ASTRI Mini-Array
Common Technical Standards

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DOCUMENT HISTORY		
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1.0	22/12/2020	Initial draft for internal discussion and comments
1.1	07/01/2020	First release

1. Introduction

The ASTRI Array will exploit the imaging atmospheric Cherenkov technique to measure the energy, direction and arrival time of gamma-ray photons arriving at the Earth from astrophysical sources. In the almost unexplored energy range 1-300 TeV this technique requires an array of optical telescopes (~ 4 m in diameter) at a site located at an altitude of > 2000m. The telescope shall have UV-optical reflecting mirrors focusing the Cherenkov light produced by atmospheric particle cascades (air-showers) onto ultra-fast (nanosecond timescale) cameras. Most of the collected data will come from the large number of charged cosmic-ray initiated air-showers, that shall also be recorded, then appropriate data analysis methods shall be employed to reduce the level of this background and allow an efficient detection of gamma-ray coming from astronomical sources. On the other hand, the great amount of reordered cosmic-ray allows to measure some of their main properties like compositions, position of the “knee” in the spectral energy distribution. To exploit the cosmic-ray science the ASTRI Array telescope shall be able to be pointed at large (>70°) zenith angles.

The site selected for the ASTRI Array is the Observatorio del Teide in Tenerife, that is operated by the Instituto de Astrofisica de Canarias (IAC).

Scope

This document provides the list of all international and national standard to be followed in designing, construct and install all systems that are part of the ASTRI Mini-Array.

Abbreviations and acronyms

The following abbreviations and acronyms are used in this document:

1oo1	One out of one
1oo2	One out of two
AC	Alternating Current
AIT	Assembly Integration and Testing
AIV	Assembly Integration and Verification
ASIC	Application Specific Integrated Circuits
ASTRI	Astrofisica con Specchi a Tecnologia Replicante Italiana
AR	Camera Acceptance Review
ATM	Asynchronous Transfer Mode
ATRR	Acceptance Test Readiness Review
BEE	Back End Electronics
BOM	Bill of Material

CAN	Controller Area Network
CB	Circuit Breaker
CDR	Critical Design Review
CE	Conformité Europeenne
CEN	European Standards Coordinating Committee
CENELEC	European Committee for Electrotechnical Standardisation
CFI	Customer Furnished Item
CITIROC	Cherenkov Image Telescope Integrated Read Out Chip
COTS	Commercial Off The Shelf
EHSR	Essential Health and Safety Requirements
EM	Electromagnetic
EMC	Electro Magnetic Compatibility
EN	European Norm
ESD	Electrostatic Discharge
ESO	European Organisation for Astronomical Research in the Southern Hemisphere
EU	European Union
EUT	Equipment Under Test
FEE	Front End Electronics
FEM	Finite Element Analysis
FC	Frequency Converter
FPGA	Field Programmable Gate Array
FMECA	Failure Mode Effects and Criticality Analysis
HF	High Frequency
HFT	Hardware Failure Tolerance
HW	Hardware
I/O	Input/Output
IAC	Instituto de Astrofísica de Canarias
IEC	International Electrotechnical Commission
ILS	Interlock and Safety System
INAF	Istituto Nazionale di Astrofisica

IP	International Protection (EN 60529)
ISO	International Organisation for Standardisation
ITE	Information Technology Equipment
ITW	Integration Time Window
IZO	Izaña Atmospheric Observatory
KOM	Kick Off Meeting
LAN	Local Area Network
LCU	Local Control Unit
LED	Light Emitting Diode
LEMP	Lightning Electromagnetic imPulse
LLI	Long Lead Items
LPZ	Lightning Protection Zone
LRU	Line Replaceable Unit
LSZH	Low-Smoke Zero-Halogen
LV	Low Voltage
MA	Mini Array
MIUR	Ministero dell'Istruzione, dell'Università e della Ricerca
MTTR	Mean time to repair
N/A	Not applicable
n.c.	Normally closed
n.o.	Normally open
OT	Observatorio el Teide
PA	Product Assurance
PBC	Protective Bonding Circuit
PBS	Product Breakdown Structure
PCB	Printed Circuit Board
PDM	Photon Detection Module
PDR	Preliminary Design Review
PELV	Protective Extra Low Voltage
PFD	Probability of Failure on Demand

PFH	Probability of dangerous Failure per Hour
QA	Quality Assurance
QR	Qualification Review
QTRR	Qualification Test Readiness Review
PLC	Programmable Logic Controller
POE	Power over Ethernet
RAMS	Reliability, Availability, Maintainability and Safety
RAM	Reliability, Availability and Maintainability
RR	Camera Requirements Review
SCADA	Supervisory Control And Data Acquisition system
SE	System Engineering
SIL	Safety Integrity Level
SiPM	Silicon Photo-Multiplier
SLN	Serra La Nave
SMM	Structural Mathematical Model
SOW	Statement of Work
SPD	Surge Protective Device
SRCF	Safety Related Control Function
SRECS Control System	Safety-Related Electrical, electronic and programmable electronic
SRS	Safety Requirements Specification
SW	Software
TCS	Telescope Control Software
TE	Test Equipment
TMM	Thermal Mathematical Model
UPS	Uninterruptible Power Supply
VCD	Verification Control Document
VDB	Voltage Distribution Box
VHE	Very High Energy
WR	White Rabbit

2. Related Documents

Applicable Documents

[AD1] ASTRI Mini Array Environmental Conditions, ASTRI-INAF-SPE-2000-002

[AD2] Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on Machinery, and amending Directive 95/16/EC

[AD3] MIL-HDBK-338B, MILITARY HANDBOOK: ELECTRONIC RELIABILITY DESIGN HANDBOOK

[AD4] MIL-HDBK-217F, MILITARY HANDBOOK: RELIABILITY PREDICTION OF ELECTRONIC EQUIPMENT

[AD5] EN Eurocode 0 - Basis of Structural Design

[AD6] EN Eurocode 3 Steel – Design of Steel Structures – All parts

[AD7] EN Eurocode 4 Design of Composite Steel and Concrete Structures – All parts

[AD8] EN Eurocode 9 Design of Aluminium Structures – All parts

[AD9] EN 61010-1, “Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements”.

[AD10] EN 62061, “Safety of machinery, Functional safety of safety-related electrical, electronic and programmable electronic control systems”

[AD11] EN ISO 13849-1, “Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design”

[AD12] EN ISO 13850, “Safety of Machinery – Emergency Stop – Principles for design”

[AD13] EN 60364 series, “Low-voltage electrical installations”

[AD14] EN 60445, “Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors”, 2010

[AD15] EN 60664 series, “Insulation coordination for equipment within low-voltage systems”

[AD16] MIL-STD-756B Reliability Modeling and Prediction

[AD17] MIL-STD-882E System Safety

[AD18] MIL-STD-1629A Procedures for performing a Failure Mode, Effects and Criticality Analysis

[AD19] ASTRI Mini-Array Common Technical Requirements ASTRI-INAF-SPE-2000-0001

[AD20] EMC Directive 2004/108/EC

[AD21] EN 61000 series, “Electromagnetic Compatibility (EMC)”

[AD22] Functional Safety and IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems

[AD23] IEC 61131-3, Programmable controllers - Part 3: Programming languages

[AD24] Telecommunications and information exchange between systems - Local and metropolitan area networks - Part 3. IEEE Std 802.3-2018

[AD25] Industrial Communication Networks - Fieldbus Specifications - Part 6-10:

[AD26] Application layer protocol specification - Type 10 elements. IEC 61158-6-10:2019

[AD27] OPC Unified Architecture Specification. IEC 62541.

[AD28] Precision clock synchronization protocol for networked measurement and control systems. IEEE Std 1588-2019.

[AD29] Network Time Protocol. RFC 1305, Version 3.

[AD30] Quantities and Units. ISO 80000

[AD31] Data Elements and interchange formats - Information Interchange - Representation of dates and times. ISO 8601-1:2019

[AD32] EN 60204-1, “Safety of machinery - Electrical equipment of machines - Part 1: General requirements”.

[AD33] DECRETO 141/2009, de 10 de noviembre, por el que se regulan los procedimientos administrativos relativos a la ejecución y puesta en servicio de las instalaciones eléctricas en Canarias.

[AD34] REAL DECRETO 1955/2000, de 1 de diciembre, por el que se regulan las actividades de transporte, distribución, comercialización, suministro y procedimientos de autorización de instalaciones de energía eléctrica.

[AD35] Reglamento Electrotécnico para Baja Tensión aprobado por el REAL DECRETO. 842/ 2002 e Instrucciones Técnicas Complementarias.

[AD36] Orden de 16 de abril de 2010, por la que se aprueban las normas particulares para las instalaciones de enlace en el ámbito de suministro de Endesa Distribución Eléctrica S.L.U. y Distribuidora Eléctrica del Puerto de La Cruz.

[AD37] Resolución de 5 de diciembre de 2018, de la Dirección General de Industria y de la Pequeña y Mediana Empresa, por la que se aprueban especificaciones particulares y proyectos tipos de Endesa Distribución Eléctrica, SLU.

[AD38] Ley 24/2013, de 26 de diciembre, del Sector Eléctrico.Real

[AD39] Decreto 1048/2013, de 27 de diciembre, por el que se establece la metodología para el cálculo de la retribución de la actividad de distribución de energía eléctrica.

[AD40] Ley 7/2011, de 5 de abril, de actividades clasificadas y espectáculos públicos y otras medidas administrativas complementarias

[AD41] Decreto 52/2012, de 7 de junio, por el que se establece la relación de actividades clasificadas y se determinan aquellas a las que resulta de aplicación el régimen de autorización administrativa previa.

