



The ASTRI-Horn Telescope Control System

Federico Russo – INAF OAS Bologna

for the ASTRI Project

TEchnologies for Telescopes and Instruments control Software



ASTRI-Horn



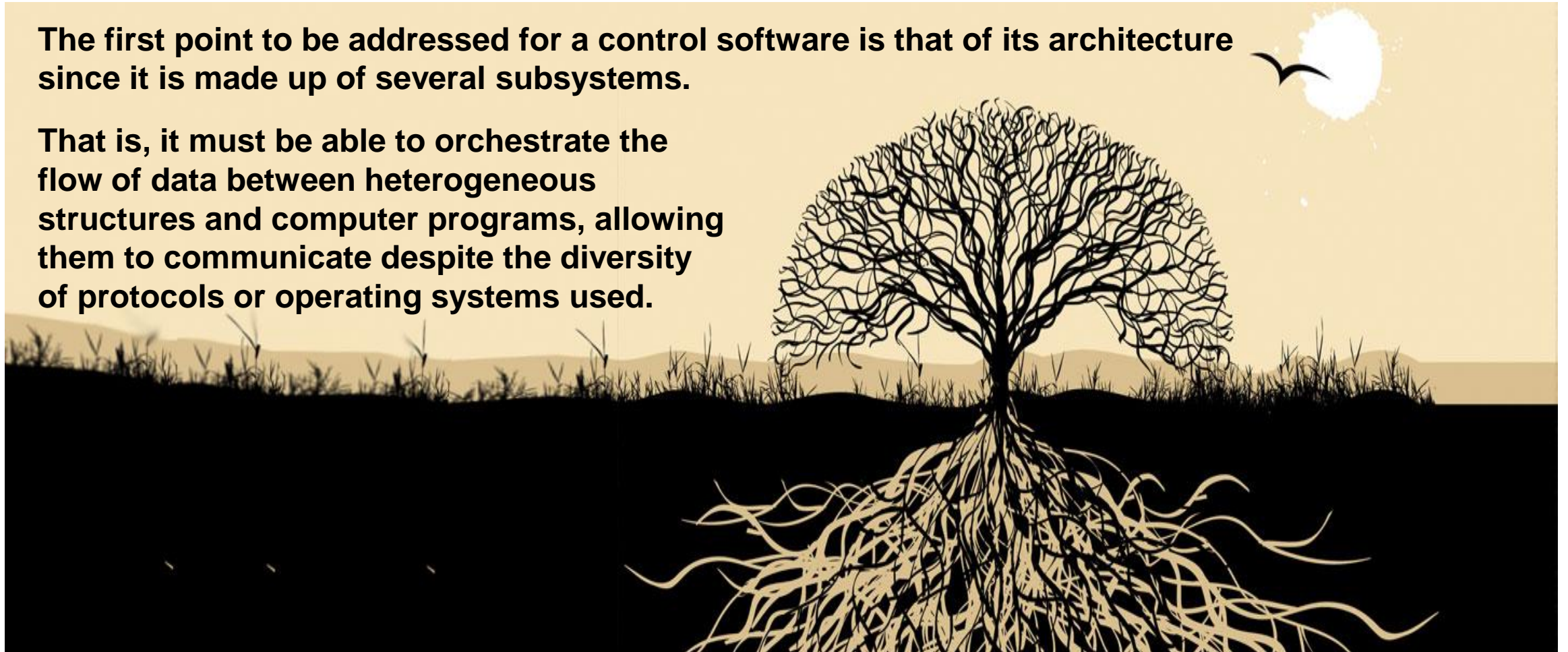
- The ASTRI-Horn Cherenkov telescope, installed at Serra La Nave on the Mount Etna (Italy), has been developed by INAF in the context of the "Astrofisica con Specchi a Tecnologia Replicante Italiana" (ASTRI) Project.
- INAF proposed a prototype for the Small Size class of Telescopes of the future Cherenkov Telescope Array (CTA), and for the INAF Mini-Array which will be installed at the Observatory of Teide in Tenerife (Spain).
- Astri-Horn uses a dual-mirror configuration and a Cherenkov camera having a detector composed of an array of monolithic silicon photomultiplier sensors (SiPM), coupled with a specifically designed front-end and back-end electronics.
- The Astri-Horn telescope represents a successful innovative solution for the detection of very high energy gamma-rays with ground-based atmospheric Cherenkov telescopes, as was demonstrated by the detection of the Crab Nebula during the Science Verification phases.

ASTRI-Horn Telescope Control System



The first point to be addressed for a control software is that of its architecture since it is made up of several subsystems.

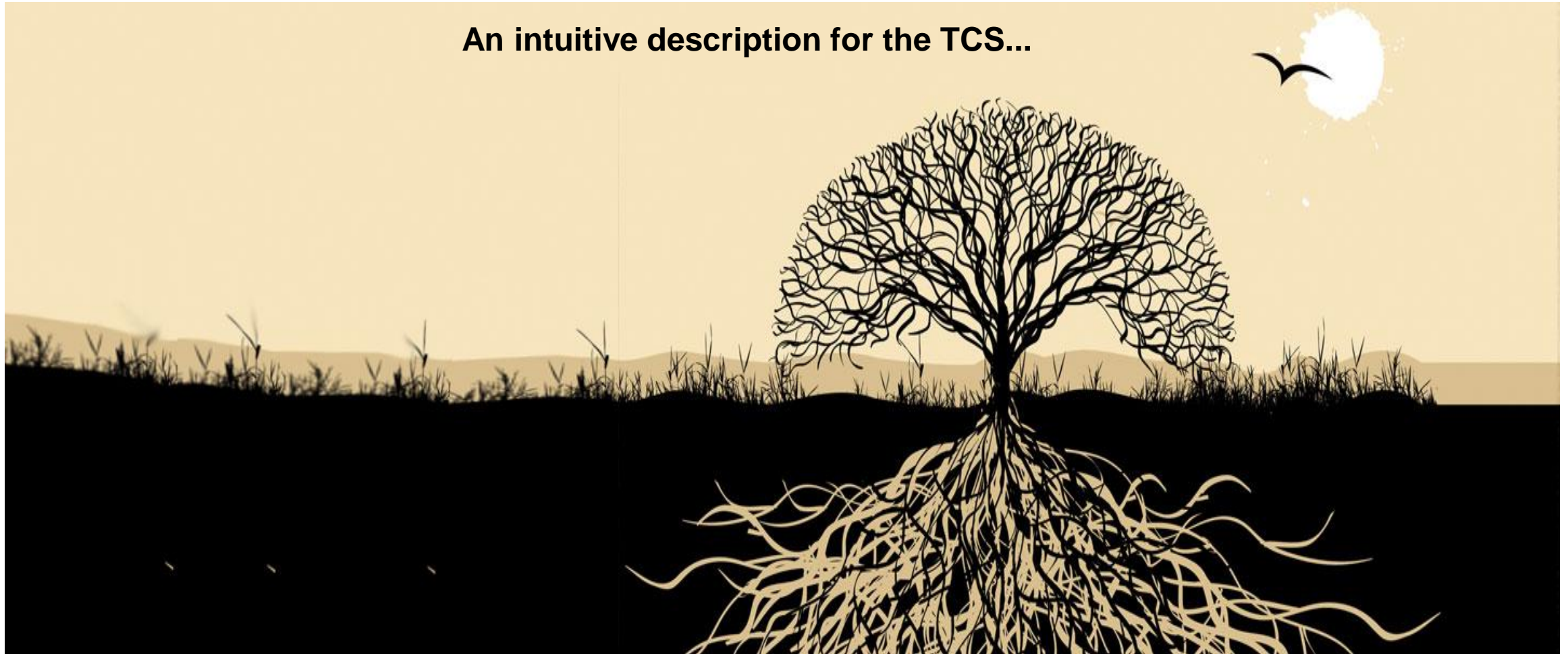
That is, it must be able to orchestrate the flow of data between heterogeneous structures and computer programs, allowing them to communicate despite the diversity of protocols or operating systems used.



ASTRI-Horn Telescope Control System



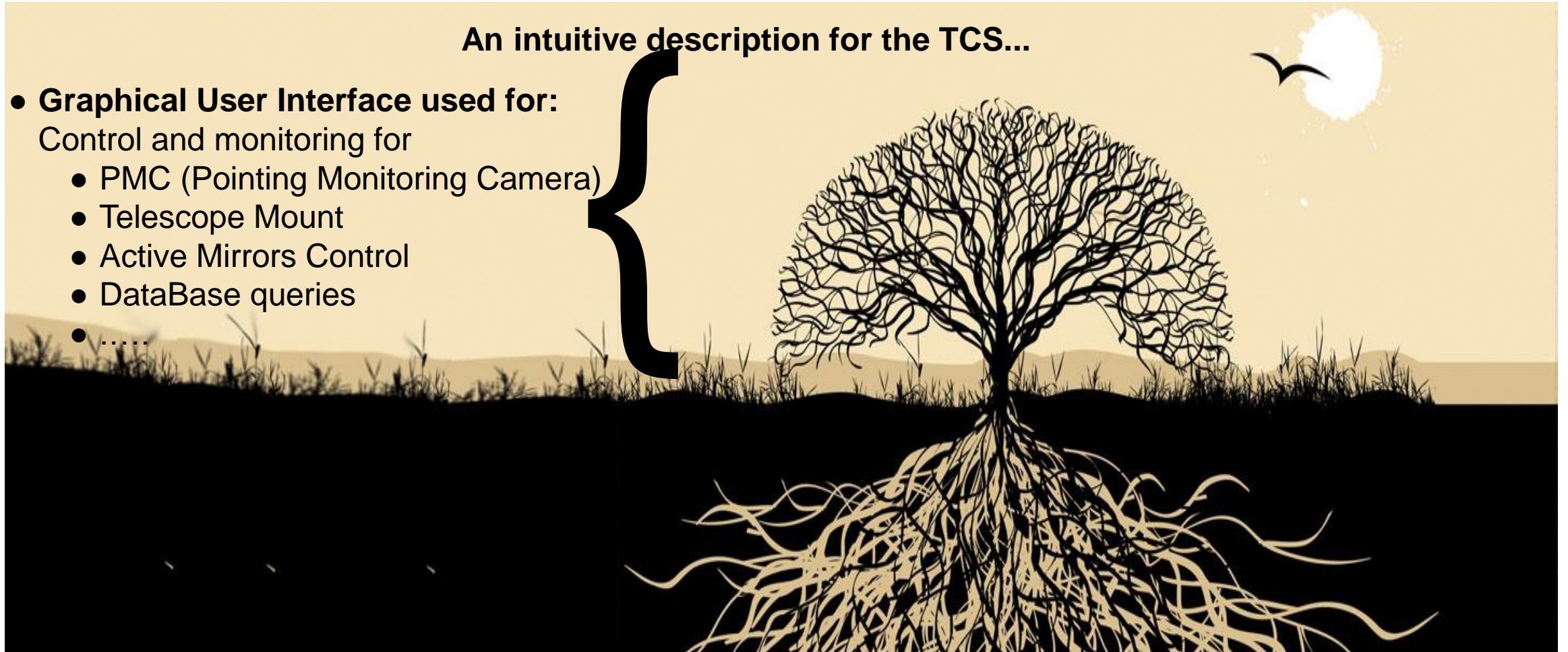
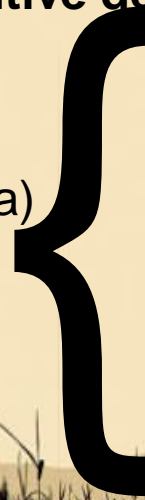
An intuitive description for the TCS...



ASTRI-Horn Telescope Control System

An intuitive description for the TCS...

- **Graphical User Interface used for:**
Control and monitoring for
 - PMC (Pointing Monitoring Camera)
 - Telescope Mount
 - Active Mirrors Control
 - DataBase queries
 -

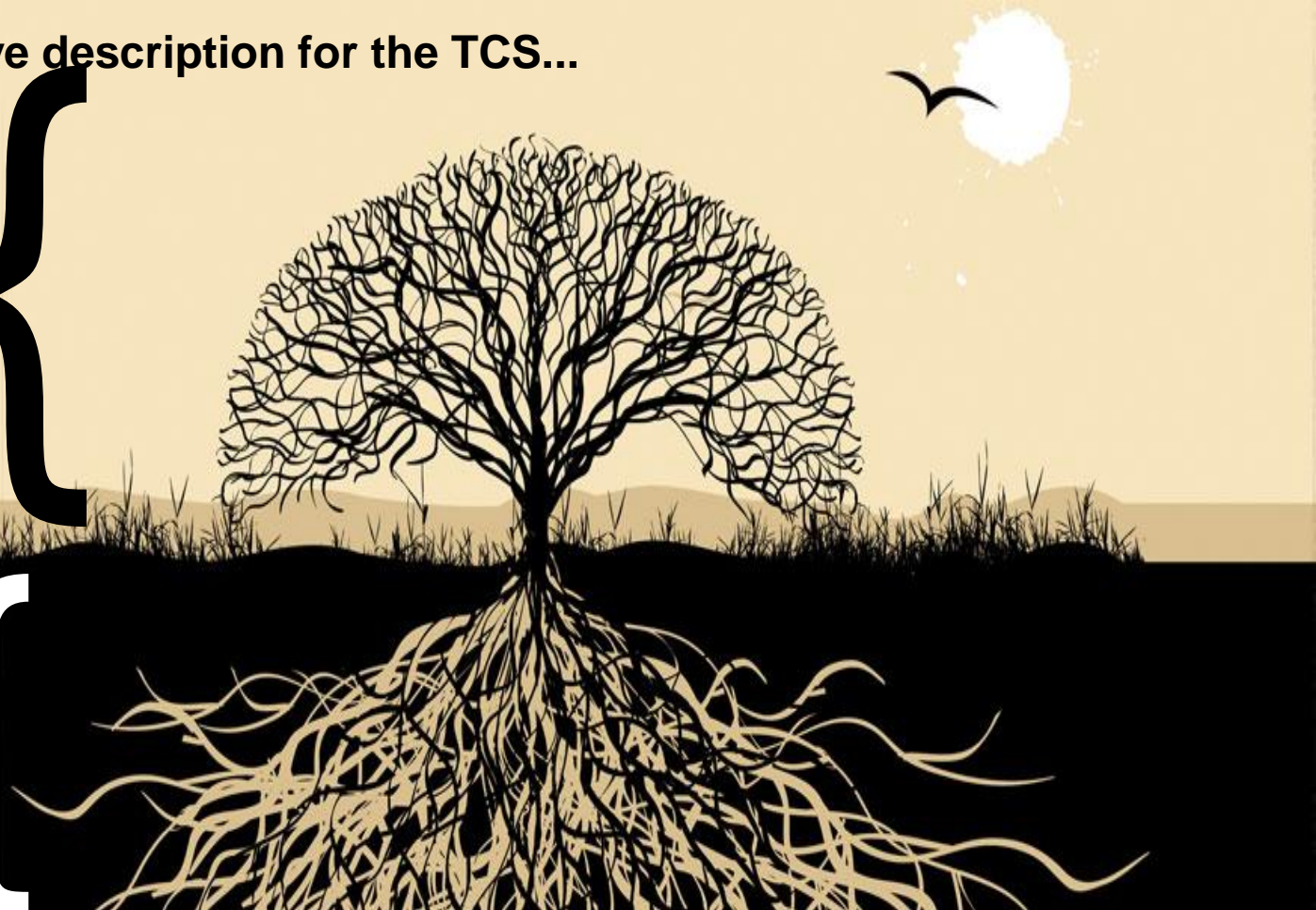


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- **Local Control systems for the management of Hardware devices**
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OPC-UA OPC-UA OPC-UA OPC-UA OPC-UA OPC-UA OPC-UA OPC-UA OPC-UA OPC-UA OPC-

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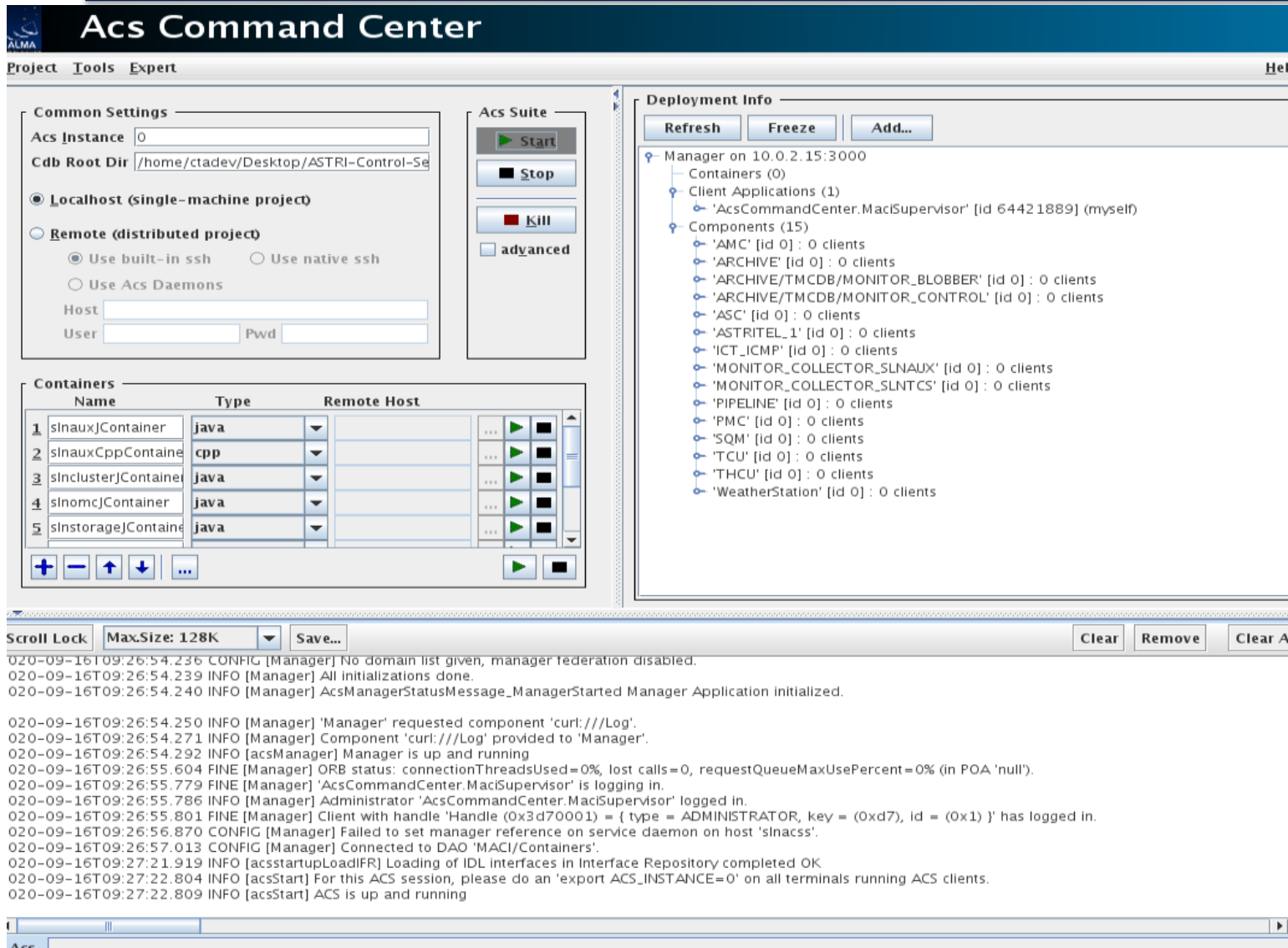
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ALMA COMMON SOFTWARE

- **Local Control systems for the management of Hardware devices**
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Alma Common Software (ACS)



The screenshot shows the Acs Command Center interface. The title bar reads "Acs Command Center" with "Project Tools Expert" on the left and "Help" on the right. The interface is divided into several panels:

