European Organisation for Astronomical Research in the Southern Hemisphere

Programme: PIP

Project/WP:

Common Requirements for VLT Instruments

Document Number: ESO-379353

Document Version:

Document Type: Specification (SPE)

Released On: 2021-06-01

Document Classification: ESO Internal Use [Confidential for Non-ESO Staff]

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Date: 2021.06.01 17:48:45 +02'00'

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Change Record from previous Version

Affected Section(s)	Changes / Reason / Remarks
§2.2	RD24 ESO-272195 was removed
#677	Changed reference from RD24 to RD28

Contents

1. Introduction

1.1 Scope

[INFO-VLT-5] This specification establishes the set of requirements that are common to all VLT, VLTI, infrastructures and post focal Adaptive Optics (AO) modules. Hereinafter, "instruments" refers to both, scientific instruments, infrastructure and post-focal AO modules, as defined in Sec. 3.

1.2 Conventions and Definitions

1.2.1 Requirements and Information

[INFO-VLT-8] This document contains two types of item: requirements and information. Requirements have to be verified for compliance by the Consortium while information items do not. Both types are binding.

[INFO-VLT-9] Requirements are identified with a requirement tag following the format [R-VLT-NNN], where NNN is a unique, number.

[INFO-VLT-10] In addition, each requirement carries a verification tag stating the minimum verification method(s) applicable for that requirement verification (D: Design Review; A: Analysis; I: Inspection; T: Test).

[INFO-VLT-11] Information items are identified with the tag [INFO-VLT-NNN], NNN being a unique, number, not used in any requirement identifier. These information items, which are binding, refer usually to context, conditions or definitions that have to be taken into consideration for all or for specific requirements.

[INFO-VLT-12] NNN numbers do not necessarily follow a sequential order. They remain unchanged across all versions of this document. Within this document, cross-references to an item (either requirement or information) are made by referring to the number NNN preceded by the prefix "#".

1.2.2 Abbreviations and Acronyms

[INFO-VLT-14] The following abbreviations and acronyms are used in this document:

AD	Applicable Document
ADC	Atmospheric Dispersion Compensator
AIV	Assembly, Integration and Verification (only in Chile)
AO	Adaptive Optics
AOF	Adaptive Optics Facility
ATE	Automatic Test Equipment
BITE	Built-In-Test-Equipment
BoM	Bill of Materials
CAS	Critical Alarm System
CIDL	Configuration Item Data List
CMMS	Computerized Maintenance Management System
CoG	Centre of Gravity
COTS	Commercial Off-The-Shelf
CPL	Common Pipeline Library
CTE	Coefficient of Thermal Expansion
DICD	Data Interface Control Document
DFS	Data Flow System
DRL	Data Reduction Library
DSM	Deformable Secondary Mirror
E-ELT	European Extremely Large Telescope
EQ	Earthquake
EMC	Electro-Magnetic Compatibility
ESO	European Southern Observatory
ETC	Exposure Time Calculator
FDR	Final Design Review
FDIR	Fault Detection, Isolation and Recovery
FITS	Flexible Image Transport System
FPT	Flat Platform Truck
HA	Hazard Analysis
HALT	Highly Accelerated Life Test
HDRL	High Level Data Reduction Library
HSM	Health Status and Monitoring

ICS	Instrument Control System
ISO	International Standards Organization
ITU	Intermodal Transport Units or isotainers
IWS	Instrument Workstation
LGS	Laser Guide Star
4LGSF	Four Laser Guide Star Facility (at UT4)
LPO	La Silla Paranal Observatory
LRU	Line-Replaceable Unit
M1	Primary Mirror
M2	Secondary Mirror
M3	Tertiary Mirror
MAIT	Manufacturing, Assembly, Integration and Test (only in Europe)
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NIH	New Integration Hall
Non-UPS	Non- Uninterrupted Power Supply
OHS	Observation Handling Subsystem
OLAS	On-Line Archive System
PAE	Provisional Acceptance in Europe
PBS	Product Breakdown Structure
PDR	Preliminary Design Review
PLC	Programmable Logic Controller
PSD	Power Spectral Density
PWV	Precipitable Water Vapour
QC	Quality Control
RAM	Reliability, Availability & Maintainability
RD	Reference Document
RMS	Root Mean Square
RTC	Real Time Computer
RTC Tk	Real Time Computer Toolkit
SCP	Service Connection Point
SDP	Science Data Products
SRTC	Soft Real Time Computer
SRU	Shop Replaceable Unit
TR	Time to Repair
TRS	Technical Requirement Specifications

UPS	Uninterrupted Power Supply
UT	Unit Telescope
UT4	Unit Telescope 4
VLT	Very Large Telescope
VLTI	Very Large Telescope Interferometer
WFS	WaveFront Sensor
WPM	Wood Packing Material

1.2.3 Coordinate Systems

[R-VLT-16] D/ /I/ Unless otherwise specified, the coordinates systems and conventions that shall be applied for the Very Large Telescope (VLT) are given in AD1.

1.2.4 Naming Conventions

[INFO-VLT-18] ***chopping*** A process by way of which the ***pointing*** of the telescope is changed rapidly and periodically by a small amount (ideally with a square wave oscillation). This technique is primarily used to improve suppression of sky background with infrared observations. The oscillation is not necessarily provided by the telescope kinematics; it can be provided by a fast-steering mirror (ideally in a pupil).

[INFO-VLT-19] ***mode*** Within this document an operational mode is defined as a group of capabilities or functionalities related to an aspect of use.

[INFO-VLT-20] ***secondary guiding*** Secondary guiding is the use of on-instrument systems to control the position of a source on the instrument focal plane. This is typically used to improve the accuracy of guiding delivered by the telescope.

[INFO-VLT-21] ***state*** A state is an exact required, permitted or prohibited operating condition of the instrument.

[INFO-VLT-22] ***use case*** A use case describes the functionality that an instrument must provide in order to achieve some user goals.

2. Related Documents

2.1 Applicable Documents

[R-VLT-25] D/ / / The following documents form part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the content of this document, the content of this document shall be considered as superseding the others.

2.1.1 ESO Documents

AD1 Basic telescope definitions;
VLT-SPE-ESO-10000-0016
https://pdm.eso.org/kronodoc/HQ/ESO-222133/2

AD2 VLT Optics: Design of Telescope Optics;
VLT-TRE-ESO-10000-0526
https://pdm.eso.org/kronodoc/HQ/ESO-221445

AD3 Relevant Atmospheric Parameters for E-ELT AO Analysis and Simulations;
ESO-258292
https://pdm.eso.org/kronodoc/HQ/ESO-258292

AD4 Common Interface Control Document between VLT Scientific Instrument and the VLT Observatory;
ESO-379345
https://pdm.eso.org/kronodoc/HQ/ESO-379345

AD5 Interface Control Document between the Adaptive Optics Facility and Instrument;
ESO-348294
https://pdm.eso.org/kronodoc/HQ/ESO-348294

AD6 Interface Control Document between VLTI and its Instruments (Part I);
ESO-045686
https://pdm.eso.org/kronodoc/HQ/ESO-045686

AD7 ICD between the PAO CAS and its clients;
ESO-385645
https://pdm.eso.org/kronodoc/HQ/ESO-385645

AD8 New Integration Hall User Manual;
ESO-272224
https://pdm.eso.org/kronodoc/HQ/ESO-272224

AD9 ESO Safety Conformity Assessment Procedure;
SAF-GEN-MAN-3444
https://pdm.eso.org/kronodoc/HQ/ESO-193497

AD10 Safety Manual Garching/Santiago;
SAF-GAR-MAN-0002
https://pdm.eso.org/kronodoc/HQ/ESO-201102

AD11 Health, Safety & Environment Manual - La Silla Paranal Observatory;
ESO-201112
https://pdm.eso.org/kronodoc/HQ/ESO-201112

AD12 LPO Driving procedure;
LPO-PRO-ESO-20100-0003
https://pdm.eso.org/kronodoc/HQ/ESO-201113

AD13 Hazardous Material Procedure LPO;
ESO-201115
https://pdm.eso.org/kronodoc/HQ/ESO-201115

AD14 Personal Protective Equipment Procedure LPO;
LPO-PRO-ESO-20100-0010
https://pdm.eso.org/kronodoc/HQ/ESO-231077

AD15 ESO Safety Policy and Organization;
SAF-GEN-POL-0001
https://pdm.eso.org/kronodoc/HQ/ESO-201089

AD16 Contractor Safety Procedure. La Silla Paranal Observatory;
ESO 231076
https://pdm.eso.org/kronodoc/HQ/ESO-231076

AD17 ESO Mechanical Standards;
GEN-SPE-ESO-50000-4645
https://pdm.eso.org/kronodoc/HQ/ESO-192984

AD18 Execution of steel structures and aluminium structures;
EN 1090

AD19 ESO Engineering Analysis Standards;
ESO-191462
https://pdm.eso.org/kronodoc/HQ/ESO-191462

AD20 Standard Components and Guidelines for Cooling Circuits;
ESO-254314
https://pdm.eso.org/kronodoc/HQ/ESO-254314

AD21 Vacuum and Cryogenic Standard Components;
ESO-046147
https://pdm.eso.org/kronodoc/HQ/ESO-046147

AD22 Electronical and Electronic Design Standards;
ESO-044295
https://pdm.eso.org/kronodoc/HQ/ESO-044295

AD23 PLC standards;
ESO-253475
https://pdm.eso.org/kronodoc/HQ/ESO-253475

AD24 Earthing Bonding and Protection against Lightning and LEMP of ESO Buildings and Structures;
GEN-SPE-ESO-50000-0072
https://pdm.eso.org/kronodoc/HQ/ESO-193873

AD25 Dataflow for ESO Observatories Deliverables Standard;
ESO-037611
https://pdm.eso.org/kronodoc/HQ/ESO-037611

AD26 Data Interface Control Document;
ESO-044156
https://pdm.eso.org/kronodoc/HQ/ESO-044156

AD27 VLT Interferometer - VLTI Data Interface Control Document;
VLT-SPE-ESO-15000-2764
https://pdm.eso.org/kronodoc/HQ/ESO-045695

AD28 ESO Science Data Products Standard;
ESO-044286
https://pdm.eso.org/kronodoc/HQ/ESO-044286

AD29 Instrument Control System Standard Architecture;
ESO-380034
https://pdm.eso.org/kronodoc/HQ/ESO-380034

AD30 Instrument Control Software Specifications;
ESO-351071
https://pdm.eso.org/kronodoc/HQ/ESO-351071

AD31 Control System Development Standards;
ESO-193358
https://pdm.eso.org/kronodoc/HQ/ESO-193358

AD32 Software Assurance Requirements for E-ELT Contracts;
ESO-224035
https://pdm.eso.org/kronodoc/HQ/ESO-224035

AD33 E-ELT Programming Language Coding Standards;
ESO-254539
https://pdm.eso.org/kronodoc/HQ/ESO-254539

AD34 ICD between ICS and OHS;
ESO-375289
https://pdm.eso.org/kronodoc/HQ/ESO-375289

AD35 ICD between the ICS and On-Line Archive System;
ESO-384590
https://pdm.eso.org/kronodoc/HQ/ESO-384590

AD36 Common ICD between CCS/ICS and Detector Control Software;
ESO-305615
https://pdm.eso.org/kronodoc/HQ/ESO-305615

AD37 E-ELT Instrument Control System Development Process Requirements;
ESO-267497
https://pdm.eso.org/kronodoc/HQ/ESO-267497

AD38 E-ELT Instrument Control System Common Requirements;
ESO-264642
https://pdm.eso.org/kronodoc/HQ/ESO-264642

AD39 Adaptive Optics Real Time Computer Standard Architecture;
ESO-384404
https://pdm.eso.org/kronodoc/HQ/ESO-384404

AD40 Standard for Technical and Wavefront Sensor Cameras;
ESO-319951
https://pdm.eso.org/kronodoc/HQ/ESO-319951

AD41 ICD between the WFS Cameras and the ELT Instruments;
ESO-302894
https://pdm.eso.org/kronodoc/HQ/ESO-302894

AD42 PBS and Document Mass Upload Template for External Parties;
ESO-385734
https://pdm.eso.org/kronodoc/HQ/ESO-385734

AD43 CAD data Format Requirements;
GEN-SPE-ESO-59100-5516
https://pdm.eso.org/kronodoc/HQ/ESO-193712

AD44 NGC II Interface Control Document;
ESO-362949
https://pdm.eso.org/kronodoc/HQ/ESO-362949

AD45 Cryogenic developments: VLT Vibration Specification for UT Instruments;
VLT-SPE-ESO-20200-5926
https://pdm.eso.org/kronodoc/HQ/ESO-230837

AD46 ESO IT Server Standard;
ESO-250683
https://pdm.eso.org/kronodoc/HQ/ESO-250683

AD47 Organization and Conduct of reviews;
GEN-PRO-ESO-10000-5247
https://pdm.eso.org/kronodoc/HQ/ESO-044301

AD48 VLT-Instrumentation Software Specification;
VLT-SPE-ESO-17212-0001
https://pdm.eso.org/kronodoc/HQ/ESO-043105

2.2 Reference Documents

[INFO-VLT-76] The following documents, of the exact version shown herein, are listed as background references only. They are not to be considered as binding.

RD1 Instrument packing specifications and recommendations;
GEN-SPE-ESO-70500-5942
https://pdm.eso.org/kronodoc/HQ/ESO-225669

RD2 NIH Interface control drawing;
ESO-288379
https://pdm.eso.org/kronodoc/HQ/ESO-288379

RD3 Common Pipeline Library User Manual;
VLT-MAN-ESO-19500-2720
https://pdm.eso.org/kronodoc/HQ/ESO-037639

RD4 HDRL Pipeline Developer Manual;
ESO-299492
https://pdm.eso.org/kronodoc/HQ/ESO-299492

RD5 Control GUI Developer Guidelines;
ESO-288608
https://pdm.eso.org/kronodoc/HQ/ESO-288608

RD6 Guide to Developing Software for the EELT;
ESO-288431
https://pdm.eso.org/kronodoc/HQ/ESO-288431

RD7 CCD-Lenslet Assembly;
VLT-DWG-ESO-14850-0-131100
https://pdm.eso.org/kronodoc/HQ/ESO-239361

RD8 Technical Detector Control Software for COTS Cameras - User Manual;
ESO-310063
https://pdm.eso.org/kronodoc/HQ/ESO-310063

RD9 ESO Control Engineering Handbook;
GEN-SPE-ESO-50000-4908
https://pdm.eso.org/kronodoc/HQ/ESO-044249

RD10 Document Requirement Definition (DRD);
ESO-213265
https://pdm.eso.org/kronodoc/HQ/ESO-213265

RD11 Auxiliary Equipment List Template (handling & maintenance tools) for Storage at Paranal;
ESO-332980
https://pdm.eso.org/kronodoc/HQ/ESO-332980

RD12 Spare Part List Template;
ESO-332979
https://pdm.eso.org/kronodoc/HQ/ESO-332979

RD13 List of PLC modules;
ESO-253356
https://pdm.eso.org/kronodoc/HQ/ESO-253356

RD14 Real Time Computer Toolkit Design;
ESO-349737
https://pdm.eso.org/kronodoc/HQ/ESO-349737

RD15 Coding Conventions for IEC61131-3 PLC Development;
ESO-266508
https://pdm.eso.org/kronodoc/HQ/ESO-266508

RD16 Hardening and Thermal aging Procedure;
VLT-INS-0053
https://pdm.eso.org/kronodoc/HQ/ESO-276510

RD17 Paranal DataLab User Manual;
ESO-303679
https://pdm.eso.org/kronodoc/HQ/ESO-303679

