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Project: **ELT MCAO Construction – MAORY**

Instrument Control Hardware Requirements for MORFEO Subsystems

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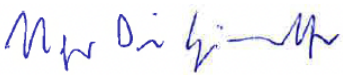
Released by PM:	Ugo Di Giammatteo		2023-02-16
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Change Record from previous version

Date	Affected Section(s)	Changes / Reason / Remarks
2021-09-17	All	General update of standards for cabinet management, employed devices, connectors. Additional information on cabinets interface with platform and internal layout. Change of power supply model.
2022-04-28	All	Update to single-PLC solution. Update of cabinet standards and employed devices, power distribution. Guidelines on schematics production.
2022-10-26	All	Update of PLC modules, safety. Change of name from MAORY to MORFEO. Merging with ICH Guidelines.
2022-12-02	Section 8	Guidelines on schematics preparation.
2023-03-02	All	Minor changes.

Contents

1. Introduction

1.1 Scope

This document provides a description of the aspects of the Instrument Control Hardware general design that are applicable to all MORFEO subsystems for their respective control hardware design. The subsystems shall follow these guidelines in the design of the respective control electronics. Justified deviations from said guidelines required for specific applications and needs can be discussed individually.

1.2 Definitions, Acronyms and Abbreviations

ADS	Automation Device Specification
BLDC	Brushless DC Motor
CU	Calibration Unit
CM	Cabinet Management
CP	Control Panel
DM	Deformable Mirror
EAP	EtherCAT Automation Protocol
E-ELT	European Extremely Large Telescope
ELT	Extremely Large Telescope
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
ESD	Electro Static Discharge
FDR	Final Design Review
FSoE	Fail Safe over EtherCAT
HE	Heat Exchanger
ICH	Instrument Control Hardware
ICS	Instrument Control Software
ILS	Interlock and Safety System
I/O	Input Output
LCU	Local Control Unit
LGS	Laser Guide Star
LGSWFS	Laser Guide Star WaveFront Sensor
LOR	Low-Order and Reference
LSU	Local Safety Unit
MAORY	Multi conjugate Adaptive Optics RelaY
MCAO	Multi-Conjugate Adaptive Optics

MICADO	Multi-AO Imaging Camera for Deep Observations
MORFEO	Multiconjugate adaptive Optics Relay For ELT Observations
MS	Main System
NGS	Natural Guide Star
NGSWFS	Natural Guide Star WaveFront Sensor
NTP	Network Time Protocol
PCU	Power Control Unit
PD	Power Distribution
PDC	Power Distribution Cabinet
PEC	Proximity Electronics Cabinet
PFRO	Post Focal Relay Optics
PFROC	Post Focal Relay Optics Cabinet
PLC	Programmable Logic Controller
PS	Power Supply
PTP	Precision Time Protocol
SA	Safety
SCAO	Single-Conjugate Adaptive Optics
SCP	Service Connection Point
SoE	Safety over EtherCAT
TBC	To Be Confirmed
TBD	To Be Defined
TCU	Thermal Control Unit
TRS	Time Reference System

2. Related Documents

2.1 Applicable Documents

The following applicable documents form a part of the present document to the extent specified herein. In the event of conflict between applicable documents and the content of the present document shall be taken as superseding.

AD1 Instrument Control Hardware Technical Specifications
Version 1

AD2 ESO Mechanical Standards
GEN-SPE-ESO-50000-4645 Version 2

AD3 E-ELT Electrical and Electronic Design Requirements
ESO-262825 Version 1

AD4 MAORY (E-ELT MCAO) Technical Specification
ESO- 254311 Version 1

AD5 E-ELT CONSTRUCTION -SAFETY MANUAL
ESO-206280 Version 1

AD6 Common Requirements and Interfaces for MAORY Subsystems
E-MAO-I00-INA-ICD-001

AD7 MAORY System Overview
E-MAO-000-INA-RER-001 Version 1

AD8 ICD between the E-ELT SCPs and the SCP Clients
ESO-262869 Version 1

2.2 Reference Documents

The following documents, of the exact version shown herein, are listed as background references only. They are not to be construed as a binding complement to the present document.

RD1 List of PLC Modules
ESO-253356 Version 4

RD2 MAORY Instrument Control Hardware Design and Analysis Report
E-MAO-PH0-INA-DER-001

RD3 MAORY Instrument Control Hardware Interface Control Document
E-MAO-PH0-INA-ICD-001

RD4 Electrical and Electronic Design Standards
GEN-SPE-ESO-50000-5401 Version 4

RD5 Standard Components and Guidelines for Cooling Circuits
ESO-254314 Version 4

RD6 Thermal Control System Design Report
E-MAO-PT0-INA-DER-001

RD7 MAORY System Analysis Report
E-MAO-SE0-INA-ANR-001

RD8 MAORY List of electrical functions
E-MAO-SE0-INA-LIS-001

RD9 MAORY Hazard List and Analysis
E-MAO-000-INA-ANR-003

RD10 ICD between the Instruments and the Central Control System
ESO-311982 Version 3

3. Instrument Control Hardware Overview

The design of the MORFEO control electronics is shared between the work packages.

In particular, the Instrument Control Hardware WP is responsible for the control electronics of the Post Focal Relay Optics motorized functions and of the movement of the Calibration Unit selector, the internal illumination of the MORFEO Main Support Structure, the harness to the Main Support Structure and for power distribution to the entire MORFEO system. It also represents the interface point with ESO, and is responsible for compliance to ESO requirements and for harmonizing the overall MORFEO control electronics design. Finally, the ICH WP provides general guidelines to the other subsystems, and parts of the design that are shared between them.

The other subsystems, listed below, are in charge of their respective electronics:

- Calibration Unit
- Deformable Mirrors
- Thermal Control
- NGS WFS module
- LGS WFS module

The division into subsystems allows the independent design and testing of MORFEO functions, helping parallel development and simplifying the interfaces, which are based on the essential services.

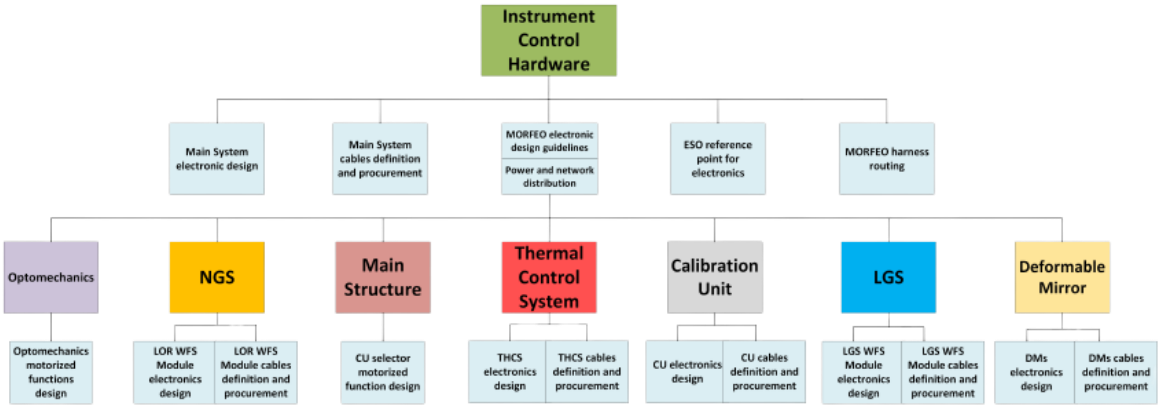

Figure 1. Diagram of MORFEO subsystems electronics design activities

All the cabinets are placed on an intermediate platform, 7 meters (TBC) below the Nasmyth platform, with the following exceptions:

- NGS WFS module cabinets, that are on the MICADO co-rotating platform.
- Post Focal Relay Optics cabinet, placed under the MICADO-MORFEO thermal duct support structure, on the Nasmyth platform.

- A smaller cabinet (Proximity Electronics Cabinet), placed on the Nasmyth platform, near the LGS WFS module, hosting electronics for the LGS module with critical cable lengths.

Figure 2 shows the intermediate platform where most of the cabinets will be located, while the position of the PFRO cabinet and the Proximity Electronics cabinet on the Nasmyth Platform is shown in Figure 3.