[AD42] 26 DECRETO 90/2010, de 22 de julio, por el que se regula la actividad turística de restauración y los establecimientos donde se desarrolla.

[AD43] DECRETO 53/2012, de 7 de junio, por el que se regulan los requisitos y el procedimiento aplicable al régimen de comunicación previa en materia de actividades clasificadas.

[AD44] Ley 12/2012, de 26 de diciembre, de medidas urgentes de liberación del comercio y de determinados servicios.

[AD45] REAL DECRETO 314/2006, de 17 de marzo, por el que se aprueba el Código Técnico de la Edificación.

[AD46] Real Decreto 2267/2004, de 3 de diciembre, por el que se aprueba el Reglamento de seguridad contra incendios en los establecimientos industriales.

[AD47] DECRETO 16/2009, de 3 de febrero, por el que se aprueban Normas sobre documentación, tramitación y prescripciones técnicas relativas a las instalaciones, aparatos y sistemas contra incendios, instaladores y mantenedores de instalaciones.

[AD48] REAL DECRETO 513/2017, de 22 de mayo, por el que se aprueba el Reglamento de instalaciones de protección contra incendios

[AD49] DECRETO 134/2011, de 17 de mayo, por el que se aprueba el Reglamento por el que se regulan las instalaciones interiores de suministro de agua y de evacuación de aguas en los edificios.

[AD50] REAL DECRETO 1890/2008, de 14 de noviembre, por el que se aprueba el Reglamento de eficiencia energética en instalaciones de alumbrado exterior y sus Instrucciones técnicas complementarias EA-01 a EA-07.

[AD51] REAL DECRETO 1027/2007, de 20 de julio, por el que se aprueba el Reglamento de Instalaciones Térmicas en los Edificios.

[AD52] REAL DECRETO 238/2013, de 5 de abril, por el que se modifican determinados artículos e instrucciones técnicas del Reglamento de Instalaciones Térmicas en los Edificios, aprobado por Real Decreto 1027/2007, de 20 de julio.

[AD53] Reglamento (UE) nº305/2011, de 9 de marzo de 2011, por el que se establecen condiciones armonizadas para la comercialización de productos de la construcción y se deroga la Directiva 89/106/CEE del Consejo.

[AD54] Reglamento Delegado (UE) 2016/364, de 1 de julio de 2015, relativo a la clasificación de las. propiedades de reacción al fuego de los productos de la construcción.

[AD55] REAL DECRETO 773/97 sobre disposiciones mínimas de seguridad y salud relativas a la utilización por los trabajadores de equipos de protección personal.

[AD56] REAL DECRETO 614/2001, de 8 de junio, sobre disposiciones mínimas para la protección de la salud y seguridad de los trabajadores frente al riesgo eléctrico.

[AD57] Ley 31/1995, de 8 de noviembre, de Prevención de Riesgos Laborales.

[AD58] REAL DECRETO 39/1997, de 17 de enero, por el que se aprueba el Reglamento de los servicios de prevención. Memoria 01-02_MEM_BT_29-20 Septiembre de 2020 11/44

[AD59] REAL DECRETO 485/1997, de 14 de abril, sobre disposiciones mínimas en materia de Señalización de Seguridad y Salud en el trabajo.

[AD60] REAL DECRETO 486/1997, de 14 de abril, por el que se establecen las disposiciones mínimas de seguridad y salud en los lugares de trabajo.

[AD61] REAL DECRETO 487/1997. Del 23 de abril. Disposiciones mínimas de seguridad y salud, relativas a manipulación manual de cargas que entrañen riesgos, en particular dorso lumbares para los trabajadores.

[AD62] REAL DECRETO 1627/1997, de 24 de octubre, por el que se establece las disposiciones mínimas de seguridad y salud en las obras de construcción.

[AD63] REAL DECRETO 1215/1997, de 18 de julio. Utilización de los equipos de trabajo.

[AD64] REAL DECRETO 1523/1999, de 1 de octubre, por el que se modifica el Reglamento de instalaciones petrolíferos, aprobado por Real Decreto 2085/1994, de 20 de octubre, y las instrucciones técnicas complementarias MI-IP03, aprobada por el Real Decreto 1427/1997, de 15 de septiembre, y MI-IP04, aprobada por el Real Decreto 2201/1995, de 28 de diciembre.

[AD65] RAEE: Real Decreto sobre aparatos eléctricos y electrónicos y la gestión de sus residuos.

[AD66] ROHS Directiva 2002/95CE: Restricciones de la utilización de determinadas sustancias peligrosas en aparatos eléctricos y electrónicos.

Reference Documents

3. Glossary, Definitions and Conventions

According to [AD2], '*machinery*' is defined as:

- an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application,
- an assembly referred to in the first indent, missing only the components to connect it onsite or to sources of energy and motion,
- an assembly referred to in the first and second indents, ready to be installed and able to function as it stands only if mounted on a means of transport, or installed in a building or a structure,
- assemblies of machinery referred to in the first, second and third indents or partly completed machinery referred to in point (g) which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole,
- an assembly of linked parts or components, at least one of which moves, and which are joined together, intended for lifting loads and whose only power source is directly applied human effort

The safety of designs falling into this category will be dealt with via the Machinery Directive (See [AD2]).

- Burst: A sequence of a limited number of distinct pulses or an oscillation of limited duration.
- Electromagnetic compatibility (EMC): The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.
- Electromagnetic interference (EMI): Degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance. Note: Disturbance and interference are respectively cause and effect.
- Emission level (of a disturbing source): The level of a given electromagnetic disturbance emitted from a particular device, equipment or system in a specified way.
- Emission limit: The specified maximum emission level of a source of electromagnetic disturbance.
- Enclosure port: The physical boundary of the apparatus through which electromagnetic fields may radiate or impinge.
- Harmonic (component): A component of order greater than one of the Fourier series of a periodic quantity.
- (Total) harmonic factor: The ratio of the r.m.s. value of harmonic content to the r.m.s. value of an alternating quantity.
- Immunity (to a disturbance): The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

- Immunity level: The maximum level of a given electromagnetic disturbance incident on particular device, equipment or system for which it remains capable of operating at a required degree of performance.
- Immunity limit: The specified minimum immunity level.
- Port: Particular interface of the specified apparatus with the external electromagnetic environment.

Harmonised standard means a non-binding technical specification adopted by a standardisation body, namely the European Committee for Standardisation (CEN), the European Committee for Electrotechnical Standardisation (CENELEC) or the European Telecommunications Standards Institute (ETSI), on the basis of a remit issued by the Commission in accordance with the procedures laid down in Directive 98/34/EC of the European Parliament and of the Council of 22 June 1998 laying down a procedure for the provision of information in the field of technical standards and regulations and of rules on Information Society services.

4. Electrical and Electronic Standards

This section describes the requirements for electrical and electronic equipment and systems of the ASTRI Mini Array project.

4.1. General principles

The design of any device, equipment or system containing electrical and/or electronic parts shall be compliant with the standards described in section 3 and shall consider the environmental conditions at Teide Observatory including altitude. All electronic components shall be mounted on standardized printed circuit boards and contained into standardized boxes and cabinets. All cables and connector shall be of high quality and standardized. Control systems shall use standardized Local Control Units (LCUs, e.g. PLCs). Any of any device, equipment or system shall be suitable to be powered by the ASTRI Mini Array electric power supply system at Teide Observatory.

Safety-Related Electrical Control Systems[1] (SRECS) shall satisfy the appropriate Safety Integrity Level[2] for functional safety.

Any of any device, equipment or system shall be designed in a modular way, making use of Line Replaceable Units (LRU) to minimize the repair time.

Any of any device, equipment or system shall be designed considering that it can be accessed by other systems to obtain the status signals of electronic units.

4.2. Safety

Systems and subsystems (made up of components and equipment) shall comply with the health and safety requirements (EHSR) contained in all applicable EU Directives.

In case a system is classified as a machinery EN 60204-1 shall be compliant with the Machinery Directive and Low Voltage Directive plus any additional applicable harmonised standard.

Components and equipment used on systems shall comply with their harmonised EN product or product-family standard or, in case this is not available, a generic standard. The following hierarchy of Standards shall be applied:

1. EN standards
2. ISO standards
3. DIN, BS, or other equivalent national standards
4. Design guidelines from professional organizations

[1] **Safety-Related Electrical Control System**: electrical control system of a machine whose failure can result in an immediate increase of the risk(s). (SRECS includes all parts of an electrical control system whose failure may result in a reduction or loss of functional safety and this can comprise both electrical power circuits and control circuits).

[2] **Safety Integrity Level**: discrete level (one out of a possible three) for specifying the safety integrity requirements of the safety-related control functions to be allocated to the SRECS, where safety integrity level three has the highest level of safety integrity and safety integrity level one has the lowest.

Commercially available equipment (COTS) shall bear the CE mark. In case suitable equipment with a CE mark is not available, the usage of non-CE marked equipment shall receive explicit approval by the ASTRI Project and shall follow the EHSRs of the applicable Directives (the latest edition/revision in effect at this time shall be considered).

Custom made products shall be checked for compliance to the most appropriate harmonised standards under the scope of the applicable Directives.

4.3. EU Directives

The main EU directive of interest for all the device, equipment or system to be built or acquired for the scope of the ASTRI Mini-Array are briefly introduced.

