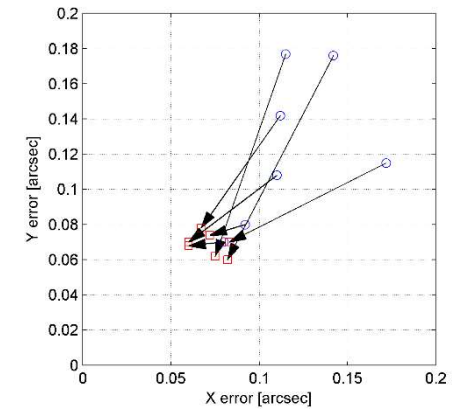
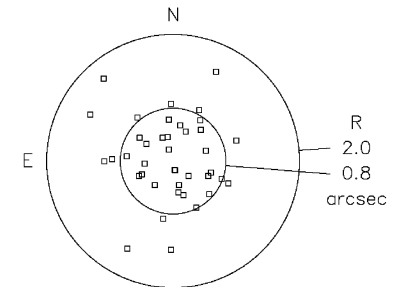
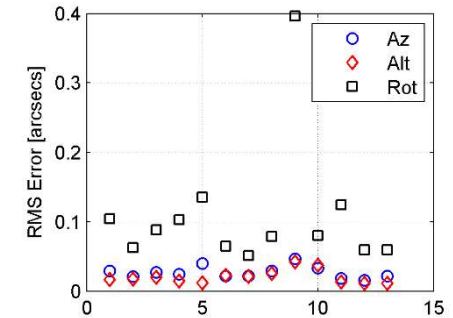
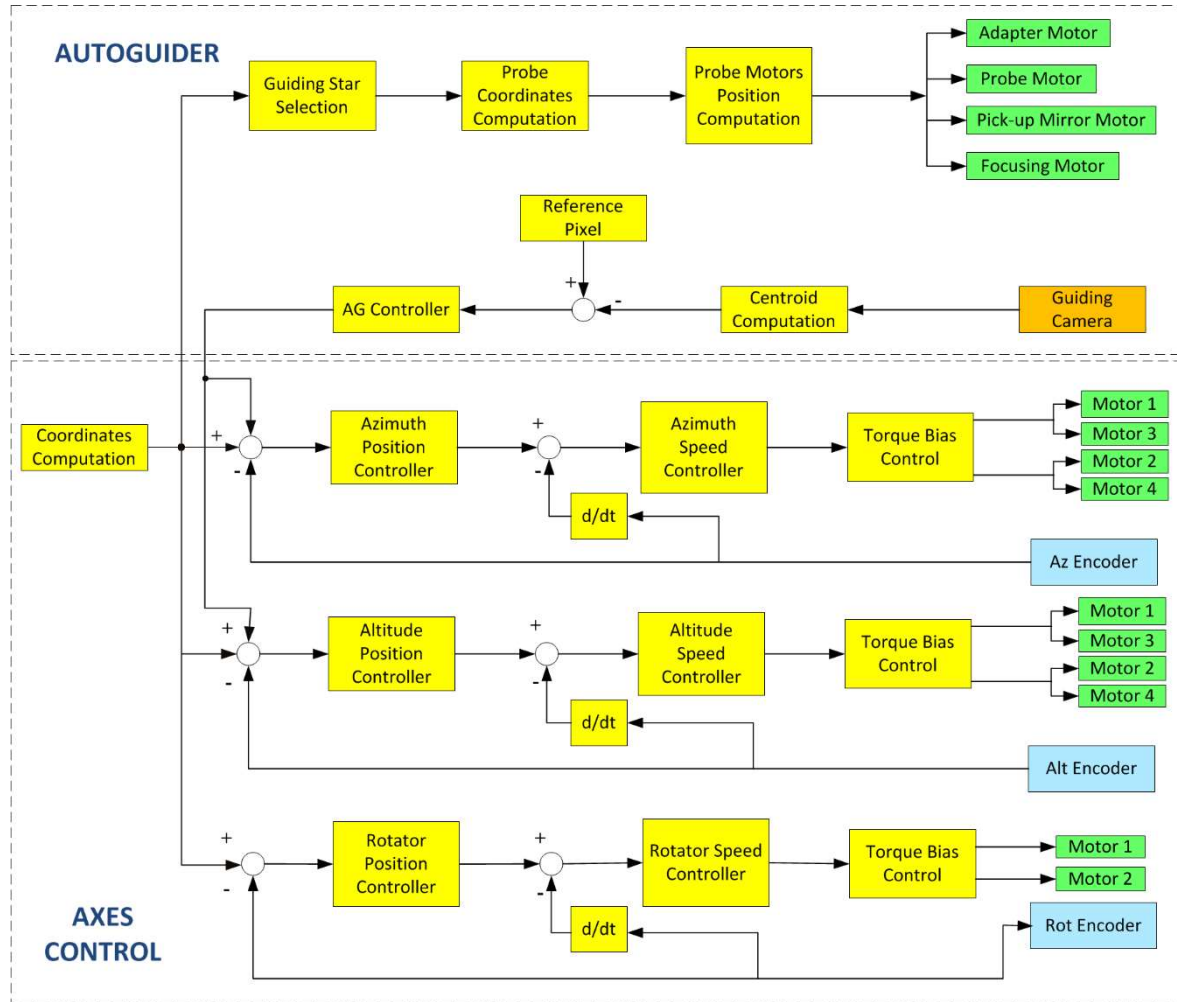