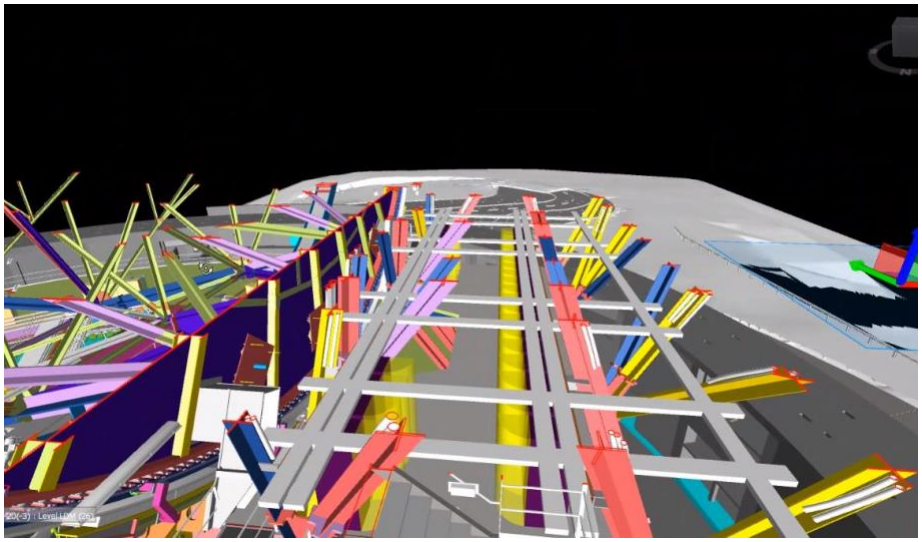

Figure 2. Intermediate platform hosting the remaining MORFEO cabinets, with cable tray (image provided by ESO)

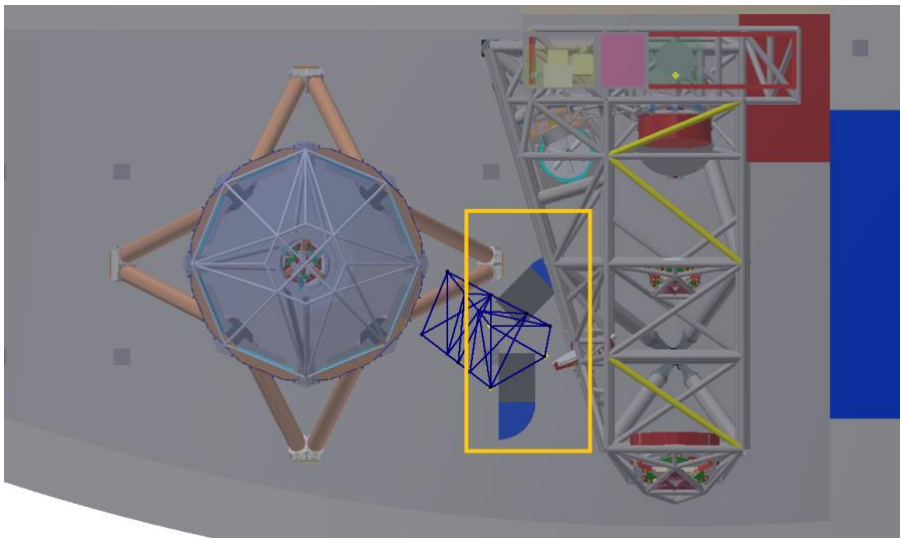

Figure 3. Position of MORFEO electronics cabinets on the Nasmyth Platform

The MORFEO control electronics are managed by a single PLC, that is part of the Main System. Each sub-system has dedicated cabinets, or cabinet volumes, and PLC modules, connected via EtherCAT, in order to facilitate the independent integration and verification for every sub-system. An overview of the various subsystems cabinets and their connections to the Main System is given in the following figure.

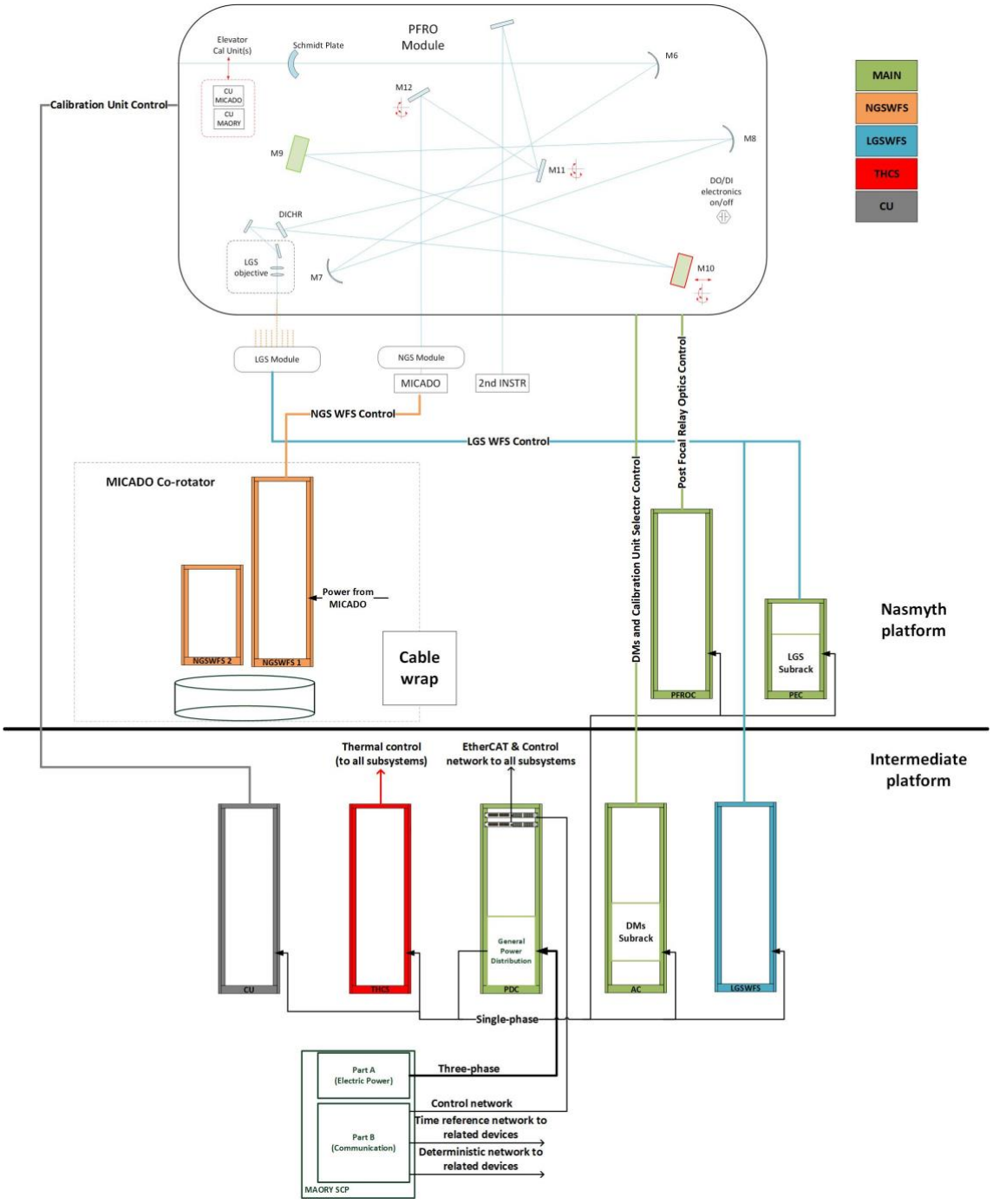

Figure 4. MORFEO Instrument Control Hardware Overview - The cabinets belonging to the MORFEO Control Electronics are shown in different colours: the Main System cabinets are in green; the NGSWFS subsystem cabinets are in orange; the LGSWFS subsystem cabinet is in blue, the Calibration Unit cabinet in grey and the Thermal Control cabinet in red.

The following sections of the document will describe design choices and aspects that shall be followed as guidelines by all the subsystems listed above.

4. Power Distribution

4.1 Power distribution scheme

The ICH Main System will comprise a Power Distribution Cabinet, with the main function of receiving three-phase power directly from the SCP, to then distribute single-phase power to all the other subsystems, while balancing the loads on the three phases.

The power distribution scheme for single-phase power, with all the protection devices that are foreseen to be used, shall be designed as shown in the following figure (TBC).