4.3.1. Machinery Directive

The Machinery Directive 2006/42/EC applies to machinery. It requires a hazard analysis /risk assessment to be completed for all products falling under its scope. Also, Annex 1 specifies health and safety requirements (EHSR) that are to be considered.

4.3.2. Low Voltage Directive

The Low Voltage Directive 2006/95/EC specifies EHSRs to ensure that electrical equipment within certain voltage limits provide an acceptable level of protection. It covers electrical equipment with voltage between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current.

For the electrical installation of the ASTRI Mini-Array at Teide the reference is the Spanish “Reglamento Electrotécnico para baja tensión e ITC” (www.boe.es/biblioteca_juridica/) that transposes the EU directive.

4.4. Digital Logical Signals

All interconnection with relays or optocouplers and shall be galvanically isolated according to the applicable norms. The interconnection cable shall be shielded. The voltage level of logic signals shall be 24 VDC.

4.5. Analog Signals

Analog signals shall either be of voltage or current type. Cables used for these connections shall guarantee the proper shielding properties to fully ensure electromagnetic compatibility (EMC) of the carried signal. For long cable interconnections, current-type analog signals shall be used and restricted to 4-20mA level.

4.6. Cabling

Cables installed for any purpose and application (power, control, telecommunication, data, signal, etc.), whether electrical or optical, shall be fire retardant and UV radiation

resistant. The same properties shall be exhibited by any cable routing means (e.g. ducts) made of non-metallic materials.

4.6.1. Cables protection

In order to be protected against mechanical damages, where feasible and necessary, all cables shall be put inside conduit, ducts, or cable ways. Additionally, the cables shall be protected against damage from abrasion, contact with sharp edges or protrusions and environments. All utilities shall be strain relieved at all disconnects and end points.

Single core cables without external sheathing or jacket, i.e. insulated conductors, shall be installed only in conduits or in protective PVC trunking cases, e.g. in switchboards or apparatus.

4.6.2. Cable ways type

Carriers and ways shall be based upon Common off the Shelf (COTS) equipment. Where cable carriers and ways are used they shall have removable dividers and shelves installed to maintain the relationships between cables and hoses. Cable carriers shall be made of self-lubricating materials and be capable of all required bend radii and movements.

4.6.3. Cable ways materials

All cable trays, ladder and accessories for external installations shall be made of non-corroding materials or they shall be protected by hot-dip galvanizing or equally effective corrosion inhibiting process. The materials shall not be affected by sun radiation or heat.

4.6.4. Cable ways clearance

Inside cable conduits and ducts at least 20% spare space (where feasible) shall be reserved for future use.

4.6.5. Electrical bonding

In case of metallic cable ways, there shall be the provision for electrical bonding of adjacent lengths to each other, thereby ensuring, that the entire length of a run of cable tray or ladder will be electrically continuous.

4.6.6. EMC constraints

Power and signal cables shall be preferably shielded from low and high-frequency interference. The shielded cables, where possible, shall be bonded at each ends with 360° iris connection, avoiding “pig tail” connection. Whenever possible, power and signal wires shall be routed separately. The cabling design shall avoid ground loops.

4.6.7. Cables bending radius

The bending radius shall not be smaller than the minimal value as specified by the cable (or cable conduit) manufacturer.

4.6.8. Cable voltage levels

Cables for different voltage levels shall always be separated by a physical barrier, or the cables for lower voltages shall be insulated for the highest voltage in the parallel run.

4.6.9. Conductors identification

The conductors of the cables shall be identified by colours or numerals in conformity with IEC 60445.

4.6.10. Power Cables

At Teide the ASTRI Mini Array voltage AC power distribution systems are implemented as a TN-S system.

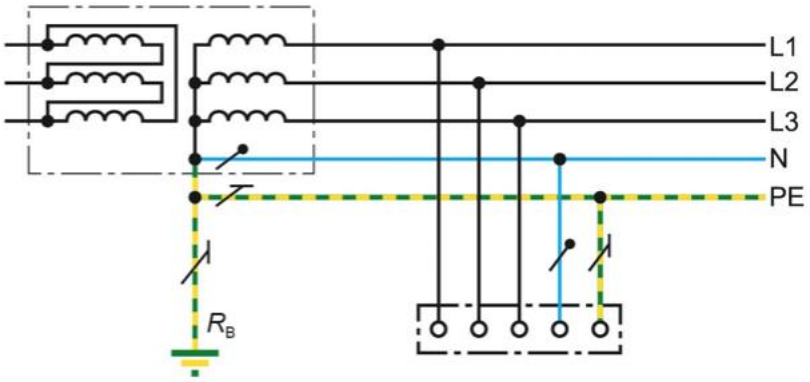

Figure 4-1: TN-S system

AC power cables shall therefore contain:

- L1, L2, L3, N (neutral) and PE (protective earth) for three phase power cables.
- L (line conductor), N (neutral) and PE (protective earth) for single phase power cables.

All power cables (AC or DC) and relevant connection terminals shall bear identification in full compliance with the requirements of EN 60445.

Table A.1 – Colours, alphanumeric notations and graphical symbols used for identification of conductors and terminals

Designated conductors/terminals		Identification of conductors / terminals by				
		Alphanumeric notations [a]		Colours		Graphical symbols [b]
		Conductors	Terminals			
AC conductors		AC	AC	-		~
	Line 1	L1	U	●	BK [d] or	
	Line 2	L2 [c]	V	●	BR [d] or	
	Line 3	L3 [c]	W	●	GR [d]	
	Mid-point conductor	M	M	●	BU [e]	No recommendation
	Neutral conductor	N	N			
DC conductors		DC	DC	-		⎓
	Positive	L+	+	●	RD	+
	Negative	L-	-	○	WH	—
	Mid-point conductor	M	M	●	BU [e]	No recommendation
	Neutral conductor	N	N			
Protective conductor		PE	PE	▨	GNYE	⏚
	PEN conductor	PEN	PEN	▨	GNYE [f]	No recommendation
	PEL conductor	PEL	PEL			
	PEM conductor	PEM	PEM	●	BU [f]	
Protective bonding conductor [g]		PB	PB	▨	GNYE	⏚
	– earthed	PBE	PBE			No recommendation
	– unearthed	PBU	PBU			
Functional earthing conductor [h]		FE	FE	●	PK	⏚
Functional bonding conductor		FB	FB	No recommendation		⏚

Figure 4-2: IEC 60445 Cable Colours

4.6.11. Local Area Network

Preferred colour for cable of TIA/EIA 568A type using RJ45 connectors (also for Power over Ethernet)

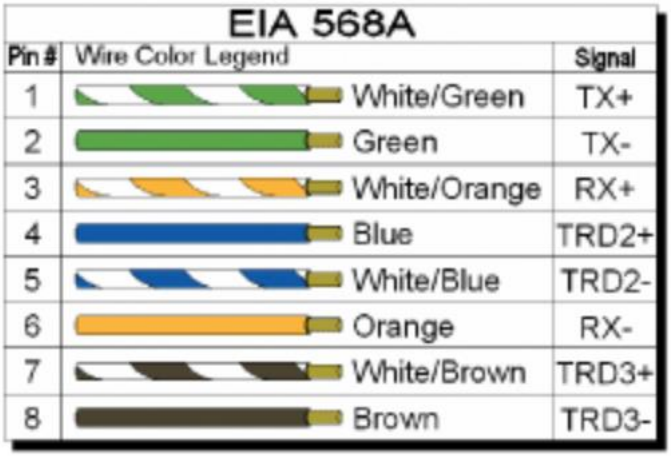

Figure 4-3: EIA 568A colour codes

4.6.12. Optical Fibres

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 multi-mode with 50µm core (OM4 transmission standard) for link distances up to 400 meters and single-mode (OS2 transmission standard, 1550 nm and 0.4db/km maximum attenuation) for link distances over 400 meters. All fibres shall be certified for 10Gbit/s operation according to ANSI/TIA-568-C.3.

4.6.13. Conductors termination

All cables shall be connected to both ends (to avoid antenna effects) and shall be chosen according to their transported signal, the type of the expected disturbances and of the apparatus to be connected. Wire ferrules shall be used to terminate all wires prior to insertion to a terminal block (if applicable). Terminations shall be arranged in functional groups and each group shall be clearly identified by a suitable label. All main voltage terminations shall be shrouded and labelled to warn of live connections. Segregation shall be maintained between AC circuits and DC circuits and between circuits of different voltage levels.

4.6.14. Labelling

All component mounted connectors shall be labelled to allow identification during installation and maintenance of the equipment. Switches and controls used by operators or technical personnel shall have their functions marked in the English language. All wiring harnesses and their connectors shall be labelled to allow identification of the harness/connector while the harness is installed.

4.6.15. Plugs and connector

Only high-quality, rough-service electrical connectors consistent with high reliability operation shall be used. Connectors shall be capable of being rapidly disconnected for service of all subassemblies. Connectors shall be sized so that within a localized assembly and/or subsystem incorrect connection is not possible. Proper and appropriate strain relief shall be provided to ensure reliability and to minimize effect of cabling loads on the telescope.

Plugs, socket-outlets, appliance inlets, connectors and similar accessories for three-phase circuits and equipment, or for single phase UPS circuits and equipment shall conform to IEC 60309.

Plugs, socket-outlets, appliance inlets, connectors and similar accessories for single phase normal power circuits and equipment shall be SCHUKO type.

Within racks, cabinets, assemblies, consoles, control desks, etc. or for specific sub-systems (mainly information technology equipment), appliance couplers may be used for single-phase circuits and equipment other than those corresponding to the standard IEC 60309. In such a case, the appliance couplers shall conform to the standard IEC 60320.