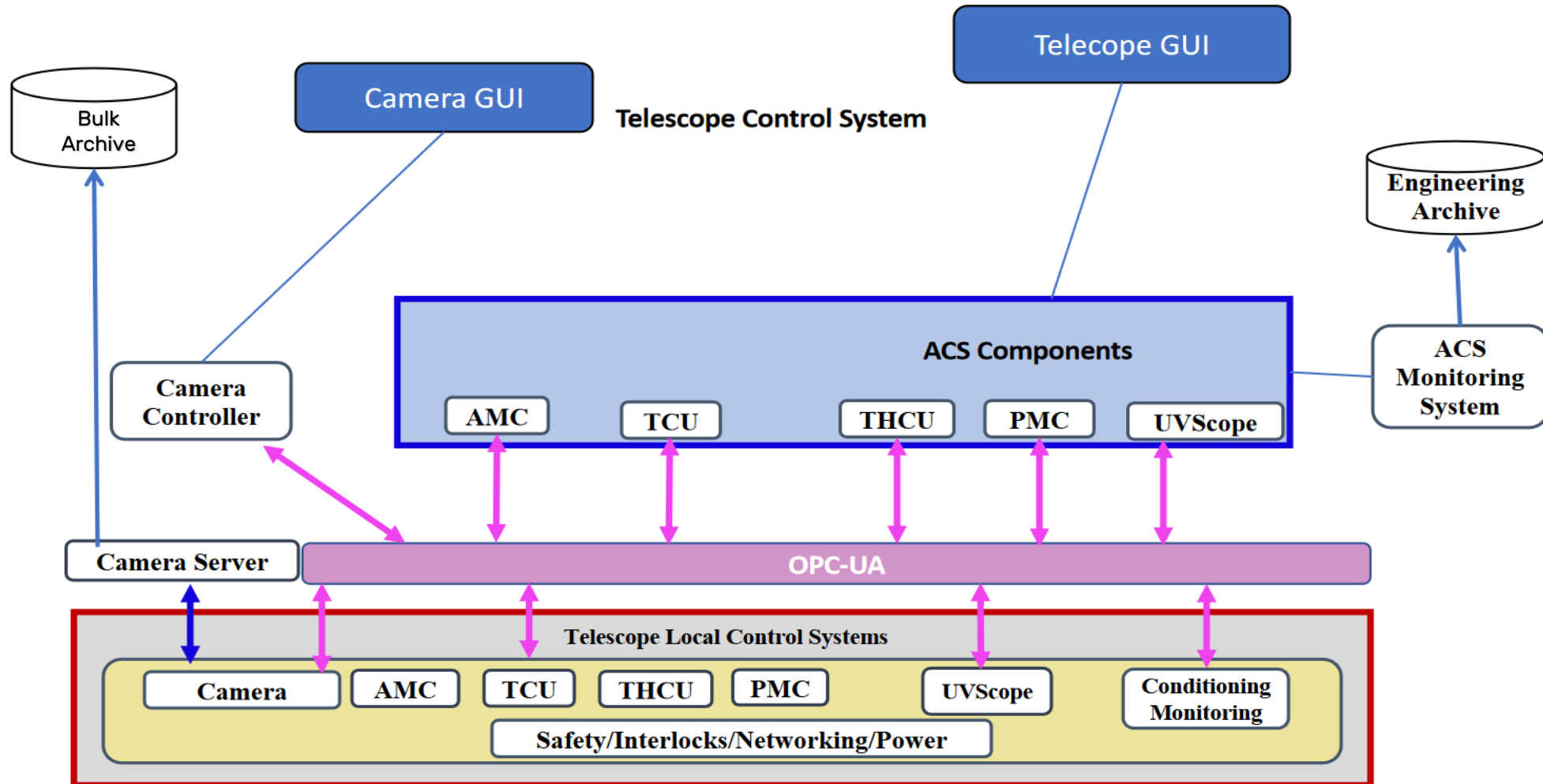
- Common Settings:** Includes fields for "Acs Instance" (0) and "Cdb Root Dir" (/home/ctadev/Desktop/ASTRI-Control-Se). It has radio buttons for "Localhost (single-machine project)" (selected) and "Remote (distributed project)". Under "Remote", there are options for "Use built-in ssh", "Use native ssh", and "Use Acs Daemons". Fields for "Host", "User", and "Pwd" are also present.
- Acs Suite:** Contains buttons for "Start", "Stop", "Kill", and an "advanced" checkbox.
- Containers:** A table with columns "Name", "Type", and "Remote Host". It lists five containers: slnauxJContainer (java), slnauxCppContaine (cpp), slnclusterJContainer (java), slnomcJContainer (java), and slnstorageJContaine (java). Each row has control icons (plus, minus, up, down, refresh, stop).
- Deployment Info:** A tree view showing the system hierarchy: Manager on 10.0.2.15:3000, Containers (0), Client Applications (1) including 'AcsCommandCenter.MacSupervisor', and Components (15) including 'AMC', 'ARCHIVE', 'ASC', 'ASTRITEL_1', 'ICT_ICMP', 'MONITOR_COLLECTOR_SLNAUX', 'MONITOR_COLLECTOR_SLNTCS', 'PIPELINE', 'PMC', 'SQM', 'TCU', 'THCU', and 'WeatherStation'.
- Log Console:** A scrollable area at the bottom showing system logs with timestamps and messages from the Manager and AcsManager.

ACS

- A middleware software infrastructure
- Based on distributed **Components**
- C++, Java, Python **Containers**
- Logging services
- Errors and alarms management
- Configuration database
- Lifecycle management
- OPC-UA libraries

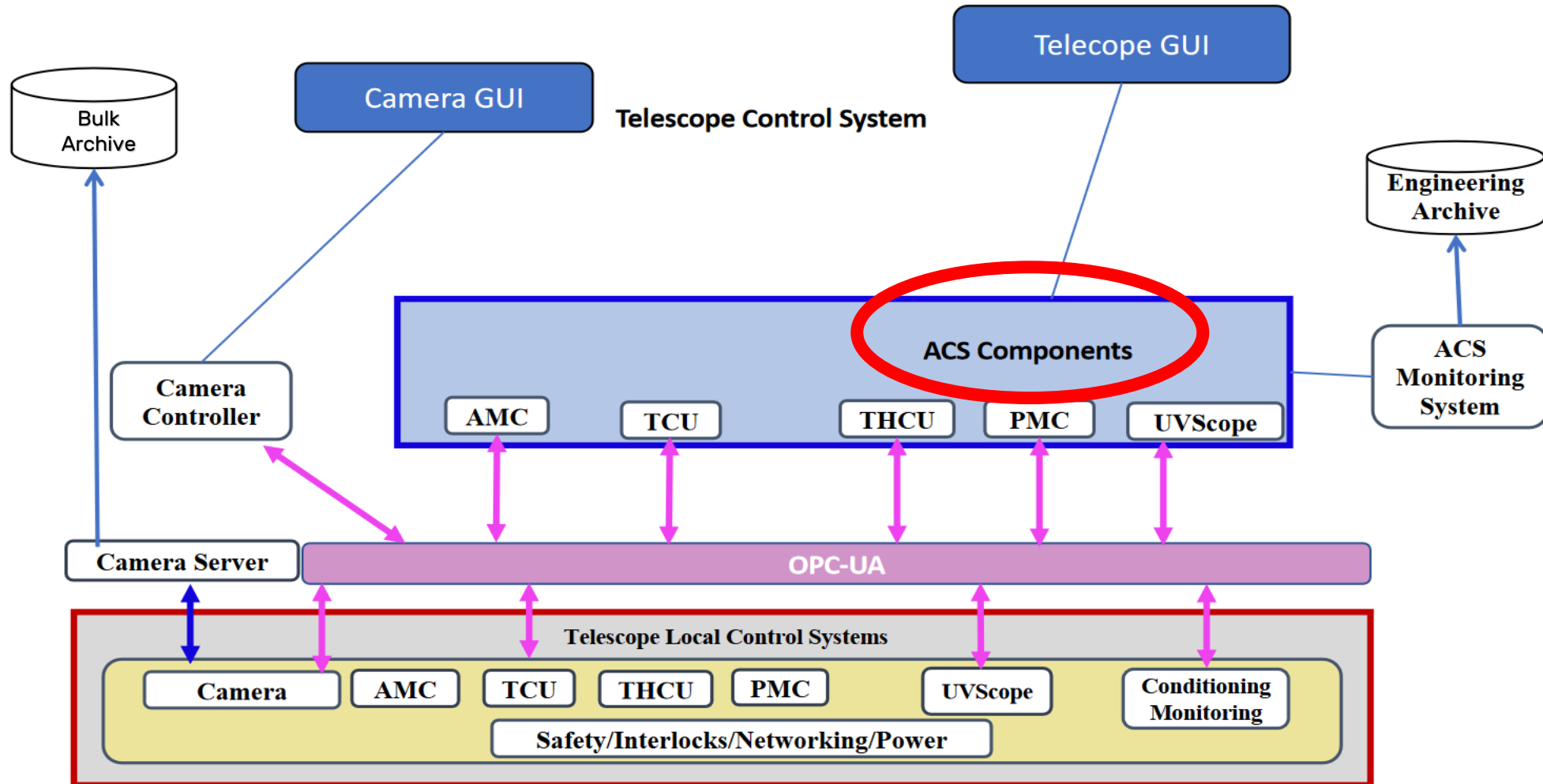
ASTRI-Horn Telescope Control System

ACTUAL Telescope Control Architecture



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TCU ACS Component

THCU ACS Component

AMC ACS Component

DB ACS Component

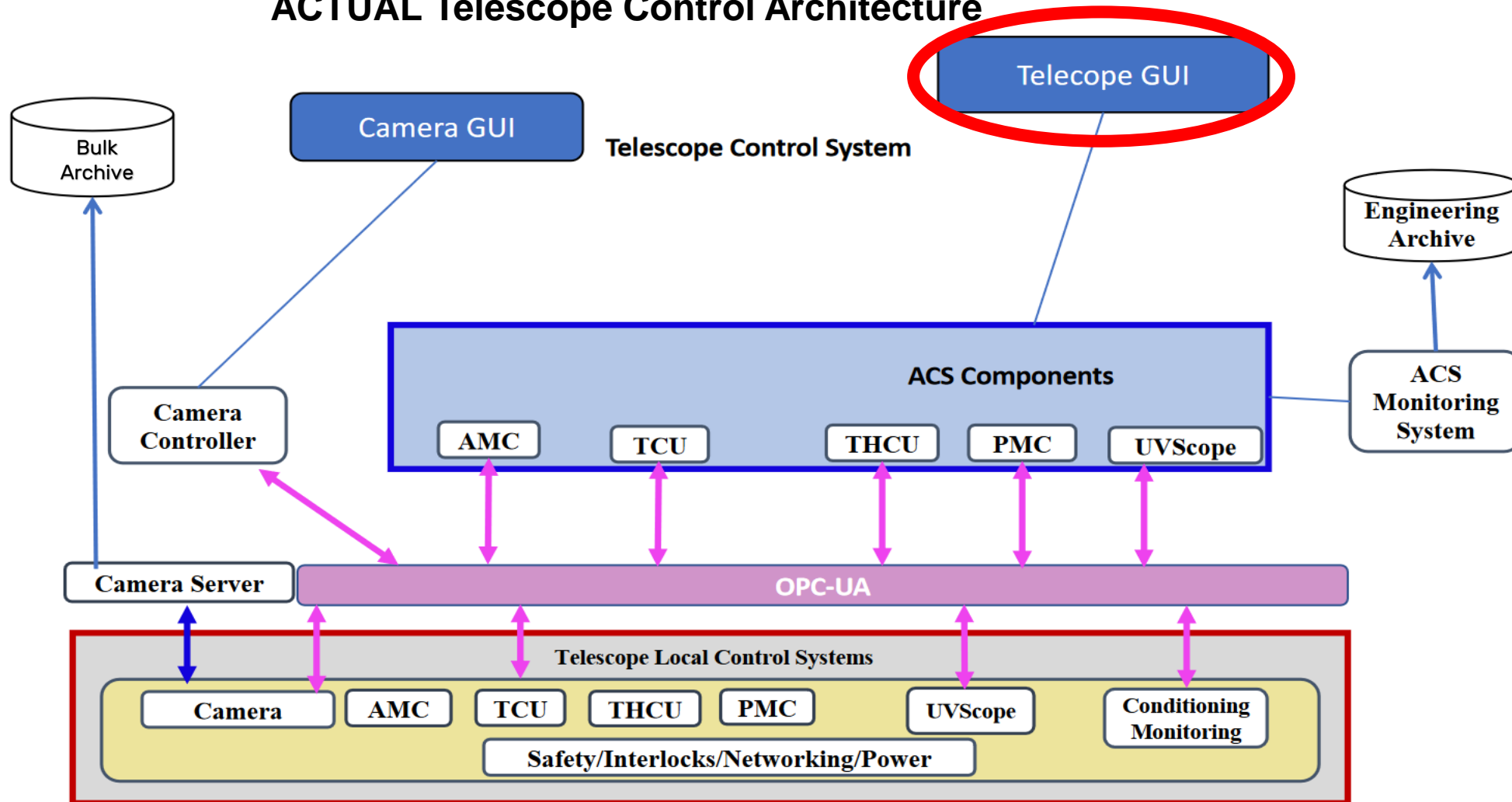
ALMA COMMON SOFTWARE

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ASTRI-Horn Telescope Control System

ACTUAL Telescope Control Architecture



The ASTRI-Horn GUI

File AcS Tools Monitoring Help

Main Weather Station THCU Mount PMC Scheduler (beta) ACS

GET ERROR INFO **ERROR RESET** **ICT ALARM**

THCU ACK ERROR: **0** ERROR NUMBER: **0** ERROR NUMBER RECOVERED: **0**

THCU RESET ACK

TCU ACK ERROR: **0** ERROR RECOVERED THCU: **0**

TCU RESET ACK

EMERGENCY STOP

TELESCOPE CONTROL

START-UP OFFLINE COLD START RECOVER FROM EMERGENCY EMERGENCY PARKING

RESTART PARK MAINT

AZ ENC INIT INITIALIZED

CABINET TEMPERATURES

HPC: **5.800**

LPC1: **13.500**

LPC2: **13.400**

TELESCOPE STATUS

TELESCOPE MODE: EMERGENCY ACTIVE SAFETY OVERRIDE **REMOTE** LOCAL

| THCU | STATUS | SWITCH STATUS | ON/OFF | NETWORK STATUS | ERROR | ALARM | WARN | MONITOR (acs/db) |
|----------|---------|---------------|------------|----------------|-------|-------|------|------------------|
| THCU | ONLINE | ON | REBOOT OFF | REACHABLE | | | | ●●●● |
| TCU | STANDBY | ON | OFF | REACHABLE | | | | ●●●● |
| CAMERA | UNKNOWN | ON | OFF | UNREACHABLE | | | | ●●●● |
| CAM THER | | ON | OFF | | | | | |
| CAM SERV | | ON | OFF | | | | | |
| UVSCOPE | UNKNOWN | ON | OFF | REACHABLE | | | | ●●●● |
| PMC | LOADED | ON | OFF | REACHABLE | | | | ●●●● |
| PMC HEAT | | ON | OFF | | | | | |
| SQM | UNKNOWN | ON | OFF | UNREACHABLE | | | | ●●●● |
| DATA LOG | | ON | OFF | | | | | |
| AMCU | UNKNOWN | ON | OFF | UNREACHABLE | | | | ●●●● |
| M1 | | ON | OFF | | | | | |
| M2 | | ON | OFF | | | | | |
| UVSIPM | UNKNOWN | ON | OFF | UNREACHABLE | | | | ●●●● |
| ASC | | ON | OFF | REACHABLE | | | | ●●●● |
| WS | | ON | OFF | REACHABLE | | | | ●●●● |
| TMADB | | ON | OFF | REACHABLE | | | | ●●●● |

AZ PARK: **IDLE** EL PARK: **IDLE**

AZ STOW PIN: **Extraction Completed** EL STOW PIN: **Extraction Completed**

DRIVE SYSTEM: AZ AXIS Disabled STANDBY EL AXIS Disabled STANDBY

WEATHER AND SKY MEASUREMENT

TEMP: **5.000** DEW PNT: **3.333**

PRESSURE: **832.442** SQM VAL: **N/A**

WIND DIR: **13.000** SQM TEMP: **N/A**

WIND SPD: **0.000** ASC ACLD: **4.000**

HUMIDITY: **0.900** ASC WCLD: **-1.000**

ASTROMETRY PMC

PMC Image: **0.0** PMCDEC ER: **0.0**

TIME

UT DATE: **2020-10-20** LST: **20:00:46**

UT TIME: **17:02:25** JD: **2459143.21**

TCU TIME: **2020-10-20T17:2:24** **SYNC OK**

SUN AND MOON

DAY/NIGHT: **NIGHT**

SUN AZ: **BELOW HOR** MOON AZ: **159.51°**

SUN EL: **BELOW HOR** MOON EL: **25.77°**

AZ Current Position (Deg.): 359.813

RA Position (Deg.): Actual Position: **120.497** Comanded Position: **0.000**

DEC Position (Deg.): Actual Position: **52.301** Comanded Position: **0.000**

VELOCITY (Deg/sec): AZ Actual Velocity: **0.000** AZ Comanded Velocity: **0.000**

EL Actual Velocity: **0.001** EL Comanded Velocity: **0.000**

AZ Current Position (Deg.): -0.006

EL Current Position (Deg.): -0.006

ASTRONOMICAL TARGET

| NAME | RA (deg hms) | DEC (deg dms) | PMRA | PMDEC | EPOCH | EQUINOX | PX | RV | Tracking time(s) |
|-------|----------------|-----------------|------|-------|-------|---------|----|----|------------------|
| pippp | 18:00:00 | 30:00:00 | 0 | 0 | 2000 | 2000 | 0 | 0 | 600 |

AZ COMMANDED POS (Deg.): **0.000** EL COMMANDED POS (Deg.): **0.000** FOLLOWING ERROR (Deg.): **0E0**

SET TARGET POINTING MODEL: ON OFF TARGET NOT VALID: IERS LOAD

SHOW TARGETS REFRACTION: ON OFF ON TRACKING: SIMBAD SEARCH

PMCAutomatic Image On Tracking: ON OFF TARGET POINTED: MY CATALOG OPEN

EPHEMERIS: 10/20/2020 SHOW

LOG BOOK ADD ENTRY SAVE TO FILE

LOG

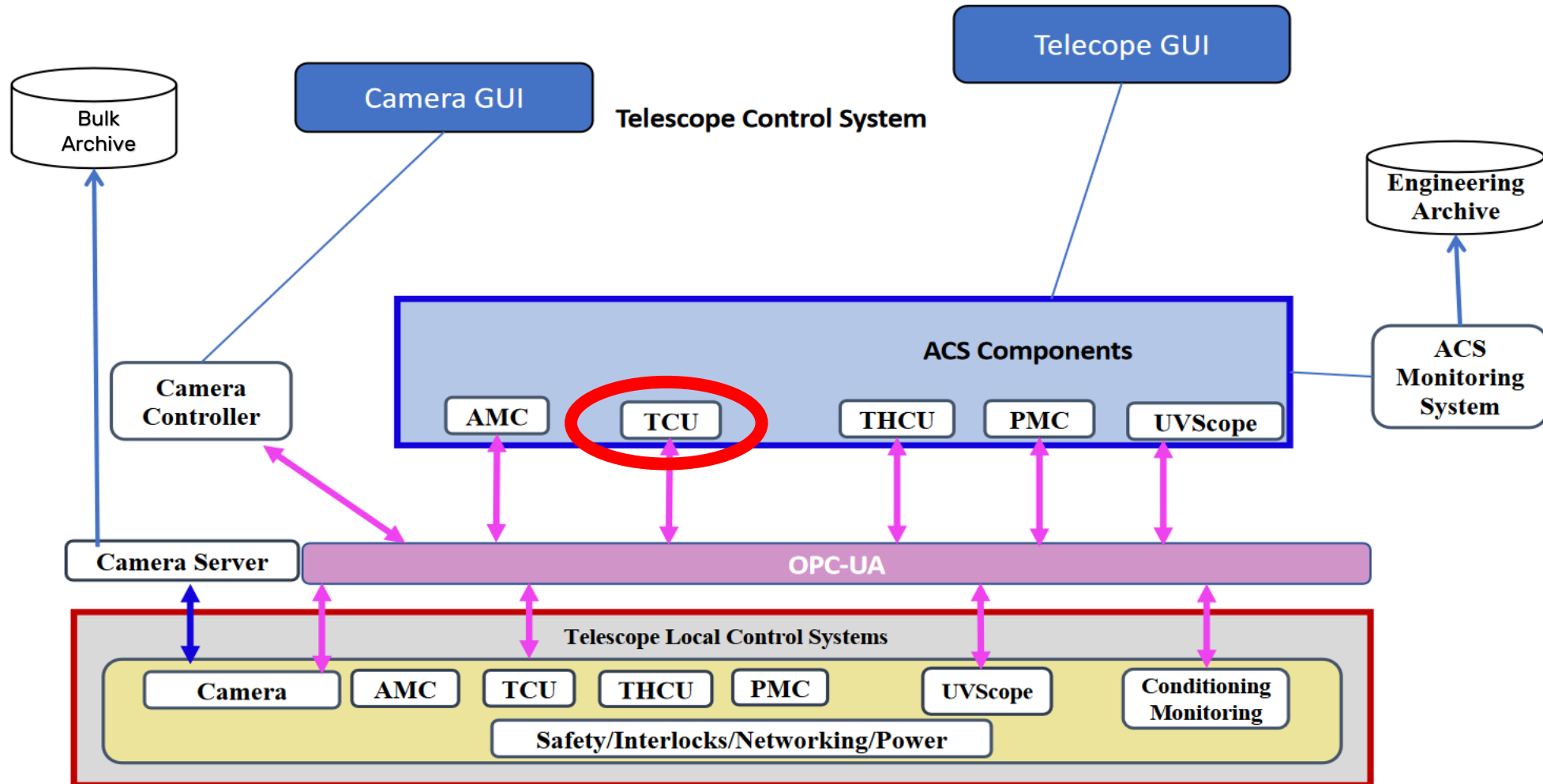
```

2020-10-20T17:02:24.000 Calling TCU.CMD_TCU_STOP_TRACKING()
2020-10-20T17:02:24.000 TCU status: IDLE -> SLEW
2020-10-20T17:02:24.000 Calling PMC.SET_AUX_PMC_DELAY_BTWN_IMGS(30)
2020-10-20T17:02:24.000 Starting PMC Automatic Images (ExpTime= 3 sec, Interval= 30 sec)
2020-10-20T17:02:24.000 TCU status: SLEW -> TRACKING
2020-10-20T17:02:24.000 Calling TCU.CMD_TCU_STOP_POINTING()
2020-10-20T17:02:24.000 Stopping Automatic Images Taking
2020-10-20T17:02:24.000 TCU status: TRACKING -> IDLE
2020-10-20T17:02:24.000 Calling TCU.MODE_TCU_GO_STANDBY()
2020-10-20T17:02:24.000 TCU shutdown complete, TCU in STANDBY
2020-10-20T17:02:24.000 TCU status: IDLE -> STANDBY
    
```