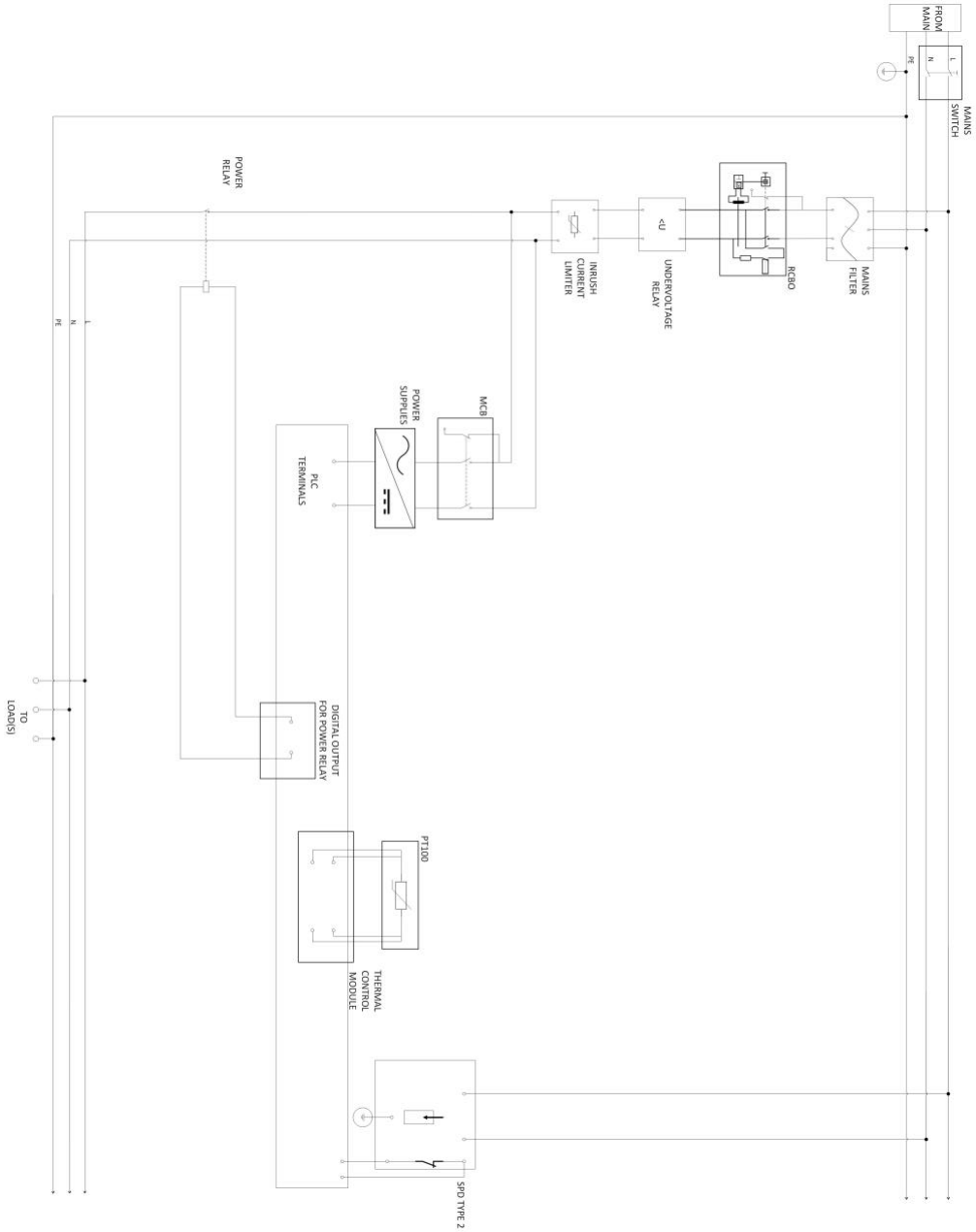

Figure 5. Single-phase power distribution scheme (TBC)

The following devices shall be employed:

- Manual switch
- Miniature circuit breaker
- EMC filter
- Undervoltage relay
- Inrush current limiter
- Residual current circuit breakers with overcurrent protection (type according to the loads)
- Surge protection device
- Power relays to manage the loads
- Auxiliary contacts to monitor the status of the devices

The safety power distribution scheme will be based on the needs of MORFEO, if any, and on recommendations from ESO.

4.2 System Power-up

The MORFEO PLC is expected to always be switched on.

The first power-up of the system will be managed by the PLC.

When power is given to the subsystem cabinet, and its mains switch is closed, the subsystem PLC digital modules shall take care of the gradual startup of the loads, by remotely controlling power relays and following an established routine.

The same process will be followed if an event occurs, bringing to the shutdown of the system.

In any case, the electronics shall be able to survive a sudden shutdown of the system.

A more detailed power-up sequence is described in RD7.

4.3 Grounding Scheme

The cabinets shall be connected to a single grounding point, in a star-like topology. This scheme will also prevent the creation of ground loops.

More specifically, every part of a subsystem that requires a ground connection (including on-field devices and cable trays) will be connected to a ground rail in the corresponding cabinet.

In turn, the ground bars of all the cabinets will be connected to the ground rail in the Power Distribution Cabinet. Finally, the PDC ground will be connected to the telescope ground through the MORFEO SCP. (TBC)

5. Network connection

5.1 Control network (TBC)

One physical copper connection to the Control network will be provided to each cabinet.

A second switch inside the subsystem cabinet is required for connection to multiple devices inside the same cabinet.

The NGS WFS module subsystem will receive one fibre connection, if required by the interface with the MICADO cable wrap.

5.2 EtherCAT network

The PLC modules of all subsystems will be controlled by a single PLC, belonging to the Main System. This way, all MORFEO electronics operate under the same EtherCAT network, allowing for easy and quick communication among subsystems.

An EtherCAT cable will be provided to each cabinet, where it is connected to an EtherCAT coupler. The subsystem PLC modules are then connected to the EtherCAT network through E-bus.

In case other EtherCAT devices are employed outside of the cabinets, they also shall be connected through EtherCAT to the rest of the system.

The subsystems will be all connected to the same network in a star-like topology, as shown in the following figure.

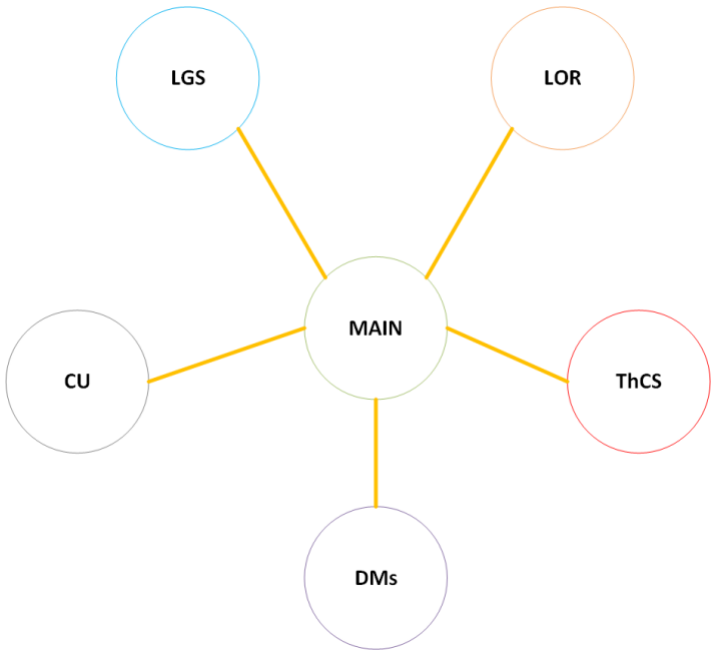

Figure 6. EtherCAT network distribution topology

One copper cable for EtherCAT connection will be provided to each subsystem, while the NGS WFS module subsystem will receive one fibre connection, if required by the interface with the MICADO cable wrap.

The subsystem shall employ EtherCAT couplers with ID switches: the Beckhoff EK1101 module for copper connections, and the Beckhoff EK1501-0010 module for single-mode fibre-optic connection.

Each module is equipped with three hexadecimal ID switches. Each EtherCAT segment is manually assigned a unique ID, and can then be located at any point in the EtherCAT network. This way, wrong connections to the EtherCAT network are prevented.

In the following table the hexadecimal IDs to be assigned to each cabinet coupler are listed.

Cabinet	EtherCAT coupler ID
Post Focal Relay Optics	0
Accessory	1
Proximity Electronics	2
Thermal Control System	3
Calibration Unit	4
LGS WFS Module	5
NGS WFS Module (ICS04)	6

Table 1. IDs of cabinets EtherCAT couplers

5.3 Time Reference and Deterministic Networks

For the subsystems that need to be synchronized, they can be connected to the ELT Time Reference Network either via NTP (Network Time Protocol) or PTP (Precision Time Protocol), for applications that need an accuracy of the order of few microseconds.

The connection can be done either via copper or fibre; either way, PTP will be available only in the time reference network, and the devices which require it will need a dedicated network interface.

For the PLC, one EL6688 module will be employed, allowing a PTP connection to the devices in the EtherCAT network.

The network connection for PTP usage shall be achieved via a devoted one-to-one connection from each PTP client to the MORFEO SCP. The media could be either copper or fibre depending on the client needs.

Likewise, Deterministic Network connections shall be made directly from the SCP to the corresponding subsystems.

6. Cabinets General Design

6.1 Cabinet Model

The control electronics of each subsystem shall be hosted into an ESO customized version of Schroff Varistar LHX3 cabinets.

The chosen standard cabinet model has external overall dimension of 600x800x2000 mm, with the two exceptions of the NGS WFS module control electronics cabinets, which will have a height of 1800 mm, and the Proximity Electronic Cabinet, which will have a custom height of 1000 mm (TBC).

Due to the insulation of its walls, and a dedicated interface to the platform, the customized cabinet model has external overall dimensions of 649x851x2083 mm (including the handles).

The doors and panels shall be opaque to prevent light pollution, unlike the standard cabinet model.

To attach the cabinets to the platform, while minimizing the transfer of vibrations from the fans inside of the cabinets to the platform itself, the ESO standard damping system, based on COTS components, will be used. In particular, Sylomer AMC-FZ 50-51 isolators will be employed.

Based on ESO directives, the cabinets shall withstand Bellcore Zone 4 earthquakes. For this reason, ESO is developing a custom made, earthquake safe cabinet pedestal.