All connectors shall be marked in order to uniquely identify them. A cable identification label shall be permanently marked at each end of the cable (if the cable is too short only one label is acceptable).

4.7. Cabinets

4.7.1. General

All the realization phases of the electronic and electrical cabinets shall be supported by specific procedures of manufacturing, inspection, and final acceptance tests.

The electrical and electronic cabinets (and all equipment which are integrated inside) shall be designed, manufactured and assembled to be installed and to be operative in the environmental conditions at Teide [AD1].

The electrical and electronic cabinets shall be for outdoor application with a protection degree (according to IEC 60529) ≥ IP55 in case of closed doors and ≥ IP2X in case of open doors.

All elements inside electrical or electronic cabinets (including terminals) shall have good access in order to allow trouble-shooting and easy replacement.

When needed all cabinets shall have a thermal (and eventually humidity) control system to maintain all internal components within their range of operations.

4.7.2. Electronic cabinets

Cabinets for mounting of electronic equipment shall be according to EN 60297. All cabinets shall not produce light pollution. They shall have opaque metallic doors and

panels in order to eliminate such pollution. Any LED or other light indicator mounted on the exterior of cabinets shall be provide with a switch to disable them.

4.7.3. Electrical Cabinets

All the electrical cabinets shall be designed, manufactured, assembled and verified according to EN 61439. This norm is applicable for Low Voltage cabinets.

Additionally, considering the telescope as a machinery, the electrical cabinets integrated on it shall be conform with the standard EN 60204-1 (“Safety of machinery - Electrical equipment of machines - Part 1: General requirements”).

CE marking is needed for all the equipment making part of the cabinets. Any deviations must be previously approved by ASTRI Project.

All materials and parts comprising the assembly shall be new and unused, of current manufacture, and free from all defects and imperfections affecting performance.

All devices and components like terminal blocks, switches, relays, circuit breakers, etc. shall have a unique label consistent with the technical documentation. The presence of this system shall be evaluated with an appropriate analysis.

4.7.4. Cabinets components

All switchgear, control gear and electric devices (e.g. contactors, relays, push buttons, switches, etc.) installed in the switchboard assemblies shall comply with the applicable parts and sections of IEC Publication 947 or equivalent and approved. All the components shall be selected according to the current and operational duties expected.

4.7.5. Circuit breakers

All electronic/electrical equipment must have over-current protection (e.g. thermal breakers, fuses, lightning arresters, ground-fault interrupts, surge protection, etc. as required). Fuses shall be easily accessible for replacement. All electronic/electrical equipment shall have a main line circuit breaker or power switch. When available, over current protection shall be provided according to the component manufacturer's specifications. Instantaneous tripping currents of overcurrent operated circuit breakers shall be selected to avoid false operation due to large inrush currents.

In case of using circuit breakers, moulded case circuit-breakers (MCCB's) shall be adopted for all the circuits above 63A. In the other cases, miniature circuit-breakers for industrial application can be used, provided that the relevant circuits are rated less than 63 A.

If needed, residual current operated protective devices supplying electronics shall correctly detect unidirectional and/or continuous components of the residual currents (typically exhibited by electronic apparatus in case of faults). That is, they shall be "class A" and/or "class B" residual current protective devices, according to the IEC definitions.

Residual current operated protective devices shall be of the type exhibiting no false-tripping in case of lightning and/or switching overvoltages.

The instructions given by the switchgear manufacturer must be strictly followed.

4.7.6. Push buttons and switches in control circuits

Colours of handles and buttons, and of signal lamps if incorporated, shall comply with IEC 60073.

Push-buttons shall be equipped with a front ring to avoid unintentional operation. In all cases, the switch actuator shall give a clear indication of the position of the contacts.

All emergencies stop and guard circuitry shall be “fail-safe” under any operation conditions.

4.8. Power Distribution

4.8.1. Local Control Unit electric power

A local control unit (LCU, e.g. a PLC) shall be powered by a UPS supply.

4.8.2. Main Power supply

All electronic components of the ASTRI Mini Array at Teide shall be connected to electric power supply system according to the TN-S power distribution principle.

The following electrical supplies are available:

- 400 VAC three-phase, 50 Hz including neutral (N) and protective earth (PE) conductor;
- 230 VAC single phase, 50 Hz including N and PE conductor.

Both types of supply come in the form of a normal and a UPS supply delivered at specific power points.

4.9. Safety related functions

4.9.1. Stop Functions

EN 60204 describes three categories of stop functions as follows:

- stop category 0: stopping by immediate removal of power to the machine actuators (i.e. an uncontrolled stop);
- stop category 1: a controlled stop with power available to the machine actuators to achieve the stop and then removal of power when the stop is achieved;
- stop category 2: a controlled stop with power remaining available to the machine actuators.

4.9.2. Emergency Stop

The emergency stop shall function either as a stop category 0 or as a stop category 1. The choice of the stop category of the emergency stop depends on the results of a risk assessment of the machine.

In some cases, to avoid creating additional risks, it can be necessary to perform a controlled stop and maintain the power to machine actuators even after stopping is achieved.

The stopped condition shall be monitored and upon detection of failure of the stopped condition, power shall be removed without creating a hazardous situation.

The emergency stop function has the following requirements:

- it shall override all other functions and operations in all modes;
- it shall stop the hazardous motion as quickly as practicable without creating other hazards;
- reset shall not initiate a restart.

The emergency stop system shall be implemented with a safety integrity level (SIL) of 2 or higher.

The emergency stop device shall be a push-button operated switch, shall be of the self-latching type and shall have positive (or direct) opening operation (EN 60947-5-1).

The actuator shall be coloured red while the background immediately around the device actuator shall be coloured yellow. The actuator shall be of the palm or mushroom head type.

It shall not be possible to restore the emergency stop device until it has been manually reset.

Where several emergencies stop devices are provided in a circuit, it shall not be possible to restore that circuit until all emergency stop devices that have been operated have been reset.

4.9.3. Interlocks

Movement or action of a machine or part of a machine that can result in a hazardous situation shall be monitored by providing, for example, overtravel limiters, motor overspeed detection.

The hazardous situation in the above definition shall be analysed and documented in a hazard analysis.

4.9.3.1. Protective interlocks

Where an operating limit (for example speed, pressure, position) can be exceeded leading to a hazardous situation, means shall be provided to detect when a predetermined limit(s) is exceeded and initiate an appropriate control action.

The reclosing or resetting of an interlocking safeguard shall not initiate hazardous machine operation.

Where the non-operation of a motor or device for an auxiliary function (for example lubrication, supply of coolant, swarf removal) can cause a hazardous situation, or

cause damage to the machine or to the work in progress, appropriate interlocking shall be provided.

Where a failure of a mechanical brake actuator can result in the brake being applied when the associated machine actuator is energized, and a hazardous situation can result, interlocks shall be provided to switch off the machine actuator.

Control circuits shall be so arranged that rotation of a motor shaft, for example by applying a manual force or any other force causing the shaft to rotate after it has stopped, shall not result in a hazardous situation.

4.9.3.2. Suspension of safety functions and/or protective measures

In the case of crossing over operational limits, an override/suspension of safeguards is necessary to move the unit out of the limit.

Where it is necessary to suspend safety functions and/or protective measures (for example for setting or maintenance purposes), the control shall simultaneously:

- disable all other operating (control) modes;
- permit operation only by the use of a hold-to-run device or by a similar control device positioned so as to permit sight of the hazardous elements;
- permit operation of the hazardous elements only in reduced risk conditions (e.g. reduced speed, reduced power / force, step-by-step operation, e.g. with a limited movement control device);
- prevent any operation of hazardous functions by voluntary or involuntary action on the machine's sensors.

4.9.3.3. Brake

The brake shall be of a safety break type of the right SIL level. No power means that the brake is engaged. The brake shall have status signals (engaged/disengaged, etc.) so that its state can be monitored.

4.10. Lockout/Tagout

Lockout/Tagout is a means to avoid potentially hazardous energy (including motion, electrical, thermal, chemical, pneumatic, hydraulic, mechanical and gravitational energy) to be present in a (sub)system during installation, repair or maintenance.

During installation, repair or maintenance a (sub)system must have the ability to lock out, block or release all forms of potentially hazardous energy. The system or equipment involved shall be designed to enable these features (e.g. by means of a main switch that is lockable in the ‘off’ position for the electrical supply, visible isolation).

The risk analysis shall determine which switches, valves, or other energy isolating devices apply to the equipment being locked out. More than one energy source (electrical, mechanical, hydraulic, pneumatic, chemical, thermal and gravitational) may be involved.

4.11. Safety functions

In all cases where drive applications may pose a hazard to people, environment or property, safety functions shall be implemented by means of adjustable speed electrical power drive systems that are suitable for use in safety-related applications. The following are examples of safety functions that may be implemented in major drive systems (e.g. Telescope drive system).

4.11.1. Safe Torque Off (STO)

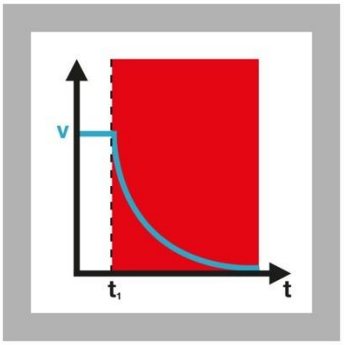

Figure 4-4: Safe Torque Off (from https://www.pilz.com)

With the STO function, the power to the motor is safely removed directly within the servo amplifier. The drive cannot generate torque/force and so cannot trigger any hazardous movements. However, if external forces influence the drive (e.g. gravity in unbalanced systems, wind pressure force) mechanical brakes are required in order to eliminate hazards. If the STO is activated when the drive is moving, the motor will run down in an uncontrolled manner. For this reason, the Safe Stop 1 function preferable because the shutdown is preceded by a controlled stop.