Save Log To File Clear Log

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ACTUAL Telescope Control Architecture



The ASTRI-Horn GUI

File AcS Tools Monitoring Help

Main Weather Station THCU Mount PMC Scheduler (beta) ACS

TCU FAILURES

RESET SYSTEM

GET ERROR INFO

ERROR RESET

EMERGENCY STOP

ACKNOWLEDGE ERROR

ERROR NUMBER 0 ERROR NUMBER RECOVERED 0

RESET ACKNOWLEDGE

ERROR RECOVERED

MOTION CONTROL

MANUAL MODE ON OFF

MOTION TYPE Absolute SET PARAMETERS

| | AZIMUTH | ELEVATION |
|--------------|---|---|
| SKY POSITION | | |
| VELOCITY | 0.5 | 1 |
| ACCELERATION | 0.5 | 1 |
| DECELERATION | 0.5 | 1 |
| JERK | 0.2 | 0.8 |
| DIRECTION | CW | Up |

TPOINT COEFF SET COEFF

AZ ENC INIT

START AZ MOTION

START EL MOTION

STOP AZ MOTION

STOP EL MOTION

INITIALIZED

START MOTION

STOP MOTION

AZ MOTOR BRAKE ON

AZ MOTOR STATUS OFF

EL MOTOR BRAKE ON

EL MOTOR STATUS OFF

OPERATION MODE

PARKING PIN MODE WITH STOW PIN INSERTION WITHOUT STOW PIN INSERTION

MOTION INFO

AZ Sky Position 359.813 deg



AZ TEL POS -90.187° AZ ENC POS 179.813° deg

EL Sky Position -0.006 deg



VELOCITY

| | |
|-------|-------|
| 0.000 | 0.001 |
| 0.000 | 0.000 |



Upper Limit Lower Limit
● AZ Actual Velocity ● AZ Commanded Velocity
○ EL Actual Velocity ○ EL Commanded Velocity

ACCELERATION

| | |
|-------|-------|
| 0.000 | 0.000 |
|-------|-------|



Upper Limit Lower Limit
● AZ Acceleration ● EL Acceleration

DECELERATION

| | |
|-------|-------|
| 0.000 | 0.000 |
|-------|-------|



Upper Limit Lower Limit
● AZ Deceleration ● EL Deceleration

JERK

| | |
|-------|-------|
| 0.000 | 0.000 |
|-------|-------|



Upper Limit Lower Limit
● AZ Jerk ● EL Jerk

MOUNT STATUS

| | | | | | | |
|-----------------|---|---|---|--|--|---|
| TCU | LOADED | STDBY | ONLINE | CALIB | MAINT | STANDBY |
| AZ VIRTUAL AXIS | STDBY | ONLINE | STANDBY | | | |
| EL VIRTUAL AXIS | STDBY | ONLINE | STANDBY | | | |
| ASTRO | LOADED | ONLINE | LOADED | | | |

MOUNT PARKING

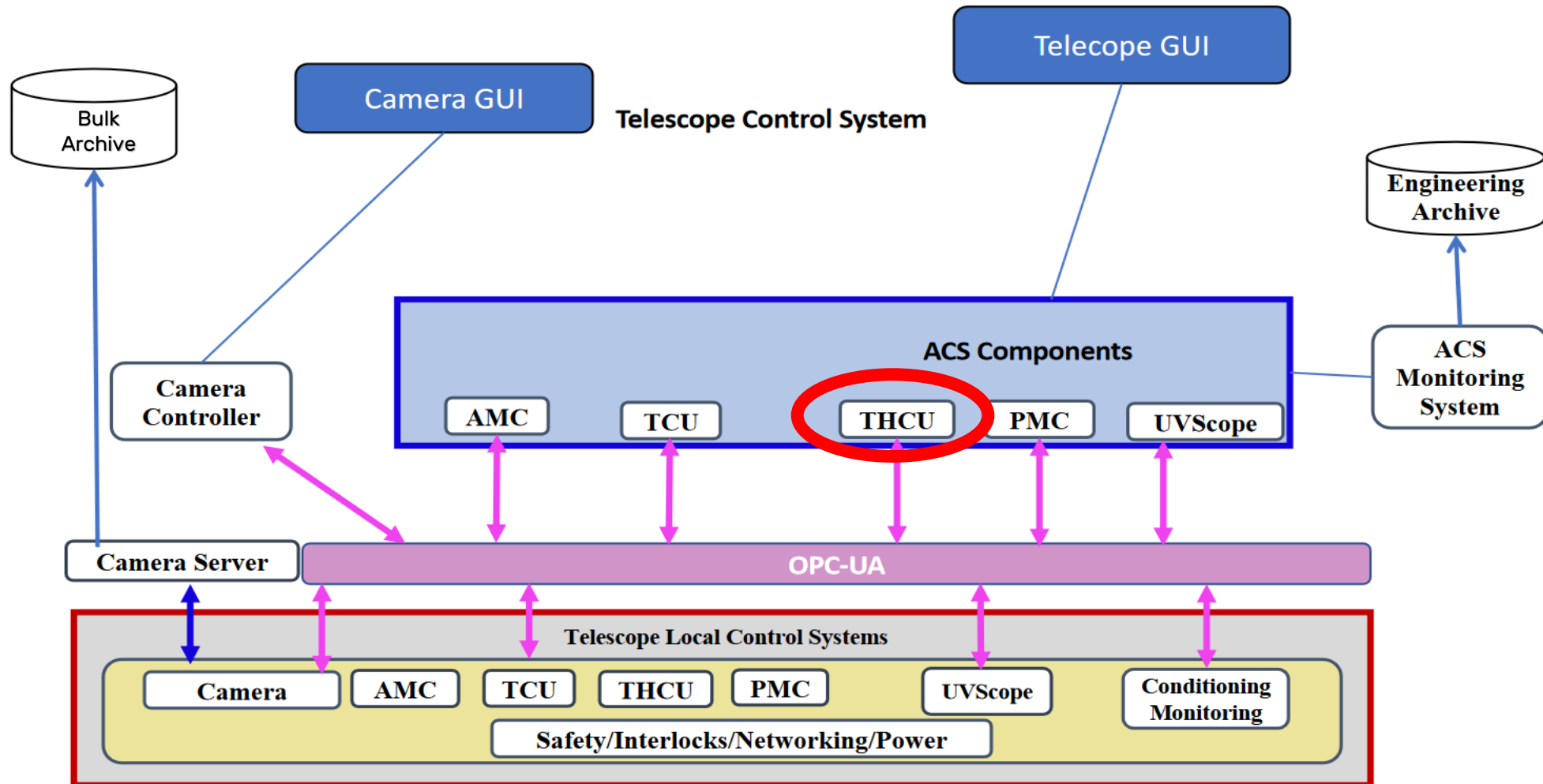
| | | | |
|--|--|--|--|
| START PARKING | START AZ PARK | START EL PARK | OVERRIDE PARK |
| STOP PARKING | STOP AZ PARK | STOP EL PARK | |
| AZ PARKING STATUS IDLE | | EL PARKING STATUS IDLE | |

OVERRIDE SAFETY FUNCTIONS

| | |
|---|--|
| OVERRIDE SUN AVOIDANCE | ENABLE SUN AVOIDANCE |
| OVERRIDE AZ S51 | ENABLE AZ S51 |
| OVERRIDE PIN SAFETY | ENABLE PIN SAFETY |
| OVERRIDE EL S51 | ENABLE EL S51 |

ASTRI-Horn Telescope Control System

ACTUAL Telescope Control Architecture



ASTRI-Horn GUI



File Acs Tools Monitoring Help

Main Weather Station **THCU** Mount PMC Scheduler (beta) ACS

TELESCOPE DEVICE CONTROL

| | | | | | |
|--------------|--------|-------|--------|-------|---------|
| THCU | LOADED | STDBY | ONLINE | MAINT | ONLINE |
| TCU | ON | OFF | | | STANDBY |
| CAMERA | ON | OFF | | | UNKNOWN |
| CAMERA THERM | ON | OFF | | | |
| PMC | ON | OFF | | | LOADED |
| UVSIPM | ON | OFF | | | UNKNOWN |
| UVSCOPE | ON | OFF | | | UNKNOWN |
| DATA LOGGER | ON | OFF | | | |
| SQM | ON | OFF | | | UNKNOWN |
| AMCU | ON | OFF | | | UNKNOWN |
| M1 | ON | OFF | | | |
| M2 | ON | OFF | | | |

DRIVE SYSTEM

MOTORS POWER: ON OFF

AZ AXIS: ENABLE DISABLE

EL AXIS: ENABLE DISABLE

STOW PIN

Override Pin Alarm: Emergency Stop:

AZ STOW PIN: INSERT EXTRACT Extraction Co...

EL STOW PIN: INSERT EXTRACT Extraction Co...

THCU FAILURES

GET ERROR INFO ERROR RESET

ACKNOWLEDGE ERROR ERROR NUMBER: 0 ERROR NUMBER RECOVERED: 0

RESET ACKNOWLEDGE ERROR RECOVERED:

RESET SYSTEM

TELESCOPE ELECTRONIC STATUS

CABINET TEMPERATURE

5.800 13.400

CURRENT

0.160 1.865

VOLTAGE

229.062 225.697

229.614 223.614

POWER

8.400 209.600

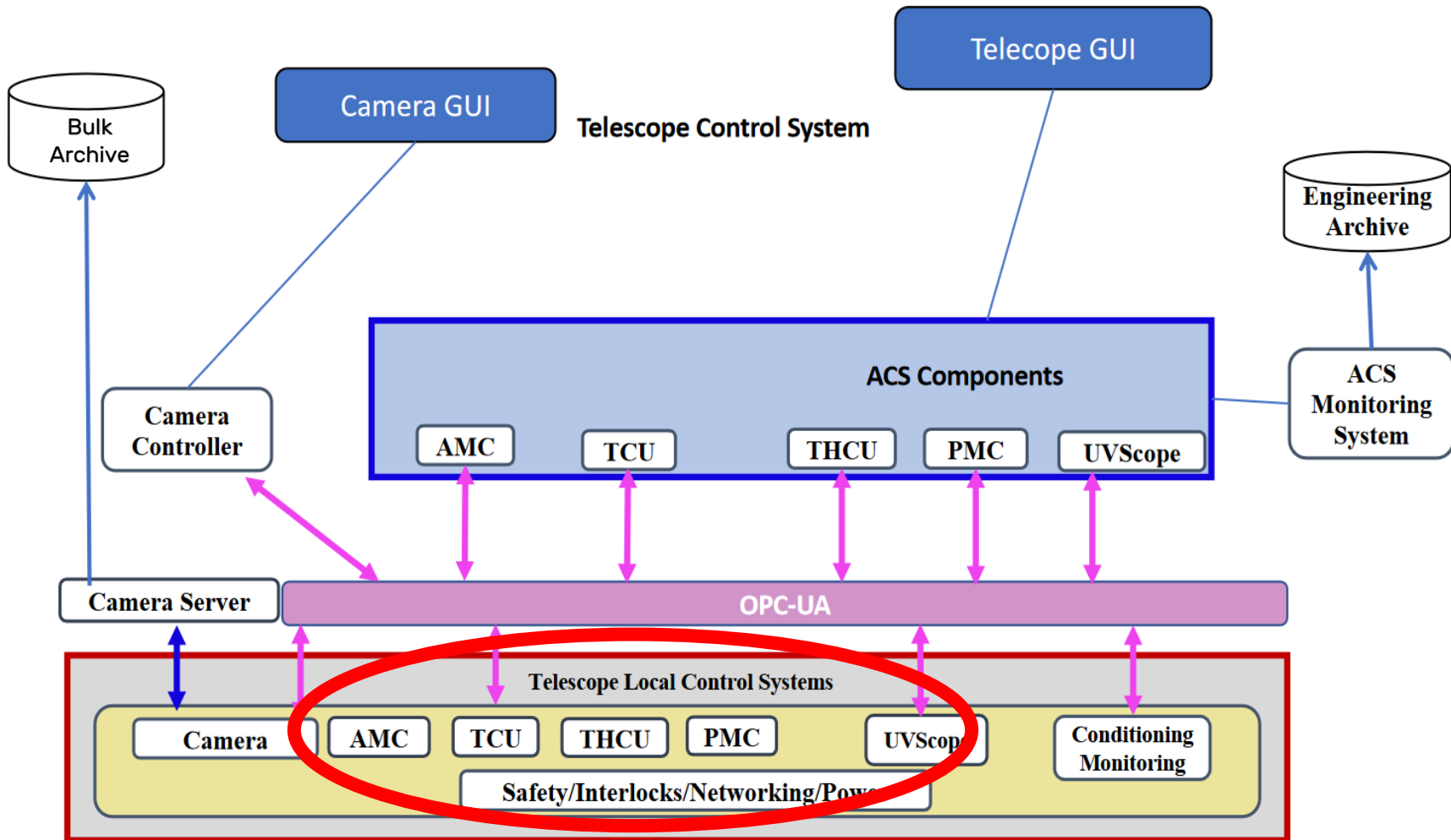
FREQUENCY

50.000 50.000

Legend: Upper Limit, Lower Limit, HPC, LPC2, Phase 1, Phase 2, Phase 3

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ACTUAL Telescope Control Architecture

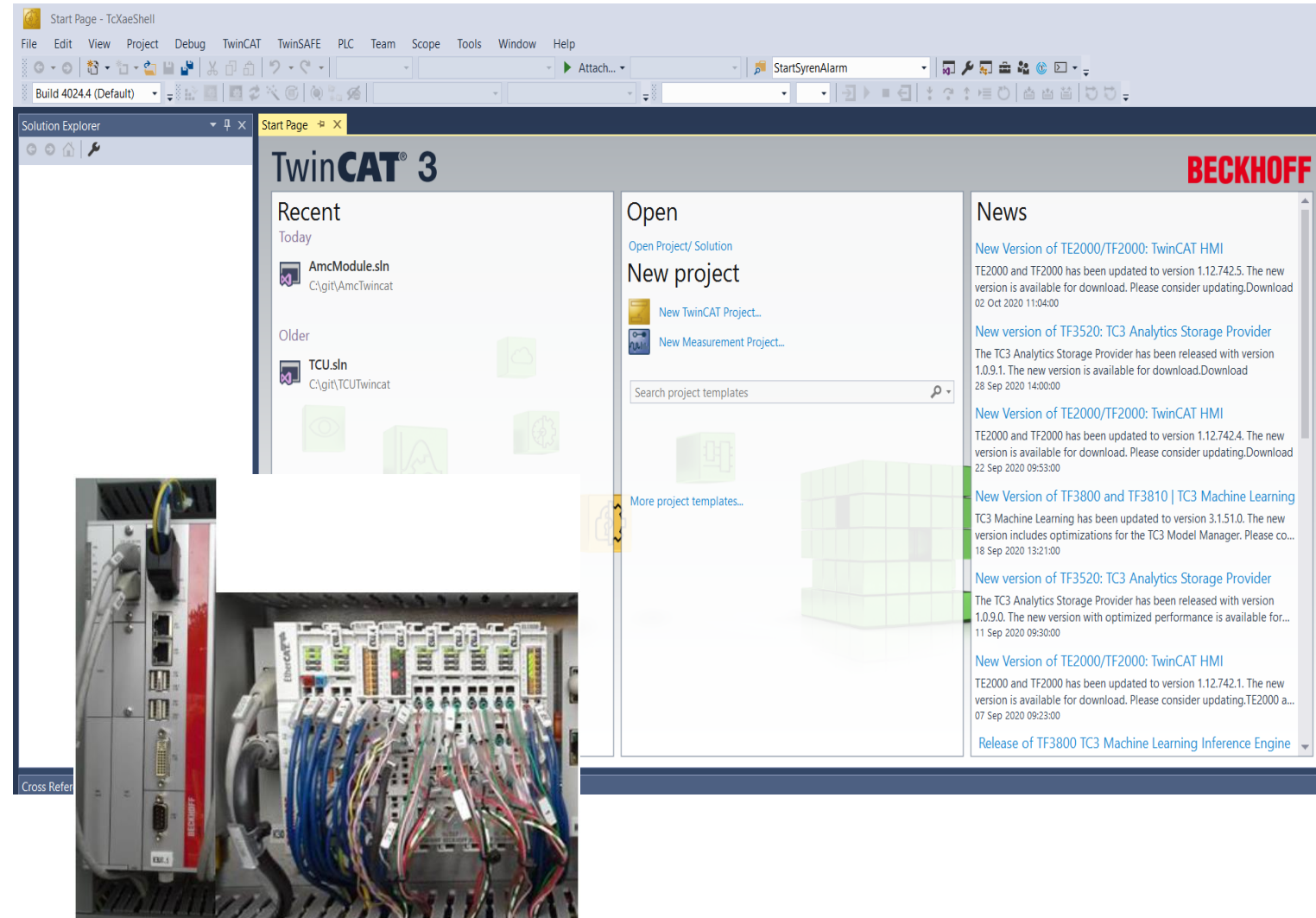


- The software that implements the local control systems has more stringent requirements regarding performance, reliability and safety.
- This software level is where the real handling logic, for the hardware management, resides.
- The software have to provide a reliable industry standard for programming numerically controlled systems.

TwinCAT

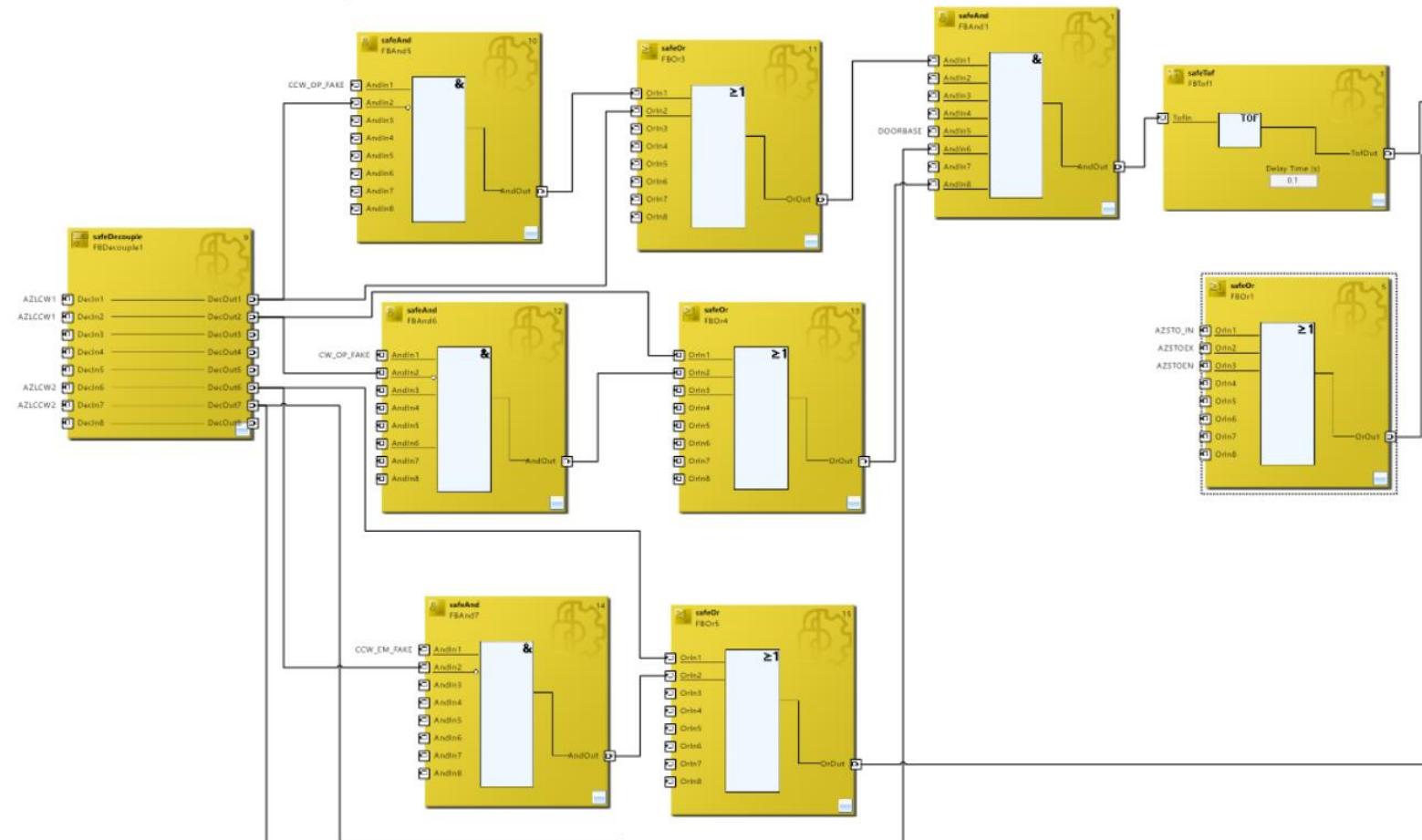
BECKHOFF TWINCAT

- **TwinCAT** (The Windows Control and Automation Technology) is a platform that meets all the above requirements by transforming a Windows PC into a real-time controller with a **multi-PLC** system, **NC axis control** PID (Proportional-Integral-Derivative) controls, **programming environment**, operating station and integration of the **Safety system**.
- Performance similar to a real-time controller: to ensure that pointing and tracking meet accuracy requirements. In particular, the interaction between the encoders and the actuators can reach a frequency of the order of milliseconds.