The design volume should take into account the maximum cabinet motions under earthquake of +/-100mm lateral motion (x-y plane) and +20/-30mm vertical motion (along z) at the top of the cabinet.

A custom low-vibration fan is also foreseen by ESO to replace the Schroff cabinet standard fan.

The MORFEO cabinet design will thus be updated following future ESO directives.

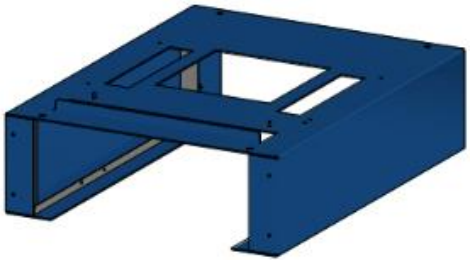

Figure 7. ESO electronic cabinet seismic pedestal

6.2 Cabinet Management and Thermal Control

As required by R-INS-757, during night time the temperature difference between the MORFEO Control Electronic subsystem (or any associated equipment) outer surface and the ambient air in still wind conditions shall not be larger than ±1.5 ºC. The maximum temperature difference during day time is of ±2.5 ºC.

An active control of the cabinet temperature will be employed to satisfy the requirement. This control will be achieved via the Varistar LHX3 cabinet built-in air/water heat exchanger.

The cabinets will be put in cascade and cooled using the coolant coming from SCP Part C, following the Thermal Control System design shown in RD6.

In the current baseline, the MORFEO PLC is in charge of the cabinet temperature monitoring and of the coolant flow regulation.

The baseline will be updated in the next phase, in case of new directives from ESO.

The following devices shall be installed in each cabinet:

- Hydraulic Valve (0-10V control valve): Siemens 3-way valve VXP47.10 (or the 2-way valve VVP47.10 for the last cabinet of the series) with SSP61/00 actuator
- Leakage sensor: OMRON K7L Series
- Humidity sensor: Vaisala HMP110 (TBC)
- Flow rate sensor: IFM SM6000 (TBC) (2 sensors are needed for the first cabinet of the series)
- Temperature sensors: 4 x 2-wire PT100 sensors, to monitor the cabinet, ambient air, inlet and outlet temperatures
- Check Valve: Swagelok SS 8C4 1/3 (only in cabinets with 3-way valve)

A leakage strip sensor will monitor the presence of leakage in the coolant pipes. The OMRON leakage sensor is operational in an ambient humidity interval of 45% to 85%. With higher relative humidity the sensor can issue false alarms.

For this reason, a humidity sensor shall also be installed inside the cabinet, to bypass the leakage sensor when the measured ambient humidity is higher than a defined value.

Two PT100 sensors shall be used to monitor the cabinet temperature and compare it to the ambient temperature.

As further means of keeping the outer temperature of the cabinets in the interval specified by the requirement, their walls shall be thermally insulated with a layer of Kalifex ST insulating foam.

Given the design of the Varistar LHX 3 cabinet, with its air/water heat exchanger located on the base with a fan tray on the top, and air ducts along the sides of the cabinet, the insulating layer has to be applied to the external walls of the cabinet, with the exception of the front and rear walls, and then covered with metal panels to prevent degradation of the material.

Despite all precautions, the occurrence of condensation cannot be completely ruled out and subsystems shall not suffer damage from condensing humidity.

For this reason, all cabinets shall foresee a condensate drain.

Finally, a temperature limiter like Martens TL4896, a SIL2 device, shall be employed to directly prevent damage due to over temperature, and issue warnings to the PLC.

6.3 Cabinets Space for Connectors

Since the base of the cabinet is occupied by the heat exchanger and its sides by the cooling air path, in order to keep both doors functional, the cables shall exit the cabinet through the area of the top that is not occupied by the fan tray.

In the following figure a technical drawing of the cabinet, and in particular its top cover, is shown. There are two areas next to the fan tray, each of about 470 mm x 96 mm, where the connectors can be installed.

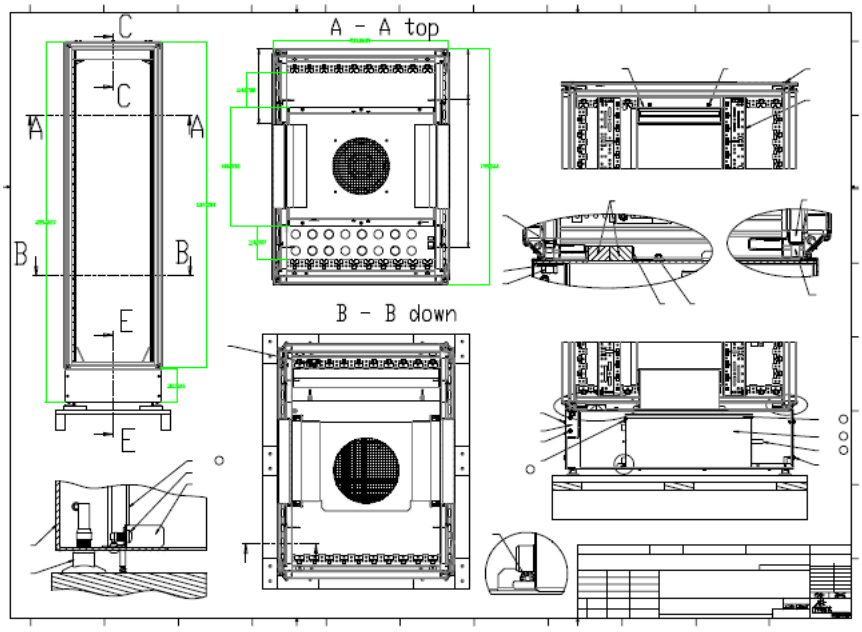

Figure 8. Schroff Varistar LHX 3 cabinet technical drawing

Figure 8 shows a CAD model of the LHX 3 cabinet with the connectors installed on its top.

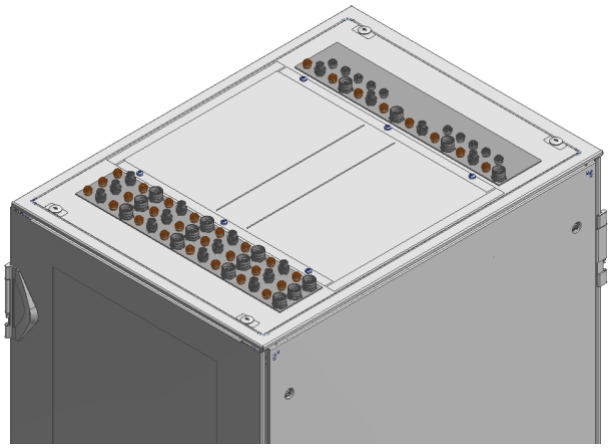

Figure 9. Position of the connectors on the top of the cabinet

Power cables will instead arrive from the bottom of the cabinet (TBC), and plugged into terminal blocks inside of it.

6.4 Cabinet Electronic Devices

In this section the list of electronic devices that shall be used for all MORFEO ICH is presented.

6.4.1 PLC Modules

The electronic components are mainly based on Beckhoff PLC and EtherCAT fieldbus. In the current baseline, the PLC CPU will be located in the Main System Power Distribution Cabinet (PDC).

The PLC modules that are recommended, chosen among the ones listed in the ESO *List of PLC Modules* (RD1) are shown in the following tables.

RD1 offers a wide variety of choices for each type of module.

In absence of specific needs of the subsystem, a smaller subset of modules shall be used in MORFEO.

The same models shall be used for the same functions across all subsystems, when possible, in order to reduce the number of different spares.

The full list of ESO standard modules is reported in Appendix A.

For each type of module, it is suggested that a spare module is installed in every cabinet.

The PLC will be fully equipped with the necessary TwinCAT 3 licences.

Type	Model
PLC	CX2033-0175
Internal Power Supply	CX2100-0004
Licence key module	EL6070
Ethernet module, 10/100/1000 Mbit/s	CX2500-0060

Table 2. PLC model with additional modules

The chosen PLC CPU model is the CX2033 with TwinCAT 3 runtime installed.

This model does not have a cooling fan and can be hosted inside a cabinet without introducing vibrations. It will be put inside the Power Distribution Cabinet.

The CPU computational power is expected to suffice for all MORFEO tasks (TBC).

The licences will be hosted on the EL6070 module, to be placed immediately next to the controller.

An additional Ethernet interface connection, the CX2500-0060, can be put before the PLC CPU.

With copper connections, the EK1122 modules will be employed to distribute EtherCAT connection to all subsystems. Fibre optic junctions will be used otherwise.

When possible, the EtherCAT coupler with ID switch, with copper cabling, is to be used.

Type	Model
EtherCAT coupler	EK1100
EtherCAT coupler with ID switch	EK1101
EtherCAT extension	EK1110
EtherCAT junction for star topology	EK1122
EtherCAT multi-mode fiber optic coupler with ID switch	EK1501
EtherCAT single mode fiber optic coupler with ID switch	EK1501-0010
EtherCAT multi-mode fiber optic junction	EK1521
EtherCAT single mode fiber optic junction	EK1521-0010
Bus cover	EL9011

Table 3. EtherCAT distribution modules

It is recommended that all devices like sensors and actuators communicate directly with the I/O Beckhoff modules listed in Table 5 and Table 6. For non-Beckhoff modules, like motor drives, EtherCAT interface is recommended.