4.11.2. Safe Stop 1 (SS1)

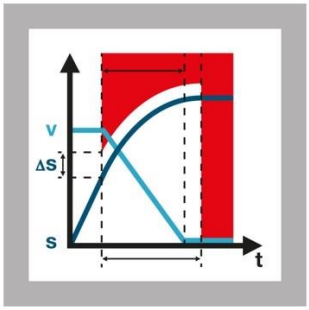

Figure 4-5: Safe Stop 1 (from https://www.pilz.com)

With a SS1 function, the drive is brought to a controlled stop and then the power to the motor is safely removed. Once at standstill the drive cannot generate torque/force and so cannot trigger any hazardous movements. The Safe Stop 1 function corresponds to controlled braking in accordance with EN 60204-1, Category 1

4.12. Network and Fieldbus systems

The communication between different control systems shall make use of any of the following standardised network:

- Ethernet
- EtherCAT and TwinSafe

To communicate to control units UDP/IP shall be used, and for the specific case of PLC communication OPC-UA and MODBUS shall be used.

4.13. Interlock and Safety Network

The interlock and safety provide the infrastructure for the integration of control and safety.

This network shall use the open protocol safety over EtherCAT (FailSafe over EtherCAT).

4.14. Time Reference Network

This network shall use a combination of PTP distributed through the White Rabbit transmission protocol and NTP for the systems that do not require sub-ns precision.

5. Mechanical standards

The following hierarchy of Standards shall be applied:

1. EN standards
2. ISO standards
3. DIN, BS, or other equivalent national standards
4. Design guidelines from professional organizations

Additionally, for moving structures (e.g. the telescope main structure, domes, etc.) the design and safety rules for machinery and cranes shall be applied accordingly. They cannot be treated as purely a building because unlike buildings they are subject to dynamic loading.

Standard eurocode to be applied are AD10, AD11, AD12, AD13 depending of the structure and the material used.

5.1. Materials

5.1.1. General

All materials and supplies used shall meet requirements in NTC 2018 and in the mentioned product standards.
The Contractor shall make certifications and declarations of conformity (provided by suppliers of all used materials) available to the Customer before their usage.

5.1.2. Steel Products

All steel used shall comply with NTC 2018. The steel used for components to be subject to PWHT for the stress relieving or other thermal process and the relevant welding procedures shall be qualified, in terms of mechanical properties, for the total thermal cycle effectively used.
The Contractor shall specify to the steel Supplier the thermal cycle at the time of the enquiry and order. Thermal cycle shall be reported on steel supplier certifications and on WPQRs. Addition or deletion of PWHT is not permitted, without a new qualification of the material and of the welding procedures.

5.1.3. Structural Steel

Materials shall be steel in rolled sections, structural hollow sections, plates or bars. Unless otherwise stated in design drawings the grade material, depending on thickness, shall be chosen according to the following table. Steel shall comply with the following quality and Standards:

Table 5-1: Correspondence form/standard for steel sections

Form	Standard for	Standard for	Standard for

	material quality	dimensions	material tolerances
Angles	UNI-EN 10025-2	UNI-EN-10056-1	UNI-EN-10056-2
Hollow sections thickness ≤25 mm	UNI-EN-10210-1	UNI-EN-10210-2	UNI-EN-10210-2
Plates thickness ≤25 mm	UNI-EN-10025-2	-	UNI-EN-10029 UNI-EN-10051
Plates 25≤ thickness ≤60 mm	UNI-EN-10025-2	-	UNI-EN-10029 UNI-EN-10051
Plates 60≤ thickness ≤100 mm	UNI-EN-10025-2	-	UNI-EN-10029 UNI-EN-10051
Plates thickness >100 mm	UNI-EN-10025-3	-	UNI-EN-10029 UNI-EN-10051
Plates for counterbalance	UNI-EN-10025-2 UNI-EN-10025-3	-	UNI-EN-10029 UNI-EN-10051

Unless otherwise stated in design documents for the steelwork plates thickness class A EN 10029 shall apply.
Passing plates to be used for welded cruciform, tee and corner joints shall have the following Z class according to UNI-EN 10164:

- Thickness ≤ 12mm class Z15
- 12mm < thickness ≤ 30mm class Z25
- Thickness >30mm class Z35.

Surface defects in hot rolled sections, plates and wide flats revealed during surface preparation which are not in accordance with the requirements of EN 10163 shall be rectified accordingly.
Surface defects in hot finished hollow sections revealed during surface preparation which are not in accordance with the requirements of EN 10210-1 shall be rectified accordingly.

Stainless Steel

Components marked as stainless steel on the design drawings shall be realized in stainless steel AISI 317L (EN 1.4439) – UNI EN10088-2.

Aluminium Components
Alloy EN AW-5083 shall be adopted for aluminium components marked on the drawings. Execution of structural components in aluminium shall be performed in accordance to NTC-2018 and Eurocode 9.

Bolts, Screws and Studs
All bolted connections shall be slip resistant connections. Unless otherwise stated in design documents, bolts, nuts and washers shall be chosen and coupled according to the following prescriptions:

Table 5-2: bolts/nuts/washers: standard

Bolt/Screw	Nut	Washer
Grade 8.8 UNI-EN 14399-1/3/4 K class= K2 according to EN 14399-1, UNI EN 898-1	Grade 8 UNI-EN-14399-1/3/4, UNI-EN 20898-2	Steel C60+QT (HRC32-40) UNI-EN 14399-5/6, UNI-EN 10083-2

5.1.4. Bolts, nuts and washers shall be electro-galvanized.

Whenever the adoption of corrosion resistant stainless steel bolts is required on design drawings, the following bolts and nuts shall be adopted:

- Bolts: Grade A4 Class 70 according to UNI EN ISO 3506 -1.
- Nuts: Grade A4 Class 70 according to UNI EN ISO 3506 -2.

5.1.5. Foundation Anchor Bolts

Anchor bolts, nuts and washers shall be hot dip galvanized. It is required that the tensile strength test of three anchor bolts at least. The three anchor bolts shall be randomly taken from the provision at site, with their final surface coating, and tested till failure, so the provision at site shall have at least three complete anchor bolts (+ nuts and washers) in excess to be used for mechanical tests.
Mechanical tests shall be in charge of the Contractor and they shall be carried out by a laboratory approved by the Customer.
Yielding stress, ultimate stress and stress strain curve shall be registered and supplied for each anchor bolt. All tested anchor bolts shall fulfil the strength requirements of the 8.8 grade. Test report shall be delivered to the Customer before the anchor bolts installation.

Table 5-3: Anchor bolts: standards

Bolt/Screw	Nut	Washer
Grade 8.8 UNI-EN 14399-	Grade 8 UNI-EN-14399-	Steel C60+QT (HRC32-40)

1/3/4	1/3/4, UNI-EN 20898-2	UNI-EN 14399-5/6, UNI-EN 10083-2

5.1.6. On site acceptance tests on materials

The following material acceptance tests prescribed on site and at workshop by the NTC 2018 shall be carried out.
If requested by the Customer, material acceptance tests shall be carried out under his supervision.

5.1.7. Concrete and Grouts

Concrete and grouts pourings on site shall be checked according to the “check type A” as per chapters 11.2.4 and 11.2.5 NTC 2018.

5.1.8. Reinforcement Bars

Reinforcement bars shall be checked according to the criteria reported at chapter 11.3.2.10.4 NTC 2018.

Material of rolled sections, structural hollow sections, plates or bars and bolts to be used for the manufacture of the structural elements shall be checked according to the criteria at chapter 11.3.4.11.3 NTC 2018.

5.1.9. Additional material tests

Material of rolled sections, structural hollow sections, plates or bars and bolts to be used for the manufacture of the structural elements shall be checked according to the criteria at chapter 11.3.4.11.3 NTC 2018.

In addition to above-mentioned tests requested, the Customer reserves the right to have the Contractor submit for testing, as and when directed by the Customer, test specimens of any material or item supplied under this contract and used or intended to be used in the structure. Any material or item failing to meet the requirements specified for the appropriate test or failing to comply in any way with the specification may be rejected with the Customer final decision.
The Contractor shall retain some waste materials in case additional tests are required by the Customer. Also waste materials shall be marked for their traceability in case additional material tests are required. In the event of INAF requiring a test specimen to be cut from an existing member, and the test proving unsatisfactory, the entire member may be rejected or repaired as directed by the Customer at the Contractor’s expense. Should the test prove satisfactory, all repairs to the member will be carried out at the Customer expenses. Should any test specimen fail to meet the required specification the entire cost of preparing tests specimen and carrying out the test shall be borne by the Contractor. Laboratory for tests shall be approved in advance by the Customer.