TwinCAT Safety integration

BECKHOFF TWINCAT

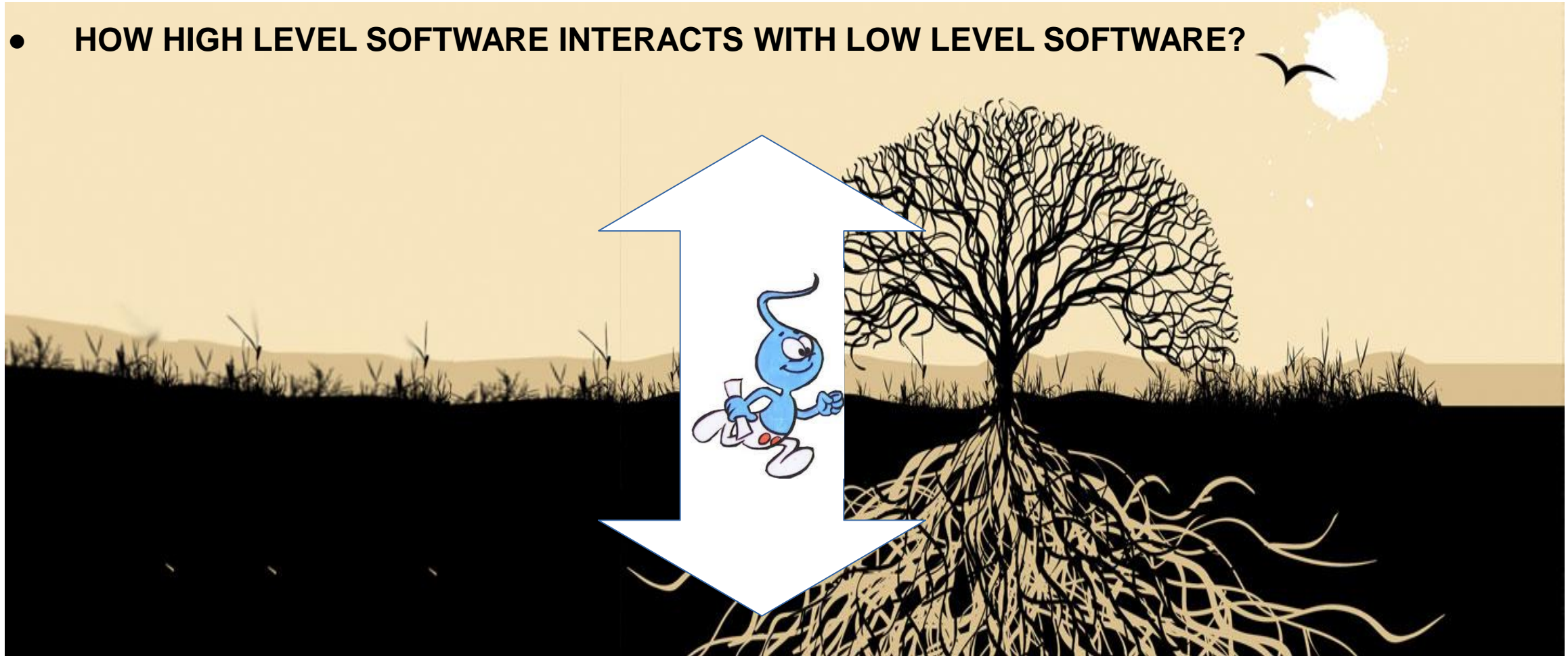


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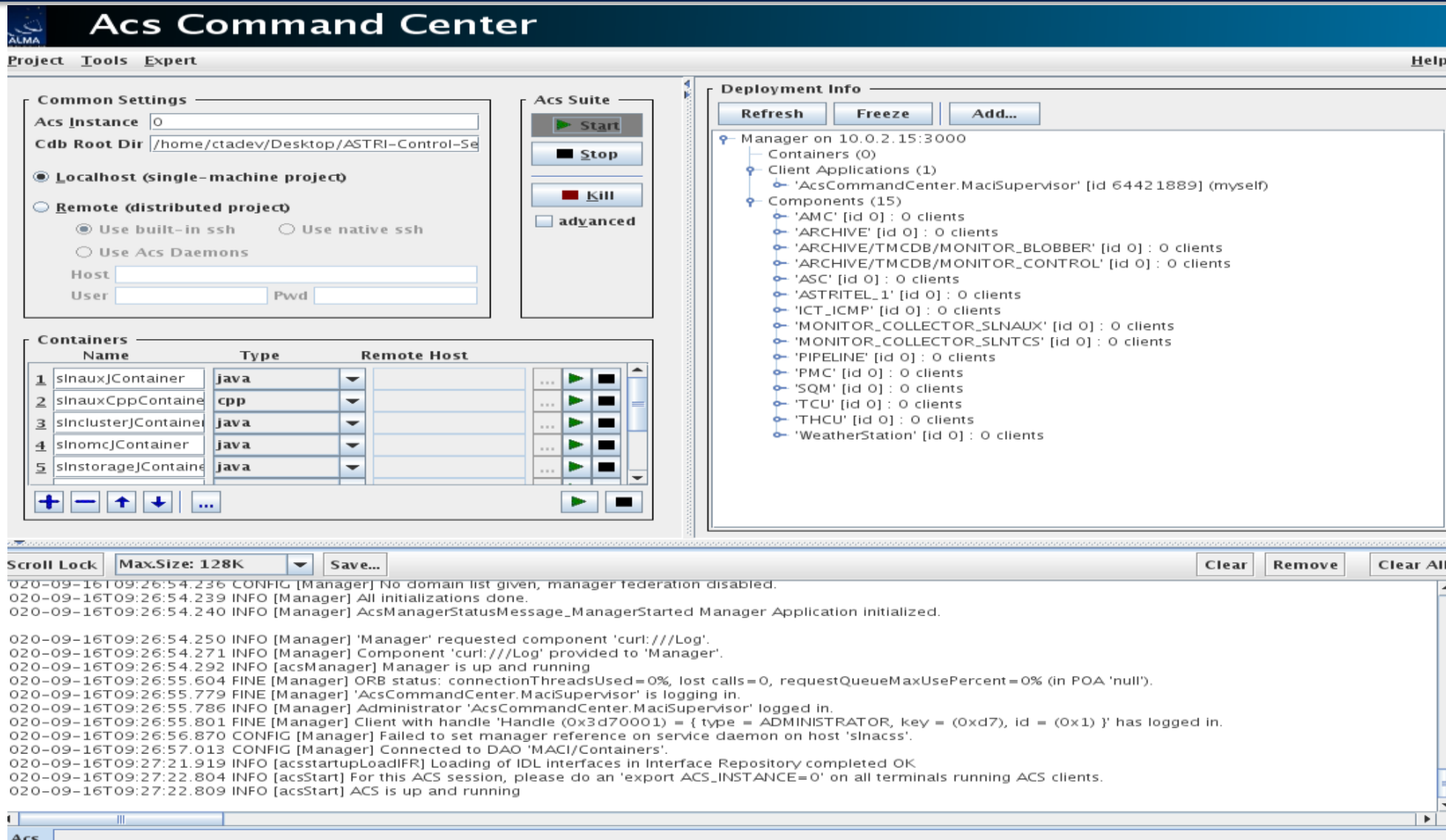
- Performance similar to a real-time controller: to ensure that pointing and tracking meet accuracy requirements. In particular, the interaction between the encoders and the actuators can reach a frequency of the order of milliseconds,

ASTRI-Horn Telescope Control System

- HOW HIGH LEVEL SOFTWARE INTERACTS WITH LOW LEVEL SOFTWARE?



A trip among the TCS software levels



Acs Command Center

Project Tools Expert Help

Common Settings

Acs Instance: 0
Cdb Root Dir: /home/ctadev/Desktop/ASTRI-Control-Se

Localhost (single-machine project)
 Remote (distributed project)
 Use built-in ssh Use native ssh
 Use Acs Daemons
Host: _____
User: _____ Pwd: _____

Acs Suite

Start Stop Kill advanced

Containers

| Name | Type | Remote Host |
|------------------------|------|-------------|
| 1 slnauxJContainer | java | |
| 2 slnauxCppContaine | cpp | |
| 3 slnclusterJContainer | java | |
| 4 slnomcJContainer | java | |
| 5 slnstorageJContaine | java | |

Deployment Info

Refresh Freeze Add...

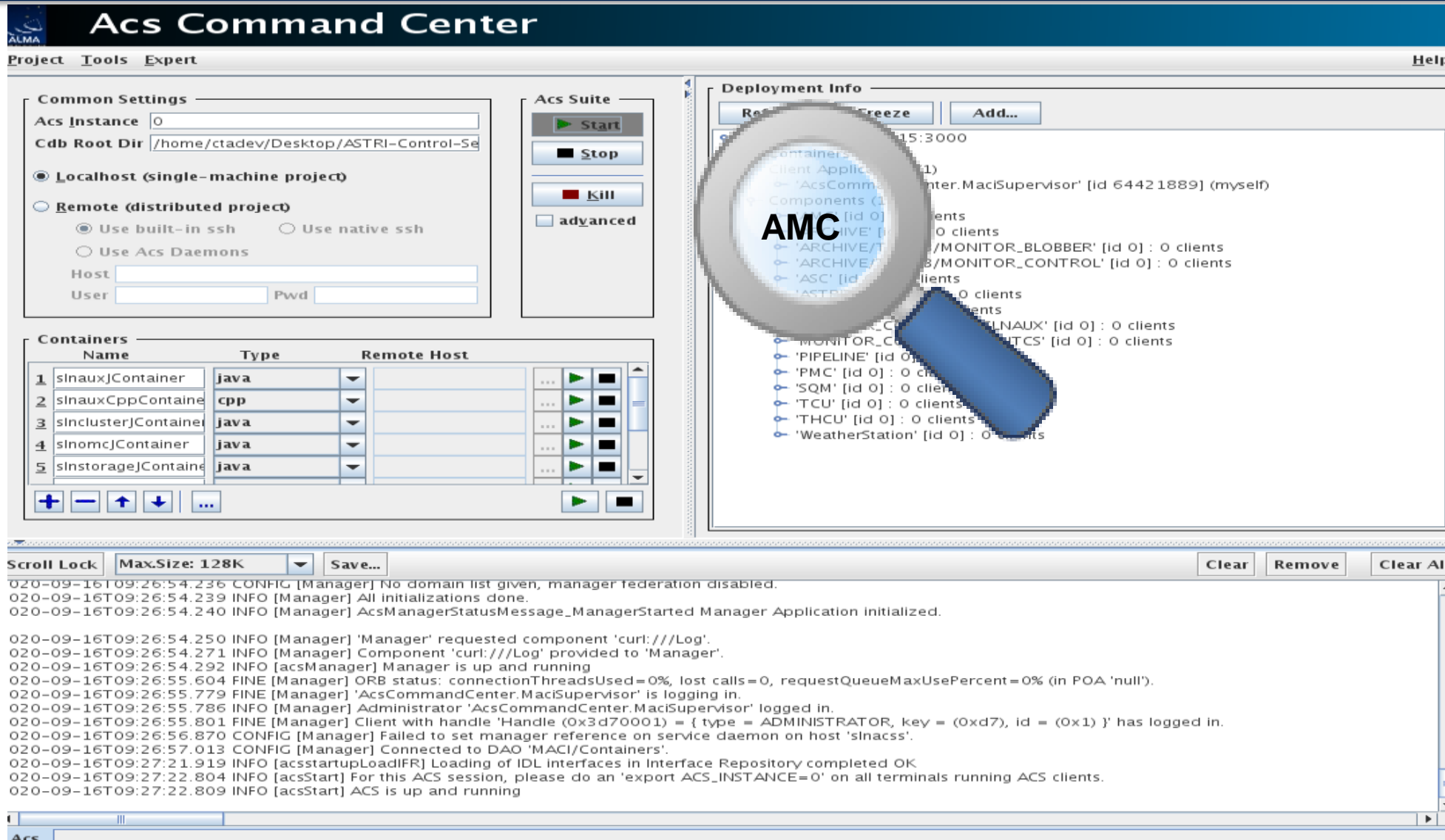
- Manager on 10.0.2.15:3000
 - Containers (0)
 - Client Applications (1)
 - 'AcCommandCenter.MacSupervisor' [id 64421889] (myself)
 - Components (15)
 - 'AMC' [id 0] : 0 clients
 - 'ARCHIVE' [id 0] : 0 clients
 - 'ARCHIVE/TMCDB/MONITOR_BLOBBER' [id 0] : 0 clients
 - 'ARCHIVE/TMCDB/MONITOR_CONTROL' [id 0] : 0 clients
 - 'ASC' [id 0] : 0 clients
 - 'ASTRITEL_1' [id 0] : 0 clients
 - 'ICT_ICMP' [id 0] : 0 clients
 - 'MONITOR_COLLECTOR_SLNAUX' [id 0] : 0 clients
 - 'MONITOR_COLLECTOR_SLNTCS' [id 0] : 0 clients
 - 'PIPELINE' [id 0] : 0 clients
 - 'PMC' [id 0] : 0 clients
 - 'SQM' [id 0] : 0 clients
 - 'TCU' [id 0] : 0 clients
 - 'THCU' [id 0] : 0 clients
 - 'WeatherStation' [id 0] : 0 clients

Scroll Lock Max.Size: 128K Save... Clear Remove Clear All

```
020-09-16T09:26:54.236 CONFIG [Manager] No domain list given, manager federation disabled.
020-09-16T09:26:54.239 INFO [Manager] All initializations done.
020-09-16T09:26:54.240 INFO [Manager] AcsManagerStatusMessage_ManagerStarted Manager Application initialized.

020-09-16T09:26:54.250 INFO [Manager] 'Manager' requested component 'curl:///Log'.
020-09-16T09:26:54.271 INFO [Manager] Component 'curl:///Log' provided to 'Manager'.
020-09-16T09:26:54.292 INFO [acsManager] Manager is up and running
020-09-16T09:26:55.604 FINE [Manager] ORB status: connectionThreadsUsed=0%, lost calls=0, requestQueueMaxUsePercent=0% (in POA 'null').
020-09-16T09:26:55.779 FINE [Manager] 'AcCommandCenter.MacSupervisor' is logging in.
020-09-16T09:26:55.786 INFO [Manager] Administrator 'AcCommandCenter.MacSupervisor' logged in.
020-09-16T09:26:55.801 FINE [Manager] Client with handle 'Handle (0x3d70001) = { type = ADMINISTRATOR, key = (0xd7), id = (0x1) }' has logged in.
020-09-16T09:26:56.870 CONFIG [Manager] Failed to set manager reference on service daemon on host 'slnacss'.
020-09-16T09:26:57.013 CONFIG [Manager] Connected to DAO 'MACI/Containers'.
020-09-16T09:27:21.919 INFO [acsstartupLoadIFR] Loading of IDL interfaces in Interface Repository completed OK.
020-09-16T09:27:22.804 INFO [acsStart] For this ACS session, please do an 'export ACS_INSTANCE=0' on all terminals running ACS clients.
020-09-16T09:27:22.809 INFO [acsStart] ACS is up and running
```


A trip among the TCS software levels



Acs Command Center

Project Tools Expert Help

Common Settings

Acs Instance: 0
Cdb Root Dir: /home/ctadev/Desktop/ASTRI-Control-Se

Localhost (single-machine project)
 Remote (distributed project)
 Use built-in ssh Use native ssh
 Use Acs Daemons
Host:
User: Pwd:

Acs Suite

Start Stop Kill advanced

Containers

| Name | Type | Remote Host |
|------------------------|------|-------------|
| 1 sinauxJContainer | java | |
| 2 sinauxCppContaine | cpp | |
| 3 sinclusterJContainer | java | |
| 4 sinomcJContainer | java | |
| 5 sinstorageJContaine | java | |

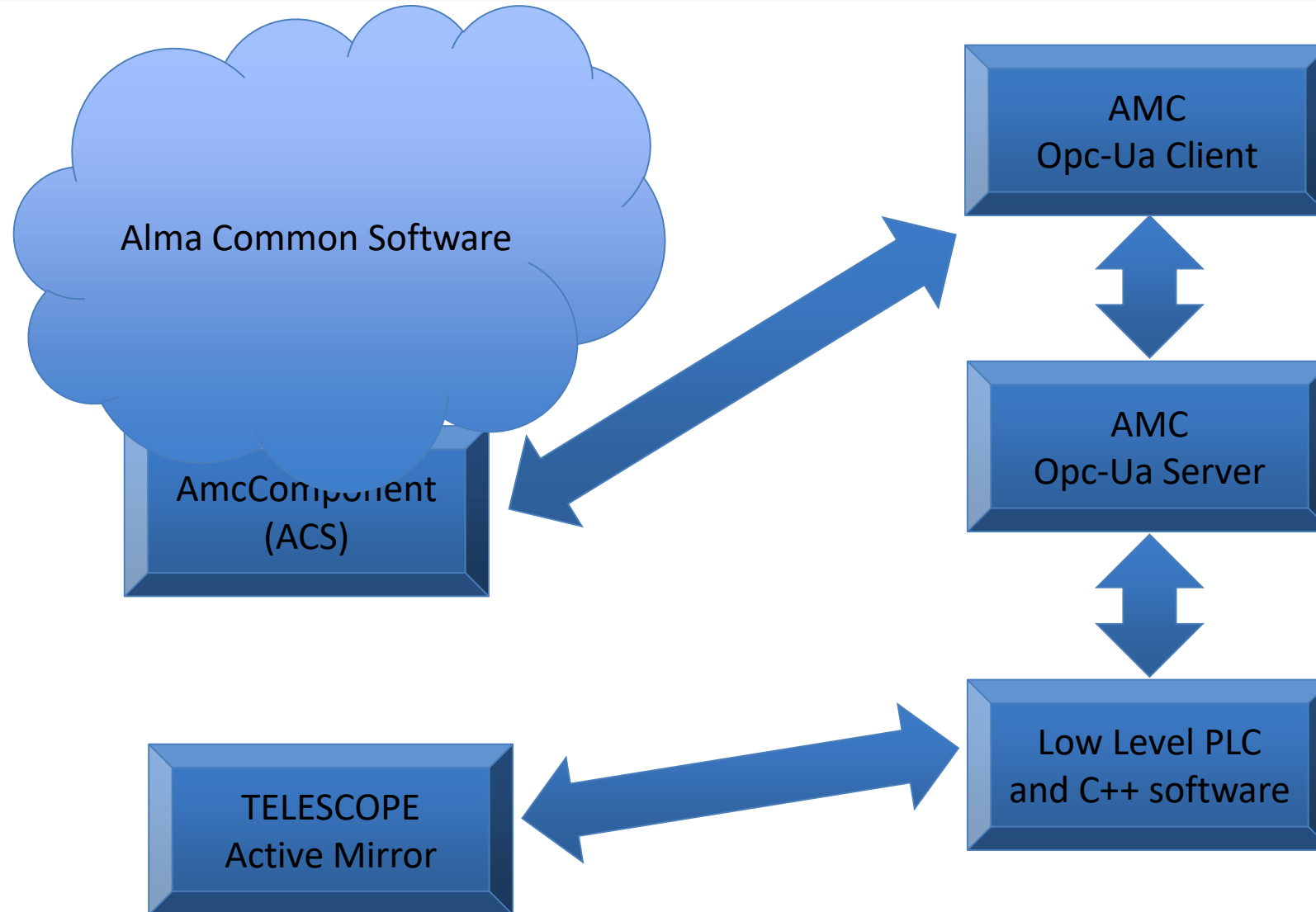
Deployment Info

- Container
- Client Applic
- 'AcsComm...nter.MacSupervisor' [id 64421889] (myself)
- Components (1)
- 'ARCHIVE/T...B/MONITOR_BLOBBER' [id 0] : 0 clients
- 'ARCHIVE/T...B/MONITOR_CONTROL' [id 0] : 0 clients
- 'ASC' [id ...] clients
- 'ASTR...NAUX' [id 0] : 0 clients
- 'MONITOR_C...TCS' [id 0] : 0 clients
- 'PIPELINE' [id 0] :
- 'PMC' [id 0] : 0 cli
- 'SQM' [id 0] : 0 cli
- 'TCU' [id 0] : 0 clients
- 'THCU' [id 0] : 0 clients
- 'WeatherStation' [id 0] : 0 clients