Only when necessary, the modules listed in Table 4 can be employed.

Type	Model
RS232 / clamp contacts / one channel / 15m Serial Interface Communication (2400…115.2 kBaud)	EL6001
RS232 / D-Sub9 / two channel / 15m Serial Interface Communication (300…115.2 kBaud)	EL6002
RS422-485 / clamp contact / one channel / 1000m twisted pair Serial Interface Communication (2400 … 115.2 kBaud)	EL6021
RS422-485 / D-Sub9 / two channel / 1000m twisted pair Serial Interface Communication (300 … 115.2 kBaud)	EL6022
IO – Link / four channel, 20m, three wire technics Communication (4.8, 38.4 & 230.4 kBaud)	EL6224
Ethernet / RJ45 / one channel / 100m twisted pair Communication 10BASE-T/100BASE-TX	EL6601
EtherCAT Module, 4-port Ethernet switch port	EL6614
PROFINET RT Controller / RJ45 / Two Ports / 100m Max. 15 PROFINET RT Slaves / Line Topology	EL6631
PROFIBUS Master / D-Sub-9 / one channel Communication (6 kBaud…12 MBaud)	EL6731
CANopen Master-Slave Module D-Sub9 / one channel Communication (20… 1000 kBaud)	EL6751

Table 4. EtherCAT communication and converters modules

In the following table, a subgroup of the digital input and output modules from RD1 is shown. As shown in the table, for digital modules current sinking types are preferred, since most sensors available in Europe are of the sourcing PNP type.

Type	Model
4-channel digital input 24VDC, 3ms filter, 2w	EL1004
8-channel digital input 24VDC, 3ms filter, 1w	EL1008
4-channel digital input 24VDC, 10us filter, 2w, potential-free	EL1034
2-channel counter, 24VDC, up to 100kHz, with 2-channel digital output	EL1502
8-channel digital input, 24VDC, 3ms filter, 2w, internal 0V contact	EL1808
4-channel digital output 24VDC, 0.5A max per channel, 2w	EL2004
8-channel digital output 24VDC, 0.5A max per channel, 1w	EL2008
4-channel digital output 24VDC, 2A max per channel, 2w, with diagnostics	EL2044
4-channel relay output, 250VAC, 30 VDC, 4A per channel (2A per channel for inductive loads)	EL2634

Table 5. Digital input and output modules

Table 6 shows a list of analog inputs and outputs to be employed.

Type	Model
4-channel differential input, ±10V, 16-bit	EL3104
4-channel differential input, 4-20mA, 16-bit	EL3124
4-channel single-ended input, 4-20 mA, 16-bit	EL3154
4-channel single-ended input, 0-10V, 16-bit	EL3164
2-chanel PT100 module, 4w	EL3202-0010
4-channel PT100 module, 2w	EL3204
3-phase power measurement, 24-bit	EL3443
1-channel multimeter, 300V AC/DC, 10A, 19-bit	EL3681
4-channel analog output, 0-10V, 16-bit	EL4104
4-channel analog output, 4-20mA, 16-bit	EL4124

Table 6. Analog input and output modules

Finally, Table 7 lists possible system modules to close the E-bus and distribute power.

Type	Model
Shield module	EL9070
Potential supply module 24 VDC, with diagnostics	EL9110
Potential distribution, 8x24VDC, 8x0VDC	EL9184
Potential distribution, 16x24VDC	EL9188
Potential distribution, 16x0VDC	EL9189
Power supply module for E-bus, with diagnostics	EL9410

Table 7. List of system terminal modules

The selection of motor drivers and encoder modules is described in Section 9 of this document. The selection of safety modules is shown in Section 11.

6.4.2 Power Supplies

The recommended power supplies are:

Function	Type
PLC modules Power Supply (24 V)	Siemens SITOP PSU8600 Single-phase input
Field I/O Power Supply (24 V)	
Motor Power Supply (48 V)	Siemens SITOP PSU6200 Single-phase input

Table 8. List of Power supplies

The types of power supplies considered are:

- PLC modules: to power PLC and bus modules
- Field I/O: used to power the electronics I/O pins, in order to guarantee the galvanic isolation with the field I/O
- Motor: to power the motors through the motor drivers

All Power Supplies have soft start, short-circuit and overheat protection.

Additionally, the SITOP PSU8600 power supplies are provided with an OPC UA interface for remote control and monitoring of each output independently, and are expandable in a modular approach. By connecting the PSU8600 to the Control network it is then possible to remotely manage and monitor the loads of a subsystem (including the PLC itself).

To increase the operational safety of the system the implementation of redundancy mode for power supplies is under investigation, depending on the results of the RAMS analysis.

In this mode if, for some reason, there is a failure in one of the units, the others will seamlessly take over to prevent the loss of power to the electronic devices. In addition, the damaged unit can be replaced without taking the system down.

This strategy can be achieved by adding a redundant power supply to each power supply shown in the previous table. The two power supplies are managed through a dedicated Siemens redundancy module.

Finally, Siemens buffer modules can be implemented to protect the system for a few seconds from sudden power failures, allowing for a safe shutdown.

6.4.3 Cabinet management devices

In the following table the devices to be mounted inside each cabinet, for cabinet management and power distribution purposes, are listed.

Device	Function	Quantity
Mains switch	Power manual switch	1
MCB	Circuit protection	1
RCBO	Circuit protection	Depending on number of loads and their type
SPD Type 2	Overvoltage protection	1
EMC filter	EMC management	1
Undervoltage relay	Undervoltage protection	1
Inrush current limiter	Inrush current protection	Depending on number of loads
Auxiliary contacts	Monitoring of protection devices status	One for each device
Beckhoff EL1008	Digital input for auxiliary contacts, leakage, cabinet door status, general warnings	Depending on subsystem needs
Beckhoff EL2008	Digital output for control of power relays, reset of circuit breakers	Depending on subsystem needs
Beckhoff EL1502 (TBC)	2-channel up/down counter for flow meter	1
Beckhoff EL9184/9185/9188	Potential distribution modules	Depending on subsystem needs
Beckhoff EL3204	4-channel PT100 module	1
Beckhoff EL6021 (TBC)	RS485 interface module for humidity sensor	1
PT100 011-L2-LG2-PT100D2L-2.0 (TBC)	2-wire PT100 for cabinet temperature monitoring	1
Jumo 902520/10-572-1001-2/000 (TBC)	2-wire PT100 for ambient air temperature monitoring	1
PT100 014-L3-LG3-PT100D-2L-2.0 (TBC)	2-wire PT100 for inlet and outlet temperature monitoring	2
Martens Safety TL-4896 + TR296/293	Overtemperature protection	1
IFM SM6000 flow meter	Coolant flow rate monitoring	1 (2 for first cabinet in the cooling series)
Beckhoff ES4104	Analog output for valve control	1
Siemens VXP47.10/VVP47.10 - SSP61/00	Valve/actuator for coolant flow control	1
Door switch	Cabinet door state monitoring	1
Omron K7L-AT50DP + Omron F03-16	Leakage detection	1
Vaisala HMP110 (TBC)	Humidity monitoring	1

Table 9. List of cabinet management devices (TBC)

6.4.4 Cabinets layout

The internal layout of the cabinets should be, when applicable, uniform across all subsystems.

The electronic devices will be mounted on DIN rails, when possible, to facilitate the air flow inside the cabinet.

Manufacturer guidelines for installation position shall be observed for all components. Derating for the installation altitude shall also be considered if required.

From top to bottom, the order of the devices mounted inside each cabinet is as follows (TBC):

- Ethernet switch for control network (if needed) and PLC modules
- Other devices specific to the subsystem
- Power supply units
- Power distribution and protection devices
- Power distribution unit (multi-purpose sockets)

Enough space for cabling and connectors must be left at the top of the cabinet and between each unit.

An example, showing the layout of the Power Distribution Cabinet, can be seen in the following figure.