Materials standard list

- *UNI-EN 10025-2;*
- *UNI-EN 10025-3;*
- *UNI-EN10056-1;*
- *UNI-EN 10056-2;*
- *UNI-EN 10210-2;*
- *UNI-EN 10029;*
- *UNI-EN 10051;*
- *UNI-EN 10164;*
- *UNI-EN 10088-2;*
- *UNI-EN 14399-1/3/4/5/6;*
- *UNI-EN 898-1;*
- *UNI-EN 20898-2;*
- *UNI-EN 10083-2;*
- *NTC 2018;*
- *Eurocode 9;*

5.1.10. Steel Structure

All steel products to be used in the works shall have a reference to a suitable declaration of conformity so that the properties are known and can be verified. Individual pieces shall be traceable to a particular inspection document.
The material grade, quality and other relevant properties shall be identifiable.
Individual pieces shall be capable of positive identification at all stages of fabrication. Completed components shall be marked with a durable and distinguishing erection mark in such a way as not to damage the material.
Where areas of steelwork are indicated on the drawings as being unmarked, they shall be left free of all markings and hard stamping. All machined surfaces shall be left free of all markings and hard stamping.

5.1.11. Handling and Storing

Steelworks shall be bundled, packed, handled, transported and stored in a safe manner so that overstressed and permanent distortions do not occur, surface and protective coating damage is avoided. Particular care shall be taken to stiffen free ends and adequately protect any machined surfaces.
Members shall not be stored directly in contact with the ground. Parts bent or buckled by the Contractor shall be liable to rejection. Any steel work damaged as a result of handling, storing and transporting and which prevents the proper assembling and fitting up of parts shall be replaced or corrected by the Contractor. The method of correction shall be subject to the prior agreement of the Customer's Technical Office.
Loose pieces for connections shall be attached to their respective members and clearly marked for identification.
All painted and protected steelwork damaged shall be cleaned, prepared and restored according to the original requirements.

5.1.12. Straightening

All materials shall be straight and free from twist and bend. If necessary, before being worked, they shall be flattened by cold process to shape as shown on drawings. Straightening of components during fabrication shall be usually performed by mechanical means, taking care to minimize indentations or change of cross-section.
In case thermal process is used, a qualified procedure shall be followed.
The procedure shall include at least:

- Grade and status of the steel material.
- Equipment to heat the component, the temperature value, the heating times, the heating and cooling ramps.
- Method and tools to measure and to control the temperatures.
- Operational mode to perform the straightening
- Test carried out to qualify the procedure and the equipment.

After straightening the material properties shall comply with original requirements.

Furthermore, steel material and welds shall be qualified for the total thermal cycle supported (including PWHT in case). At the end of straightening operation all welds within the area of straightening shall be visually inspected. In accessible welds the final NDT (MT, LP, UT, RX) shall be carried out after straightening operations.

5.1.13. Cutting and Shaping

Cutting shall be carried out by appropriate cutting methods. Shear cut and punched notches are not allowed. Cut edges are to be properly reworked by grinding so that they are free of notches, cracks, burrs and irregularities. Bending and forming in the blue heat range (250°C-380°C) is not permitted. After forming and shaping, material properties shall comply with original requirements.

5.1.14. Machining

The thickness of machined parts shown on the drawings shall be intended as the thickness obtained at the end of machining operations. Contractor shall procure steel plates having proper extra thickness to allow machining.

5.1.15. Holing

Holes for fasteners, bolts and pins should generally be obtained by drilling.
Punching is admitted, for thickness up to 20mm, provided that the holes are punched at least 4mm less in diameter than the required size and then the hole is reamed to the full diameter. Gas cutting process is not admitted. Holes shall be dressed to remove burrs and protruding edges. Slotted holes shall be formed by drilling two holes and completed by cutting and dressing. Holes for fitted bolts shall be drilled to a smaller size and reamed out after assembly. If separate parts are tightly clamped together, drilling is permitted through more than one thickness. The parts shall be separated after drilling and any burrs removed. Oversized and slotted holes for bolts are not permitted unless shown on the design drawings.

5.2. Welding

5.2.1. General

It shall be the responsibility of the Contractor to ensure that all welding is carried out in accordance with the terms of this specification and relevant Standard. The Contractor shall provide all the supervision to fulfill this requirement. The same requirements, prescribed for the welding of the ASTRI structural members, shall be applied also to the welding needed for the arrangement of any devices and auxiliary systems onboard. Particular care shall be taken to fulfill the requirements in chapter 4.14 EN 1993-1-8 when welding in cold-formed zones.

Adequate protection against rain, dust, snow and wind shall be provided to the welding personnel and to the structural members during welding operations. In the absence of such a protection no welding shall be carried out. In case the temperature is lower than 5°C at least +50°C pre-heating shall be adopted. In spot welding operations pre-heating values shall raise 25°C in temperature. No welding is permitted if the temperature is below -5°C.

According to the design drawings all fillet welds shall be continuous weld. Intermittent welds are not permitted except where explicitly prescribed on the design drawings. In full penetration joints with sealing run at one side, the tack welds shall be carried out on the sealing run side. Tack welds shall be at least 50mm long. Tack welds to be included in the final weld shall be grinded at the ends, moreover they shall be inspected for the removal, by grinding, of cracks and defects. Start and stop in full penetration but welds shall be carried out by run on and run off tab to be removed and ground at the end. In full penetration joints after the first pass on one side the weld metal and base metal from the opposite side shall be removed to facilitate complete joint penetration before starting the weld on the opposite side (back gouging).

In full penetration T joint, unless otherwise stated on design drawings, the cross section of the weld shall be gradually increased according to the sketch on the right. The weld width shall be increased at list to 1.3×t, being “t” the thickness of the non-passing plate (see figure 14.1).

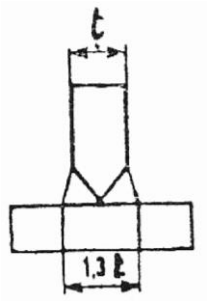

Figure 5-1: Full penetration T joint

In correspondence to the scallops, the fillet welds shall turn around the scallop edge, avoiding any notch and cut in the scallop edge. In case the scallop edge shall be dressed by grinding.

All welds shall be regular, smoothly jointed to the adjacent parent material without exaggerated excess of weld metal.

5.2.2. Welding Procedures

Written WPSs shall be available in accordance with EN ISO 15609-1, and qualified in accordance with EN ISO 15614-1 by the Contractor. They shall comply with the guidance of EN 1011-2 Annex C Method A to avoid hydrogen cracking, and Annex D to

provide adequate toughness in HAZ. Hardness taken on macro view shall be not greater than 350 HV30.
In fusion zone and in heat affected zone ductility, yielding, strength and toughness shall be at least equal or greater to the base material.
Chemical composition of consumables shall be equivalent to the base materials. In case of welding between non-homogeneous materials, consumables shall be chosen according to the recommendations of the material supplier.
Appropriate WPSs and work instructions shall be produced from WPQRs under the authority of welding coordinator. They shall be provided for the welders prior to the commencement of welding and shall be suitable for the joint configuration and material to be welded.
If requested, all welding documentation (welder qualifications, WPQRs, WPSs and associated work instructions) shall be made available to the Customer in order to check their compliance with EN ISO 15614-1.

5.2.3. Welder qualification and welding documentation

Welders for semi-automatic and manual processes shall be qualified by Third Party to meet the requirements of EN 287-1.
Welders for automatic welding processes and for robotic welding shall be qualified by Third Party to meet the requirements of EN 1418-1.
Lacking specific request from the Customer the Third Party for welders qualifications shall be chosen by the Contractor.
Notwithstanding the criteria in EN 287-1 welders realizing T fillet joints shall be specifically qualified, they cannot be qualified just by the execution of butt joints.
Welders certification shall remain valid providing it complies with the conditions for re-approval of certification specified in EN 287-1.
Contractor shall have a qualified responsible for welding operation.
Contractor shall keep the book record up-to-date, with the names of the welders, their qualifications for different welding processes, positions and so on and, in case, no active times. Each welder shall have a code used to mark performed welds.
The welding operation responsible shall keep up to date the proper documentation registering, for each weld, at least the following data:

- code identifying the weld with reference to the shop drawings,
- reference WPS and process used,
- code identifying the welder who carried out the job,
- NDTs which have been carried out, tests results, and reference to the test reports.

If requested, all welding documentation shall be promptly made available to the Customer.
In case weld tests show systematic defects, the Customer can require repeating the welder qualification by another Authority.

5.2.4. Fusion face preparation

Joints shall be prepared in accordance with EN ISO 9692-1 and -2.
Fusion face preparations shall be defined by the Contractor according to the welding process used. Bevel angles reported on design drawings are estimated, they need to be adapted according to the welding process adopted.
Fusion face preparations shall be reported on the shop drawings. Tools used for the fusion face preparations shall be mentioned on the welding procedures.
Edge preparation shall be realized by machining, thermal cutting, gouging or grinding.
All surface roughness shall be removed by grinding. Precautions shall be taken to ensure cleanliness of the joints prior welding. The surface to be welded must be free from oil, grease, paint, dirt, oxides, and other foreign material. Preparation of J or U joints shall be obtained by machining.
Fusion faces shall be inspected by MT or LP.

5.2.5. Assembly

Joints shall be fitted up to the dimensional accuracy required by the welding procedures, depending on the process used, to ensure that the prescribed quality is achieved.
Tack welds may be used provided that at least one of the following conditions apply:

a) They are laid in an area to be later welded and are thoroughly removed by grinding or gouging such that the subsequent welding is unaffected, after grinding MT shall carried out on the surface to check that no cracks exist;
b) They are laid in an area to be later welded and they are undertaken by a welder qualified as short length normal weld, of a length at least four time the thickness of the thicker part being joined and at least 50mm long, according to a qualified welding procedure; any case the tack weld ends shall be ground, and the tack weld shall be examined before the new weld;

The sequence of welding a joint or a sequence of joints shall be such that distortion is minimized.
Welding of attachments required for fabrication or erection purposes shall be made in accordance with the requirements for permanent welds.
Provisional welds shall be removed. They will be flame cut or gouged at a point not less than 3 mm from the surface of parent material. The residual material shall be ground flush, the affected area shall be visually inspected, and MT or PT shall be carried out to verify that no surface defects or damages have occurred. Attachments shall not be removed by hammering.
When the profile of a weld is sustained on its free end using extension pieces, they shall be of material of a similar composition but not necessarily the same grade, as the component. They shall be arranged so as to provide continuity of preparation and shall be removed after completion of the weld and the end surface of the weld ground smooth and visually inspected.