RD18 NGC II Requirements;
ESO-372233
https://pdm.eso.org/kronodoc/HQ/ESO-372233

RD19 NGCII Interface Control Document;
ESO-362949
https://pdm.eso.org/kronodoc/HQ/ESO-362949

RD20 NGC II User and maintenance Manual;
ESO-382530
https://pdm.eso.org/kronodoc/HQ/ESO-382530

RD21 NGC II Safety Compliance Assessment;
ESO-382531
https://pdm.eso.org/kronodoc/HQ/ESO-382531

RD22 ELT-VLT Gateway Software Design Description;
ESO-351097
https://pdm.eso.org/kronodoc/HQ/ESO-351097

RD23 ELT-VLT Gateway SW User and Maintenance Manual;
ESO-351098
https://pdm.eso.org/kronodoc/HQ/ESO-351098

RD24 REMOVED

RD25 LPO IT Interface and Integration Requirements for New Instruments and Facilities;
ESO-231472
https://pdm.eso.org/kronodoc/HQ/ESO-231472

RD26 A Guideline to Product and Quality Assurance for ESO Projects;
ESO-193269
https://pdm.eso.org/kronodoc/HQ/ESO-193269

RD27 Execution of steel structures and aluminium structures;
EN1090

RD28 ESO Template – Qualitative FMECA (Excel);
ESO-327340
https://pdm.eso.org/kronodoc/HQ/ESO-327340

RD29 NEAR Experiment Mechanical Design Infrastructure Modifications;
ESO-299442
https://pdm.eso.org/kronodoc/HQ/ESO-299442

RD30 Flux return statistics from AOF LGS WFSs;
ESO-380757
https://pdm.eso.org/kronodoc/HQ/ESO-380757

RD31 ESO Template Hazard analysis (Doc);
ESO-254355
https://pdm.eso.org/kronodoc/HQ/ESO-254355

RD32 ESO Template Hazard analysis (Excel);
ESO-315142
https://pdm.eso.org/kronodoc/HQ/ESO-315142

RD33 Instruction for delivering Maintenance Actions List;
ESO-272238
https://pdm.eso.org/kronodoc/HQ/ESO-272238

RD34 Maintenance Actions List Template;
ESO-335752
https://pdm.eso.org/kronodoc/HQ/ESO-335752

3. Product Description

[INFO-VLT-112] This section provides a short general description of instruments, as distinct from the telescope with the purpose of defining the systems to which this requirement specification applies.

[INFO-VLT-113] The primary role of the telescope (in this case Very Large Telescope (VLT) or VLT Interferometer -VLTI-) is to collect light and to form an image or an interferogram at the focal plane.

[INFO-VLT-114] Instruments will be conceived as complete self-contained units which are installed on the telescope as single pre-tested and functioning units that analyses the light collected by the telescope after a final focus position.

[INFO-VLT-115] Based on the analysis the instrument might provide feedback on the telescope. If the analysis of the light collected by an instrument has a scientific purpose the system is referred to as "Scientific Instrument", if it has a purely technical purpose the system is referred to as "Post-Focal Module" if post-focal and “infrastructure system” if inserted into the telescope optical train (i.e. Adaptive Optics (AO) in the Coudé train).

[INFO-VLT-116] An instrument normally consists of:

- An optical system that takes the light coming from the telescope and processes it according to the specific functions of the instrument (e.g., imaging, spectroscopy, polarimetry).
- An optomechanical system that keeps the optical elements in their nominal positions and that changes their positions to allow for different configurations and functions. This system also performs the function of protecting the optical elements from the environment.
- A detector system placed at the focus of the optical system which converts the light into electrical signals.
- An electronic system that processes the signals from the detector to be read by the control system.
- A vacuum and cryogenic system if required to satisfy the temperature conditions requested by specific applications.
- A control system that interacts with the user implementing commands, feeding back status information and delivering data products (raw data).
- A calibration system to remove systematic errors or effects from the instrument, and instrumental signatures from the raw data.
- Auxiliary equipment needed for installation, maintenance and removal from the telescope.

In addition, scientific instruments have a data flow system including tools for preparing the science observations and for producing reduced data from raw data.

- A documentation package.

4. Environmental Conditions

4.1 Nominal Operating Conditions

[R-VLT-119] D/A/ / Unless otherwise specified all the requirements in this document shall be met under these nominal operating conditions.

Operational Conditions:

The Operational Conditions are those under which the instrument shall meet all the performance requirements specified in its TRS and applicable documents.

Functional Conditions:

The Functional Conditions are those under which the Instrument shall still be fully functional albeit not necessarily meeting all the performance requirements specified in its TRS.

Survival Conditions:

Survival Conditions are occasional (2-5 times within 10 years) accidental conditions of different severity which may be experienced by the instruments during their lifetime. The instrument shall survive such events and shall be able to restart operation after their occurrence:

a) No damage of the Instrument is allowed.

b) All the functional and performance requirements defined in the present technical specifications shall still be met after actions taken as defined in the Operations Manual agreed with ESO.

4.1.1 Nasmyth & Cassegrain Instruments

[R-VLT-121] D/A/ / The Nominal Operating Conditions which shall be assumed for Nasmyth and Cassegrain instruments are provided in Table 1:

[R-VLT-122] D/A/ /

	Operational	**Functional**	**Survival**
Air density	0.96kg/m³ (Median)		*1kg/m³*
Air Pressure	750 mbar ± 50 mbar		*1050 -650 mbar*
Air Temperature	0ºC to +15ºC	-5ºC to +25ºC	*-10ºC to +30ºC*
Air temperature gradient at nighttime	-0.45ºC/h to +0.4ºC/h	+1.0 ºC/h to -1.4ºC/h	*-10.0ºC/h to +10.0ºC/h (over 30 min)*
Relative Humidity range	5% to 95%		*3% to 100% with condensation*
Average wind speed	<2 m/s	<3 m/s	*<16 m/s*
Ozone Concentration	<180µg/m³		
Dust and Sand	ISO 7.2 (median) and ISO 8 (90% percentile), according to EN ISO 14644-1: 1999.		
Aggressive Atmosphere	NO ≤ 3ppb, NO_2 ≤ 3ppb, SO_2 ≤ 3ppb		
Vibration and Acoustic Noise	See section 8.13.1		
Accelerations	Max Angular tracking velocity: 25'/sec Max angular tracking acceleration: 8"/sec^2 Max slewing speed: 7.5 deg/sec Max angular slewing acceleration: 1deg/sec2 Max deceleration (emergency braking): tel. structure 10deg/sec^2 rotator: 12deg/sec^2		

Table 1: Nominal Operating Conditions for Nasmyth and Cassegrain instruments

[R-VLT-123] D/A/ / **Earthquake Requirements:** By design, the subsystems shall survive earthquakes, when they are on the telescope. Figure **1** and Table **2** provides the Earthquake frequency-dependent quasi-static accelerations at **Cassegrain,** Nasmyth **Adaptor/rotator, Nasmyth platform and Coudé platform** that the instrument design shall assume in their design and analysis.

[R-VLT-124]
D/A/ /

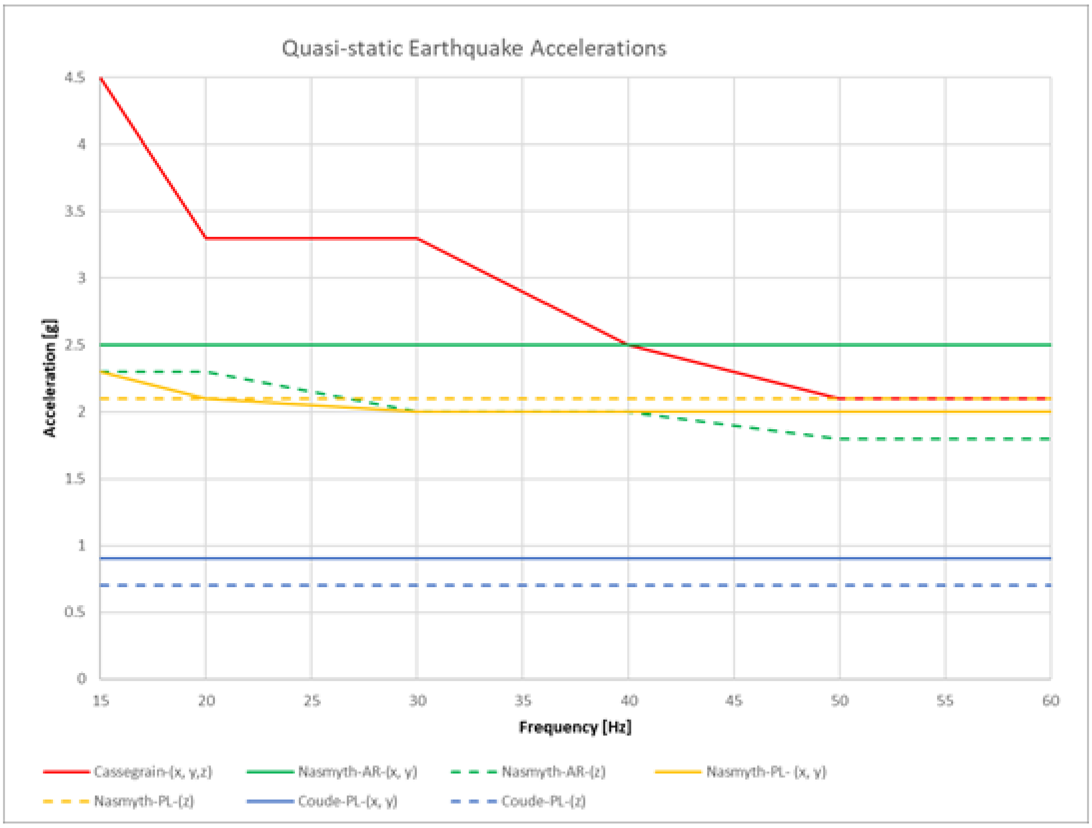

Figure 1: Earthquake frequency-dependent quasi-static accelerations at Cassegrain, Nasmyth Adaptor/rotator, Nasmyth platform and Coudé platform.

[R-VLT-125]
D/A/ /

	Cassegrain	NP-Adapter		NP-Instruments		Coude	
INS 1st Eigenfrequency	Cassegrain-(x, y,z)	Nasmyth-AR-(x, y)	Nasmyth-AR-(z)	Nasmyth-PL-(x, y)	Nasmyth-PL-(z)	Coude-PL-(x, y)	Coude-PL-(z)
[Hz]	[g]	[g]	[g]	[g]	[g]	[g]	[g]
15	4.5	2.5	2.3	2.3	2.1	0.9	0.7
20	3.3	2.5	2.3	2.1	2.1	0.9	0.7
30	3.3	2.5	2	2	2.1	0.9	0.7
40	2.5	2.5	2	2	2.1	0.9	0.7
50	2.1	2.5	1.8	2	2.1	0.9	0.7
60	2.1	2.5	1.8	2	2.1	0.9	0.7

Table 2: Earthquake frequency-dependent quasi-static accelerations

4.1.2 Coudé Instruments

[R-VLT-127] D/A/ / The Nominal Operating Conditions which shall be assumed for Coudé instruments are listed in the Table 3:

[R-VLT-128] D/A/ /

	Operational	**Functional**	**Survival**
Air density	0.96kg/m^3 (Median)		1kg/m^3
Air Pressure	750 mbar ± 50 mbar		N/A
Air Temperature	0ºC to +15ºC	0ºC to +25ºC	-5ºC to +30ºC
Air temperature gradient at nighttime	-0.45ºC/h to +0.4ºC/h	+1.0 ºC/h to -1.4ºC/h	*-10.0ºC/h to +10.0ºC/h (over 30 min)*
Relative Humidity range	5% to 95%		3% to 100% with condensation
Average wind speed	N/A	N/A	N/A
Ozone Concentration	<180µg/m^3		
Dust and Sand	ISO 7.2 (median) and ISO 8 (90% percentile), according to EN ISO 14644-1: 1999		
Aggressive Atmosphere	NO ≤ 3ppb, NO_2 ≤ 3ppb, SO_2 ≤ 3ppb		
Vibrations and Acoustic Noise	See section 8.13.1		
Accelerations	N/A		

Table 3: Nominal Operating Conditions for Coudé instruments

[R-VLT-129] D/A/ / **Earthquake Requirements:** By design, the subsystems shall survive earthquakes, when they are on the telescope.

[R-VLT-130] D/A/ / Figure **1** and Table **2** provides the Earthquake frequency-dependent quasi-static accelerations at **Cassegrain,** Nasmyth **Adaptor/rotator, Nasmyth platform and Coudé platform** that the instrument design shall assume in their design and analysis.

4.1.3 Sky Background at Paranal

[INFO-VLT-132] The following table provides the typical IR Backgrounds at Paranal (mag/arcsec-2), from *J. Cuby et al., The Messenger 101, p.3, September 2000*. Note that K, L and M values include telescope background:

Band	J	H	Ks	L	M-NB
Magnitude	16.5	14.4	13.0	3.9	1.2

[INFO-VLT-133] The following table provides the typical zenith corrected average sky brightness during dark time at Paranal. Values are expressed in mag arcsec-2.

[INFO-VLT-134] Columns 3 to 7 show the root mean square (RMS) deviation, minimum and maximum brightness, number of data points and expected average contribution from the zodiacal light, respectively. Average background at Paranal (mag/arcsec-2), from >4000 FORS1 exposure during Apr.-Sep. 2001, by *F. Patat,* UBVRI Night Sky Brightness at ESO-Paranal during sunspot maximum.

[INFO-VLT-135]

Filter	Sky Brightness	Sigma	Min	Max	N	Delta_m_{ZL}
U	22.28	0.22	21.89	22.61	39	0.18
B	22.64	0.18	22.19	23.02	180	0.28
V	21.61	0.2	20.99	22.10	296	0.18
R	20.87	0.19	20.38	21.45	463	0.16
I	19.71	0.25	19.08	20.53	580	0.07

NFO-VLT-136] More accurate values of full radiance spectrum anywhere between 300nm and 30micron can be obtained using the SkyCalc web application It also has the option to output the broadband background radiation in magnitudes/arcsec^2 in all bands from U to Q. There are references to the filter profiles and zero points.

https://www.eso.org/observing/etc/skycalc

[INFO-VLT-137] The details in the sky model is described in the document:

https://www.eso.org/observing/etc/doc/skycalc/helpskycalc.html

4.1.4 Astroclimatology

[INFO-VLT-139] Additional ESO astroclimatology data of Paranal are available for instrument designers at the following location:

https://www.eso.org/gen-fac/pubs/astclim/paranal/index.html

4.2 Specific Conditions

[R-VLT-141] D/A/ / The Specific Operating Conditions shall apply to:

- Instrument (Re-)assembly at the Observatory
- Instrument Integration
- Maintenance
- Transport and Storage

4.2.1 Conditions Applicable to (Re)-Assembly, Integration and Maintenance

[R-VLT-143] D/A/ / The conditions defined Table 4 below shall apply to the (re)-assembly, integration and maintenance of the instrument at the observatory.

[R-VLT-144] D/A/ /

	Typical	**Survival**
Gravity orientation (Z_C w.r.t vertical*)	≤ 2 deg**	NA
Air Pressure	750 mbar +/-50mbar	600 mbar ±100 mbar
Air Temperature	0°C to +15°C	NA
Earthquake	none	±1.3 g quasi static in any direction

Table 4: Environmental conditions for (re)-assembly, integration and maintenance of the instrument at the observatory

* Z_C is the axis that is locally aligned with the gradient of the gravity field in the instrument's center-of-mass coordinate system.