Control Engineering

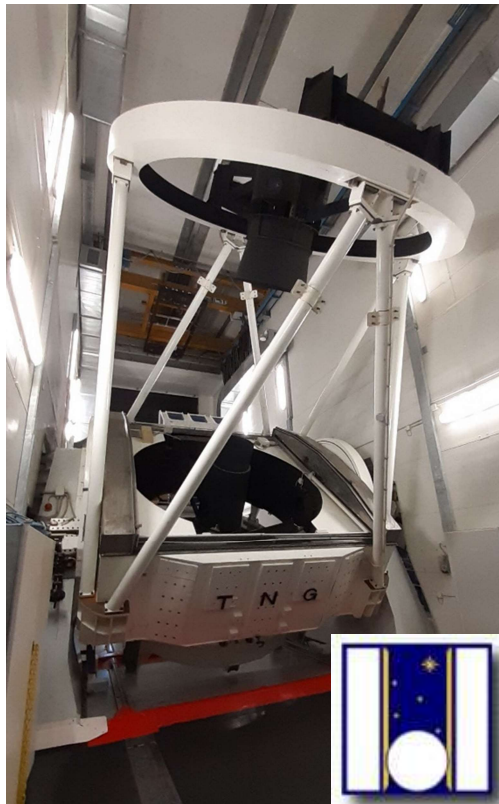
- ❑ Inside Telescope Control Software
- ❑ Uses Telescope Control Electronics
- ❑ System Identification
- ❑ Control Scheme
- ❑ Design and implementation of controllers
- ❑ Tightest requirements for optical telescopes
- ❑ Done for major INAF optical telescopes (TNG, VST)
- ❑ *Sets the telescope performance*