If production test plates are required for testing purposes, they shall be clamped in line with the joint. The grade and quality of the material, carbon equivalent and rolling direction shall match the parent grade, but need not be cut from the same plate or cast.

5.2.6. Consumable Storage

Welding consumables (wires, electrodes, fluxes) shall be stored in a closed room with relative humidity not greater than 50%. Once the original sealed package is open, consumables must be dried two hours in an oven at a temperature in the range 350-400 °C. Then they shall be stored in an oven at 150 °C until they are used.
Welders shall have a small portable oven at 100°C to maintain electrodes during the work. At the end of each work turn the consumables shall be collected and stored in a proper container. They can be used just after a new drying thermal treatment, having the same times and temperature mentioned above.
Unless different stated by the manufacturer thermal drying treatment cannot be repeated more than two times.
Also, unused fluxes shall be removed from equipment and stored in a proper container. It can be used just after drying thermal treatment, having the same times and temperature mentioned above.

5.2.7. Preliminary Inspection

Prior to the welding and between the weld passes it is necessary:

- Checking that the weld preparation is correct in accordance with the welding work instruction (WPS). Items to be checked include preparation angles, root gap, root face conditions, depth of preparation for PPW, minimal gap for fillet welds.
- Checking the correct alignment between the weld edges.
- Checking that the area to be welded is not contaminated with greases, oil, dirt, paint, oxides, and other foreign materials or moisture.
- Checking the edges to be welded and an adjacent zone at least 100mm wide for the absence of defects, cracks, lamellar tearing and so on. Defects repair by weld in these zones are not admitted.
- Checking that any tack welds have been removed or are suitable for welding over.
- For multi-pass welds, check the suitability of the surface of previously deposited weld metal.

In addition to checking any re-preparation and cleanliness, the area to be welded shall be des-lagged and free of weld spatters. If necessary proceed with the grinding of the previous pass before starting the new bead. A record shall be kept that visual inspection has been carried out and any problem identified.

5.2.8. Weld Testing

Welds shall undergo, by the Contractor, NDT to check the compliance with the quality requested. Proper NDT shall be adopted to check that no defects occurred, as lack of penetration, lack of fusion, undercutting, porosity, worm, holes, cracking, solid or gas inclusions, lamellar tearing, defects of the weld shape, errors in the fusion, face assembly misalignment and so on.
Assembly phases shall take into account the need of NDT execution. Tests shall be carried out in advance when subsequent assembly phases would make difficult or impossible the test execution. NDT shall be carried out by surface checks (LP – MT) and volumetric checks (UT – RX). Usually MT, RX, UT shall be used at the end of the weld and LP shall be used on back gouging of FP welds.
In case MT for the surface flaw detection is impractical, LP may be used.

The minimum hold time, i.e. the period to be allowed after completion of welding before commencement of final NDT is reported in the following table.

Table 5-4: minimum hold time before NDT

Minimum Hold Time		
Weld Size [mm]	**Heat Input [kJ/mm]**	**Hold Time [hours]**
a or s ≤ 6	**All**	**Cooling period only**
6 < a or s ≤ 12	≤3	8
	>3	16
a or s >12	≤3	16
	>3	40

- Size applies to the nominal throat thickness (a) of a fillet weld, the nominal depth (s) of a partial penetration butt weld, or the nominal thickness (s) of a full penetration weld.
- If two fillet welds are separated and un-fused root face of less than 10mm the governing weld size (a) shall be taken as the sum of their individual weld sizes.
- Heat input to be calculated in accordance with clause 19 of EN 1011-1.
- The time between weld completion and commencement of NDT shall be stated in the NDT report. In case of “cooling period only” this will last until the weld is cool enough for NDT to commence.
- If a welding procedure requires an inspection after initial weld runs before further welding is performed, such inspections may be carried out when the weld metal has cooled to room temperature.

Unless otherwise stated on the design drawings the following minimum NDT percentage (respect to the total length of each weld class) are prescribed:

- Full penetration butt welds: 100%VT, 50% MT, 25% UT or RX depending on the thickness.
- Full penetration T and cruciform joints: 100% VT, 50% MT, 25% UT or RX depending on the thickness.
- Full penetration butt welds on backing bar/strip: 100%VT, 50% MT, 25% UT or RX depending on the thickness.
- Full penetration T and cruciform joints on backing bar/strip: 100% VT, 50% MT, 25% UT or RX depending on the thickness.
- Partial penetration welds; 100% VT, 25% MT
- Fillet welds: 100% VT, 25% MT

NDT percentages reported above shall be increased (roughly doubled) in case a significant level of not acceptable defects are detected.
Welds having a not acceptable defects shall be 100% checked, using the same procedure used to detect the defect.
All defects must be repaired and checked again with the same NDT. Structural members and components affected by many repairs or where systematic not acceptable defects have been detected shall be rejected.
In case systematic defects are not ascribable to the welder unskillfulness or to errors in WPS application the Contractor shall repeat the welding procedure qualification.

Test operators shall be qualified at least for the II level according to EN 473. Documentation proofing the operator qualification shall be made available if requested by the Customer. NDT test reports, signed by the test operators and by the QC Responsible, shall register at least the following information:

- Date and procedures of the tests.
- Identification of the weld tested (which weld with reference to the relevant design or shop drawing, weld kind, component who the weld belongs to, relevant WPS, welder identification).
- Status of the component (for instance before or after PWHT, before or after final machining in case of welds in zones to be machined and so on).
- Fit up propriety.
- Results of the test: no defects or in case defects are detected the precise identification of detected defects, (location, kind of defect, dimensions).
- Reference to the relevant NCR, if it is the case.
- Other eventual comment/information deemed necessary.

Checks have to be traceable. NDT shall be carried out according to EN-ISO 17635. For NDT-RX technique level B according EN 1435 shall be adopted, with level 2 for the acceptability according EN 12517 unless otherwise requested by the Customer.
For NDT-UT at least technique level A according EN 1714 shall be adopted, with level 3 for the acceptability according EN 1712 unless otherwise requested by the Customer.
Usually VT should be carried out before other NDT. For VT usually the surface condition is “as welded”, even though in some cases it could be required some grinding to detect if discontinuities exist. All surfaces need to be cleaned in advance and a proper illumination shall be supplied.

During VT at least the following checks shall be carried out:

- Check the weld size. Visual estimation may be used to assess the acceptability provided that visual estimation is confirmed periodically by measurements. Measurements shall be adopted in all doubtful cases.
- Check that welds are complete. Items to be checked include whether the weld extends fully to the end of the preparation (or run-on/run-off plates to be used in butt welds) and back welds are completed.
- Check that any crater has been filled and that no crater cracks are visually evident.
- Check for undercut and measure for evaluation if identified.
- Check that weld beads are of even appearance and that fillets have a slightly convex profile. Measure any concave profiles to ensure that the specified throat thickness has not been compromised.
- Check for absence of any cracking or significant porosity.
- Check for absence of cold-lapping, lack of fusion.

Corrective actions on minor defects capable of immediate rectification may be taken under the authority of the visual inspector. More significant defects shall be reported using a nonconformance procedure, and corrective action undertaken before further NDT. A record shall be kept that visual inspection has been carried out and any problem identified and repaired.
In case of thick welds it is recommended to carry out intermediate NDT (VT+UT), so that any unacceptable defect is detected before weld completion, reducing the impact of repair actions. In case RX are used, the Contractor shall draw a sketch to be enclosed to the RX output, reporting the weld extension with the identification of RX positions and welder stamp. Similar information shall be reported on the correspondent films.
A proper penetrometer shall be placed on each film to detect the quality of the image. Film sensitivity shall comply the maximum size of the defect admitted for the detail.
In case of PWHT the final NDT in accessible welds shall be carried out after the thermal treatment, checking that no crack occurred due to PWHT and cooling.
If requested, all documents concerning weld NDT, weld repair and following NDT shall be delivered to the Customer.

The Customer retain the right to make further independent NDT, the Contractor shall provide assistance for the test execution. Contractor shall repair all not-allowable defects unveiled by these NDT at its own expenses. In case a significant defect level is found, the Contractor shall increase, at its own expenses, the NDT percentages.
If requested by the Customer, the Contractor shall provide edge weld extensions, whose number has to be agreed, with the same material of the connected plates, to be used for destructive tests as for instance the hardness in FZ and in HAZ, toughness, weld penetration, macro examinations and so on.

5.2.9. Weld Repairs

The Contractor shall appoint proper procedures for the weld repairs, adopting qualification criteria similar to the welds qualification.
Weld repair procedures shall report at least the method and the tools used for the boring, the preheating temperature, and all weld process parameters.
In order to avoid high local hardness, very small fillet to fill borings or undercuts are not allowed. Repairs shall have a smooth surface, well joined to the adjacent material by grinding.