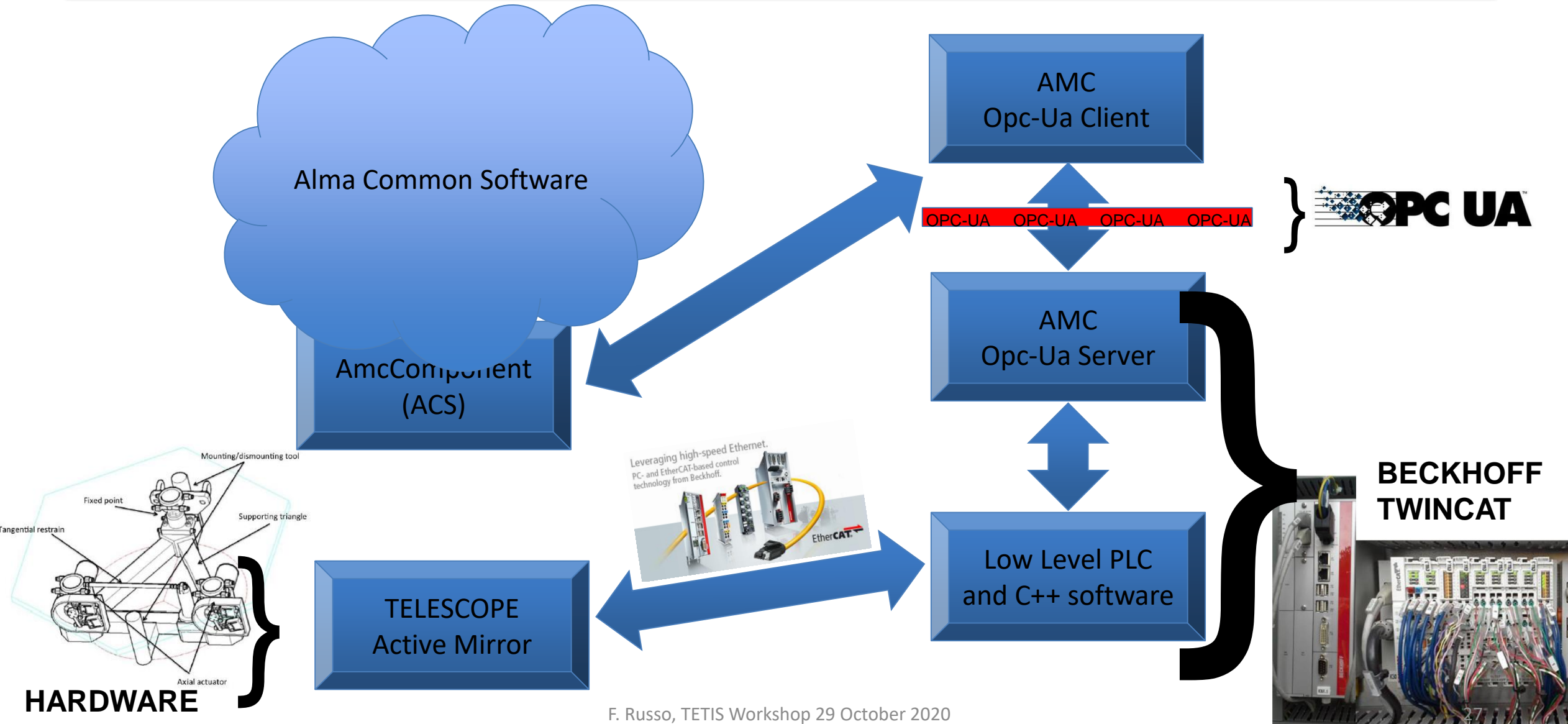
AMC

020-09-16T09:26:54.236 CONFIG [Manager] No domain list given, manager federation disabled.
020-09-16T09:26:54.239 INFO [Manager] All initializations done.
020-09-16T09:26:54.240 INFO [Manager] AcsManagerStatusMessage_ManagerStarted Manager Application initialized.
020-09-16T09:26:54.250 INFO [Manager] 'Manager' requested component 'curl:///Log'.
020-09-16T09:26:54.271 INFO [Manager] Component 'curl:///Log' provided to 'Manager'.
020-09-16T09:26:54.292 INFO [acsManager] Manager is up and running
020-09-16T09:26:55.604 FINE [Manager] ORB status: connectionThreadsUsed=0%, lost calls=0, requestQueueMaxUsePercent=0% (in POA 'null').
020-09-16T09:26:55.779 FINE [Manager] 'AcsCommandCenter.MacSupervisor' is logging in.
020-09-16T09:26:55.786 INFO [Manager] Administrator 'AcsCommandCenter.MacSupervisor' logged in.
020-09-16T09:26:55.801 FINE [Manager] Client with handle 'Handle (0x3d70001) = { type = ADMINISTRATOR, key = (0xd7), id = (0x1) }' has logged in.
020-09-16T09:26:56.870 CONFIG [Manager] Failed to set manager reference on service daemon on host 'sinacss'.
020-09-16T09:26:57.013 CONFIG [Manager] Connected to DAO 'MACI/Containers'.
020-09-16T09:27:21.919 INFO [acsstartupLoadIFR] Loading of IDL interfaces in Interface Repository completed OK.
020-09-16T09:27:22.804 INFO [acsStart] For this ACS session, please do an 'export ACS_INSTANCE=0' on all terminals running ACS clients.
020-09-16T09:27:22.809 INFO [acsStart] ACS is up and running

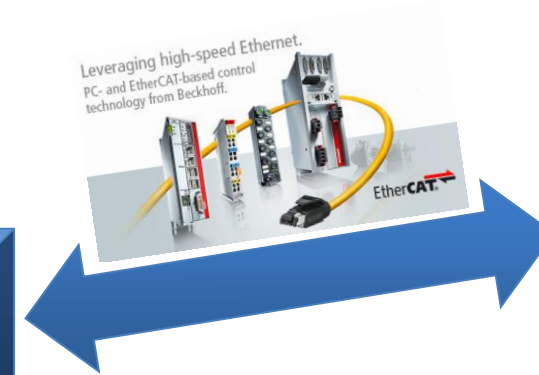
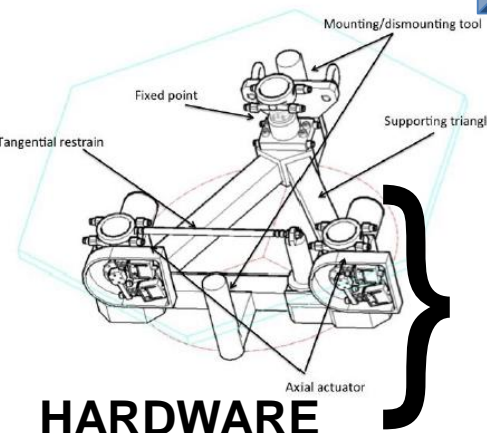
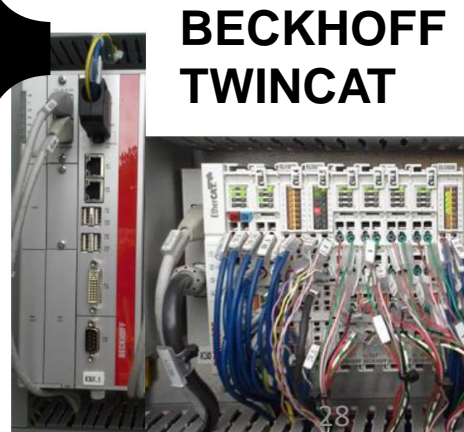
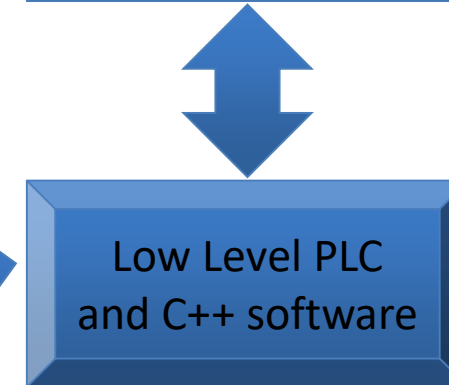
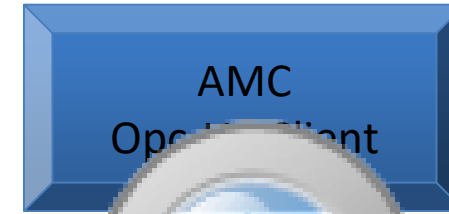
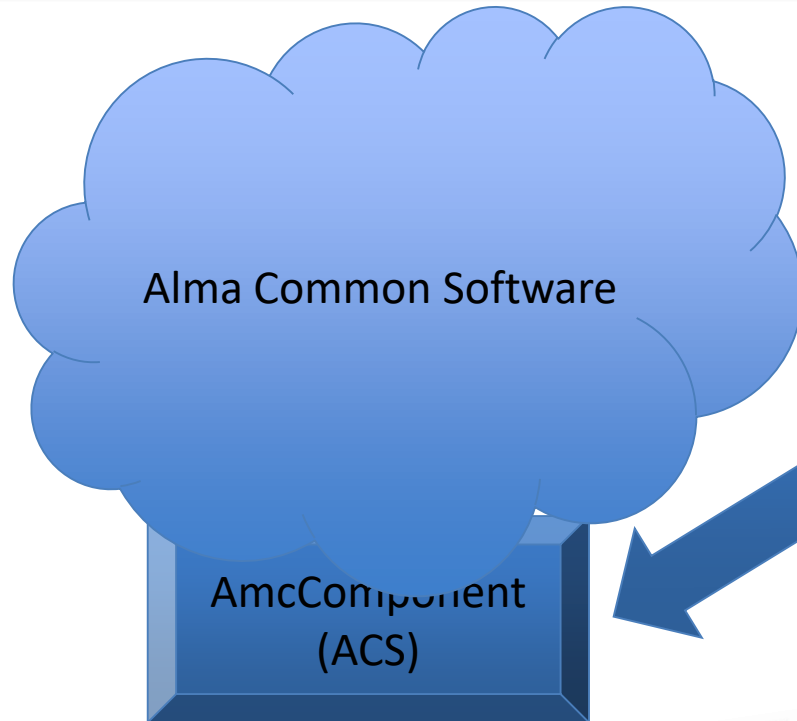
A trip among the TCS software levels



A trip among the TCS software levels



A trip among the TCS software levels



ASTRI-Code Generator

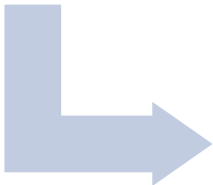
| | | | |
|-------------------------------|---|--|------------|
| GET_AMC_MAXTEMPWARNING | | | |
| Node ID: TBD | ns=4;s=MAIN.AMC_MAXTEMPWARNING | | |
| Description: | Read the set temperature limit for the Nanotec boards | | |
| Data size/type: | INT64 | | |
| Sampling Interval: | On request | | |
| Units: | °C | | |
| Range: | ALARM LOW | | ALARM HIGH |
| Operation States: | MAINTENANCE | | |

ICD Document

Excel File

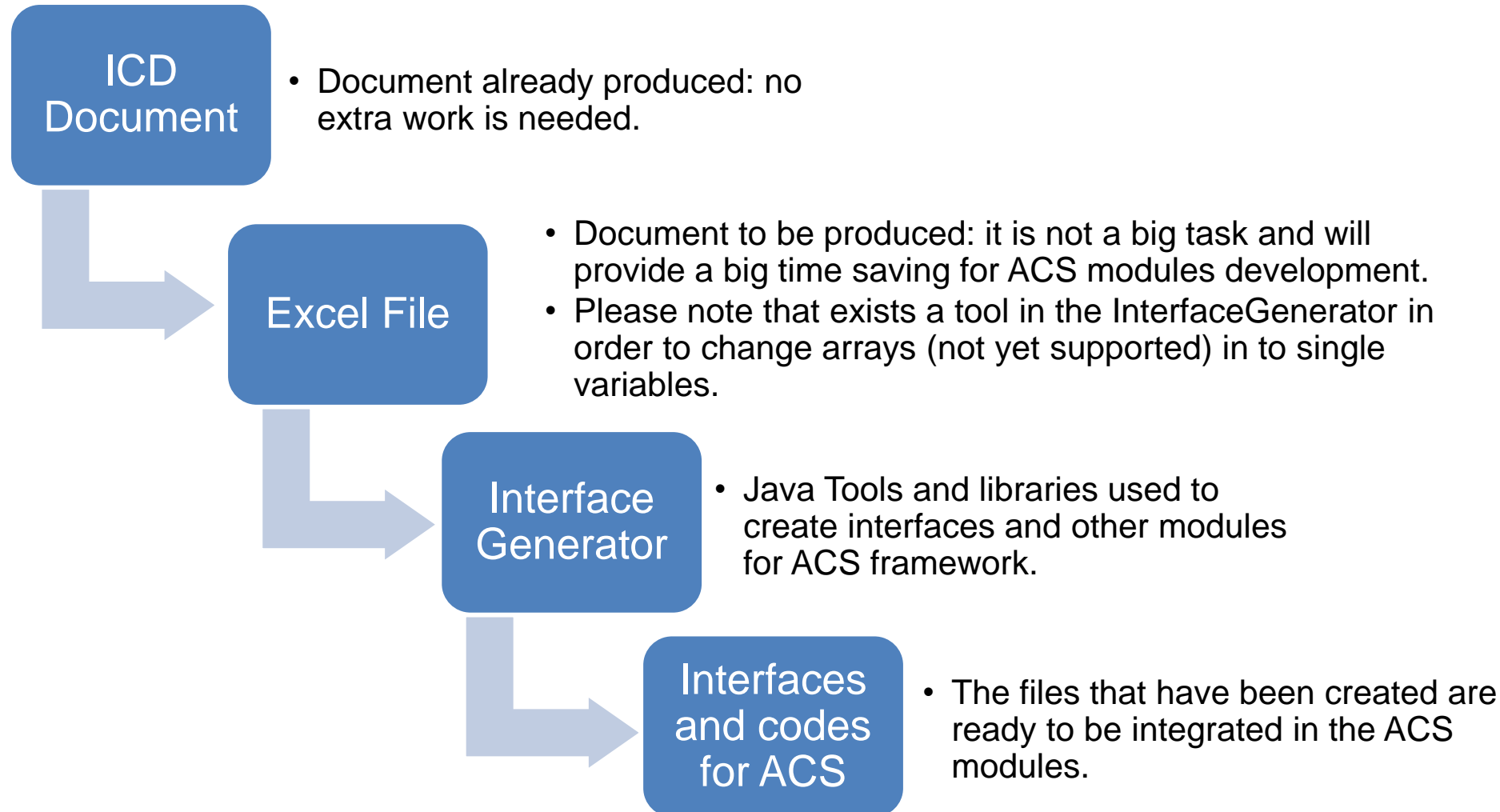
| | | | |
|------------------------------|---|------------|----------------|
| GET_AMC_M1TEMPWARNING | | | |
| Node ID: TBD | ns=4;s=MAIN.AMC_M1TEMPWARNING | | |
| Description: | Read the actual temperature of the Nanotech boards for M1 | | |
| Data size/type: | ARRAY<INT64> [36] | | |
| Sampling Interval: | 10 | | |
| Units: | °C | | |
| Range: | ALARM LOW | ALARM HIGH | MAXTEMPWARNING |
| Operation States: | ONLINE | | |

| | |
|------------------------------|---|
| GET_AMC_M2TEMPWARNING | |
| Node ID: TBD | ns=4;s=MAIN.AMC_M2TEMPWARNING |
| Description: | Read the actual temperature of the Nanotech boards for M2 |
| Data size/type: | ARRAY<INT64>[3] |
| Sampling Interval: | 10 |

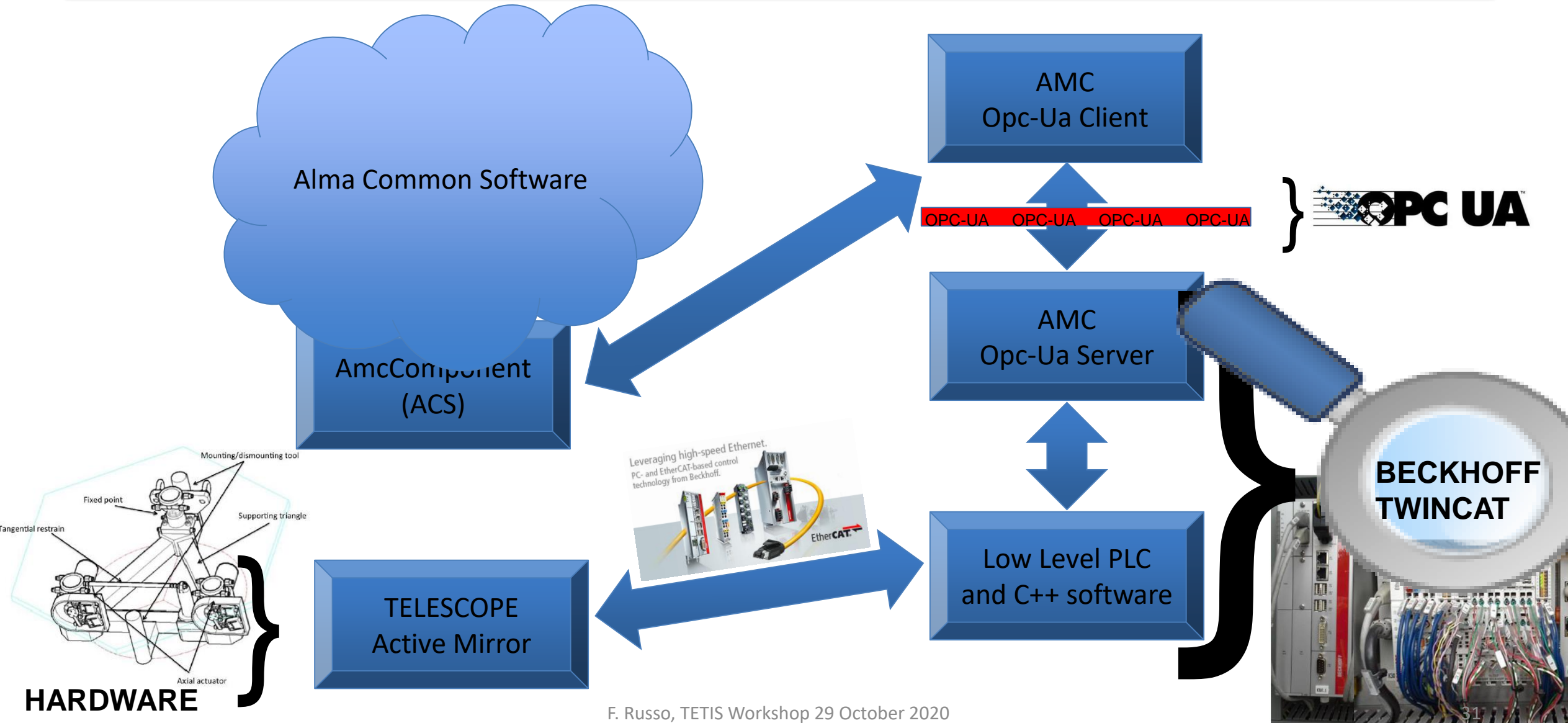


| | A | B | C | D | E | F | G | H | I |
|----|------------------------|--------|----------------|--------------|--------------------------------|--------------------|----------------|-----------------------------------|---------------|
| | Name of command | Action | Short name | ADS variable | OPC-UA node | OPC-UA Data type | CMD/MODE value | Sampling Interval (s) / ON CHANGE | Default value |
| 1 | | | | | | | | | |
| 2 | GET_AMC_MAXTEMPWARNING | AMC | MAXTEMPWARNING | | ns=4;s=MAIN.AMC_MAXTEMPWARNING | INT64 | | On request | |
| 3 | GET_AMC_M1TEMPWARNING | AMC | M1TEMPWARNING | | ns=4;s=MAIN.AMC_M1TEMPWARNING | ARRAY<INT64> [36] | | | |
| 4 | GET_AMC_M2TEMPWARNING | AMC | M2TEMPWARNING | | ns=4;s=MAIN.AMC_M2TEMPWARNING | ARRAY<INT64>[3] | | | |
| 5 | GET_AMC_MAXPOWRCONSUMP | AMC | MAXPOWRCONSUMP | | ns=4;s=MAIN.AMC_MAXPOWRCONSUMP | INT64 | | On request | |
| 6 | GET_AMC_M1POS | AMC | M1POS | | ns=4;s=MAIN.AMC_M1POS | ARRAY<DOUBLE> [36] | | | |
| 7 | GET_AMC_M2POS | AMC | M2POS | | ns=4;s=MAIN.AMC_M2POS | ARRAY<DOUBLE> [3] | | | |
| 8 | GET_AMC_M1POSABS | AMC | M1POSABS | | ns=4;s=MAIN.AMC_M1POSABS | ARRAY<DOUBLE> [36] | | On request | |
| 9 | GET_AMC_M2POSABS | AMC | M2POSABS | | ns=4;s=MAIN.AMC_M2POSABS | ARRAY<DOUBLE>[3] | | On request | |
| 10 | GET_AMC_M1ABSLIMITS | AMC | M1ABSLIMITS | | ns=4;s=MAIN.AMC_M1ABSLIMITS | ARRAY<DOUBLE>[72] | | On request | |
| 11 | GET_AMC_M2ABSLIMITS | AMC | M2ABSLIMITS | | ns=4;s=MAIN.AMC_M2ABSLIMITS | ARRAY<DOUBLE>[6] | | On request | |
| 12 | GET_AMC_M1ACTSTATUS | AMC | M1ACTSTATUS | | ns=4;s=MAIN.AMC_M1ACTSTATUS | ARRAY<INT64> [36] | | | |