4.2.2 Conditions Applicable to Transport and Storage

[INFO-VLT-146] Transport Conditions are those to which the Instrument will be exposed on the way to its intended place of operation. This might refer to transport from instrument construction premises (Europe, Australia, others) to Chile as well as transport at the LPO observatory site.

[R-VLT-147] D/A/ / The conditions defined in **Table 5** shall apply when transporting and storing the instrument.

[R-VLT-148] D/A/ /

	Typical	**Survival**
Gravity orientation (w.r.t Z_C axis)	As specified in packing requirements	NA
Air Pressure	570 mbar to 1045 mbar	NA
Air Temperature	-15°C to +45 °C	-33°C to +85 °C
Rain	None	10 cm/h with a droplet size of 0.5 to 4.5 mm and a wind velocity of 18 m/s
Relative Humidity range	3% to 100% condensing	NA
Blowing Dust and Sand	Particle size 74 to 1000 micrometers, mostly 74 to 350 micrometers Particle concentration: 1.0 g/m^3 Wind speed 18 to 30 m/s	NA
Shipping vibration loads	As defined in Figure 2	NA
Salt concentration	5% ± 1%	20%
Mechanical shocks	none	Drop height 20 cm
Earthquake	none	± 1.3 g quasi static in any direction

Table 5: Environmental conditions for when transporting and storing the instrument.

[R-VLT-149]
D/A/ /

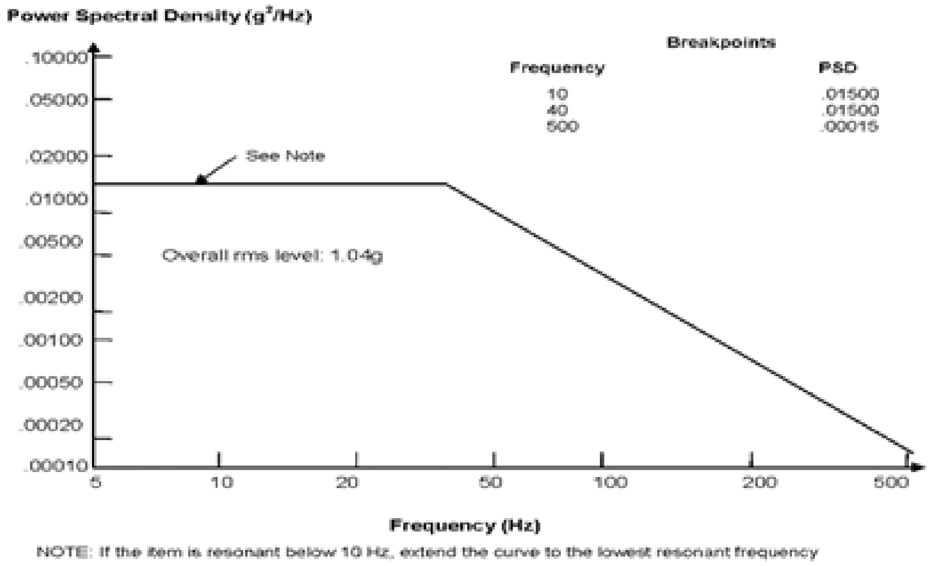

Figure 2: Power spectral density of accelerations applicable to transport

4.3 Load Combination Factors

[R-VLT-151]
D/A/ /
For the verification of the performance and structural integrity, as a minimum the following load combinations and corresponding factors shall be analyzed:

[R-VLT-152]
D/A/ /

				Load combination factor	
Load combination	**Load Category**	**Section**	**Permanent load**	**Survival temperature**	**Maximum acceleration (earthquake, shock)**
LC1	Operational Conditions	4.1	1.0 x O (1)		
LC2	Survival/Accidental	4.1	1.0 x O (1)	1.0	
LC3	Survival/Accidental	4.1	1.0 x O (1)		1.0
LC4	Survival/Accidental	4.2.1	As per section 4.2.1		1.0
LC5	Survival/Accidental	4.2.1	As per section 4.2.1		1.0
LC6	Survival/Accidental	4.2.2	As per section 4.2.2	1.0	
LC7 (Shock Load)	Survival/Accidental	4.2.2	As per section 4.2.2	0.7	1.0
LC8 (Earthquake)	Survival/Accidental	4.2.2	As per section 4.2.2		1.0

(1) *O: Operational load conditions (i.e. gravity, operational temperature range, internal stress.*
"1.0 x O (1)" means that the operational load conditions defined in section 4.1 has to be multiplied with the load combination factor of 1.0. The operational load conditions are defined in **Table 1** and in **Table 3** in the column "Operational".

4.4 Atmospheric Parameters

[INFO-VLT-154] Atmospheric parameters of the LPO site relevant for instrument development are given in AD3.

[R-VLT-155] D/A/ /T Instruments that provide or possess AO capabilities shall consider the atmospheric turbulence of the LPO site as characterized in AD3 as the basis for development of the AO system, in particular for analysis and simulations.

4.5 Precipitable Water Vapor

[INFO-VLT-157] The distribution of precipitable water vapor (PWV) over Paranal Observatory is given in Figure 3. The median PWV is 2.4 mm from "*Support for site testing of the European Extremely Large Telescope: precipitable water vapor Paranal*" Florian Kerber et al. SPIE Proceedings Volume 7733, Ground-based and Airborne Telescopes III; 77331M (2010) https://doi.org/10.1117/12.856390 .

[INFO-VLT-158]

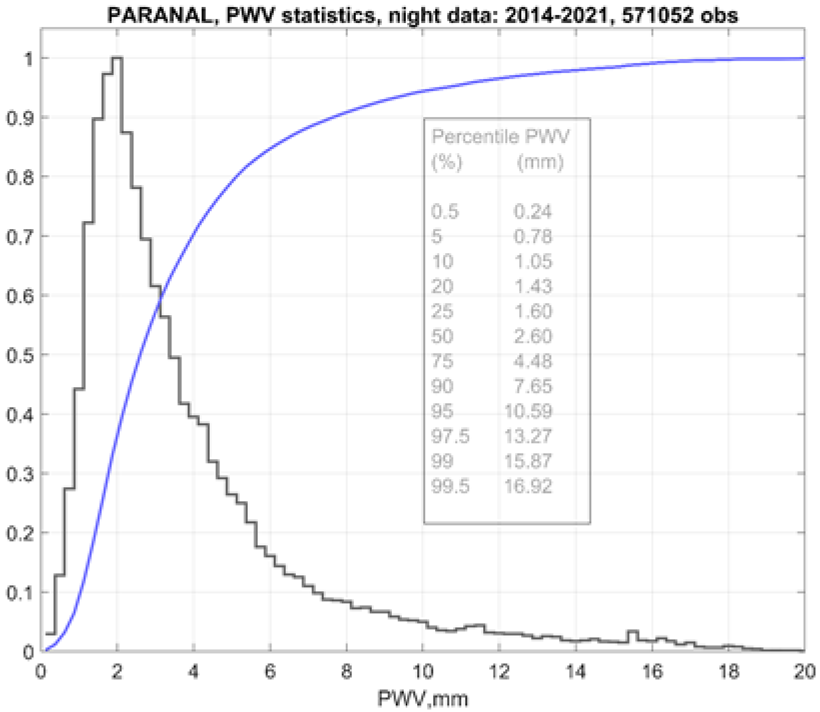

Figure 3: Histogram, Cumulative Function and Statistics of night-time PWV measurements at the Paranal Observatory. From Observations in the period Jan-2014 until Jan-2021.

5. Physical, Functional and Performance Requirements

5.1 General requirements

[R-VLT-161] D/ /I/ Instruments shall be conceived as complete self-contained units which -as far as possible and to be agreed with ESO at PDR- can be installed on the telescope as a single pre-tested and functioning unit.

[R-VLT-162] D/ /I/ Instruments shall preferably be designed such that the full instrument or major instrument modules can be shipped pre-assembled with minimum re-integration time and personnel on-site for AIV.

[R-VLT-163] D/ / / Instruments requiring re-assembly and verification on-site before installation at the telescope shall be re-assembled in one of the integration facilities described in AD4.

[INFO-VLT-164] Nasmyth /Coudé / VLTI instruments may be re-assembled after the transport directly on the respective assigned Nasmyth platform, Coudé room VLTI laboratory location after validation by ESO.

5.1.1 General requirements for Cassegrain instruments

[R-VLT-166] D/ /I/ All Cassegrain instruments shall be attached directly to the Cassegrain rotator according to interfaces defined in AD4.

[INFO-VLT-167] Due to the location below the main mirror cell, Cassegrain instruments will be routinely (i.e., at least once a year) dismounted from the telescope, e.g. every time the main mirror is removed for re-coating, or in case access to the Cassegrain adapter/rotator is necessary for maintenance or repair.

[INFO-VLT-168] The Azimuth platform may be used for the temporary location of transport, handling and test equipment during the installation of Cassegrain instruments and for access for test and maintenance purposes (see also AD4).

5.1.2 General requirements for Nasmyth instruments

[R-VLT-170] D/ /I/ Nasmyth instruments shall be either attached directly to the Nasmyth rotator or to the Nasmyth platform independently of the rotator according to interfaces defined in AD4.

[INFO-VLT-171] Apart from instrument attachment, the Nasmyth platform may be used for the installation of independent ancillary equipment associated with the instruments, for example control electronic, thermal enclosures, etc.

[R-VLT-172] D/ /I/ Ancillary equipment associated with instrument at Nasmyth shall be designed and agreed with ESO in such a way as to allow them to be installed and removed in as few units as is practical.

[R-VLT-173] D/ /I/ Any electronic units not attached directly to a Nasmyth instrument shall be mounted in a free-standing cabinet with the minimum -to be justified by design- of interconnecting cables between the cabinet and the instrument.

[R-VLT-174] D/ /I/ Any electronic units not attached to a Nasmyth instrument shall be anchored to the platform via the use of ESO standard dampers according to AD4.

[R-VLT-175] D/ /I/ The design of the instrument shall have provision for passageway and access requirements to the base VLT Adaptor-rotator at Nasmyth or other VLT equipment at Coudé for maintenance personnel as well as to instruments and modules as specified in AD4.

[R-VLT-176] D/ /I/ A passageway next to the staircase shall be permanently kept free on the Nasmyth platforms (AD4)

[R-VLT-177] D/ /I/ It shall be possible to remove any instrument related equipment from an area in front of the adapter/ rotator to allow access in case the adapter/ rotator needs servicing or need to be removed completely (AD4) in less than 2 hours for two technicians (values TBC).

5.2 Physical Characteristics

[R-VLT-179] D/A/I/ The design of the instrument shall be compliant with the mechanical interfaces, mass, torque limits and design volumes specified in AD4 for Cassegrain, Nasmyth and Coudé instruments/systems.

[R-VLT-180] D/A/I/ If any of the mechanical interface on the side of the telescope needs to be modified this shall be discussed and agreed upon with ESO at PDR and validated by an ESO approved CRE.

[R-VLT-181] D/ /I/ Instrument hardware configuration shall not be modified after instrument is mounted on the telescope without prior permission by the ESO Paranal contact point.

[INFO-VLT-182] Instrument weights change larger than 20kg requires a rebalancing of the telescope.

[R-VLT-183] D/A/I/T Instrument weight shall therefore not change by more than 20 kg during operation at Cassegrain.

5.3 Eigenfrequencies

[R-VLT-185] D/A/ /T The lowest eigenfrequency of each Nasmyth and Coudé instrument shall be higher than 15 Hz. The corresponding analytical verification shall assume infinitely rigid interfaces. See also section 4.1.1 and 4.1.2.

[INFO-VLT-186] The EQ accelerations defined in this document may be superseded by the individual Instruments Specs based on specific design constrains (instrument mounted on dampers, cold structure, etc.)

5.4 Calibration

5.4.1 General

[R-VLT-189] D/ / / Calibration of instruments not necessarily needing the night sky shall be performed during daytime.

[R-VLT-190] D/A/ / If any calibrations are necessary during night-time due to very well justified reasons and demonstrating that this will not affect any other operations/observations then approval from ESO shall be requested at the latest at ***the Final Design Review (FDR).***

[R-VLT-191] D/A/ /T The formula to calculate and predict the duration of all calibrations shall be provided by the project team.

[R-VLT-192] D/ /I/T Calibrations shall be fully automated and shall not require any action from an operator.

5.4.2 Temporal variation

[INFO-VLT-194] The telescope has active optics; hence the exact optical configuration will vary slightly with time over periods of minutes or longer. In particular, this includes both, wandering of the beam footprints on the telescope mirrors. This will lead to changes in the intensity distribution in the focal plane and pupils, see AD3 for more details on this.

[R-VLT-195] D/ / /T The calibration plan (see section 8.11.4) to be provided with the instruments shall be designed to take into account these varying conditions to the extent required for the instrument to meet its performance requirements.

[R-VLT-196] D/A/ /T Sky flat calibrations shall be valid for longer than two weeks.

[R-VLT-197] D/A/ /T The frequency of skyflat calibrations shall be smaller than once every four days.

[INFO-VLT-198] Validity of sky flats should be longer than 2 weeks in order to be able to cover periods when clear skies are not accessible, such as VLTI-UT runs, during the altiplano winter, or, rarely, long period of bad weather.

5.4.3 Light Tightness

[INFO-VLT-200] During daytime various activities will be usually scheduled to take place inside the telescope enclosure, requiring varying levels of illumination.

[R-VLT-201] D/A/I/T Instruments shall be designed and built to be insensitive to outside illumination so that all calibration procedures needed by the instrument can be performed without affecting or being affected by routine observatory operations (including also the operation of other instruments).

5.4.4 Calibration Sources

[R-VLT-203] D/ /I/ All artificial calibration sources needed by the instrument shall be part of the instrument.

[R-VLT-204] D/ /I/ All calibration sources that illuminate the entrance aperture of the instrument directly shall be integrated into the instrument.

[R-VLT-205] D/A/ / If external calibration sources are needed for very well justified reasons, then written approval from ESO shall be requested (at the latest at the ***Preliminary Design Review (PDR)***). These external calibration sources shall not prevent the other instrument calibrations.

[R-VLT-206] D/A/ /T The maximum time allowable for using these external calibration sources shall be also agreed with ESO no later than PDR (as a reference, no more than 30 minutes per day).

[R-VLT-207] D/ /I/ The procurement of external calibration lamps or sources, their power supplies and interface circuitry shall be the responsibility of the instrument consortium. The control of such lamps shall be defined on a case-to-case basis by ESO in close coordination with the consortium.

[R-VLT-208] D/ / /T The intensity of the provided calibration sources shall be high enough to keep exposure times for calibration reasonably short while meeting the requirements given in section 8.13.3. What is regarded as “reasonably" shall be agreed by ESO and the consortium on a case-by-case basis ***at latest by PDR***.

5.5 Operational Requirements

5.5.1 Instrument States and Transitions

[R-VLT-211] D/ /I/ For each instrument at least the following three use cases shall be identified:

- Observation
- Calibration
- Maintenance

[INFO-VLT-212] Specific modes for each use case are given in the corresponding Technical Requirement Specification of the individual instrument.

[R-VLT-213] D/ /I/T For each use case, the instrument or individual subsystems shall have at least the four main states defined in AD30 which are different to the ones used by instrument based on the old VLT software standard:

- Off
- Not Ready
- Ready
- Operational/Idle

[R-VLT-214] D/ / /T The instruments shall be capable to switch from Off to Ready and vice versa within time limits of reaching the operational temperature, see section 8.4.

[R-VLT-215] D/A/ /T The control system shall be capable to switch from Off to Ready and vice versa within less than 10 minutes.