5.2.10. Post Weld Heat Treatment

Post weld heat treatment at the end of weld operation and before machining is necessary.
The main purpose of post-weld treatment is the stress relieving, reducing the internal or residual stresses resulting from welding operation and the consequent shape distortion during machining. All materials and welds shall be qualified for the PWHT effectively used. Required PWHT shall be defined before entering the material and welding qualification phase.
Contractor shall define the PWHT specification stating at least the equipment envisaged to heat the components, the temperature value, the heating times, the heating and cooling ramps, number of thermocouples used to measure the temperatures and the allowable ranges around nominal values. The temperature control system shall guarantee a post weld heat treatment within the limits of the specification. PWHT report with the temperature registration shall be available and, if requested, it shall be delivered to the Customer.
In consideration of detrimental effects that thermal treatment could have on stainless steel properties, it is recommended to carry out the PWHT before assembling any stainless steel component on the components.
If PWHT does not conform to specified requirements a Non Conformance Report shall be generated, and the satisfactory result of any corrective action shall be demonstrated.

5.2.11. Welding Standard List

- *EN ISO 4063;*

- *EN ISO 3834-3;*
- *EN ISO 5817 level B;*
- *EN 1993-1-8;*
- *EN ISO 15609-1;*
- *EN ISO 15614-1;*
- *EN 1011-2;*
- *EN 287-1;*
- *EN 1418-1;*
- *EN ISO 9692-1;*
- *EN ISO 9692-2;*
- *EN 473;*
- *EN ISO 17635;*
- *EN 1435;*
- *EN 12517;*
- *EN 1714;*
- EN 1712.

5.3. Tolerance and fabrication Accuracy

5.3.1. General

Tolerances are usually specified on design drawings.

For dimensions without tolerance the medium tolerance class of EN 22768-1 shall apply. Roughness of the machined surfaces shall be defined by the Contractor.
Furthermore unless otherwise specified on the design drawings or in the present document the following tolerances shall apply:

- Diameters of holes: -0 / +0.2mm
- Length of dead hole: -0 / +2mm
- Position of center of the holes: ±0.1mm
- Straightness of member axes: ≤L/1000 being L the member length

During manufacturing process the contractor shall carry out all the measurements necessary to assess and to certify that the required tolerances have been fulfilled. Measures shall be taken with proper instruments and procedures suitable for the precision level required.
If requested this documentation shall be delivered to the Customer. The Customer reserve the right to carry out independent additional checking measures. The contractor shall make available the components to be checked and shall give assistance to the Customer measurements.

5.3.2. Tolerance and Fabrication Accuracy Standard List

- EN 22768-1.

5.4. Protective treatments

5.4.1. General

The following coatings shall be applied for the corrosion protection of steel structures with exception of:

- Machined surfaces of steel components/structures bolted/screwed together.
- Components where other protective treatments are prescribed.
- Stainless steel components (e.g. annular pads welded to the dish).

Before starting the application and reapplication of protective coating, a method statement shall be prepared and given to the Customer for acceptance.
A copy of the approved method statement shall be available where the work is being carried out. A single source of coating supply shall be used unless otherwise agreed with INAF.
Coating material shall be prepared and coatings applied to surfaces in accordance with the manufacturer recommendations. The procedures for the transportation, handling and storage of coated steel work shall be defined in order to minimize the risk of damage to the coating.
The surface cleanliness of the steelwork to be coated shall be in accordance with EN ISO 8501. The surface profile of the steelwork to be coated shall be compatible with the coating to be applied in accordance with EN ISO 8503-2.
Measurement of the surface profile of steelwork to be coated shall be performed using the method given in EN ISO 8503.
The following coating sequence, or equivalent cycle to be submitted to INAF for acceptance, shall be used for the steelwork:

- Surfaces shall be sand blasted (Sa 2 ½)
- Inorganic zinc reach epoxy primer – dry minimum thickness 40µm.
- Epoxy undercoat – dry minimum thickness 80 µm.
- Polyurethane or polyurethane modified top coat – dry minimum thickness 50 µm.

Top coat color shade and solar energy reflectance shall be defined by the Customer.
All the coating layers and the whole coating cycle shall be suitable for the environmental conditions at site, both during service, and during the application and the reinstatement of damaged coatings i.e.

- Elevation about sea level: approximately 2400m;
- Service temperature range: -15°C +35°C;
- Average summer humidity approximately 60%;
- Average winter humidity approximately 60%;
- Precipitations approximately 250 mm/years;
- Risk of Aerosols volcanic ash: very low;
- Distance from sea <20km.

The priming and the undercoat shall be applied at workshop, while the top coat could be applied on site or at workshop. In case the latter option applies, the Contractor shall verify the integrity of the top coat after transportation and erection and shall perform a

proper repainting of any damaged surface. Application of paint coat to bolts, nuts and other local surfaces left unpainted at the end of the erection is anyway mandatory.
The colour shade of each coating shall be different. The colour shade of the undercoat shall be hidden by the top coat.
The performances of the surface preparation and coating work shall be supervised during all the operations. The supervisory personnel shall be suitably qualified and experienced. The Customer reserves the right to arrange additional random controls of the surface preparation and coating work for the individual assemblies on the premises of the contractor and at site.
The controls will be performed: - visually, in compliance with EN ISO 8501-1 and EN ISO 8503-2 with a measuring instrument, non-destructively, for the dry film thicknesses. At the end of each coating (primer, undercoat, top coat) the total thickness shall be checked. Whenever the total thickness is smaller than prescribed value, it shall be compensated-for by renewed application of the last coat applied upon adequate preparation of the surface. In case insufficient thickness is evidenced by controls, the control sample shall be increased (approximately doubled). Control surfaces shall be identified on the structure.
Checks shall be carried out for each assembly, in the workshop, after:

- surface preparation, prior to coating,
- each application of primer / undercoat / top coat.

For each assembly, on site, after:

- the touching-up of primer / undercoat / top coats
- the second top coat in case of application at site.

A proper corrosion protective treatment few tenths of μm thick shall be applied to the M1 segment spacers. Such a treatment shall be resistant to bimetallic corrosion when coupled to stainless steel (annular pads welded to the M1 dish) and to the protective treatment prescribed for M1 segment support triangles. It shall be suitable for the particular appliance (machined flanges connected by bolting) with friction coefficient similar to steel. The treatment choice shall be submitted to the Customer for approval.
In addition the painting cycle applied to other steelworks shall be applied to the lateral exposed surfaces of the segment spacers. Surfaces in contact with annular pads welded to the dish and with the interfaces of the M1 segment support triangle shall be left unpainted.
Box elements and hollow components and all interior volumes not accessible shall be water tight.

Scallops of box elements, end sections of hollows components shall be closed and sealed by welded plates according to the details reported on the design drawings.
Drain holes for rainwater shall be realized wherever rainwater stagnation is possible. Drain hole pattern shall be submitted to INAF for preliminary acceptance.

Structural steel surfaces to be encased in concrete shall be left unpainted. These surfaces shall be cleaned using a steel brush and shall be free from rust and from all contaminants such as oil, dirt etc.
Fastener and bolts (electro galvanized) shall be painted to ensure similar properties, performance and compatibility with the protective treatment system used on the steelwork surfaces, according to the following coating sequence (or equivalent coatings to be submitted to INAF for acceptance):

- Primer specific for electro-galvanized surfaces – dry minimum thickness 40µm.
- Epoxy undercoat – dry minimum thickness 80 µm.
- Polyurethane or polyurethane modified top coat – dry minimum thickness 50 µm.

Anchor bolts, nuts and washers shall be hot dip galvanized. Nuts shall be checked after being galvanized and re-tapped if necessary to ensure a satisfactory tightening performance.
After anchor bolt pre-load the anchor bolt heads shall be suitably protected against water stagnation effects by grease + plastic caps with periodic inspection and maintenance or by epoxy sealant.

5.4.2. Protective Treatment Standard List

- *EN ISO 8501;*
- *EN ISO 8503;*
- *EN ISO 8503-2.*

5.5. Aluminium Items

5.5.1. General

Fabrication and execution of structural components in aluminium shall be performed in accordance with NTC 2018 and EN 1999-1-1 Eurocode 9.
Alloy EN AW-5083 shall be adopted for aluminium components marked on the drawings.

5.5.2. Welding

Provisions at NTC 2018 and Eurocode 9 apply.

5.5.3. Bolting

Unless stated otherwise, provisions at NTC 2018 and Eurocode 9 apply.

Bolts in stainless steel grade A4-70 are generally envisaged on design drawings for connections involving at least one aluminium component.
In presence of a connection involving two different metal surfaces, in order to prevent corrosion phenomena, the Contractor shall:

- Prevent contact between different metal surfaces by means of interposed anti-corrosion PVC sheets or other suitable devices.
- Inhibit the contact between the bolt and the joint surfaces as well as the hole sides by means of shoulder washers or other suitable devices.

5.5.4. Tolerances and fabrication accuracy

Provisions at NTC 2018 and Eurocode 9 apply.

5.5.5. Protective Treatment – painting

Unless stated otherwise, provisions at NTC 2018 and Eurocode 9 apply.

5.5.6. Aluminium Items Standard List

- NTC 2018;
- Eurocode 9.

5.6. Erection at site

5.6.1. General

The Customer shall provide to the Contractor the necessary information relevant to:

- Identification at site of the exact location of the telescope and allowed tolerances.
- Orientation of the telescope in “neutral position”. (i.e. 0° of azimuth) and allowed tolerances.
- Orientation of azimuth axis and allowed tolerances.

5.6.2. Erection at Site Standard List

- *NTC 2018*
- *UNI EN 1090-2*