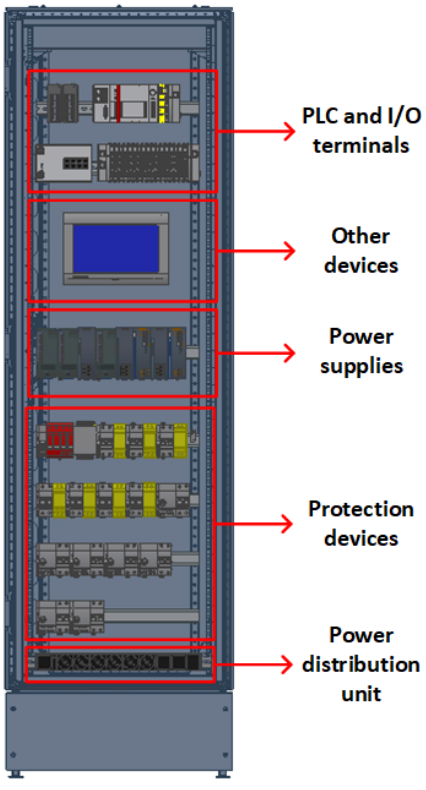

Figure 10. Power Distribution Cabinet layout

7. Harness

7.1 Harness Layout

Harness shall be reliable and maintenance friendly and shall be done according to the following basic principles:

- All cables, inside and outside the cabinets, shall be put in metallic conduit or metal ducts.
- Cables shall be protected against damage from abrasion, contact with sharp edges or protrusions and environments.
- Accessibility of cables shall be provided to the maximum extent possible. For this reason, the harness supporting devices shall provide the possibility for removal and replacement of cables for maintenance. In addition, the harness design shall foresee connector replacement capability.
- The bend radius shall not be smaller than the minimal value as specified by the cable manufacturer. Flexible cable shall be used for functions requiring movements.
- In all conduit and ducts, a spare space of 40% will be reserved.
- All cables shall be positioned as close as possible to structural components, according to the EMC requirements.
- Power and signal cables will be routed as far away as possible from each other.
- Earthed conductors shall be routed parallel to live conductors to keep earth loop areas small.
- Fibre optic cables shall be able to withstand movement and bending where applicable and shall be compliant with their harmonised product standard.
- Optical fibre type shall be single-mode (OS2 transmission standard). All fibres shall be certified for 10Gbit/s operation according to ANSI/TIA-568-C.3.

The ICH WP will provide the routing and the length of the cables, based on a harness layout design and calculations through design tools.

Each subsystem shall provide information about the subsystem cables (type, quantity, cross-section, bend radius and other relevant parameters) and the position of the devices to be routed.

Cables shall be dimensioned considering ESO thermal requirements (R-INS-757) and the position of the cabinets to be routed, as described in Section 3 of this document.

Each subsystem shall also physically procure the corresponding cables and connectors.

For the choice of the connectors the guidelines in section 7.3 shall be followed, unless COTS devices with specific connectors, different from those suggested in this document, are employed.

The coding of the connectors must be chosen to prevent incorrect mating.

7.2 Cable Identification

All cables shall be individually identifiable by means of alphanumeric codes attached to the conductor.

Identification tags will be realized in order to be legible, permanent and appropriate for the ELT environment, resistive to wear from abrasion, from presence of water, oils, etc.

The cable-labelling scheme will allow identifying as to which subsystem, equipment or part the cable belongs to.

A labelling scheme that is common to all MORFEO cables and compliant with requirements R-EED-303 to R-EED-308 of AD3 will be agreed upon in the next phase.

Colours of power cables shall be according to harmonised standard EN 60445.

7.3 Connectors

All connectors shall be marked in order to uniquely identify them.

All mating sockets shall also be correspondingly marked.

Cable connectors have to be labelled on the cable, just behind the connector, and the panel sockets have to be labelled on the panels where they are mounted.

In the following subsections connectors are recommended based on RD3.

7.3.1 PLC modules wiring

PLC modules will be wired through screwless spring connections.

The ES series of modules, with a pluggable connection level will not be selected, following the recommendations in RD1.

7.3.2 Electrical Connectors

Single-phase cables will be connected inside each cabinet through terminal blocks.

Electric power for temporary loads will be supplied from the following standardized set of connectors:

- Single-phase 230 VAC connectors: according to CEE 7/4 (SCHUKO type F). Rated current 16A.
- Single-phase 230 VAC connectors: L+N+PE, 220/250V blue type (acc. to EN 60309), earthing contact at 6h. may be used in cases where the CEE-el 7/VII (SCHUKO) type connector cannot be used.

7.3.3 Signal Connectors

Signal connectors shall be of crimped pins/terminals type and they will be chosen between the following typologies, all belonging to the M-series of circular connectors:

- M8 circular connectors for PT100 sensors, limit switches
- M8 or M12 circular connectors for other I/O signals
- M8 X-coded circular connectors for EtherCAT cables
- M12 or M23 circular connectors for motor encoder cables
- M12 or M23 circular connectors for motor cables
- LC-type connectors for optical fibres

8. Schematics

Schematics for one ELT instrument are of the size of the schematics of one complete UT.

The schematic shall be produced with a dedicated electrical schematic CAD system.

Only CAD system producing professional schematics with support of auto generation of cable lists, PLC signal lists, terminal lists etc. shall be used.

For FDR the delivery in form of a PDF file is required. A PDF file including crosslinks for connections is recommended. It is preferred if also the complete or a part of the schematic is provided as archive file of the original CAD software, in order for ESO to evaluate how to handle and maintain schematic changes.

It is not expected that schematics will be fully completed for FDR. Some missing information or estimations (e.g. on cable lengths, definitions, cross sections) can be allowed. Nevertheless, schematics should be completed on a best effort basis.

Similar functions shall be drawn in an identical manner to improve readability.

The schematics shall be constantly updated during the build process if changes are required.

8.1 Overview

The schematic shall include:

- Cover page with document reference number, title, version, date of last modification, name of editor
- Table of content
- General definitions:
  - Wiring colors
  - Item designator description/legend
- Wiring diagrams
  - Power distribution
  - PLC supplies
  - Network diagram
  - Chapters separated according to subsystems where required
- PLC assignment list
- Cabinet layout
- Automatic generated pages
  - Terminal overview
  - Terminal connection diagram
  - Cable list
  - Part list (including order no., manufacturer)

8.2 Item designation

Identifiers for electrical schematics shall be according to EN 81346 and shall be used in the label number as much as possible.

Identifier	Description
A	PLC modules, devices with no single purpose.
B	All sensor types: temperature, proximity switch, pressure measure device, photo resistor.
C	Capacitor, coil buffer battery, CD ROM, EPROM.
E	Laser, heaters, lamp, chiller.
F	Fuse, RCD, CB, overvoltage protector.
G	Tacho generator, fan (generator of air), oscillator, battery.
K	Relay, opto-coupler, analog digital converter.
M	Motor, electromagnetic valve, mechanical unit controlled by electrical signal.
P	Acoustic indicator/alarm, alarm flash light (attached to instrument cabinet)
Q	Power switch, contactor to switch power, on/off valve.
R	UPS, diode, resistor, inductor, proportional valves.
S	Command unit (button, switch).
T	Power supply, transformer, media converter (Ethernet/Fibre), signal converter (current to voltage), amplifier, frequency converter, antennas.
U	Cabinets, rooms, ducts cable wrap, casing.
V	Filter, semiconductor.
W	Cable, fiber, busbar, antenna.
X	Terminal, connector, socket, multi-sockets.
Y	Electrically controlled flow valves (as used for temperature control in cabinets).

Table 10. Identifiers for electrical schematics according to EN 81346

8.3 Wiring and schematics information

Signals flow is best shown from PLC IO to sensor on the same page, indicating locations if not at the same location. Multiple signals can be shown on one page, but the pages should be not too crowded.

Where signals go over multiple pages, the reference number of following pages shall be indicated (as done automatically in modern CAD systems). The cable item designators should always be shown for all cables on a page.

Where necessary, components can be displayed as multiple parts i.e. a power part, shown in the power distribution, a signal part shown elsewhere. The subparts are related by the item designator. Splitting power and signal makes the schematic more readable.

The cross section of wires should always be indicated in the schematic. Otherwise it is not clear if the wire cross section is sufficiently selected according to current requirements of the device and protective equipment i.e. CB in front of it.

The following information shall also be included in the schematics:

- Motorized functions schematics shall include: gearbox ratios where applicable; encoder resolution; maximum motor currents, reference motor current, nominal current; motor voltages
- Circuit breaker trip values (in particular the default value in case the trip value is selectable)
- PLC I/O variables, when possible. Otherwise, the variables shall be updated in the documentation before the next review.

Finally, the schematic pages showing safety relevant circuits shall be indicated with a yellow rectangular, with a size of at least 20mmx10mm, in the top right corner of the schematic.

9. Functions

This section provides some guidelines for the electrical functions of each subsystem, with particular focus on the choice of the devices to use for a motorized function.

In general, every command issued in a MORFEO subsystem must provide a feedback to verify whether the action was successfully executed.

24 VDC signals shall be employed for on-field I/O.

A list of all MORFEO functions, divided per subsystem, is available in RD8.

A live version of the list is constantly kept updated. The subsystem sheets can be updated by the corresponding teams on the live document.

9.1 Motor selection

When applicable, the recommended choice is a brushless DC motor.

Since a BLDC motor does not have mechanical brushes that wear down with time, it requires a lower level of maintenance. Plus, no dust is generated by the action of the brushes.

The recommended connectors for motor cables are of the M12/M23 type.

9.2 Encoder

The choice of the encoder is strongly dependent on the application, e.g. on the accuracy needed for feedback or the length of the motion.

Absolute encoders with EnDat 2.2 interface are generally recommended. This type of interface allows for longer cables compared to other standards like SSI. This characteristic proves to be particularly useful with the current position of the MORFEO control electronics cabinets.

The ELMO Gold DC Whistle is compatible with the EnDat 2.2 interface. For Beckhoff drivers, the EL5032 module is available.