[R-VLT-216] D/A/ /T The transition from Ready to Operational and vice versa shall require less than 1 minute.

5.5.2 Science Operations

[R-VLT-218] D/A/ /T After target acquisition by the telescope, the instruments with no adaptive optics capabilities shall finish the setup and the acquisition of the target and be ready to start science integration in less than 3 minutes.

[R-VLT-219] D/A/ /T After target acquisition by the telescope, the adaptive optics capabilities shall acquire the guide stars and provide full image correction in less than 5 (goal 2) minutes.

[R-VLT-220] D/ / /T For guiding systems, an audio warning shall be raised when limit guiding conditions are approached (flux, residuals, …., requirement refence if possible). The warning criteria shall be agreed with ESO by PAE.

[R-VLT-221] D/ / /T In case of unexpected interruption of an exposure, detector data accrued before the interruption shall not be lost and there shall be a mean to reconstruct fits headers.

[R-VLT-222] D/ /I/ Operation and monitoring of the instrument shall be possible remotely -within the ESO network- and shall not require the presence of humans at, or near, the operation site.

5.5.3 Technical Operations

[R-VLT-224] D/A/ /T Instrument preparation for night-time operation shall take less than 15 minutes per day and shall be limited to one single observatory technician.

[R-VLT-225] D/A/ /T Routine night-time operation of an instrument, as well as very basic troubleshooting (as detailed in the Maintenance Manual), shall require no more than one person.

[INFO-VLT-226] Operation tasks may include routine external inspections, and the running of self-test programs.

[INFO-VLT-227] During instrument AIT in Europe a portable DataLab system can be provided on loan to start recording the instrument engineering telemetry indicator data later transferred to Paranal DataLab.

[R-VLT-228] D/ /I/T For calibration and observation, the interaction of the users with the instruments shall take place by means of Observation Blocks (possibly via observation preparation tools) defining the telescope and instrument parameters needed to fully characterize the execution of a calibration or observation.

[R-VLT-229] D/ /I/ Cleaning procedures shall be provided for each individual optical surface in the maintenance manual.

5.5.4 Monitoring and Control Capabilities

[R-VLT-231] D/ / /T Over or under illumination (requirement reference if possible) of the detector in closed loop control system shall trigger an audio alarm.

[R-VLT-232] D/ / /T Motorized functions reaching the last XX % of their operational stroke shall trigger an alarm to warn the operator of a possible saturation. XX shall be agreed between the project and ESO at latest at FDR.

[R-VLT-233] D/ / /T It shall be possible to reboot and power-cycle remotely any electronics unit (lcu, controllers, PLC).

[R-VLT-234] D/ /I/ All position-controlled devices shall be equipped with diagnostics identifying possible drifts and saturations risks.

[R-VLT-235] D/ /I/ Elements with a limited lifetime, such as calibration sources, shall have an operation hour and switch-on/off counter.

5.5.5 Performance monitoring

[R-VLT-237] D/ /I/T The instruments shall provide a list of relevant engineering telemetry indicators for permanent health monitoring of the instrument by the on-site maintenance team whenever the instrument is not switched off. These data shall be recorded while the instrument is observing and/or during daily health-check. These engineering telemetry indicators shall be transferred to the ESO Datalab system (see RD17) and shall be analyzed using algorithms provided by the instrument team.

[R-VLT-238] D/ / / Part of the delivery shall be a “diagnostics and performance monitoring plan” to be agreed by FDR and its implementation in DataLab by PAE.

[R-VLT-239] D/ /I/ Close loop control system shall be delivered with a mean to measure their transfer function from a computer in the control network.

[R-VLT-240] D/ /I/ The instrument shall record relevant system parameters (e.g set point, command signal, error signal) of the first 30 seconds after the system control loops are closed (adaptive optics, fringe trackers, pupil/ image trackers, etc..). The set of parameters and acquisition frequency shall be agreed with ESO by PDR.

[R-VLT-241] D/ / /T The instrument shall be delivered with a template and corresponding processing routine to compute the zero point of the system instrument + telescope with the adequate magnitude convention for the operational wavelengths.

[R-VLT-242] D/ /I/ The instrument shall have the capability to image the pupil in order to detect vignetting.

[R-VLT-243] D/A/ / A validated model of the expected instrument performance for various environmental conditions (to be agreed upon by the project team and ESO) shall be provided.

[R-VLT-244] D/ /I/ It shall be possible to illuminate remotely the whole detector for monitoring purposes.

[R-VLT-245] D/ /I/ All sensors shall be connected to the instrument control network and logged at a frequency X. No sensor shall require reading in-situ by a maintenance operator. X shall be agreed between the project and ESO at latest at FDR.

5.6 Sky baffles

[R-VLT-247] D/ / /T The principal sky-baffling shall be provided by an adequate design of the instrument: in particular it is recommended to insert a light stop at a pupil image. The optical design of the instrument shall provide a good quality pupil image (quality to be agreed with ESO on an Ad-Hoc basis) as an accessible position for this stop.

[INFO-VLT-248] The secondary mirror (M2) baffle available at the VLT and described in AD4 may be used to supplement the internal baffling.

5.7 Atmospheric Dispersion Compensation

[R-VLT-250] D/ / / If an Atmospheric Dispersion Compensator (ADC) is deemed necessary for an instrument, it shall be incorporated in the instrument itself.

5.8 Secondary Guiding

[R-VLT-252] D/ / / Instruments for which there is a possibility of varying axial misalignment, differential flexure between instrument and the adapter/rotator shall incorporate a secondary guiding system in the instrument design to correct any residual image drift.

[INFO-VLT-253] Secondary guiding at the VLT is performed by offsetting the guide probe while the telescope is under the primary guiding loop.

[R-VLT-254] D/ / / Instrument for which differential tracking between instrument and the adapter/rotator is needed (for instance for AO or Tip-tilt guide stars) shall incorporate a secondary guiding or Field Selector system in the instrument design to provide on or off axis differential tracking.

5.9 Chopping & Nodding

[INFO-VLT-256] The telescope provides chopping capabilities. Performance and interfaces are described in AD4.

[R-VLT-257] D/ / /T No provision is made within the telescope control system for nodding, Normal offsets of the telescope shall be used for this purpose. Instrument shall calculate the appropriate value for the RA and Dec of the offset to achieve the specific aim of nodding.

5.10 Optical requirements

[R-VLT-259] D/ /I/ Instrument or subsystem developed for the VLT shall use the telescope design and interfaces described in AD4 and AD2.

[R-VLT-260] D/ /I/ Instrument or subsystem developed for the VLTI shall use the optical interfaces described in AD6.

5.11 Pupil Motion and Alignment

[INFO-VLT-262] The Telescope does not provide active pupil motion control.

[R-VLT-263] D/ / / The instrument shall provide pupil motion control (sensor, controller and actuator), if a stabilized pupil motion (better than the one specified in AD4) is required for the instrument's operation.

5.12 Differential Tracking/Guiding

[INFO-VLT-265] The telescope supports differential tracking and guiding, see AD4.

[R-VLT-266] D/ / / Any requirements on differential tracking/guiding for the instrument shall be defined in the individual instrument technical requirement specification as far as necessary.

6. Interfaces

[R-VLT-268] D/ /I/ VLT Instruments, Adaptive Optics Systems and systems shall be compliant with the VLT interfaces defined in AD4 and AD5 for those installed on UT4 and using the Adaptive Optics Facility.

[INFO-VLT-269] AD6 defines the Interfaces between the VLTI and its beam combining instruments. It is applicable to any beam combining instrument located in the Interferometric Laboratory whether it is intended for scientific purposes or for technical purposes and more specifically to the second generation of instruments of the VLTI.

[R-VLT-270] D/ /I/ VLTI Instrument, Adaptive Optics systems and other systems shall be compliant with the VLTI interfaces described in AD6.

7. Access and Handling

[R-VLT-272] D/ / / Specifications of the facilities and equipment mentioned in this section shall be taken from AD8 and RD2.

7.1 General requirements

7.1.1 General Requirements for Access

[R-VLT-275] D/ / / Access to the Instruments shall be for the following purposes:

- assembly and integration
- installation and deinstallation
- commissioning
- maintenance (preventive and corrective)

[INFO-VLT-276] Access up to the instrument's design volume is provided by the telescope AD4.

[R-VLT-277] D/ /I/ The instrument shall provide access within its design volume to its sub-systems for the various purposes defined above.

[R-VLT-278] D/ /I/ The access provided by the Instrument within its design volume shall be consistent with the maintainability requirements given in section 10.3.

[R-VLT-279] D/ /I/ Size and mass of loads intended for transport via the stairs shall be compliant with the limits and restrictions given in AD4.

[R-VLT-280] D/ /I/ Size and mass of loads intended for transport via the elevator shall be compliant with the limits and restrictions given in AD4.

[R-VLT-281] D/ /I/ Loads that can neither be transported via elevator nor via stairs shall be handled with the dome crane or an external crane through the dome slit considering the specifications given in AD4.

7.1.2 Handling and Packing

[R-VLT-283] D/ / / After Provisional Acceptance in Europe (PAE) the instrument shall be disassembled to the degree necessary for transport and packed for the mode of transport (air/sea) see also section 13.2.

[INFO-VLT-284] The packing material used for the incoming transport will normally not be reused and will be disposed of following applicable regulations.

[R-VLT-285] D/ /I/ In case instruments need to be stored in an indoor or outdoor storage space before integration then the packing can be used to protect the equipment in that period. In this case, the packing shall be qualified for such use.

7.1.3 General Requirements for Handling at LPO site

[R-VLT-287] D/ / / As baseline, the Paranal New Integration Hall (NIH) shall be used for instrument assembly AD8.

[INFO-VLT-288] In exceptional cases, the Auxiliary Telescope Hall could be used after agreement by ESO. Information about the AT Hall will be made available in that case.

[R-VLT-289] D/ / / For instrument integration, the limitations of the existing facility shall be taken into account.

[INFO-VLT-290] The incoming transport weight and dimensions at NIH are limited by the halls' entrance door sizes and the cranes' lifting capacity for unloading (see AD8 & RD2).

[R-VLT-291] D/ /I/ Major instrument carriages and handling tools shall be certified for compliance with applicable safety regulations by an approved agency (TÜV or equivalent).

7.1.4 Tools

[R-VLT-293] D/ /I/ If special tools or equipment other than the one provided by the observatory (see AD8) is needed for the instrument, its handling, integration, maintenance, transportation and/or modification, then such tools shall be delivered together with the instrument and become property of the observatory.

[R-VLT-294] D/ /I/ Such tools shall be designed and fully documented in order to allow their safe use by ESO personnel over the full lifetime of the instrument.

[R-VLT-295] D/ /I/ A maintenance plan shall be available as well as a list of all auxiliary tools / equipment - handling and maintenance tools- in a readable electronic format RD11 for appropriate storage at LPO.

[R-VLT-296] D/ /I/ Lifting tools shall come with a proper certification (as defined in RD11) that is still valid for at least two years from the time when it is handed over to ESO.

[INFO-VLT-297] Retrofit or modifications of these tools may be done by ESO under ESO responsibility to improve the usage of the tools, or to make the tool usable for other use cases.

[R-VLT-298] D/ /I/ Storage space at the observatory is limited. Large handling equipment shall allow to be stored in an outdoor storage area with a levelled gravel surface, including protection covers for rain/snow/high humidity protection. Cleaning and inspection of the equipment before use is planned. Protection covers, e.g., for rubber or plastic parts, shall be included when needed for long term outdoor storage.

[R-VLT-299] D/ / / In the case of delicate tools for optics or vacuum use, or when delicate mechanisms are incorporated, then indoor storage in an unheated shelter with concrete floor will be possible. This shall be discussed and agreed with ESO on a case-by-case basis by latest at FDR.

[R-VLT-300] D/ /I/ The tools and/or components exceeding a mass of 25 kg shall have both, interfaces for forklift handling and interfaces for crane handling and shall be compatible (e.g., include rigging points) with the transport on a flatbed truck.

[R-VLT-301] D/ /I/ Transport containers for Line Replaceable Units (LRUs) or other instrument components which are needed for maintenance shall be considered as “Special tools” in the sense described above in this section.

7.1.5 Instrument Arrival and Integration

[R-VLT-303] D/ / / Instrument transport and installation inside the Observatory shall be possible with, and make use of, the dedicated Observatory services as described in AD8.

[R-VLT-304] / /I/ Before entering the integration facilities, the load shall be cleanable from dust.

[R-VLT-305] D/ / / The load shall enter the entrance hall on the public road transport vehicle.

[R-VLT-306] / /I/ The packing shall be inspected by a nominated person from the instrument consortium for obvious damage and included in an incoming inspection report.

[R-VLT-307] / /I/ The responsibility of the shipping company and transport insurance shall end once the shipment arrives on site at the integration facility and inspection is performed and properly reported.

[R-VLT-308] D/ / / In the hall entrance the load shall be unloaded using an external crane, the NIH entrance hall crane or a forklift.

[R-VLT-309] / /I/ The packing shall be opened by a nominated person from the instrument consortium and an incoming inspection prepared and provided to ESO and to the transport company.

[R-VLT-310] / /I/ The unpacking shall be completed, and the packing material disposed of.

[INFO-VLT-311] Paranal Flat Platform Truck or a forklift can be used to move the instrument components into the NIH, where they are unloaded with the instrument hall crane.

[R-VLT-312] D/ /I/ The instrument shall be assembled and verified according to the on-site AIV plan and procedures agreed upon with ESO latest at the PAE.

[INFO-VLT-313] Instruments will be exceptionally removed from the telescope foci only for very major maintenance or overhaul interventions or based on science operation decision from the observatory (change of UT foci for instance).

7.1.6 Instrument Installation at the telescope

[R-VLT-315] D/ / / At the end of the AIV in the NIH when the instrument is ready to go on the telescope and after the appropriate on-site laboratory readiness review with ESO, it shall be disassembled to the degree necessary for transport and installation at the telescope.

[R-VLT-316] D/ / / The disassembly, transportation from NIH to the VLT telescope and installation at the telescope shall be planned and procedures carefully described in the on-site Assembly Integration and Verification (AIV) plan and procedure and agreed with ESO.

[R-VLT-317] D/ / / Mounting the instrument at the telescope for the first time shall require less than 120 person hours and shall be possible without interference with the night-time operations and daytime science calibrations.

[R-VLT-318] D/ / / The instrument sections shall be transported using existing standard handling and transportation devices that are available at the observatory as provided in AD8.

[R-VLT-319] D/ /I/ Instruments or their equipment that have to be lifted by using a crane shall be provided with dedicated lifting eyes/hooks suitable for the purpose.

[R-VLT-320] D/ /I/ If not otherwise specified, when passing through doors or another type of access path, there shall be a minimum clearance of 0.3 m on both sides and 0.2 m at the top.

[INFO-VLT-321] The same handling scenario will be used if an instrument is dismounted from the telescope for decommissioning, major maintenance or other interventions.

[R-VLT-322] D/ /I/ The instrument shall be designed to undertake all non-major maintenance activities while installed at the telescope.

7.1.7 Dismounting

[R-VLT-324] D/A/ / Dismounting an instrument from the telescope shall require less than 16 hours by a crew of up to 3 ESO engineers and technicians (i.e., a total of 48 person hours) excluding pumping and cool down time of the instrument and shall be possible without interference with the night-time operations.

7.1.8 General requirements for storage

[R-VLT-326] D/ / / At the latest, prior to packing in Europe it shall be determined whether enough space for indoor storage is available upon arrival on site. If outdoor storage is necessary or cannot be excluded the packing shall be suitable for outdoor storage and allow opening for incoming inspection and re-closing for storage.