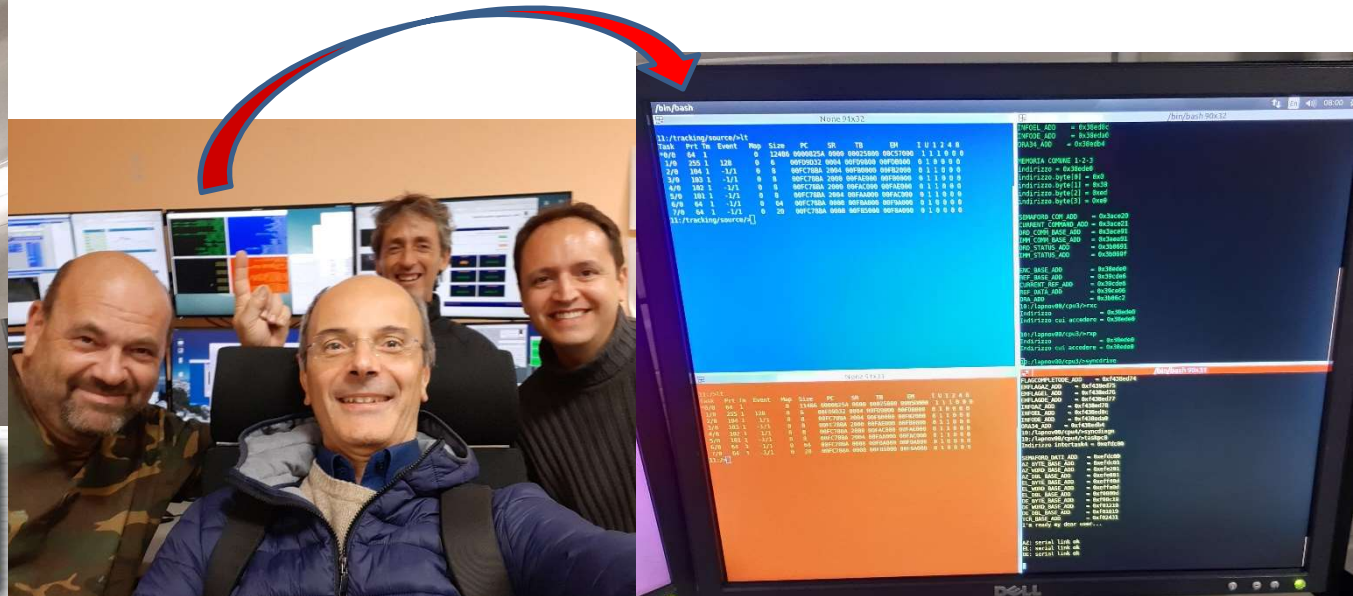
Tracking Control



Tracking Control



- Trip back to the TNG
- TNG Servo Control Redesign
- Azimuth Axis Completed



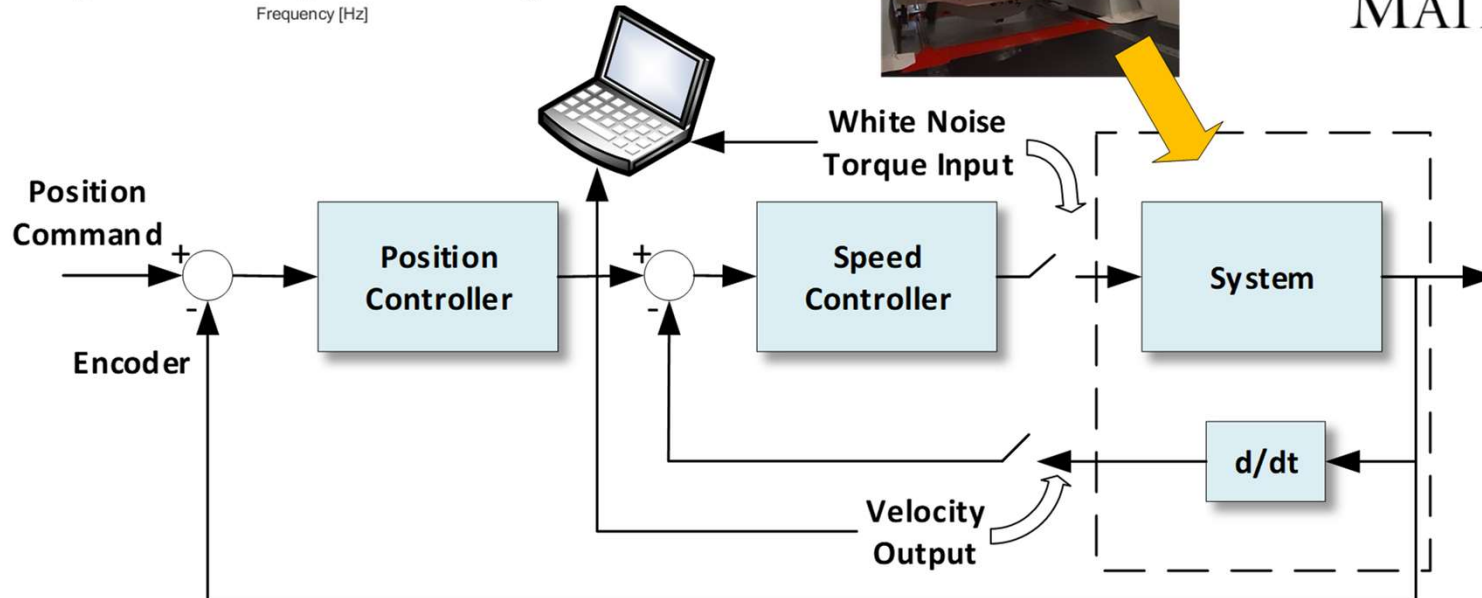
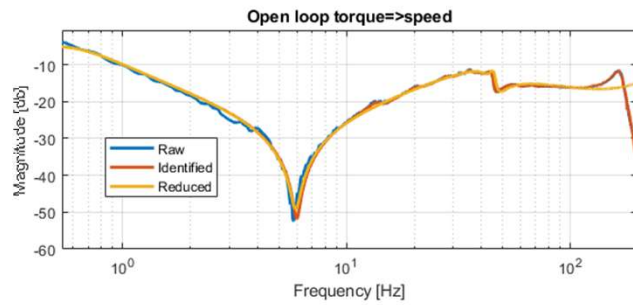
"After all this time"