The recommended connectors for encoders are of the M12 or M23 type.

9.3 Limit switch

As for the encoders, the choice of limit switches to use for a motorized function depends on the application.

A proximity type limit switch might be preferable over a mechanical limit switch, since the absence of physical contact provides longer life and better repeatability.

A PNP Normally Closed switch is recommended, in order to break the circuit when the switch is activated.

An M8 type circular connector is recommended.

9.4 Motor drive

The chosen motor drive is the ELMO Gold DC Whistle servo drive G-DCWH15/100EE, which communicates via EtherCAT with the Beckhoff PLC and behaves as an EtherCAT slave like any other Beckhoff module.

It can control both DC brushed and brushless motors, and can receive feedback from multiple types of encoder. It also has an advanced control strategy that makes it useful for tracking devices.

Furthermore, the Gold Whistle allows to achieve up to SIL3 for safe stop functions, through Safety Torque Off (STO). This way, a controlled stop of the motor can be executed, potentially increasing the overall lifetime. It is to be noted that the Gold DC Whistle STO cannot be used to control DC brushed motors.

Beckhoff DC motor drivers are currently being evaluated as an alternative to the ELMO Gold DC Whistle. However, currently the BLDC motor drive, Beckhoff EL7411, does not have a STO function.

A driver with an integrated safe stop function, Beckhoff EL7411-9014, is expected to be available for purchase starting from the second quarter of 2023 (TBC).

Even then, for other types of Beckhoff drivers where the STO function is already available, the SIL3 compliance is achieved through optimistic assumptions on the probability of faults in the module, and contactors need to be employed.

For these reasons, the ELMO Gold DC Whistle is currently still the baseline motor drive.

Only in case other types of motor need to be used, a different corresponding driver has to be employed.

For stepper motors, the Beckhoff EL7037 or EL7047 modules can be used.

ELMO Gold Oboe servo drive, G-OBO13/230FESO1, shall be used for synchronous AC motors.

10. EMC Design

During design and integration all the recommendations to avoid EMC problems will be followed.

A possible, non-exhaustive set of guidelines is:

- Common grounding of metallic parts as chassis, boards panel, structures inside the electronic cabinets.
- Galvanic insulation of the signals from the field and separation of the analogue circuit from the digital ones.
- Grounding separation between analogue and digital circuits, except one point of ground connections. In this point, situated near the entrance of the main power cable, the PE cable is also connected.
- Use of components that are EMC compliant, and, where necessary, use of EMI filter.
- Ground connections designed to offer the minimal impedance
- Special discharge parts disposable to the operator, to avoid ESD.
- Use of twisted cable.
- Minimizing the cable length
- Separation between signal cable and power cable

Potential sources of EMI are:

- DC motors
- Contactors, relays and coils

Potential victims of EMI are:

- Analog I/O
- Electrical lines

System compliancy to EMC to requirement will be verified on the basis of an agreed plan starting with verification/test/certification at subsystem level.

11. Interlocks and safety

11.1 Interlocks and safety functions

Interlocks are used to inhibit some undesired movements with intrinsic safety. Depending on the analysis (at least of hazards) of the specific case the function could also be disabled until explicitly re-enabled. They are derived directly from limit switches or indirectly from motorized function circuitry that can be set to give interlock in all possible motor status or combinations.

Interlocks will be implemented as a result of the Hazard Analysis, following the required Safety Integrity Level.

Both interlocks and other safety functions, like emergency buttons and functional lockouts, can be controlled with dedicated Beckhoff safety modules. At least one safety controller needs to be included in the entire system, but multiple controllers can also be employed. The safety modules can be chosen from the table below.

Topology	Model
Logic Module	EL6910
Digital Input	EL1904/EL1918
Digital Output	EL2904/EL2912

Table 11. PLC Safety Modules list

Examples of safety applications will be available in RD2.

The interface between the Local Safety Unit and the Central ILS is achieved via a hardwired IO connection, as shown in the following figure (TBC).

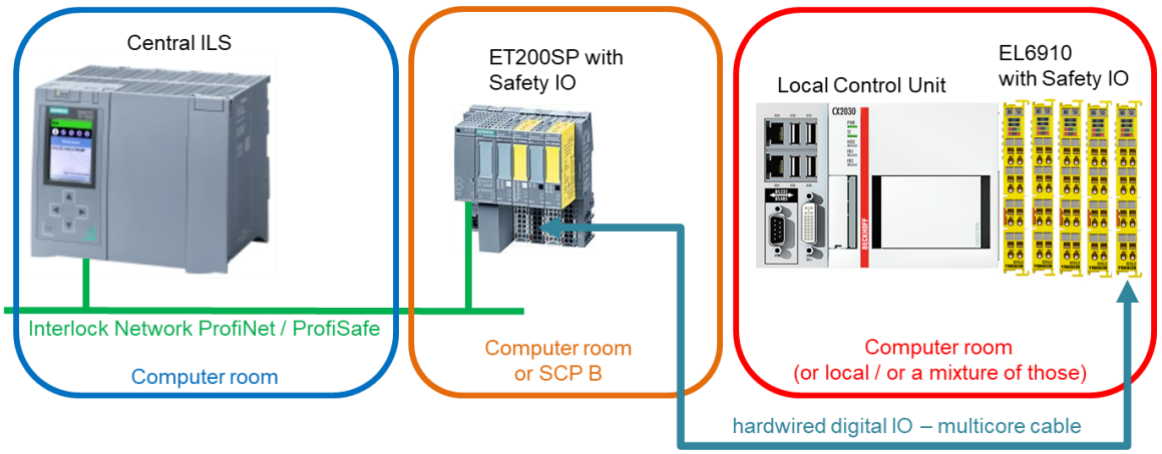

Figure 11. Interface between Central ILS and LSU

11.2 Safety measures

ESO safety requirements specified in *E-ELT electrical and Electronic Design Requirements* (AD3) shall be considered as applicable for the MORFEO instrument control hardware.

The electronic HW design follows the safety requirements, as described in AD6, taking into account:

- Grounding connection
- Earth connection
- Functions monitoring
- Levels monitoring
- Use of low voltage where possible.
- Electrical interlocks
- Overload and short circuit protection
- Clear identification of cables, connectors, boards, sockets.
- Safety label and separation wall in case of dangerous zone.

The following alarms need to be issued:

- Overtemperature inside the cabinet
- Leakage detection
- Open cabinet door
- Tripped circuit breaker
- Emergency button pressed
- Functional lockout switched on
- Interlock activated

12. Subsystems integration

12.1 Documentation

The control electronics documentation for each subsystem should follow, where possible, the structure used for RD2. This solution is functional to a potential integration of all the subsystem documents, since the matching table of contents would allow the creation of subsections for each subsystem in the same paragraph of the general report.

12.2 Power and mass budgets

The MORFEO Instrument Control Hardware system has the following overall allocated budgets for power and mass:

- Average normal power (over 24 hours): 10.4 kW
- Peak normal power: 25 kW
- Average safety power (over 24 hours): 0.5 kW
- Total mass: 3000 kg

Starting from these requirements, each subsystem has its own power and mass allocated budgets for its electronics, as described in the specific Interface Requirements document with the ICH WP (e.g. PHO2PLO Interface), and the respective section of the Instrument Control Hardware Interface Control Document (RD3). A comprehensive list of all subsystems budgets can be found in RD2.

Appendix A. List of ESO standard PLC modules

The following is a list of all the ESO standard PLC modules, according to RD1. The use of these modules is possible without any further interaction with ESO.

The modules to be used in MORFEO are a subset of this list, as described in the previous sections of this document. Other modules from this list can be chosen if needed, after an interaction with ICH.

Modules for specific applications that are not present in this list can also be chosen, but only after a Request for Deviation is approved by ESO and an alternative solution from this list is not found.