[R-VLT-327] D/A/I/ A separate storage stand, or base shall also be provided for the instrument when it is not attached to the telescope and the transportation carriage cannot fulfil this function. The requirements for the earthquake and other safety aspects apply to these devices, especially when they transport the instrument.

[R-VLT-328] D/ / / The project shall develop a concept for the storage phase, this shall include requirements for a suitable storage area, for handling tools and for storage equipment at a level of detail that allows ESO to plan for an appropriate facility.

[R-VLT-329] D/ / / The volume required at the observatory to store all spare parts and tools shall be agreed by FDR with ESO.

[R-VLT-330] D/ /I/ Instruments that are not otherwise protected from dust ingression and mechanical damage when off telescope shall be provided with protective cover.

7.2 Cassegrain instruments

[R-VLT-332] D/ / / All handling and maintenance operations for Cassegrain instrument shall be carried out with the telescope axis locked and at zenith position.

[R-VLT-333] D/ / / The telescope shall not be moved in altitude after an instrument installation before it is properly balanced (and is therefore not operational) by LPO engineering staff: Time shall be inserted in the instrument AIV plan for this activity.

[INFO-VLT-334] Free space between the M1 cell and the Azimuth floor as well as all other relevant interfaces are provided in AD4.

[R-VLT-335] D/ /I/ All Cassegrain instruments shall be provided with a transportation carriage which shall allow the instrument to be moved on the Azimuth platform and adjoining floor area and include provisions for lifting the instrument on the rotator.

[R-VLT-336] D/ /I/ The instrument, including all its auxiliary equipment and electronics, shall be designed to be easily dismounted, stored and remounted.

[INFO-VLT-337] It can be assumed that the frequency of dismounting will be not more than twice per year.

[R-VLT-338] D/ / / In the specific case of Cassegrain instrument, the time needed to mount/dismount from the Cassegrain focus shall be less than 8 hours by a crew of up to 3 ESO engineers and technicians (i.e., a total of 24 person hours) excluding pumping and cool down time of the instrument when required.

[R-VLT-339] D/ / / When remounted on the UT, pumped and cooled down, the instrument shall be capable of returning to science operations (calibrated and characterized to the same level as it was before dismounting) within 4 hrs of the first night after it is remounted.

7.3 Nasmyth instruments

[INFO-VLT-341] Both Nasmyth Platforms can be accessed via elevator and stairs for transport of people or material.

[R-VLT-342] D/ /I/ All Nasmyth instruments mounted on the adapter/rotator shall be provided with a mechanism which allows to move the instrument on the Nasmyth platform, in particular give access to the adapter/rotator section 5.1.2.

[R-VLT-343] D/ /I/ Provisions shall be included in the design for mounting the instrument on the rotator or platform.

[R-VLT-344] D/ /I/ The moving mechanism shall use the rails available in the floor of the Nasmyth platforms (see AD4).

[R-VLT-345] D/ /I/ All instrument equipment that has to be lifted onto the Nasmyth platform using the enclosure crane shall be provided with lifting eyes suitable for the purpose.

7.4 Coudé instruments or systems

[INFO-VLT-347] Coudé room can be accessed via elevator and stairs for transport of people or material.

[R-VLT-348] D/ /I/ All Coudé instruments/systems mounted at the Coudé shall be provided with a mechanism which allows to move the instrument/system at the Coudé or use the existing observatory handling equipment see AD4.

8. Design and Construction

8.1 Optomechanical

[R-VLT-351] D/ /I/ Provisions shall be made to prevent objects (e.g., tools, fasteners …) and fluids (e.g., lubricants, coolants …) from falling onto optical surfaces belonging to the instrument or to the telescope, in particular if such surfaces are unprotected.

[R-VLT-352] D/ /I/ In particular, fasteners (e.g. screws, bolts, fixation devices or components) that can fall on potentially fragile elements shall remain attached to their holding components, in case of improper tightening or fixing.

[R-VLT-353] D/ /I/ The design of the instrument and its sub-systems shall ensure that, for all permitted orientations of the instrument, liquids do not become trapped. An exception to this is under survival conditions.

[R-VLT-354] D/ /I/ Items fixed to mirrors during washing (removal of reflective coating) shall either be compatible with washing agents (as required to remove the specified coating) or easy to protect in a safe manner. If lubricants are present in the said items (e.g., in joints of a permanently mounted support system) they shall also meet this requirement.

[R-VLT-355] D/ /I/ Mirrors that require recoating over the lifetime of the instrument, and any item permanently mounted onto them, shall be compatible with vacuum coating by evaporation and by sputtering. If lubricants are present in the said items (e.g., in joints of a permanently mounted support system) they shall also meet this requirement.

[R-VLT-356] D/ /I/ Lubricants may be applied onto uncoated optical substrates for transport only (e.g., to reduce friction against supports). It shall be possible to remove such lubricants by using alcohol and clean wipes.

[R-VLT-357] D/ /I/ Surfaces identified as potential sources of stray light for other components of the telescope shall be blackened and for the wavelength range agreed with ESO.

[R-VLT-358] D/ /I/ External optical surfaces shall be cleanable.

8.2 Standardization of components

[INFO-VLT-360] Technical standards are specified in the Paranal Instrument Programme for the following main reasons:

- To simplify and accelerate the design process for VLT instruments and reduce the amount of development work required

- To assure mutual compatibility between all LPO sub-systems
- To reduce the required stock of spare parts on Paranal
- To maximize the commonality between all LPO equipment and instruments installed at PAO so that observatory staff can become familiar with new systems in the shortest possible time and simplify maintenance activities
- To reduce the global cost of operation at the observatory.

[R-VLT-361] D/ /I/ In this document, standard processes, verifications, designs and components are provided; These shall be applicable to all instruments and VLT system developments unless specified otherwise in the instrument TRSs.

[R-VLT-362] D/ / / Non-standard processes, verification methods, designs or components shall only be used with the written agreement of ESO, following a formal Request for Waiver. The Waiver will only be granted in cases of exceptional justifications.

8.3 Mechanical requirements

8.3.1 Mechanical standards

[INFO-VLT-365] AD15 defines the Mechanical Standards applicable to the design and manufacturing of products operated at ESO observatories.

[R-VLT-366] D/ /I/ Instrument projects shall conform to AD15 including all its Applicable Documents and Standards.

[R-VLT-367] D/ /I/ Mounting points, such as e.g. flanges, which need to be opened for maintenance and that affect the alignment of optics or other mechanisms shall be equipped with cylindrical pins with reamed holes, or other equivalent means, that are suitable to ensure precise repositioning.

[R-VLT-368] D/ / / The meaning of "precise" depends on the particular alignment requirements that are impacted by the opening of the mounting point and shall be quantified in the individual instrument technical requirements specification.

[R-VLT-369] D/ /I/ Hardening and thermal aging procedures described in RD16 shall be applied to instrument mechanical elements and pieces in aluminium alloy for use at cryogenic temperature.

[R-VLT-370] D/ /I/ RD27 shall also be considered for the execution of steel and aluminium structures.

8.3.2 FE models

[INFO-VLT-372] AD19 specifies criteria and procedures for the analytical verification of the performance and mechanical safety requirements defined in instrument TRSs. It establishes general requirements and considerations for the development of Finite Element models used for structural, earthquake, thermal, buckling, fatigue and CFD analyses as well as procedures for checking and validating the FE Models and assess the model and analysis results reliability.

[R-VLT-373] D/A/ / Instrument design and analysis shall comply with the requirements listed in AD19 including all its Applicable Documents and standards.

8.3.3 Welding

[R-VLT-375] D/ /I/ The design of welded structures shall be done according the regulations of the EUROCODEs. For the fabrication and test of welded structures AD18 shall be applied.

8.3.4 Cooling

[INFO-VLT-377] AD20 defines standard components and workmanship principles for the construction of chilled medium cooling systems to be installed on ESO telescopes for instruments.

[R-VLT-378] D/ /I/ Instrument projects shall conform to AD20 including all its Applicable Documents.

[INFO-VLT-379] Most telescope sub-systems and equipment are connected to the telescope electrical and fluid supplies, and to the communication networks at centralized distribution point called Service Connection Points (SCP). The SCP are composed of three parts which provides electrical, communications and fluid connections -compressed air and coolant supply-, respectively.

[R-VLT-380] D/ /I/ AD4 provides the SCP characteristics and interfaces information and requirements the instrument designed shall comply to.

[R-VLT-381] D/ /I/ All hoses shall be of a type suitable for working design pressure of at least 12 bars.

[R-VLT-382] / / /T Equipment shall be filled, and leak tested at a pressure of 10 bars before connection as described in AD20.

[R-VLT-383] / /I/ The cooling circuit shall be completely flushed before shipping to Paranal using MA (algaecide) and SCA (packet inhibitor, passivator).

[R-VLT-384] / /I/T Equipment having a total coolant capacity greater than 3 liters, as well as all equipment which is not self-purging, shall be pre-filled with the appropriate cooling liquid before connecting to the SCP coolant supply. Other equipment may be filled by direct connection to the cooling system.

[R-VLT-385] D/A/ /T The return coolant flow temperature shall not be higher than 8°C above the supply temperature. The maximum thermal load for each SCP shall not be more than 6kW (30-minute average).

[R-VLT-386] D/ /I/ The instrument cooling system shall be dimensioned such that the coolant flow speed through any part of the system is not greater than 1.2m/sec.

[R-VLT-387] D/A/ /T All instruments which make use of the telescope cooling system shall incorporate any protection mechanisms necessary to prevent damage to the instrument or to its control electronics in the event of a failure in the flow of coolant.

[R-VLT-388] D/ /I/ Additional shut-off valves shall be implemented in the supply and the return lines.

8.4 Vacuum and Cryogenics

[INFO-VLT-390] AD21 describes vacuum / cryogenic design and component standards for LPO instruments and telescope infrastructure

[R-VLT-391] D/ /I/ Instrument projects shall conform to AD21.

[R-VLT-392] D/A/ /T

Evacuation time	< 24 hrs (goal < 12 hrs; from atmospheric pressure to 10^{-4} mbar)
Cooldown time	< 2 days from start of cooldown to stable operational temperature
LN_2 hold time (bath cryostats)	> 24 hours
LN_2 hold time (continuous flow)	> 2 hours
Warmup time	< 24 hours

[R-VLT-393] D/ /I/ Instrument in the Coudé shall make use of the cryo-lines and exhaust lines (for safety reasons due to the limited volume of the Coudé and outer ring).

8.5 Electric and Electronic

[INFO-VLT-395] AD22 describes the design requirements for electrical and electronic equipment and systems of instruments and systems.

[INFO-VLT-396] In this document power quality 'compatibility levels' of ESO observatories are set. The compatibility levels - by their own definition (the specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits) - constitute a neutral reference that is valid for all pieces of equipment that are connected to a power system whichever their nature and function.

[R-VLT-397] D/ /I/T Instrument design and manufacturing shall conform to AD22 and to all its Applicable Document standards.

[R-VLT-398] D/ /I/T Instruments shall be electrically bonded. The bonding shall be compliant with AD24.

[R-VLT-399] D/ /I/T The maximum total average electrical Uninterrupted Power Supply (UPS) allowed for the instrument shall conform to SCP-Part A capacities at the given focus station provided in AD4.

[R-VLT-400] D/ /I/ RD13 provides the list of the PLC modules which shall be used in ESO instruments and telescope applications. The modules listed have been tested and shall cover all actual needs for ESO application.

[R-VLT-401] D/ /I/ All interconnecting cables and hoses longer than 1 m at the telescope shall be laid in fixed cable ducts with removable covers.

[R-VLT-402] D/ /I/ For Cassegrain instruments, a cable wrap/twist/guide system for transferring cables and hoses between the SCP on the main mirror cell and the instrument shall be provided with the instrument.

[R-VLT-403] D/A/ /T The torques induced by the cable wrap/twist/guide system shall be included in the global torque budget of the instrument.

[R-VLT-404] D/ /I/ The cable wrap system and the choice of the cables/hoses shall be designed with special care such as to meet the reliability requirements of the instrument taking into account the fact that the cable wrap/twist/guide system is continuously moved whenever the instrument is observing.

[R-VLT-405] D/ /I/ For Nasmyth and Coudé instruments, there shall be no loose cables crossing the area of the Nasmyth/Coudé platform that will be frequented by observatory maintenance staffs (except cables of a temporary nature required for commissioning activities only).

[INFO-VLT-406] It is strongly recommended that Nasmyth instruments which are mounted on the adapter/rotator use as a starting point the design of the motorized cable co-rotator as implemented for NACO and VIMOS which can be provided under request by ESO.

[INFO-VLT-407] It is strongly recommended that Cassegrain instruments which are mounted on the adapter/rotator use as a starting point the design of the cable guide as implemented for ERIS and NEAR which can be provided under request by ESO. Provisional information about this design can be found in RD28.

[R-VLT-408] D/ / / The final decision for the design of the instrument cable wrap/twist/guide shall be agreed with ESO in writing.

8.6 Electromagnetic Compatibility

[R-VLT-410] D/ /I/ The instrument shall conform to the electromagnetic compatibility requirements specified in AD22 and to all its Applicable Document standards.

8.7 Alarm handling

[R-VLT-412] D/ / /T The handling of alarms by software shall be according to AD30.

[R-VLT-413] D/ / /T Alarm conditions which can seriously endanger people and/or expensive equipment shall be handled by hardware (see section 12 safety).

[R-VLT-414] D/ /I/ Alarms resulting from the vacuum or cryogenic systems of an instrument shall be indicated by a siren and a flashing light.

[INFO-VLT-415] To supplement these three primary alarms channels a Central Alarm System (CAS) alerting maintenance staff via beepers is implemented on Paranal. The beeper alerts as a consequence of particular alarm conditions generated by the instrument.

[R-VLT-416] D/ / /T VLT instrument shall be connected to the Central Alarm System (CAS) which will alert the maintenance staff in duty according to the ICD defined in AD7.

[INFO-VLT-417] Connection to the CAS does not guarantee a response time nor should it be regarded as a safety measure. It is only intended as an additional means of alerting maintenance staff. It does not replace safety devices.

[R-VLT-418] D/A/I/ The safety plan for the instrument shall not take into account CAS as means to mitigate problems.

8.8 Instrument Control System

[INFO-VLT-420] After more than 25 years of VLT operation, the Instrument Control System standards and architecture are changed to be as consistent as possible with the new technologies and architecture applied for the ELT. This is also motivated by the obsolescence of some VLT standards and by the maintainability of the LPO-Armazones observatories.

[INFO-VLT-421] This section will therefore focus on the new standards to be applied for all future instruments for the VLT, VLTI and ELT.

[INFO-VLT-422] **Evolution/new versions of some ADs and RDs referred to in this section, section 8.9 and section 8.10 have to be expected as the standard is being developed with the ELT construction.**

[INFO-VLT-423] Annex 1 provides the legacy Applicable and Reference Documents of the old VLT Control Software and NGC detector controller Standards for the instrument currently in construction at the time of this writing.

8.8.1 Instrument Control System architecture and requirement

[INFO-VLT-425] AD29 establishes the standard overall architecture for the Instrument Control System (ICS) of future VLT-I and ELT instruments at LPO. It is a **key entry point for accessing all the associated ESO control system standards**, processes and products needed to start developing an Instrument Control System for a VLT instrument.

[R-VLT-426] D/ /I/T Instrument development shall conform to the standard architecture and associated ESO standards of AD29 and to all its Applicable Document standards.