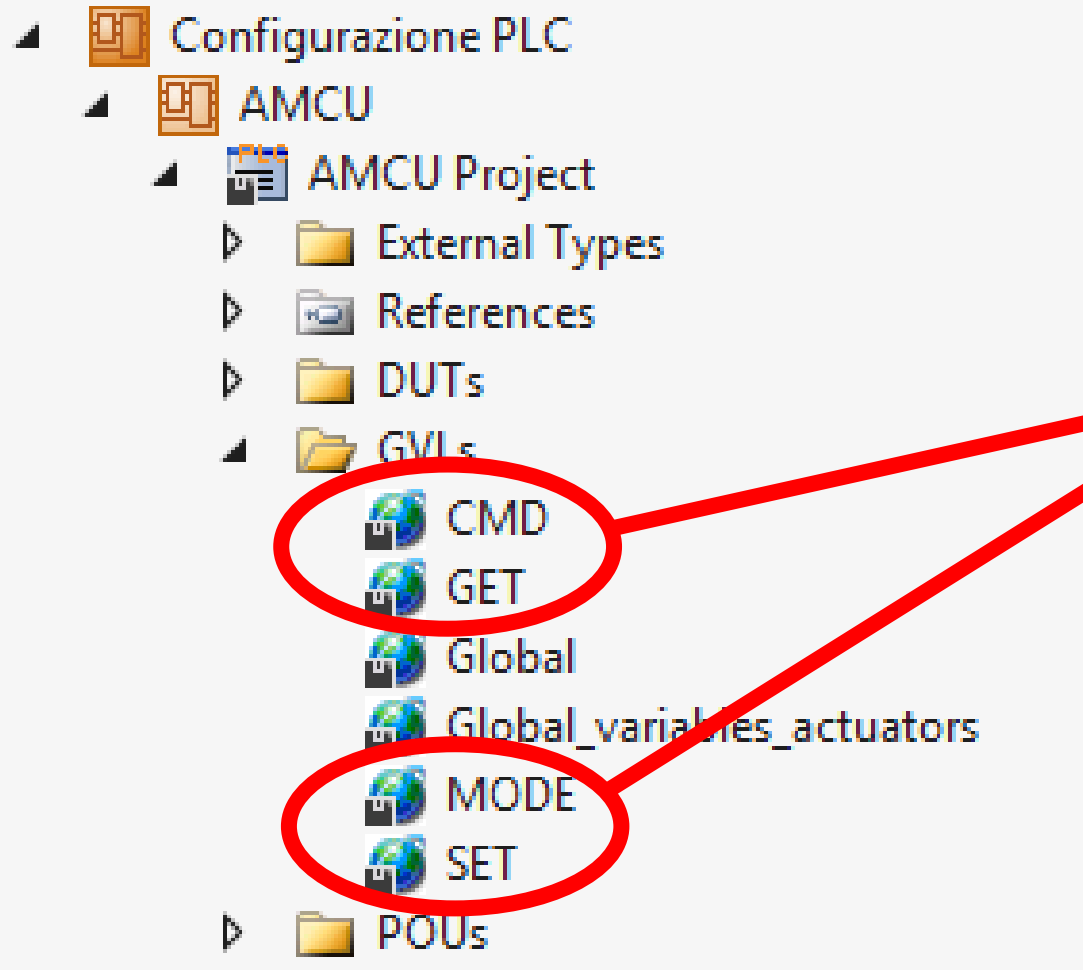
ASTRI-Code Generator



A trip among the TCS software levels

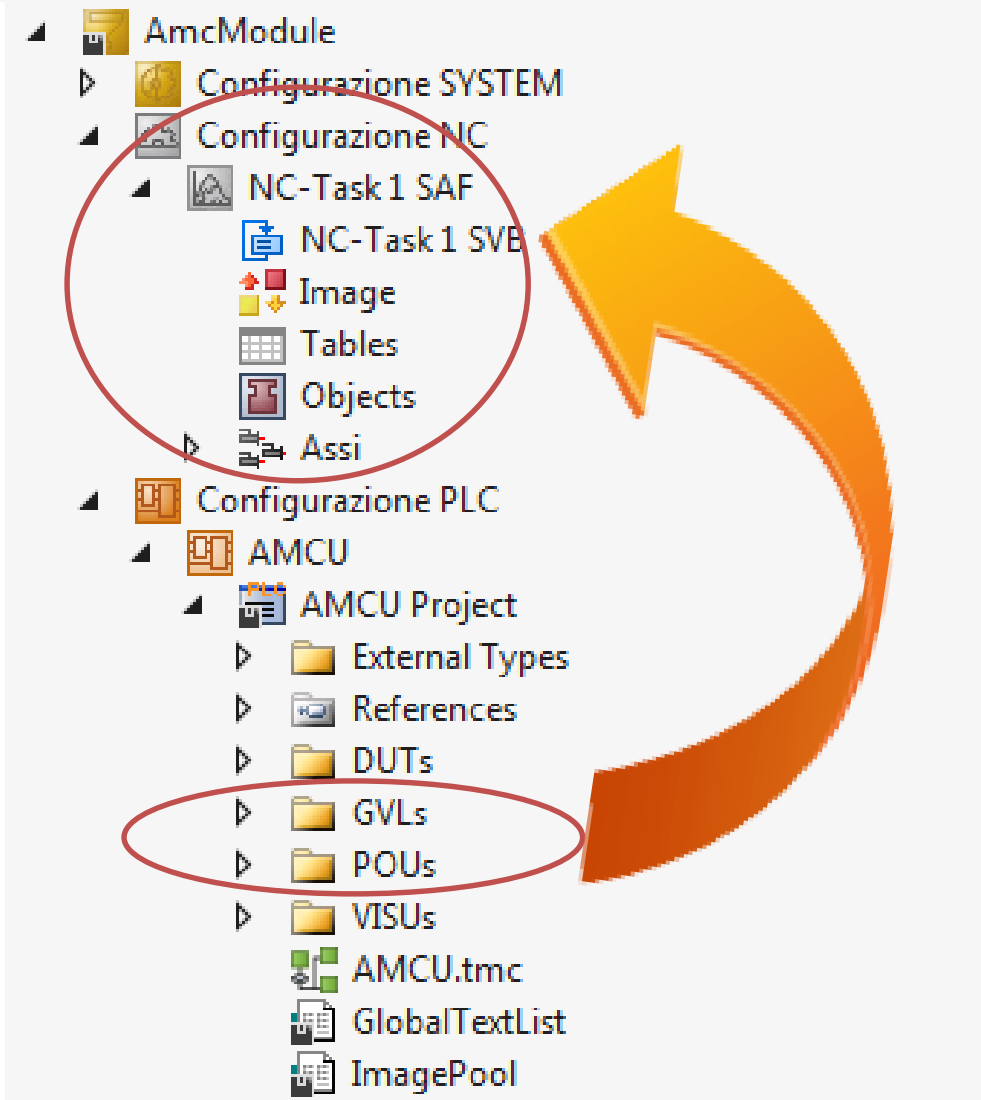


A trip among the TCS levels... (Twincat)



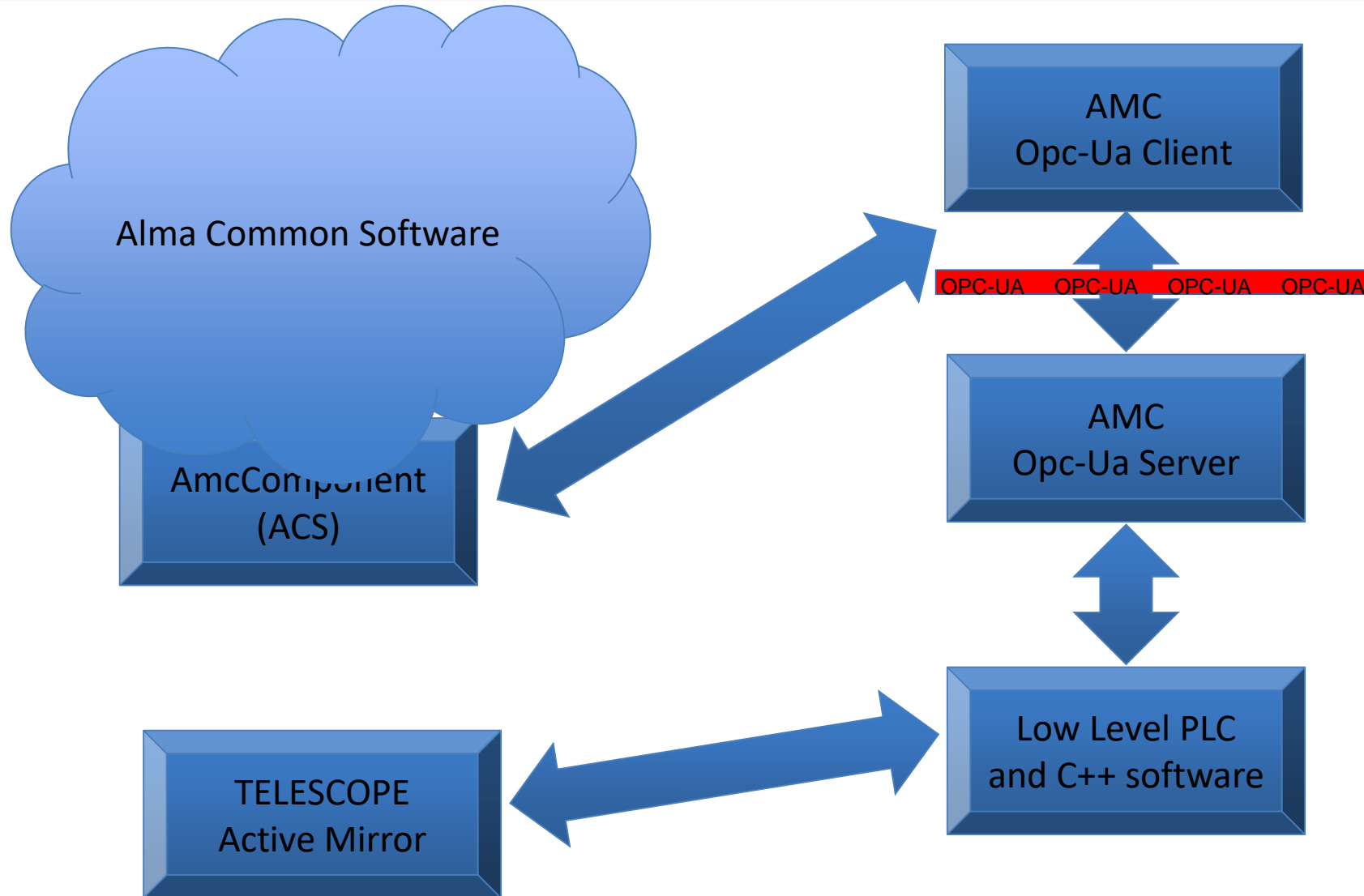
- **OPC-UA Global Variables!**
that match the ICD variables names

A trip among the TCS levels... (Twincat)

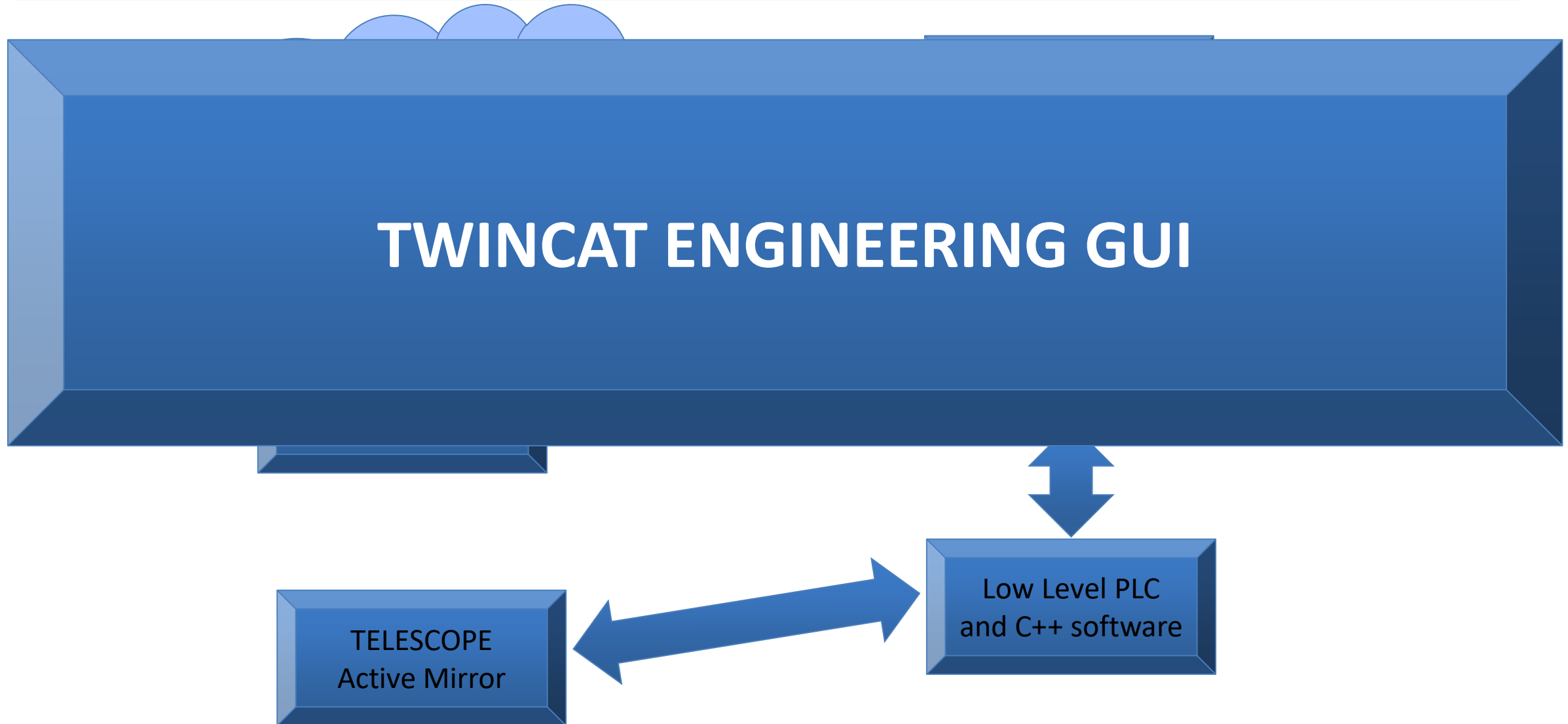


- The commands received trigger the twincat project internal logic that calculates the parameters for required movement.
- The PLC routines apply the calculated positions to the axis module (Numeric Control) and manage their executions by an interpolated mode.
- Error management, running always in background, takes care of all the unexpected behaviour of both hardware and software
- All the monitored data received from the hardware device update the corresponding opc-ua variables in every cycle.

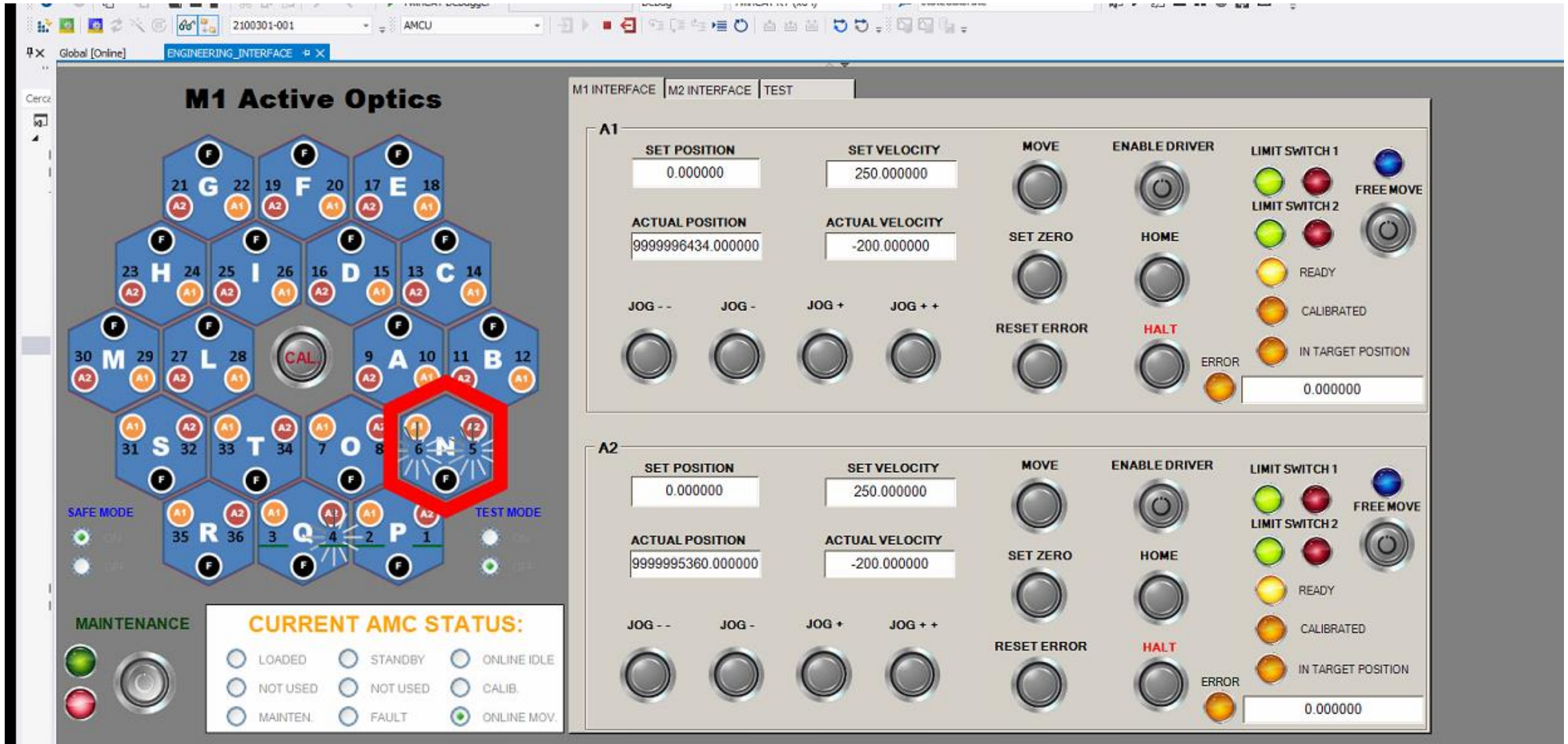
A trip among the TCS levels... (Twincat)



A trip among the TCS levels... (Twincat)



A trip among the TCS levels... (Twincat)



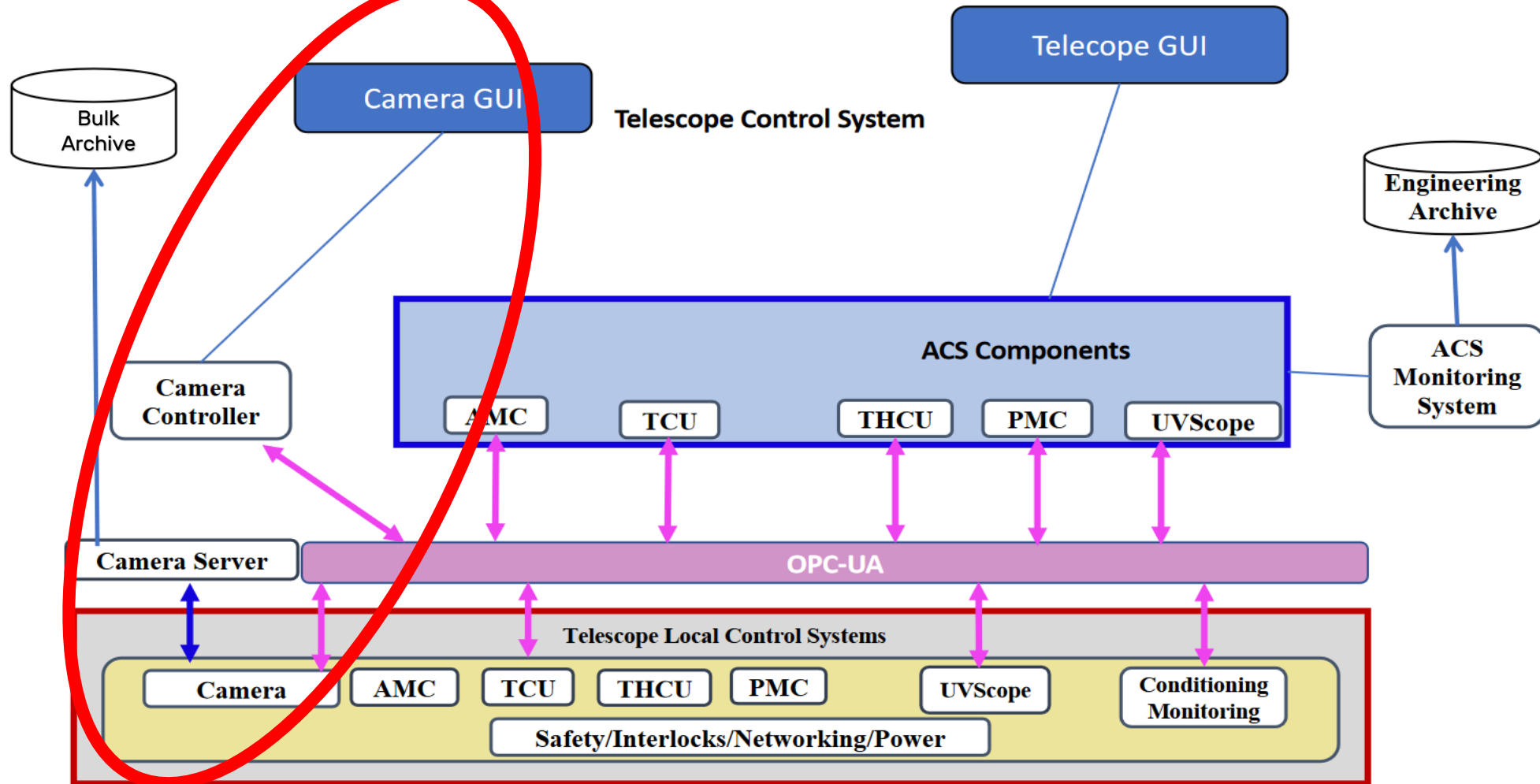
The screenshot displays the Twincat Engineering Interface for the M1 Active Optics system. The main window is titled "ENGINEERING_INTERFACE" and shows a hexagonal grid of 36 optical elements, each labeled with a letter and a number (e.g., G21, F19, E17, H23, I24, D16, C13, M30, L27, A9, B11, S31, T32, O7, N6, R35, Q3, P1). A red hexagon highlights the central element 'N6'. Below the grid, there are status indicators for "SAFE MODE", "TEST MODE", and "MAINTENANCE". A "CURRENT AMC STATUS:" table is visible at the bottom left.

| STATUS | STATUS | STATUS |
|--------------------------------|--------------------------------|--|
| <input type="radio"/> LOADED | <input type="radio"/> STANDBY | <input type="radio"/> ONLINE IDLE |
| <input type="radio"/> NOT USED | <input type="radio"/> NOT USED | <input type="radio"/> CALIB. |
| <input type="radio"/> MAINTEN. | <input type="radio"/> FAULT | <input checked="" type="radio"/> ONLINE MOV. |

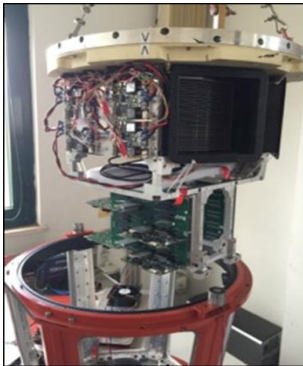
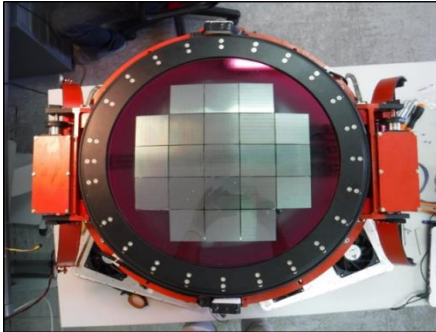
The right side of the interface shows two motor control panels, A1 and A2. Each panel includes fields for SET POSITION, SET VELOCITY, ACTUAL POSITION, and ACTUAL VELOCITY. It also features various control buttons such as MOVE, ENABLE DRIVER, SET ZERO, HOME, RESET ERROR, and HALT. Status indicators for LIMIT SWITCH 1 and 2, READY, CALIBRATED, and IN TARGET POSITION are also present.