Type	Model
CPU module	CX2033-0175
CPU module for demanding applications, fan-cooled	CX2043-0175
Intel Xeon CPU module, clock rate of 2.2 GHz (4 cores)	CX2042-0175
2 x 10G Ethernet interface (optical, 2 x SFP + cage)	CX2042-N167
Collocated Power Supply, attached to CPU for CX-2030/CX-2040	CX2100-0004 CX2100-0014
Interface module for 10/100/1000 Mbit Ethernet	CX2500-0060
Embedded PC with EtherCAT Interface & Address switch Programming via separate Ethernet Port (For simple, remote applications like cabinet cooling etc.)	CX8110
Licence module	EL6070
Licence key USB stick	C9900-L100
EtherCAT coupler	EK1100
EtherCAT coupler with ID switch	EK1101
EtherCAT extension	EK1110
EtherCAT junction for star topology	EK1122
EtherCAT multi-mode fiber optic coupler with ID switch	EK1501
EtherCAT single mode fiber optic coupler with ID switch	EK1501-0010
EtherCAT multi-mode fiber optic junction	EK1521
EtherCAT single mode fiber optic junction	EK1521-0010
Bus cover	EL9011
EtherCAT coupler with TwinSAFE I/Os	EK1914
RS232 / clamp contacts / one channel / 15m Serial Interface Communication (2400…115.2 kBaud)	EL6001
RS232 / D-Sub9 / two channel / 15m Serial Interface Communication (300…115.2 kBaud)	EL6002

Type	Model
RS422-485 / clamp contact / one channel / 1000m twisted pair Serial Interface Communication (2400 … 115.2 kBaud)	EL6021
RS422-485 / D-Sub9 / two channel / 1000m twisted pair Serial Interface Communication (300 … 115.2 kBaud)	EL6022
IO – Link / four channel, 20m, three wire technics Communication (4.8, 38.4 & 230.4 kBaud)	EL6224
Ethernet / RJ45 / one channel / 100m twisted pair Communication 10BASE-T/100BASE-TX	EL6601
EtherCAT Module, 4-port Ethernet switch port	EL6614
PROFINET RT Controller / RJ45 / Two Ports / 100m Max. 15 PROFINET RT Slaves / Line Topology	EL6631
PROFIBUS Master / D-Sub-9 / one channel Communication (6 kBaud…12 MBaud)	EL6731
CANopen Master-Slave Module D-Sub9 / one channel Communication (20… 1000 kBaud)	EL6751
4-channel digital input 24VDC, 3ms filter, 2w	EL1004
8-channel digital input 24VDC, 3ms filter, 1w	EL1008
4-channel digital input 24VDC, 10us filter, 2w, potential-free	EL1034
2-channel counter, 24VDC, up to 100kHz, with 2-channel digital output	EL1502
4-channel digital input 24VDC, 3ms filter, 2w, low-side switching	EL1084
8-channel digital input 24VDC, 3ms filter, 1w, low-side switching	EL1088
4-channel digital input 5 VDC, 0.05us filter, 3w	EL1124
8-channel digital input 24VDC, 1us filter + 8-channel digital output 24VDC, 0.5 A max per channel, 1w, multi-timestamp	EL1259
8-channel digital input 24VDC, 3ms filter, 2w, reference to 0V power contact	EL1808
16-channel digital input 24VDC, 3ms filter, 1w, reference to 0V power contact	EL1809
8-channel digital input 24VDC, 3ms filter + 8-channel digital output 24VDC, 0.5 A max per channel, flat-ribbon cable	EL1852
8-channel digital input 24VDC, 3ms filter + 8-channel digital output 24VDC, 0.5A max per channel, 1w, reference to 0V power contact	EL1859
16-channel digital input 24VDC, 3ms filter, 2w, flat-ribbon cable	EL1862-0010
4-channel digital output 24VDC, 0.5A max per channel, 2w	EL2004
8-channel digital output 24VDC, 0.5A max per channel, 1w	EL2008
4-channel digital output 24VDC, 2A max per channel, 2w, with diagnostics	EL2044
4-channel relay output, 250VAC, 30 VDC, 4A per channel (2A per channel for inductive loads)	EL2634
4-channel digital output 5VDC, 20mA max per channel, 2w, low-side switching	EL2124
2-channel digital output 24VDC, 0.5A max per channel, 4w, push-pull output, oversampling	EL2502

Type	Model
2-channel PWM output 24VDC, 1A max per channel, current-controlled, inductive loads >1mH	EL2535
2-channel relay output, 125VAC, 30VDC, 0.5A AC, 2A DC, change-over contacts	EL2612
2.channel relay output, 230VAC, 300VDC, 1A, change-over contacts	EL2652
16-channel digital output 24VDC, 0.5A max per channel, 1w, with diagnostics, reference to 0V power contacts	EL2819
16-channel digital output 24VDC, 0.5A max per channel, 1w, flat-ribbon cable	EL2872
16-channel digital output 24VDC, 0.5A max per channel, 1w, low-side switching, flat-ribbon cable	EL2872-0010
4-channel differential input, ±10V, 16-bit	EL3104
4-channel differential input, 4-20mA, 16-bit	EL3124
4-channel single-ended input, 4-20 mA, 16-bit	EL3154
4-channel single-ended input, 0-10V, 16-bit	EL3164
2-chanel PT100 module, 4w	EL3202-0010
4-channel PT100 module, 2w	EL3204
3-phase power measurement, 24-bit	EL3443
1-channel multimeter, 300V AC/DC, 10A, 19-bit	EL3681
2-channel differential input, ±10V, 16-bit	EL3102
4-channel differential input, 0-20 mA, 16-bit	EL3114
2-channel single-ended input, 0-10V, 16-bit	EL3162
4-channel analog multi-function input, differential ±10V, single-ended ±20mA, 16-bit, diagnostics according to NAMUR NE43	EL3174
4-channel analog multi-function input, differential ±10V, single-ended ±20mA, 16-bit, diagnostics according to NAMUR NE43, electrical isolation 2500VDC	EL3174-0002
8-channel PT100 module, 2w	EL3208
4-channel PT100 module, 3w	EL3214
1-channel analog input, measuring bridge, full bridge, 24-bit	EL3356-0010
2-channel differential input, ±10V, 16-bit, oversampling	EL3702
4-channel analog output, 0-10V, 16-bit	EL4104
4-channel analog output, 4-20mA, 16-bit	EL4124
4-channel analog output, ±10V, 16-bit	EL4134
2-channel analog output, ±10V, 16-bit, oversampling	EL4732
1-port communication interface, IEEE 1588/PTP, for external time synchronization	EL6688
2-channel DC motor driver, 24VDC, 1A	EL7332
2-channel DC motor driver, 48VDC, 3.5A, with incremental encoder	EL7342
1-channel BLDC motor driver, 48VDC, 4.5A, with incremental encoder	EL7411

Type	Model
1-channel stepper motor driver, 24VDC, 1.5A, with incremental encoder	EL7037
1-channel stepper motor driver, 48VDC, 5A, with incremental encoder	EL7047
1-channel servomotor driver, 48VDC, 2.8A, with resolver	EL7201
1-channel servomotor driver, 48VDC, 2.8A, One Cable Technology	EL7201-0010
1-channel servomotor driver, 48VDC, 4.5A, One Cable Technology	EL7211-0010
2-channel compact servo drive, 1.5 to 6A, multiple feedback types	AX5203
Brake chopper module	EL9576
1-channel absolute encoder, SSI interface	EL5001
2-channel absolute encoder, SSI interface	EL5002
1-channel Sin-Cos encoder	EL5021
2-channel EnDat 2.2 encoder	EL5032
2-channel absolute encoder, BiSS C or SSI interface	EL5042
2-channel displacement sensor, inductive, LVDT, RVDT, half bridge	EL5072
1-channel incremental encoder	EL5101
2-channel incremental encoder	EL5102
1-channel incremental encoder, oversampling	EL5101-0010
2-channel incremental encoder, differential RS422, TTL, open collector	EL5112
2-channel incremental encoder, 24VDC HTL, or up-down counter	EL5152
DC servo drive, 15A, multiple feedback types	Gold DC Whistle G-DCWHI15/100EE
DC integrated servo drive, 15A, multiple feedback types	Gold Solo Whistle G-SOLWHI 15/100 EES
AC servo drive, 13A, multiple feedback types	Gold Oboe G-OBO13/230FESO1
DC PCB mounted servo drive, 6A, multiple feedback types	Gold Twitter G-TWIR 06/100EE
Stepper driver, 5A, multiple feedback types	Gold DC Bell G-DCBEL 5/100 EES
Stepper driver, 5A, multiple feedback types, resolver interface	Gold DC Bell G-DCBEL 5/100 ERS
Shield module	EL9070
Potential supply module 24 VDC, with diagnostics	EL9110
Potential distribution, 8x24VDC, 8x0VDC	EL9184

Type	Model
Potential distribution, 16x24VDC	EL9188
Potential distribution, 16x0VDC	EL9189
Power supply module for E-bus, with diagnostics	EL9410
Potential distribution, 4x24VDC	EL9185
1-channel overcurrent protection, 24VDC, 4A max, adjustable	EL9221-6000
Power supply module, input 24VDC, output 5VDC 0.5A, input/output not electrically isolated	EL9505
Power supply module, input 24VDC, output 12VDC, input/output not electrically isolated	EL9512
Power supply module, input 24VDC, output 15VDC, input/output not electrically isolated	EL9515
Safety module: 4-channel digital input 24VDC, 2w	EL1904
Safety module: 8-channel digital input 24VDC, 2w, TwinSAFE logic	EL1918
Safety module: 4-channel digital output 24VDC, 0.5A max per channel, 2w	EL2904
Safety module: 2-channel digital output 24VDC, 2A max per channel, 2w, TwinSAFE logic	EL2912
Safety module: EtherCAT coupler with standard and safety digital I/Os	EK1914
Safety module: TwinSAFE SC 4-channel multi-function analog input, ±10 V, ±20 mA, 16-bit	EL3174-0090
Safety module: TwinSAFE SC, 4-channel analog input PT100 module, 3w	EL3214-0090
Safety module: TwinSAFE logic controller	EL6910

Table 12. Full list of ESO recommended PLC modules

***** End of document *****