[R-VLT-427] D/ /I/ AD38 defines the Instrument Control System Common Requirements which shall be fulfilled by instrument control system developers

[INFO-VLT-428] AD30 defines the Instrument Control Software specifications for new instrument projects at LPO.

[R-VLT-429] D/ /I/T Instrument Control Software of VLT-I instrument shall comply to AD30 and to all its Applicable Document standards tagged VLT.

8.8.2 Programming standards and languages

[INFO-VLT-431] AD33 specifies and describes the programming standards (requirements) and guidelines to be employed when working with Programming Languages for the construction of instruments for LPO. Automatic tools will be available to check adherence to standards, and where an automatic tool is not available, manual checks (code reviews) are foreseen through the development lifecycle of the software.

[R-VLT-432] D/ /I/ AD33 shall apply to all instrument software developments.

[R-VLT-433] D/ /I/ RD15 describes the Coding Conventions for IEC61131-3 Programmable Logic Controller (PLC) development and shall apply to all instruments requiring PLCs.

[INFO-VLT-434] RD6 provides guidelines for the development of instrument software for PAO.

8.8.3 Instrument Control System interfaces

[R-VLT-436] D/ /I/ AD34 describes the Interface between the Instrument Control Software and the Observation Handling Subsystem (OHS) which shall be used for all LPO instruments.

[R-VLT-437] D/ /I/ AD35 describes the interface between the ICS and the On-Line Archive System (OLAS) which shall be used for all LPO instruments

[R-VLT-438] D/ /I/ AD36 defines the common interface between the Instrument Control Software (ICS) and the Detector Control System (DCS) which shall be used by all LPO instruments. The DCS interfaces the detector (chip) electronics to control and monitor the system and provide an interface to the detector system for the upper layer SW.

[INFO-VLT-439] In order to interface the existing VLT Telescope Control System (TCS) with the new Instrument Control System Standard a “Gateway” software is needed and developed by ESO.

[R-VLT-440] D/ /I/ Instrument, AO and system builders at the VLT shall design their ICS taking into account the ELT-VLT Gateway SW.

[INFO-VLT-441] RD22 provides the ELT-VLT Gateway Software Design Description

[INFO-VLT-442] RD23 provides the ELT-VLT Software User and Maintenance Manual.

8.8.4 Control Engineering

[INFO-VLT-444] RD9 is a handbook covering all aspects of control engineering including requirements definition, analysis, design, production, verification and validation, operations and maintenance.

8.8.5 IT standards and requirements

[R-VLT-446] D/ /I/ AD46 describes the standard which shall be used for all instrument, AO systems and other delivered systems to LPO and will have to be supported by IT.

[INFO-VLT-447] This standard defines:

- the type and configuration of standard server hardware
- the procedure how the lifecycle of this standard is managed

[INFO-VLT-448] This standard does not cover any software or operating system running on servers.

[INFO-VLT-449] RD25 provides the various stages from the IT perspective to integrate a new instrument or Facility into the LPO infrastructure.

[R-VLT-450] D/ / / Instrument builders shall provide the timely necessary information listed in RD25.

8.9 Wavefront and Image Control

8.9.1 Wavefront, guiding, acquisition and other technical camera requirements

[INFO-VLT-453] Instruments, systems and Adaptive Optics systems needs Technical Cameras (TCs) for different purposes like wavefront sensing, stellar field imaging, secondary auto guiding, acquisition, guiding field stabilization and beam alignment and positioning etc…

[R-VLT-454] D/ /I/ AD40 defines the standards and standard products for these Technical and Wavefront Sensor Cameras which shall be used by instruments and Adaptive Optics systems at LPO and Armazones.

[INFO-VLT-455] AD41 provides the ICD between the WFS Cameras and the ELT Instruments applicable also for the new VLT instruments.

[INFO-VLT-456] The scope of the standard is limited to Technical and Wavefront Sensor Cameras which are integrated with, and interface to, ESO's operational and control software for example ESO's Instrument Control System (ICS) software.

[INFO-VLT-457] To limit the diversity of technical solutions for AO WFSing at the LPO and Armazones observatories, ESO developed two kind of cameras ALICE and LISA which are described in AD40.

[R-VLT-458] D/ /I/ Instrument and AO builders shall use these standards camera products whenever technically applicable for their projects in particular for AO WFSing applications for which these products have been developed.

[INFO-VLT-459] RD7 provides a typical CCD-Lenslet Assembly for information only.

[INFO-VLT-460] Deviation from these standard products is subject to an appropriate Request for Waiver.

[INFO-VLT-461] This section does not cover the Scientific camera systems -usually at the focal plane of the scientific imagers or spectrographs etc. - which are addressed in section 8.10.

8.9.2 Adaptive Optics Real Time Computer requirements

[INFO-VLT-463] This section is applicable for instrument including an Adaptive Optics system in their design.

[INFO-VLT-464] Adaptive Optics (AO) Real Time Computers (RTC) are systems which transform a wavefront measured with a WaveFront Sensor (WFS) located in the focal or pupil plane of an instrument into commands to be send to a corrective optical element like Deformable Mirrors (DM), Tip-Tilt Mirrors (TTMs). These are usually very high-speed systems requiring dedicated fast Real Time computers which are relatively complex and resource demanding to implement, subject to become obsolete very rapidly and difficult to maintain for ESO maintenance staffs who have not been involved in the initial development of the RTC by the Instrument Builder.

[INFO-VLT-465] For these reasons ESO decided to define a number of standard architecture requirements and interfaces to reduce these risks and increase the communalities between the different AO system at the LPO.

[R-VLT-466] D/ /I/ AD39 defines and specifies the Standard AO RTC Architecture and Standards -hardware and Software- which shall be followed by instrument builders with AO for LPO and ELT.

[R-VLT-467] D/ /I/ RD14 describes the design of the Real Time Computer Toolkit (RTC Tk) which shall be used in the Soft Real Time Computer (SRTC) by all Adaptive Optics builders for LPO and Armazones.

[R-VLT-468] D/ / / Request for Waiver shall be submitted to ESO for approval in case of deviations for well-justified reasons motivated, for instance, by instrument functional or performance limitations in applying the RTC standard architecture or RTC Tk above.

8.9.3 VLT wavefront control aspects and interface requirements

[INFO-VLT-470] AD4 provides all information regarding the VLT UT wavefront control aspects and wavefront Control interfaces requirements relevant for the VLT instrument, adaptive optics and system designers.

[R-VLT-471] D/ /I/T AD5 describes the main parameters and define the interfaces which shall be used between the VLT -UT4 Adaptive Optics Facility (AOF) and the instruments making use of the AOF, which are mainly defined by the following key assemblies:

- The Deformable Secondary Mirror (DSM-M2),
- The 4 Laser Guide Star Facility (4LGSF)

[R-VLT-472] D/ /I/ Instruments requiring secondary guiding shall incorporate it in the instrument design.

8.10 Science detector controller standards

[INFO-VLT-474] Science detector systems is a critical element of an astronomical instrument. Although science detector design and manufacturing expertise remains largely in industry, ESO has focused its effort and expertise in delivering state-of-the-art, reproducible standard solutions for the Science detector controller.

[INFO-VLT-475] A new standard controller, New Generation Controller II is replacing the soon obsolete New Generation Controller.

[INFO-VLT-476] Old legacy NGC Applicable and Reference Documents are listed in Annex A for currently developed instruments.

- RD18 provides the NGC II requirements to be expected
- RD19 provides the NGC II Control Software user manual
- RD20 provides the NGC II user and maintenance manual
- RD21 provides the NGC II Safety Compliance assessment
- AD44 provides the NGC II Interface Control Document

[R-VLT-477] D/ /I/ Instrument and system builders shall use the NGC II standard controller to drive and control scientific detectors whenever technically applicable for their projects.

[INFO-VLT-478] Deviation from NGC II standard products is subject to an appropriate Request for Waiver.

[R-VLT-479] D/ /I/ In the case a different science detector controller is used -after appropriate RfW- the ad-hoc controller shall fulfil the interfaces specified in AD36.

8.11 Data Flow

8.11.1 General

[INFO-VLT-482] AD25 including all its Applicable Documents, defines the interface between an Instrument and the ESO Data Flow System in terms of deliverables and dependencies.

[R-VLT-483] D/ /I/T AD25 is the key Data Flow document which lists a complete set of Data Flow System related tasks, standards and product deliverables which shall be performed by the Instrument Team.

[R-VLT-484] D/ / / Depending on the complexity of a given instrument, some of these deliveries may be waived by ESO after an explicit agreement. In that case, Request for waivers shall be submitted by the Instrument team before major milestones (e.g. PDR, FDR).

8.11.2 Data Generation

[R-VLT-486] D/ /I/ AD26 summarizes the ESO official data interface specification which shall apply to all data structures produced or used by the ESO optical telescopes.

[R-VLT-487] D/ /I/ Format and content of the raw data produced by the VLT instrument shall conform to AD26 excluding the ESO ADs.

[R-VLT-488] D/ /I/ Format and content of the raw data produced by the VLTI instrument shall conform to AD27 excluding the ESO ADs.

[R-VLT-489] D/ /I/ AD28 specifies the Science Data Products (SDP) standards for instrument scientists and pipeline developers that instruments shall comply with for successful completion of Phase 3.

8.11.3 Exposure Time Calculator and Observation Preparation Tools

[R-VLT-491] D/ /I/T AD25 -including all its Applicable Documents- shall be applicable for the instrument Exposure Time Calculator (ETC) and observation Preparation Tools activities and deliverables.

8.11.4 Instrument calibration plan

[R-VLT-493] D/ /I/T An instrument Calibration Plan shall be developed according to AD25 -including all its Applicable Documents-.

8.11.5 Data Reduction Library and Quality Control

[R-VLT-495] D/ /I/T AD25 -including all its Applicable Documents- shall be applicable for the instrument Data Reduction Library (DRL) and Quality Control (QC) activities and deliverables.

[INFO-VLT-496] RD3 and https://www.eso.org/sci/software/cpl/download.html provides the Common Pipeline Library (CPL) consisting of a set of C libraries, which have been developed to standardize the way VLT instrument pipelines are built. It provides an interface to the VLT pipeline run time environment and a software kit of medium-level tools, which allows astronomical data-reduction tasks to be built rapidly.

[INFO-VLT-497] Python-CPL bindings are being developed right now, which will allow to invoke CPL functions and recipes from Python. How exactly the two environments will work together remains to be defined, but the interface is in development.

[R-VLT-498] D/ / / Instrument builder intending to use Python-CPL, shall provide to ESO the design of the proposed implementation via a RFW to confirm this is acceptable and consistent with ESO plans.

[INFO-VLT-499] RD4 describes the High-Level Data Reduction Library (HDRL) concentrating the cross-pipeline algorithms in a single place for use into new instrument pipelines. HDRL is intended to accelerate the development of new pipelines and to benefit from bug-fixes and improvements.

[R-VLT-500] D/ / / Instrument pipeline developers are highly encouraged to use the HDRL whenever applicable for the instrument DRL - if for some reason they want to implement another solution to an already existing algorithm they shall inform ESO.

8.12 Interchangeability

[R-VLT-502] D/ / / Items produced according to identical specifications shall be interchangeable. Interchange may be contingent upon specific adjustments, provided such adjustments can be done on-site within the boundaries of the specified maintainability requirements.

8.13 Induced Environment

[R-VLT-504] D/ / / Induced environments requirements shall apply to the instrument not only in its operational state but also during the transition states of cool-down and warm up.

8.13.1 Vibration Requirements

[INFO-VLT-506] Assuming a rigid (i.e. infinitely stiff) interface, the vibration emitted by an instrument is constrained by the temporal RMS force [N] at a reference point on

- the Nasmyth platform and/or Nasmyth Adapter Rotator
- Cassegrain Adapter Rotator
- Coudé platform

[INFO-VLT-507] This reference point is defined as the 'centre of area' of the relevant instrument interface footprint.

[R-VLT-508] D/A/ /T Instrument shall be designed such that the level of vibration induced by the said instrument at the interface complies with the specifications provided in AD45.

[R-VLT-509] D/ / / Any expected deviations from AD45 shall be imperatively discussed with ESO and documented in an RFW.

[R-VLT-510] D/A/ /T AD6 provides the vibration and acoustic requirements an instrument in the VLTI lab shall fulfil.

8.13.2 Thermal Requirements

[R-VLT-512] D/A/I/ During daytime, the temperature difference between the instrument (or any associated equipment) outer surface and the ambient air shall not be larger than:

[R-VLT-513] D/A/I/ For Nasmyth and Cassegrain instruments: ±2.5 ºC

[R-VLT-514] D/A/I/ For Coudé instruments: +2.5/-8 ºC

[INFO-VLT-515] In addition, the convected heat load during daytime (averaged over 10min.) is specified in the individual instrument technical specification document.

[R-VLT-516] D/A/I/ During nighttime, the temperature difference between the instrument (or any associated equipment) outer surface and the ambient air in still wind conditions (a wind speed inside the dome of 2 m/sec and a convection coefficient of 2W/m2/K) shall not be larger than:

- Nasmyth and Cassegrain instruments : ±1.5 ºC
- Coudé instruments : +1.5/-5 ºC

[INFO-VLT-517] In addition, the convected heat load during nighttime (averaged over 10min.) is specified in the individual technical requirement specification document.

8.13.3 Contamination and Pollution Requirements

[R-VLT-519] D/ /I/ Instruments shall not have any sources inside the telescope chamber that emit light (in the wavelength range from 0.3 to 3 micrometer) when not in operational state. In operational state this is allowed as long as no other LPO system functionality is affected (to be discussed by ESO and consortium on a case-by-case basis).

[R-VLT-520] D/ /I/ In addition, no infrared remote controllers shall be used in operational state.

[R-VLT-521] D/ /I/ The design shall make sure that optical components are not exposed to contamination by dust, exhaust, fumes and contaminants (solid or liquid) or, in the circumstances where such exposure cannot be avoided, that they are protected from such contamination.

[R-VLT-522] D/ /I/ Any dust generated by the equipment shall remain compatible with the site cleanliness class which is better than ISO 7.2 (median) and ISO 8 (90% percentile).

[R-VLT-523] D/ /I/ Instruments shall not generate at any location (in particular on detectors) high energy radiation at a level of more than 10% of the natural radiation at the site (from internal, terrestrial and cosmic origins). The natural radiation shall be assumed to be 3 mSv/year (TBC).

[R-VLT-524] D/ / / Particular attention shall be paid to high energy radiation resulting from radioactive elements contained in optics substrates.

8.14 Site Adaptation

[R-VLT-526] D/ /I/ Any adjustment that may need to be done on site (e.g., due to the atmospheric pressure or site dryness) shall be identified and the related procedure defined.

9. Documentation Requirements

9.1 General documentation requirements

[INFO-VLT-529] The documentation to be delivered in the course of the development of a VLT or VLTI instrument are specified in the SoW for individual instruments.

[R-VLT-530] D/ / / All contractually requested documents shall be delivered according to AD42.

9.2 Product Breakdown Structure based documentation

9.2.1 Defining the Product Breakdown Structure based documentation

[INFO-VLT-533] The PBS structure focuses on the product's decomposition to support the development and maintenance of the product. The top levels of the PBS of the contracted product are given in the ESO Specification and/or Statement of Work.

[R-VLT-534] D/ / / The Contractor/Consortium shall extend the structure to lower levels.

[INFO-VLT-535] The structure in the “PBS Structure” contains by default the folder “Project Management Documents” on the highest level (level 0). This is just an artefact to allow assigning the non-configuration documents (i.e., documents not in the Configuration Item Data List (CIDL)) to a folder). Obviously, this folder is not part of the actual PBS.