ASTRI-Horn Telescope Control System

THE ACTUAL Telescope Control Architecture



Camera Specifications

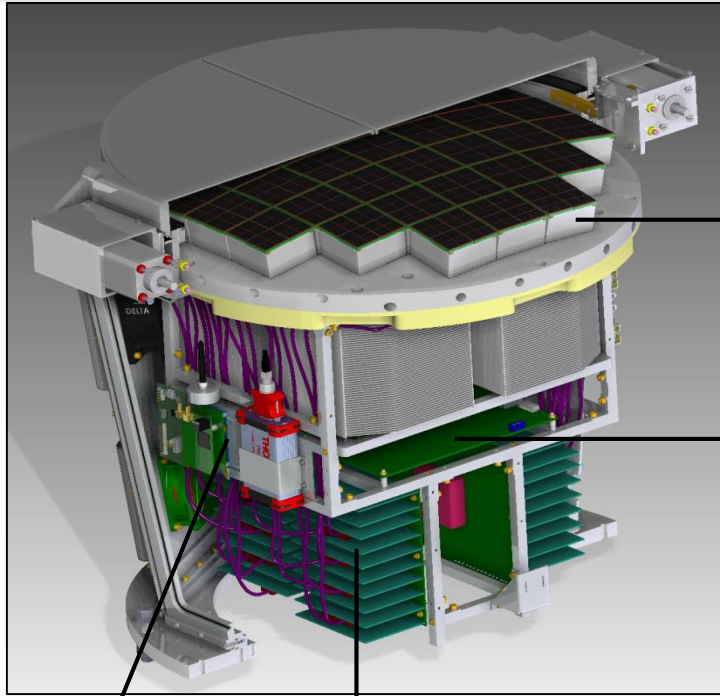


Cherenkov Camera:

- Innovative design based on SiPM (Silicon Photo Multiplier) sensors and specifically designed front-end electronics for signal capture
- Fully compliant with the CTA requirements

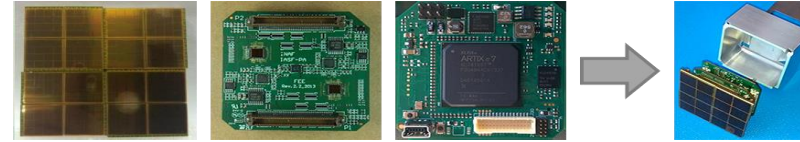
| Cherenkov Camera | |
|-----------------------------|---------------------------------|
| Camera opening Angle | 70° |
| Sensors | SiPM |
| Number of Pixels | 2368 (1344 prototype) |
| Pixel size | 7x7 mm |
| Pixel rate | 600 Hz |
| Dynamical range | 1 – 2000 pe ⁻ /pixel |
| Photon Detection Efficiency | > 35% @ 400nm |
| FoV | 10.5° (7.8° prototype) |
| Weight | 73 kg |
| Dimensions | 0.52m x 0.66m x 0.56m |
| Power consumption | 0.65 kW |

Camera Electronics



➤ **37 (21) Photo Detection Module (PDM) units containing**

- ✓ SiPM board with 9 embedded temperature sensors
- ✓ Front End Electronics (FEE) board with 2 CITIROC ASIC
- ✓ PDM FPGA Board (*Xilinx Artix 7*)



➤ **Back End Electronics (BEE) unit**



- Custom built solution based on the **Xilinx Zynq-7000** All Programmable SoCs.
- Dual ARM® Cortex™-A9 Processing System and FPGA Programming Logic.
- Custom built Linux distribution Debian Wheezy

➤ **PDM Voltage Distribution Box (PDM VDB)**

Custom built boards (2 mainboards with 19 daughterboards for each) to provide power (Low and Hi Voltages) to the PDMs with real-time control and monitor functionalities



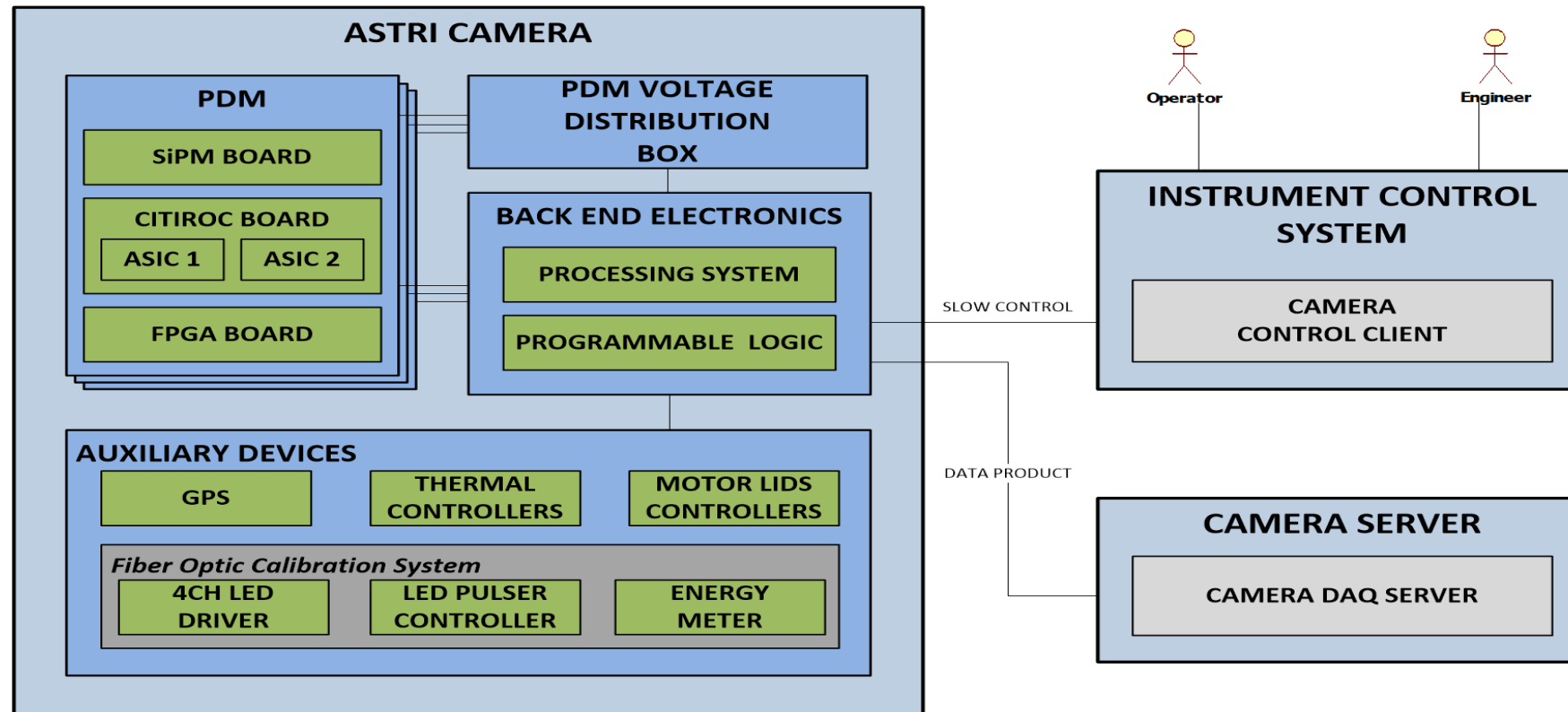
➤ **Set of auxiliary devices like GPS for synchronization, Fiber Pulser and Energy Meter for calibration, Motor Lid and Thermal controllers (provided by several vendors)**



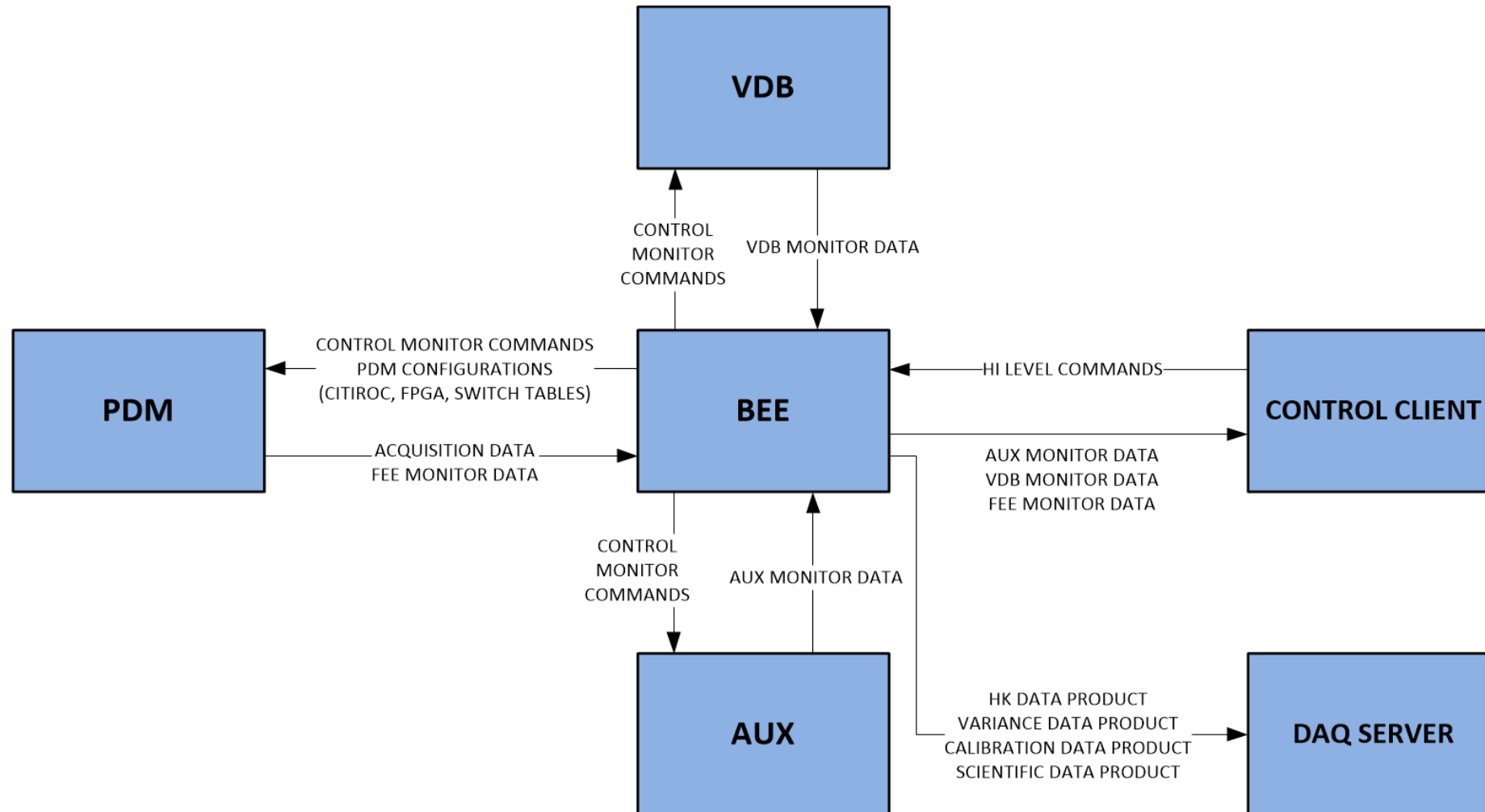
Camera Logical View

All the devices and systems are interconnected by the BEE, which is the main elaboration unit of the camera, managing all its functions:

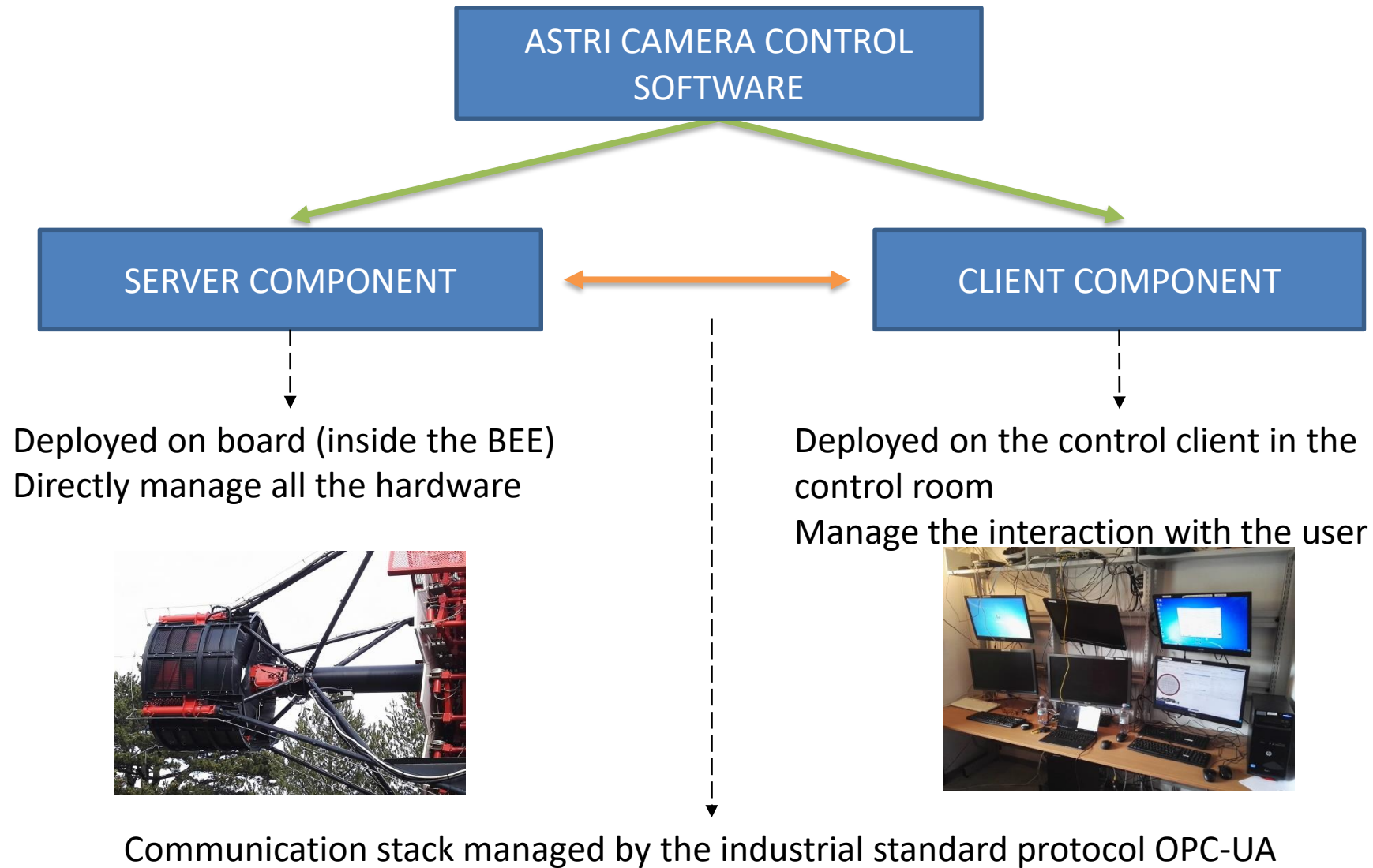
- Receive commands from the camera control client
- Control and monitor the auxiliary devices
- Manage and acquire data from the PDMs
- Prepare and send packets to the Camera Data Acquisition Server