Trigger for new activities in one historical application field

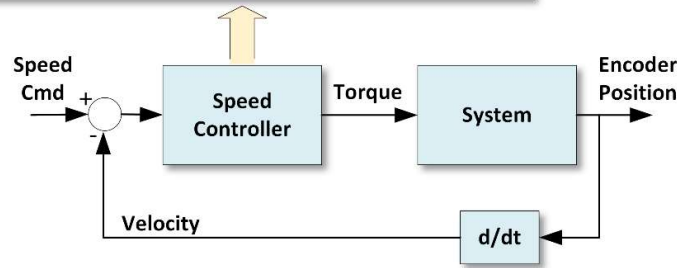
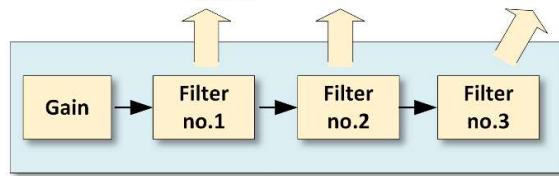
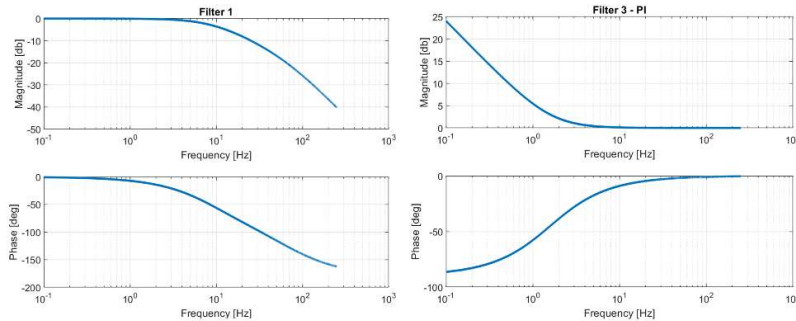
Telescope Control



System Identification



Telescope Control

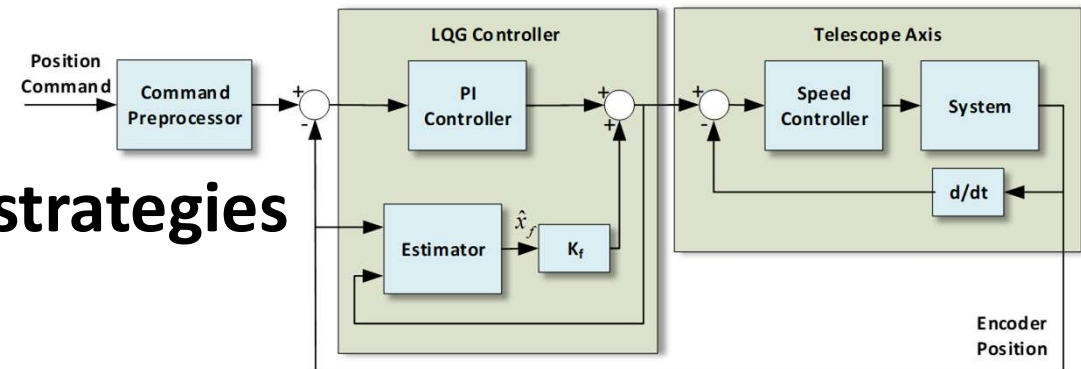


Pointing & Tracking Servo Controllers

- Design
- Implementation

Prototyping new control strategies

- Command shaper
- LQG Control



Conclusions



- Overview of some classes of applications
- Control Software
- But also control and software
- Control Electronics
- Control Engineering
- Multiwavelength 'sw' technologies (e.g. telescope control of pointing & tracking works for any optical-radio-etc. telescope or antenna)
- Possible synergies sw, sw+hw, sw+control