[R-VLT-536] D/ / / In-line with the PBS levels defined in the applicable ESO Specification and/or Statement of Work

- Decomposition down to LRU/SRU level and/or down to custom-made parts / purchased components when it could support maintenance or future instrument upgrade by providing useful information about the product
- Balanced decomposition, e.g. products at the same level shall have a similar complexity
- Clear separation of deliverable and non-deliverable products:
  - By default, only products becoming ESO property are in the PBS. The Specification and/or Statement of Work indicate which products are deliverables to ESO.
  - Products not becoming ESO property, either specified or not specified by ESO for fabrication or testing, which will have some deliverable documents associated to

them, can be part of the delivered PBS but shall go in an independent branch of it.

[R-VLT-716] D/ / / The consortium shall provide at PAE a high-level functional breakdown structure (FBS) of the instrument, based on the design of the control software.

The consortium shall also provide a mapping of the FBS to the Product Breakdown Structure (PBS), listing all hardware assemblies (down to a level of 2 to 3 of the PBS) associated with each function.

9.2.2 Allocation of configuration documents

[INFO-VLT-538] The following non-exhaustive list gives the document types considered to be configuration documents (i.e., part of the CIDL), and therefore ask for an allocation to the PBS:

- Document describing the PBS
- RAM Analysis
- Hazard Analysis
- Hazardous Material List
- Safety Compliance Assessment
- Design Report
- ZEMAX model of the instrument
- Analysis Report
- Lower-Level Specification
- Drawing Sets
- BOM/Part Lists
- Spare Part Lists
- Technical/Error Budget
- EMC Control Plan
- Manufacturing Assembly Integration and Test Plan
- On Site AIV Plan
- Site Safety Manual
- Assembly, Integration and Alignment Procedure
- Test Report
- Inspection Report
- Compliance Matrix

- Software Design Description
- Software Configuration and Release Notes
- Software Transfer Document
- Operations Manual
- Maintenance Manual
- Software User Manual
- Training plan
- Configuration Item Data List
- Analysis Tree
- Test Procedure
- Inspection Procedure

9.2.3 Allocation of non-configuration documents

[INFO-VLT-540] The following non-exhaustive list gives the non-configuration document types to be allocated to the folder "Project Management Documents":

- Statement of Work
- Project Management Plan
- Progress Report
- Action Item List
- Red Flag Report
- Risk Register
- Safety Management Plan
- Integrated Logistics Support Plan
- Configuration Management Plan
- Validation and Verification Plan
- Test Plan
- Inspection Plan
- Review Data Package Summary
- Product Assurance Plan
- Manufacturing and Production Plan
- Shipment Plan
- Software Development Plan

9.2.4 Documentation management requirements

[R-VLT-542] D/ / / The organization structure of the instrument data package delivered to ESO at major reviews (PDR, FDR, "XXR", PAE, PAC) shall follow the instrument Product Breakdown Structure (PBS) agreed upon before with ESO, latest at PDR.

[INFO-VLT-543] **In particular, organization of the documentation structure by project team member location or by field of expertise will not be accepted at the reviews.**

[INFO-VLT-544] **To save effort spent on documentation on both the project team and on ESO follow-up**, ESO strongly recommends project documentation to be, as much as possible, **incremental from one review to the next** with appropriate document track record filled in. Therefore, the structure of a given document should be thoroughly thought through at its creation to enable this incremental approach.

[R-VLT-545] D/ / / Document shall be focused on the topic to be documented and shall avoid duplication of information in several documents which might contradict each other and increase the volume of the documents unnecessarily.

9.3 CAD data requirements

[R-VLT-547] D/ / / AD43 describes how CAD Data (3D models and 2D drawings) shall be delivered to ESO. It specifies the level of detail of the data that has to be supplied as part of a deliverable document package at various milestones of an ESO project. It details the requirements for file format of mechanical CAD generated data (i.e., components, assemblies, drawings, etc.). It also stipulates the requirements for detailing and documenting the metadata which is associated with CAD data.

9.4 Document Requirement Definition

[R-VLT-549] D/ / / RD10 provides the Document Requirement Definition which shall be applied to all project development at ESO.

9.5 MAIT and AIV plans

9.5.1 Acronyms and definitions:

[R-VLT-552] D/ / / The following acronyms and definition shall apply to all La Silla/Paranal instrument and system development and documentation:

- MAIT: Manufacturing, Assembly, Integration and Test (only in Europe); MAIT shall end with the Provisional Acceptance Europe/X PAE/X
- AIV: Assembly, Integration and Verification (only in Chile); AIV starts with the reception of the crates and includes on-sky technical lights
- First Star or first light: “First” on–sky acquisition during functional and performance verification.
- Instrument commissioning starts with handover from AIV Manager to Instrument Scientist from the Consortium

9.5.2 MAIT plan

[R-VLT-554] D/ / / The MAIT plans for system and major sub-system shall include and address the following topics:

- System or Sub-system overview:
  - Description,
  - Interfaces system internal and/or to the ESO infrastructure,
  - Access (as sub-system stand-alone or after sub-system are merged in the system)
  - Active parts and control tools
- Safety:
  - Regulation,
  - Emergency procedures,
  - Personal Protective Equipment
- Strategy:
  - Milestones,
  - Flowchart (with timeline)
  - ESO involvement
  - Consortium support
  - PA/QA
- Management
  - Sub-system MAIT Manager and deputy (if any)
  - Schedule
  - Subsystem Local Acceptance Reviews (LAR)
  - FTE
  - RASCI
  - Communication and reporting

  - Training: Internal to WP, WP to consortium, To ESO staff (Chile and HQ)
- Facilities
  - Premises description, Control room, Integration hall
  - HW footprint
  - Workshops, Clean rooms, Other labs, Storage
- Support Equipment (SEQ)
  - Handling
  - Tool listing
  - Handling & Tools deliverables: Deliverable to ESO, Deliverable to System facility
  - Certification (Handling tools)
  - MAIT electronics and software tools
- Manufacturing
  - Procurement process
  - Main procurements (custom-made, COTS, modified COTS)
  - Internal/outside manufacturing
  - Acceptance process
  - Storage organization
- Assembly
  - Component listing and description
  - Drawings and documents verification
  - Procedure listing per assembly
- Integration
  - Pre-alignment, Alignment (step by step, requirements, adjustment means, tools, etc)
  - Integration procedures
  - Electronics and Software integration
  - Integration of series
- System or Sub-system Test:
  - Global inspection,
  - Tooling required for the verification,
  - Verification matrix,
  - Sub-System test Acceptance plan or final system Acceptance test plan for PAE,
  - Documentation package for Local Acceptance Review led by Consortium with or without ESO witnessing / for system PAE/X led by ESO

- Disassembly
- Transport to System Integration Facility: Packing, Crate listing (amount, sizes, weight, etc), Transport tracking, Delivery acceptance, Crate opening after delivery, inspection
- Sub-system verification in the System Integration facility: Configuration required, Verification list, Handover to system
- For System: Packing and Transport defined in a specific document

9.5.3 AIV plan

[R-VLT-556] D/ / / The Assembly Integration and Verification (on-site in Chile) shall address the following topics:

- System overview
  - Description with list of all sub-systems
  - Interfaces with and within sub-systems
  - Interfaces with telescope; Access
  - Active parts and control tools
- Safety
  - Key safety meeting
  - Regulation (local)
  - Emergency procedures: Instrument, Paranal
  - Personal Protective Equipment
- Strategy
  - Milestones
  - Each activity has a procedure flowchart (with timeline) showing each activity (what, where, when, by who, etc.)
  - ESO expected support
  - Consortium support
  - PA/QA
- Management
- Management:
  - AIV Manager and deputy
  - Schedule
  - Reviews: Readiness to get OK to move instrument from NIH to VLT, Readiness for Official First Light, Instrument handover readiness review to the instrument Local staff for maintenance activities until commissioning slot

    - FTE, RASCI
    - Communication and reporting (team internal and with ESO): Coordination meeting
    - Training: to ESO staff (Chile and HQ)
    - Facilities (including assumptions)
        - Premises description
        - Control room
        - Integration hall (Paranal)
        - HW footprint
        - Workshops (Paranal), Clean rooms (Paranal), Other labs., Storage (Paranal)
- Support Equipment (SEQ) (including assumptions)
    - Handling
    - Tool listing
    - Handling & Tools deliverables: Deliverable to ESO
    - Certification (Handling tools)
    - AIV electronics and software tools
- Assembly (including assumptions)
    - Storage organization
    - Acceptance of the sub-systems
    - Drawings and documents verification
    - Procedure listing
    - Procedure verification (Documents and related drawing package)
    - Interfaces verification
    - Assembly in hall
    - Transfer from hall to telescope
    - Installation at the telescope

- On site ESO resources required (general support, crane/truck drivers)
- On-call manufacturing to the ESO workshop
- Integration
    - Pre-alignment and alignment (in various places, and step by step, requirements, means, etc)
    - Integration procedures in the NIH
    - Integration procedures at the telescope

    - Electronics and Software integration
- System Verification (including assumptions)
    - Global inspection
    - Tooling required for the verification
    - Verification matrix
    - System test in Assembly/integration hall
    - System verification at the telescope
    - System functional and performance verification on sky
- Documentation package release in view of Instrument Commissioning
- Transfer of spare parts to the warehouse (recording, packing)
- Documentation package release in view of PAC
- Transport for equipment, crates back to Europe

10. Lifetime and Reliability, Availability and Maintainability (RAM)

10.1 Lifetime

[R-VLT-559] D/A/ / The Instrument and its Auxiliary Equipment shall have a minimum lifetime of 15 years, (goal 20 years) under the assumptions of section 10.2.2.

[R-VLT-560] D/A/ / For the demonstration of the lifetime requirements, it shall be assumed that preventive/predictive maintenance, including environmental protection will be performed as planned, but within the limits of section 10.4. Similarly, for parts having a lifetime shorter than the lifetime of the Instrument as a whole, it can be assumed that overhauls will be performed as planned, but within the limits of 10.4.4.

10.2 Reliability

10.2.1 Failure Definition

[INFO-VLT-563] A failure is a defect causing the termination of the ability of an item to perform a required function within the specified performance.

[R-VLT-564] D/ / / For the purpose of defining the Reliability and Availability requirements of the Instrument, the categories of functional failures described in Table 6 shall be considered:

[INFO-VLT-565]

Severity 3	The occurrence of a functional failure of the Instrument that will cause if not rectified, directly or indirectly, a loss of science observation time or corrective maintenance action that cannot be deferred
Severity 2	The occurrence of a functional failure or of the Instrument that will cause if not rectified, directly or indirectly, a performance degradation of science observation
Severity 1	The occurrence of a functional failure of the Instrument that does not belong to category with severity 3 or 2

Table 6: Definition of Severity

[R-VLT-566] D/ / / An exhaustive list of failures shall be provided by the Consortium in the RAM Analysis. Each failure shall be categorized according to the definition given in the Table 6.

10.2.2 Reliability Requirements

[R-VLT-568] D/ / / Component test and MTBF shall consider the PAO conditions specified in section 4.1.

[INFO-VLT-569] An instrument unavailability can be estimated using the bottoms-up modelling approach described below which involves estimates of both Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR).

[R-VLT-570] D/A/ / For the VLT the non-availability of the instrument shall be smaller than 0.84% in stable operations.

[R-VLT-571] D/A/ / The MTBF for failures of the various severity types shall be longer than Table 7

[INFO-VLT-572] For each Severity type, two different values of MTBF are identified: one related to failures whose rectification require a warming-up, pumping-down and cooling-down cycle of cryogenics subsystem(s) of the instrument (Type A) and another one for all the other types of failures (Type B).

[R-VLT-573] D/A/ / The MTBF for failures of the various severity types shall be longer than:

	MTBF [hr]	**MTBF [hr]**
	Type A	**Type B**
Severity 3	25920	17280
Severity 2	19440	12960
Severity 1	12960	8640

Table 7: MTBF versus Severity

[R-VLT-574] D/ / / The time for the identification of the MTBF shall be the clock time.

[R-VLT-575] D/ / / It shall be assumed that for a fully equipped observatory, with an instrument suite of 14-16 on four telescopes (3 foci), VLTI foci and Combined Coudé foci, instruments will be in observation mode on average at least 80 nights per year and in stand-by mode during the remaining time, except for the time needed for calibration and scheduled maintenance. Night-time shall be assumed to be typically 10 hours.

[R-VLT-576] D/ / / Instruments shall assume to be in observation on average at least 80 nights per year, starting from a peak of 150 nights per year during the initial operation period and ramping down to 80 nights towards the end of their lifetime.

[R-VLT-577] D/ / / The number of switches between “observation” and “not ready mode shall be assumed to be 3 times per night, typically 1 time.

[R-VLT-578] D/ / / Accounting of failures shall take into account only those failures whose root cause is random (non-repeatable) and not due, for instance, to human operator error, maintenance induced failures, design flaw, improper manufacturing and inspection, etc.

[R-VLT-579] D/A/ / The Consortium shall:

- identify the Instrument subsystems and components to be included in the failure mode analysis
- evaluate the potential failure modes of those items
- evaluate the impact of these failure modes on safety, readiness, availability and demand for Maintenance/Logistics support for the Instrument
- estimate MTBF and MTTR for critical components, mechanisms or sub-assemblies and model these data to obtain an overall instrument availability which meets the top-down availability allocation for instruments.

10.3 Maintainability

10.3.1 General

[R-VLT-582] D/ /I/ Where possible, maintenance shall be mainly performed at assembly and sub-assembly level by exchange of LRUs, taking into consideration that the LRU principle applies to components outside the vacuum cryogenics system that can be replaced in reasonable time.

[INFO-VLT-583] LRU's are defined as units which can be easily exchanged (without extensive calibration, of sufficient low mass and dimension for easiness of handling, etc.) by maintenance staff of technician level.

[R-VLT-584] D/ /I/ All electronics boards or controllers shall be LRUs. All motorized functions or their key components (motor, spindle, encoder) shall be treated as LRUs and shall be replaceable without requiring optical realignment. Exceptions shall be agreed with ESO by PDR.

[R-VLT-585] D/ /I/ After substitution, failed LRU's may be discarded, replaced or repaired at the Telescope (in-situ), at the consortium premises or at the factory following the prescriptions that shall be given by the Consortium in the Maintenance Manual.

[R-VLT-586] D/ /I/ The list of LRU's is design dependent and shall be identified by the Consortium.

[R-VLT-587] D/ / / Dismounting and refurbishment of the Instrument components shall be performed in-situ for as many parts as possible.

[R-VLT-588] D/ /I/ As a goal all LRU shall be replaceable in situ.

[R-VLT-589] D/ / / ESO will have standard support and test equipment tools for maintenance on site. The use of non-standard maintenance equipment specific to the selected design of the Instrument shall be minimized and subject to ESO Review (at PDR).

[R-VLT-590] D/ /I/ Where possible, provisions shall be made that replacement of cables and connectors is possible without dismounting additional elements.

[R-VLT-591] D/ / / Dismounting of system and/or interventions shall not prevent night-time operation of the corresponding UT.

10.3.2 Test and Maintenance Software

[R-VLT-593] D/ /I/ In case of system failure, the Instrument Control Software shall allow CLEAR -non-cryptic- identification and error message log of the subsystem level at which the failure happened: See also AD30.

10.4 Maintenance Requirements

[R-VLT-595] D/ / / The instrument consortium shall deliver the Preventive/Predictive and Corrective Maintenance Actions List according to the instructions and template RD33 and RD34.