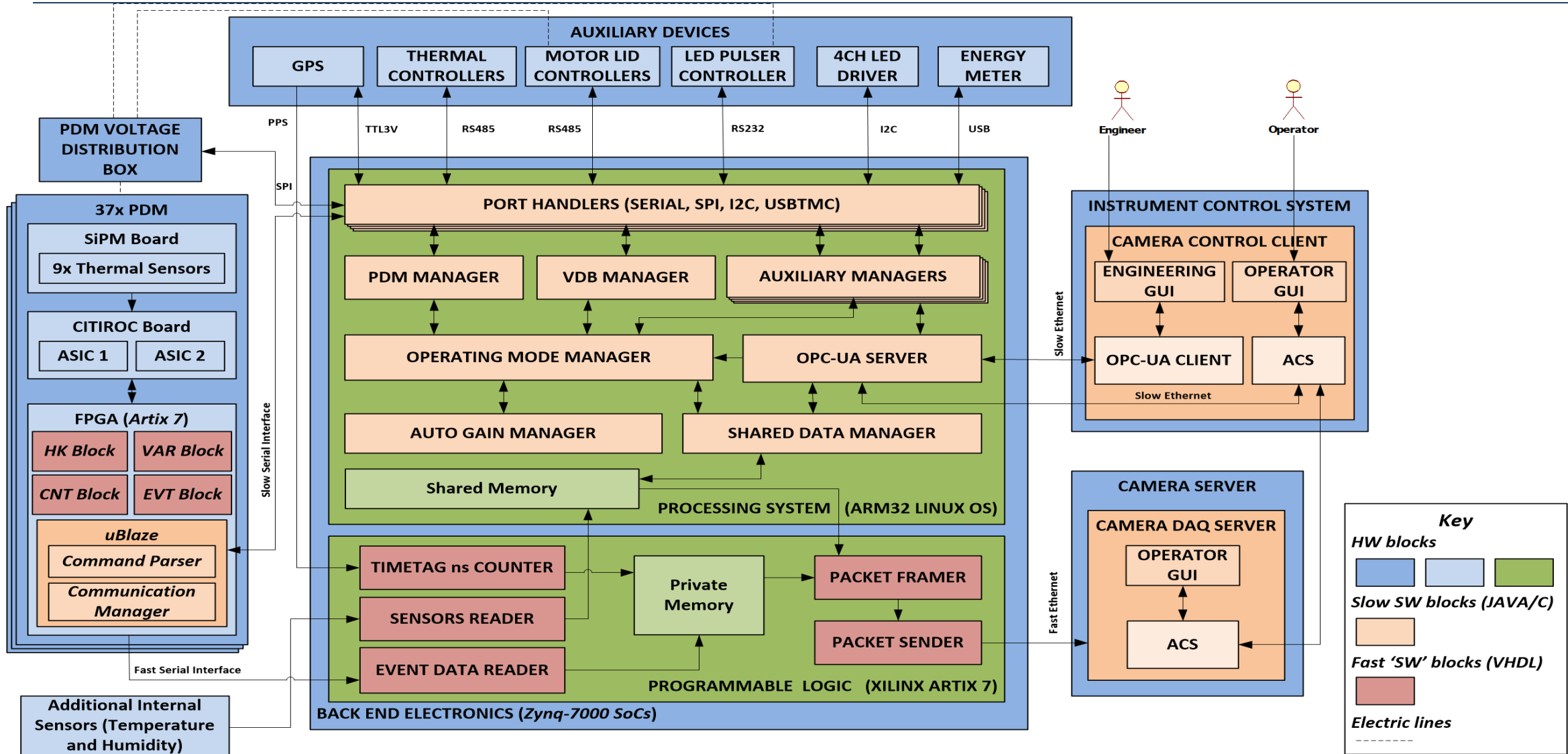
Camera Logical View



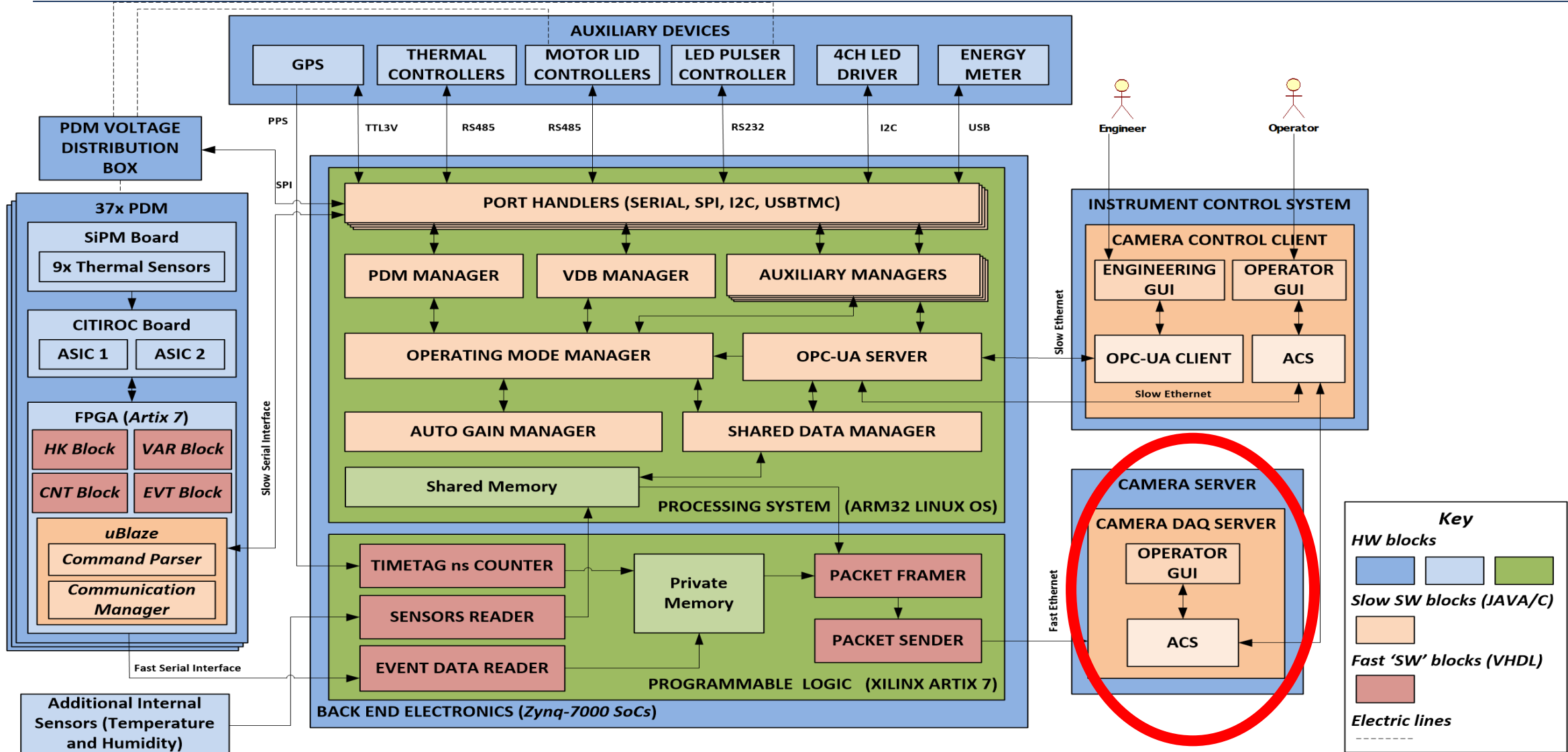
Camera Logical View



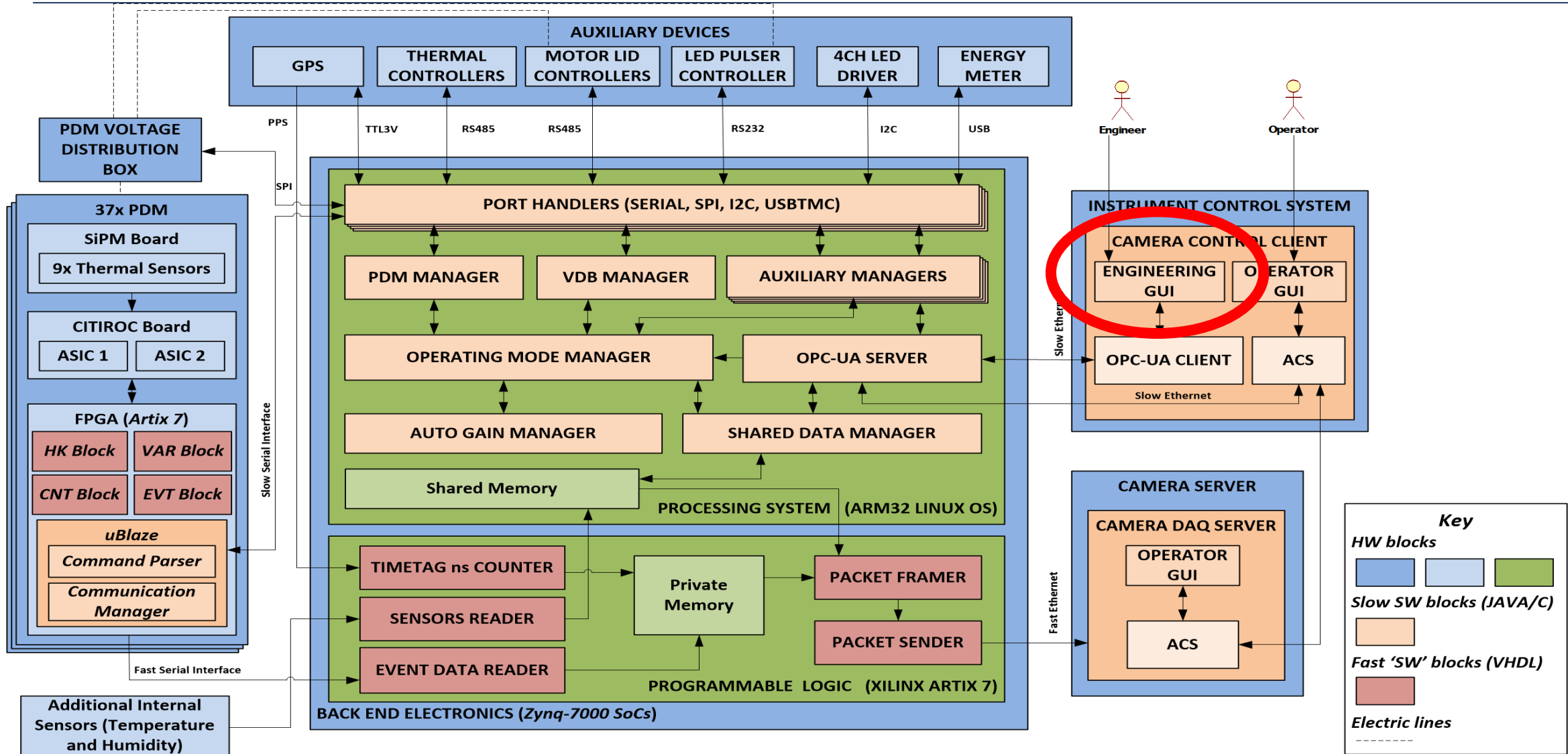
Camera Architecture



Camera Architecture



Camera Architecture



Camera Engineering GUI (Main)



The screenshot displays the 'Astri Camera Engineering Gui' interface. At the top, there's a menu bar (File, Expert, Help) and a toolbar with various subsystems (VDB, GPS, TEC, LID, FIB, LED, PEM) and tools (HK Chart Viewer, Variance Viewer, Server Connection). The main area is divided into several sections:

- Focal Plane Monitoring:** Shows monitoring parameters for Low Voltage 2 (mV), High Voltage (mV), and DaughterBoard Temperature (°C). It includes a circular diagram of the camera focal plane with a grid of temperature readings (e.g., 5807, 5817, 5792, etc.).
- Operating Mode:** Displays the current state (MODE_IDLE) and provides controls for Focal Plane Initialization, Modules Reset, and Hard Reset. It also includes settings for Housekeeping (Interval: 1 seconds), Variance (TopoTrigger: 5, Threshold: 10 pe), Stairs (C11, C12), Distributions (C13, C14), and Scientific (S21, S21 mode I, S22, S22 mode I) modes.
- Thermal Control:** A table showing various thermal parameters across four channels (Run).
- Fiber Optic Calibration:** Controls for Pulse Voltage (92 mV), Pulser Cpu/Dev Temp (0 °C), and Pulser Error Register ([NODEVICE]).
- Threshold Check & Scan:** Controls for TopoTrigger (5) and Threshold (3 pe), with options for Low, Mid, or High statistics.
- Action Log / LogBook:** A table recording system commands and their results.

At the bottom left, there is a logo for 'Astrofisica con Specchi a Tecnologia Replicante Italiana'.

| Time | ICD Command | Input or Result parameter |
|---------------------------------|-------------------------------|---------------------------|
| 2018 Sep 03 (CEST) 14:36:18.372 | cmd_tec_release | OK |
| 2018 Sep 03 (CEST) 14:36:32.741 | cmd_vdb_read_config | OK |
| 2018 Sep 03 (CEST) 14:36:33.203 | cmd_vdb_read_daugh_config | DB 16 --> OK |
| 2018 Sep 03 (CEST) 14:36:45.247 | cmd_vdb_turn_all_iv_on | Started |
| 2018 Sep 03 (CEST) 14:37:02.094 | cmd_vdb_turn_all_iv_on | Done |
| 2018 Sep 03 (CEST) 14:37:24.958 | cmd_vdb_turn_iv | DB 24 - ON --> OK |
| 2018 Sep 03 (CEST) 14:38:25.347 | opmode_perform_initialization | OK |
| 2018 Sep 03 (CEST) 14:38:47.135 | cmd_vdb_read_config | OK |
| 2018 Sep 03 (CEST) 14:38:47.629 | cmd_vdb_read_daugh_config | DB 16 --> OK |
| 2018 Sep 03 (CEST) 14:39:17.251 | opmode_start_hk | OK |

- Every high level commands (GET, SET, CMD) must be accessible from the Engineering GUI
- Lots of controls and information for expert users, but must be user friendly
- One single Main GUI with information and commands frequently useful

Camera Eng. GUI (Devices Configuration)

Motor Lid - Configuration

Monitoring

Lid Status: Closed
Position: 0 X 0 X
Ctrl Status: [Ready] [Ready]
Switches Status: ■ ■ ■ ■
Electromagnets ... ■ ■ ■
Ctrl Temp [°C]: 16.70 16.44
Ctrl Last Error: Undervoltage Undervoltage

Control

Open Close Stop

Configuration

| | LEFT | RIGHT | % |
|--------------------------|-------|-------|------|
| Phase Current | 150 | 150 | |
| Phase Current Standstill | 0 | 0 | |
| Min Speed | 400 | 400 | Hz |
| Max Speed | 1000 | 1000 | Hz |
| Acceleration | 50001 | 50001 | Hz/s |
| Squash Steps | 400 | 400 | |

Serial Interface

Request: Send
Response:

Read Config Write Config Close

Thermal Control - Configuration

Configuration Advanced

Operation

| | TEC 1 | TEC 2 | TEC 3 | TEC 4 |
|----------------------|-----------------|-----------------|-----------------|-----------------|
| Input Selection | Temperature ... | Temperature ... | Temperature ... | Temperature ... |
| Output Stage Status | Static ON | Static ON | Static ON | Static ON |
| Output Stage Current | 1.996 | 1.996 | 1.996 | 1.996 A |
| Output Stage Voltage | 7.998 | 7.998 | 7.998 | 7.998 V |
| Current Limitation | 5.000 | 5.000 | 5.000 | 5.000 A |
| Voltage Limitation | 20.000 | 20.000 | 20.000 | 20.000 V |

Apply first params to all

Temperature Control

| | TEC 1 | TEC 2 | TEC 3 | TEC 4 |
|---------------------------|-------|-------|-------|-----------|
| Target Object Temperature | 6.0 | 6.0 | 6.0 | 6.0 °C |
| Coarse Temp Ramp | 0.02 | 0.02 | 0.02 | 0.02 °C/s |
| Proximity Width | 2.5 | 2.5 | 2.5 | 2.5 °C |
| Kp | 60.0 | 60.0 | 60.0 | 60.0 %/°C |
| Ti | 20.0 | 20.0 | 20.0 | 20.0 s |
| Td | 0.0 | 0.0 | 0.0 | 0.0 s |
| D Part Damping PT1 | 0.07 | 0.07 | 0.07 | 0.07 |

Apply first params to all

Fan Control

| | FAN 1-4 | FAN 2-3 |
|--------------------|-----------------|---------------------|
| Target Temperature | 35.00 | 35.00 °C |
| Kp (Temperature) | 50.00 | 50.00 %/°C |
| Ti (Temperature) | 120.00 | 120.00 s |
| Td (Temperature) | 0.00 | 0.00 s |
| Min - Max Speed | 2500.00 5500.00 | 2500.00 5500.00 rpm |
| Kp (Speed) | 0.005 | 0.005 %/rpm |
| Ti (Speed) | 1.0 | 1.0 s |
| Td (Speed) | 0.0 | 0.0 s |

Apply first params to all

VDB - Configuration

Mainboards

| | V AUX 1 | V AUX 2 | V CCD |
|-------------|-------------------------------------|-------------------------------------|--------------------------|
| Mainboard 1 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Mainboard 2 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |

Daughterboards

Select PDM: 5 DB Address: 5 Read Config Write Config

High Voltage Value: 56500 mV
Max Temp: 70.0 °C
Max Current: 1000 mA
Max HV Current: 150 mA

Turn all Daughterboards Low Volt... ON OFF
Turn all Daughterboards High Volt... ON OFF

Set all Daughterboards High Voltage Value to: 56750 mV SET

Broadcast Supply Address: 24 ON OFF

Close

Fiber Pulser - Configuration

Configuration

Switch-off Temperature: 80 °C
Pulse Voltage: 79978 mV
Pulse Width: 10 ns
Pulse Frequency: 300 Hz
Number of Shots: 1
Trigger Mode: 2 - Internal trigger, ongoing pulses

Reset to Default Values

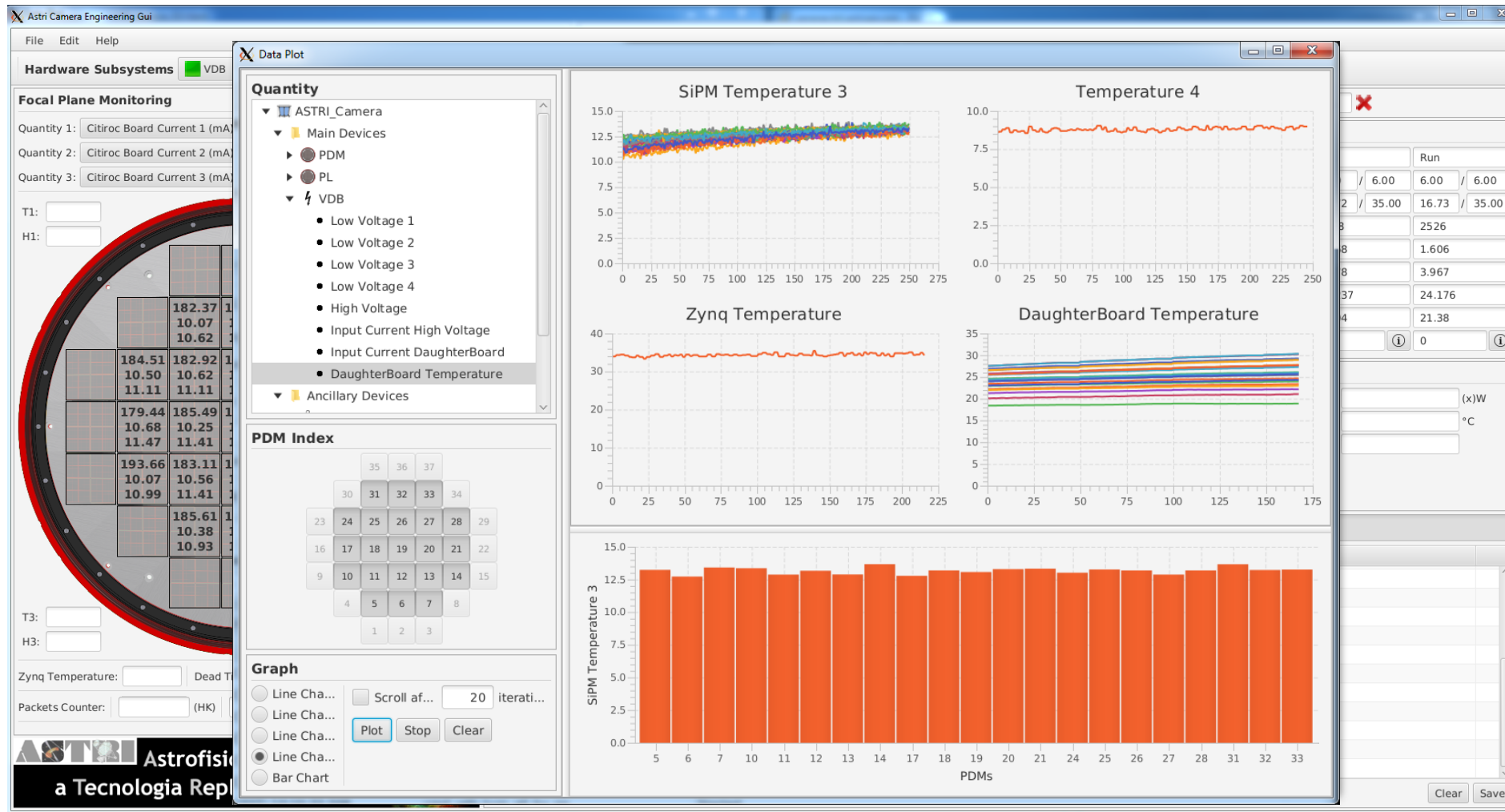
Serial Interface

Request: Send
Response:

Read Config Write Config Close

Camera Engineering GUI (HK Viewer)

A dedicated window shows in real-time all the HK information in different graph types



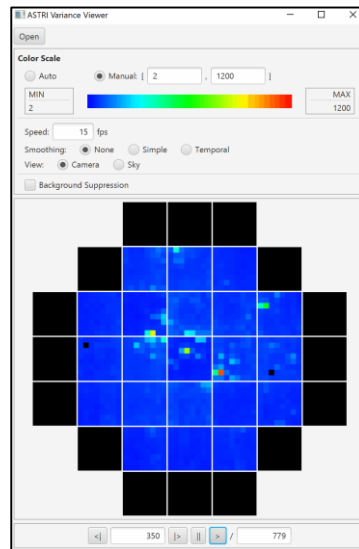
Camera Eng. GUI (Variance Viewer)

Integrated real-time viewer of Variance data (that measures the fluctuation of the signal acquired by the SiPM)

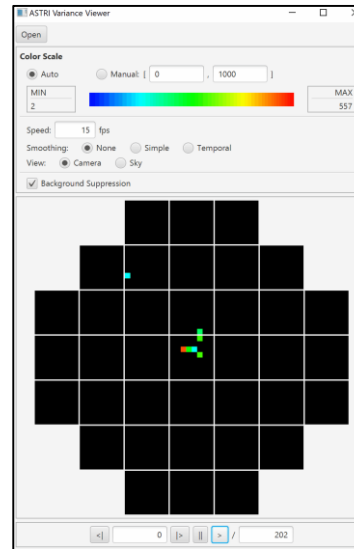
Allow us to evaluate:

- Effective Pointing of the telescope
- Presence of clouds
- Mirror alignment
- Electronics Health Status

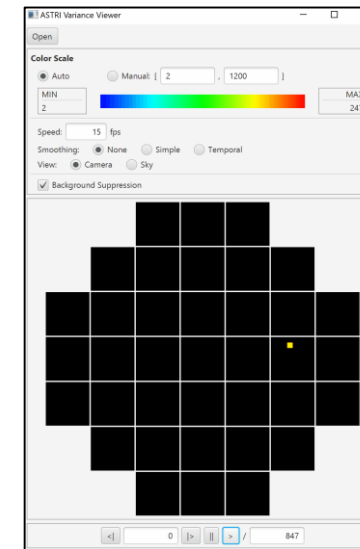
Example animations (15 fps) created using three different pointing:



a) Orion's Belt



b) Capella (*bg suppression*)



c) Fixed point at Az, El (*bg suppression*)

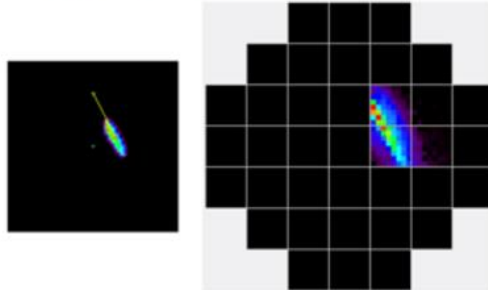
Detection of the Crab Nebula!

We started the engineering test at the astronomical site of Serra La Nave (Mount Etna) in Sicily...



...spending cold nights around bugs and lots of hard work, pizza and beer

25 and 26 May 2017: the ASTRI camera recorded its first ever Cherenkov light...



So... it works!



...Questions?