10.4.1 Corrective Maintenance

[R-VLT-597] D/ / / Any corrective maintenance action shall be performed with a maximum of 2 qualified engineers or technicians, using standard tools and/or special tools specific to the Instrument.

10.4.2 Preventive/Predictive Maintenance

[R-VLT-599] D/ / / For the Instrument all preventive and predictive maintenance actions shall be carried out during non-observational hours that are in a daytime maintenance period window of 8 (eight) hours each day.

[R-VLT-600] D/ / / If preventive/predictive maintenance action duration lasts more than 8 hours, it shall be possible to split the task over more maintenance shifts in order to not interfere with the nighttime operations.

[R-VLT-601] D/ / / Unless otherwise agreed with ESO, the maximum number of staff hours that can be used for preventive/predictive maintenance is 400 per year. Each preventive/predictive maintenance action shall require at most 2 trained technicians.

[R-VLT-602] D/ /I/ If the loss of a function caused by any failure mode will not become apparent to the operator under normal circumstances (e.g., the failure mode is not monitored) then preventive/predictive maintenance actions shall be identified for ensuring the availability of that specific function.

10.4.3 Overhaul Maintenance Requirements

[INFO-VLT-604] Overhaul is a planned major maintenance operation, performed at specific intervals.

[INFO-VLT-605] If necessary, the Consortium may assume that there is an allowance for 10 consecutive days (i.e., 336 hours of clock time, excluding time for pumping, cool down and warm up) every 3 (three) years for preventive/predictive maintenance time for the Instrument. This time may be used for large preventive/predictive maintenance actions.

10.4.4 Design for Reliability and Maintainability Requirements

[R-VLT-607] D/ / / When designing for Maintenance, the Consortium shall assume the following:

- The user is a skilled technician with access to but no prior knowledge of the as-built characteristics of the Instrument
- The user is able to run extended diagnostics to determine the scope of preventive or corrective maintenance
- The user is unable to make any hardware modification beyond replacement of spare parts (LRUs).

[R-VLT-608] D/ /I/ The design for maintainability of the Instrument shall take into account the following aspects as a minimum:

- Conditions relating to health and safety
- Handling, human and ergonomic factors
- Displays and indicators
- Visibility
- Identification
- Accessibility to and also within the piece of equipment
- Accessibility of low reliability equipment
- Testability: the potential for the use of automatic diagnostics as a means of Fault Detection, Isolation and Recovery (FDIR). The latter includes the internal diagnostic systems, referred to as Built-In-Test-Equipment (BITE), and external diagnostic systems, referred to as Automatic Test Equipment (ATE), or offline test equipment
- Health Status and Monitoring (HSM) capability
- Repair-ability
- Interchangeability (including Standardization and Modularity).

[R-VLT-609] D/ /I/ All instruments and their component LRUs, spare units, etc, shall be marked with unique identification numbers. The number shall consist of the original equipment manufacturer item number and company name.

[R-VLT-610] D/ /I/ For installation, removal and handling of equipment and LRUs consideration shall be given to the installation of fixed lugs or attachment points.

[R-VLT-611] D/ /I/ No wear-out functional failure mechanism, characterized by an increasing failure rate, shall occur in the lifetime of the equipment. Any components requiring preventive replacement in order to achieve this requirement shall be clearly highlighted for consideration and approval by ESO.

10.5 Computerized maintenance management system

[INFO-VLT-613] Paranal Engineering department uses a computerized maintenance management system (CMMS), for inventory control of spare parts and tools including their locations, planning of preventive maintenance, work order generation from preventive maintenance plans, failure reporting and tracking, workflow monitoring, etc.

[R-VLT-614] D/ /I/ All information necessary to include an instrument into the CMMS shall be delivered by the consortium in a Maintenance Plan and in computer readable form.

[R-VLT-615] D/ /I/ All replaceable components shall be entered in CMMS together with the corresponding spares as agreed at FDR.

[R-VLT-616] D/ /I/ Instrument spare part list shall be delivered using the template provided in RD12.

[R-VLT-617] D/ / / Spare part list shall be finalized by FDR and approved by ESO.

10.6 Spare Parts

[R-VLT-619] D/ /I/T Spares shall be procured, tested and delivered with the corresponding storage containers to ensure their full operational life is guaranteed after X years of storage in the (storage) conditions specified in ADs, and without any maintenance intervention (during storage)". Exceptions (like mechanism and electronic boards exercise sometimes required) may be agreed. X to be agreed between Consortia and ESO.

[R-VLT-620] D/ / / Spare parts likely to become obsolete or relying on a single supplier shall be procured for the lifetime of the instrument and their shelf time shall be compatible with that.

11. Product Assurance and Quality Assurance

11.1 Product Assurance and Quality Assurance Plans

[INFO-VLT-623] RD26 provides background information to instrument builders to help them understand Quality Management methods, procedures and tasks, and provides a template for the preparation of a customized PA Plan for their project.

[R-VLT-624] D/ / / The PA Plan shall define the PA activities to be carried out in all phases of the project by the instrument builder. These include key PA issues to be specified at the beginning of a project as well as those during design, manufacture, assembly, integration, test, transport, installation, handling and operation. It shall describe the resources (budget and manpower), tasks, responsibilities, methods and procedures to be carried out.

11.2 Organization and Conduct of reviews

[INFO-VLT-626] AD47 identifies and structures all of the activities and information which are required in an ESO project review with the input, output and activities necessary to perform a review.

12. Safety

[R-VLT-628] D/ /I/ The Instrument and all of its subsystems shall conform to the applicable EU Directives and their Essential Health and Safety Requirements given in annex 1 of these Directives.

[INFO-VLT-629] AD15 describes the responsibilities for Safety, health and environmental protection at ESO, and outlines the Safety organization applicable to all ESO Sites.

[R-VLT-630] D/ /I/ AD15 shall be applicable to everybody working at, or visiting ESO at any of the ESO sites.

[R-VLT-631] D/ /I/ In order to comply with these essential safety requirements, harmonized standards under these Directives shall be used in addition to the requirements provided in AD9 and associated Applicable documents: AD10, AD11, AD12, AD13, AD14 and AD16

[R-VLT-632] D/A/ / A hazard analysis and risk assessment shall be conducted according to the principles noted down in AD9 and using .doc or excel templates RD31 or RD32.

[R-VLT-633] D/A/ / The hazard analysis process shall commence with a preliminary Hazard Analysis (HA) in the early stages of the project and continue throughout the system life cycle.

[INFO-VLT-634] Hazards may be related to different operational states of the system. This includes (but is not necessarily limited to) operation, shutdown and maintenance including handling procedures.

[R-VLT-635] D/ /I/ The conformity shall apply under all conditions (assembly, disassembly, testing, storage, integration, verification, operation, maintenance, power off, etc.), including but not limited to all environmental factors and where sub-systems are not fully operational.

[R-VLT-636] D/A/ / Within the process of hazard analysis and risk assessment any combination of two of the following additional types of failures (including two identical ones) shall be analyzed:

a) Hardware failure,

b) Software failure,

c) Operator error.

[R-VLT-637] D/A/ / None of these events shall lead to an unacceptable or undesirable hazard as defined in AD9. This includes the mechanical limitation of stroke of all moving parts.

[R-VLT-638] D/A/ / (Sub)systems that are deemed to present a risk regarding safety on the basis of that Hazard Analysis shall be evaluated in order to propose measures for further risk reduction to an acceptable level.

[R-VLT-639] D/ / / After defining the measures to reduce risk to an acceptable level (based on the Preliminary Hazard Analysis and Risk Assessment) the Consortium shall contact ESO to assess and agree on the required Safety Integrity Level (SIL) or Performance Level (PL) in case the risk is to be reduced by a safety function. ESO shall be entitled to set a minimum SIL or PL level for any safety related control measure.

[R-VLT-640] D/ / / In case the system can be considered as a component or sub-assembly for another, bigger machine and cannot be considered as safe when delivered by the manufacturer it shall be identified which aspects of the essential requirements have been fulfilled and it shall be instructed which of them have to be fulfilled by the machine manufacturer or assembler. For this purpose, a declaration of incorporation shall be issued (as laid out in AD9).

[INFO-VLT-641] The control electronics of the instrument is also responsible for its safety aspects (see also AD22).

[R-VLT-642] D/A/I/T Safety critical electronics shall operate without supervision by humans or software. Status and alarm signals shall be however be made available. These electronic shall autonomously and adequately react to emergency conditions that may occur at any time like:

- Electrical Power failure (UPS and non-UPS)
- Failure of VLT cooling fluid supply
- Failure of cryogenic cooling system, lack of coolant
- Vacuum leak (sudden rise of pressure)

- Failure of critical sensors (e.g., pressure or temperature) or their cables/ connectors
- Overheating of electronic cabinet, cabinet door not closed
- Cable wrap/guide problem
- Earthquake

[R-VLT-643] D/A/I/T When such an event occurs, the instrument shall, if necessary, place itself automatically in a Safe State that maintains the integrity and safety of the instrument and detectors. In addition, alarm shall be sent as defined in section 8.7. The Safe State shall be compatible with the findings and requirements of the Hazard Analysis of the instrument (see AD9).

[INFO-VLT-644] The Interlock and Safety System (ILS) ensures all components of the Telescope Control System (TCS) are operated in a safe manner according to the various telescope operational modes. It provides control and monitoring of the various observatory safety components.

[INFO-VLT-645] The ILS does not implement instrument-specific safety rules that are part of the function of an Instrument's Local Control and Safety System but brings additional safeguards as may be required from subsystems interactions as they are integrated and operate together.

[R-VLT-646] D/ /I/T Instruments shall implement their own Instrument Interlock and Safety (ILS) System that controls safety functions and interlocks. The ILS system shall be based on the same hardware that is implemented in the ILS of the TCS and allow interfacing between both.

13. Preparation for Delivery

13.1 Cleaning

[R-VLT-649] / /I/ The instrument components, Auxiliary Equipment and transport equipment shall be cleaned before packing (for storage or transport, as appropriate) into their transport container. Emphasis is put on:

a) grease and lubricants

b) corrosive, abrasive dust or powders

c) cleaning and decontamination of instrument cooling system and pipes

13.2 Packaging and Transport

[R-VLT-651] / /I/ All critical and/or mounted parts shall be properly protected against liquid spills, exhaust fumes, rain and abrasive dust.

[R-VLT-652] D/ / / The instrument components shall be packed with its accompanying documentation and samples, including as-build documents and handling procedures.

[R-VLT-653] D/ / / For instrument packing and transport the specifications and recommendations given in RD1 shall be considered.

[R-VLT-654] D/ / / In addition, the following recommendations shall be considered:

[R-VLT-655] D/ / / Transport containers shall allow land sea and air freight.

[R-VLT-656] D/ / / Transport containers shall fit in standard ISO shipping containers (ITUs, Intermodal Transport Units or isotainers, ISO norm 668).

[R-VLT-657] D/ / / The dimensions of the transport containers shall be defined for minimum volume loss in standard ISO shipping containers.

[R-VLT-658] D/ / / Special transport conditions shall be avoided.

[R-VLT-659] D/ / / If wood is to be used, special regulations from Chile shall be taken into account during the material selection. All Wood Packing Material (WPM) shall be treated and certified according to the International Standards for Phytosanitary Measures No. 15 (ISPM 15), in addition WPM shall be free of bark.

[R-VLT-660] D/ / / If transport requires additional fixtures of particular sub-systems or components this shall be taken into account in the design.

[R-VLT-661] / /I/ The packing material used for the incoming transport will normally not be reused and shall be disposed of following applicable regulations.

14. Precedence

[R-VLT-663] D/ / / In the event of conflict between requirements specified herein and requirements pertinent to human safety, the latter shall take precedence.

[R-VLT-664] D/ / / Without prejudice of the provisions of the previous requirement, in the event of conflict between requirements specified herein and requirements pertinent to the integrity of the instrument, the latter shall take precedence.

15. Verification

15.1 Requirements Verification

[R-VLT-667] D/ / / Four methods of verification shall be applied to verify that the performance requirements of the instrument, and auxiliary equipment are fulfilled:

Verification by design

Verification by Design consists of using approved records or evidence (e.g. design documents and reports, technical descriptions, engineering drawings) that unambiguously show that the requirement is met.

Verification by analysis

Verification by Analysis consists of performing theoretical or empirical evaluation using techniques such as systematic and statistical design analysis, modelling and computational simulation.

Verification by Inspection

Verification by inspection consists of visual determination of physical characteristics (such as constructional features, hardware conformance to document drawing or workmanship requirements, physical conditions, software source code conformance with coding standards).

Verification by Test

Verification by test consists of measuring product performance and functions under representative conditions, or under conditions that can be clearly traced to operational ones. It includes the analysis of data derived from the test.

[R-VLT-668] D/ / / The contractor shall define the verification methods, to be approved by ESO, and as a minimum shall follow the verification tags D/A/I/T provided with each requirement.

15.2 Analysis and Simulation Requirements

15.2.1 Structural analysis of the instrument

[R-VLT-671] D/A/ / Requirements and recommendations stated in AD19 shall be applied for the structural analysis verification of the Instruments.

[R-VLT-672] D/A/ / The stress analysis shall cover as a minimum all operational conditions defined in section 4. As a minimum, any load combination required in section 4.2 shall be considered together with the load combination factors defined in section 4.3. Additional load combinations shall be verified, if required by the design or specific load conditions. The structural safety requirements (including safety factors) defined in AD19 shall be met for all the load combinations.

15.2.2 AO Analysis and Simulations

[R-VLT-674] D/A/ / For the purpose of AO analysis and simulation the atmospheric parameters defined in AD2 shall be assumed.

[INFO-VLT-675] For the purpose of sodium LGS flux return analysis and simulation at UT4 RD30 is proposed to be used.

15.2.3 Failure Mode Analysis

[INFO-VLT-677] RD28 provides the Instruction for delivering Failure Mode, Effect and Criticality Analysis (FMECA). It describes the rules and format for delivering such analysis.

[INFO-VLT-678] The Failure Mode, Effects and Criticality Analysis is a reliability evaluation/design technique which examines the potential failure modes within a System and its equipment, in order to determine the effects on equipment and System performance.

[R-VLT-679] D/A/ / The instructions presented in the above document shall be used as baseline information for performing the FMECA analysis.

15.3 Lifetime Verification Requirements

[R-VLT-681] D/ /I/ Witness samples for all optical elements in open air shall be procured and made available to ESO such that they can be tested for aging effects etc. The exact number of witness samples shall be agreed by PDR.

15.4 Reliability Verification Requirements

[R-VLT-683] D/ / /T Where data from reliability libraries (e.g. Bellcore/ Telcordia, NPRD-95, MIL-HDBK-217, etc.) for electrical, electro and electro-mechanical components are not available and where a failure of a specific component will be safety-critical (i.e. risk score (s) is high or medium), an accelerated reliability testing technique, like the Highly Accelerated Life Tests (HALT), shall be applied to ensure that the quantitative reliability requirements of the Technical Specification and RAM and Safety Analyses are achieved.

[R-VLT-684] D/ / / The list of components for which an accelerated reliability testing technique is foreseen shall be provided for approval to ESO.

[R-VLT-685] D/ / / The accelerated reliability testing technique to be adopted shall be agreed, too.

[R-VLT-686] D/ / / Where redundant components are used to achieve the availability and reliability targets, the Contractor shall demonstrate that Common Cause Failures have been taken into account in the RAM Analysis and the risk of their occurrence minimized.

[R-VLT-687] D/A/ / The instrument MTBF Maintainability Verification Requirements shall be verified by analysis.

[R-VLT-688] D/A/I/ As part of the overall verification of the Instrument, and its Auxiliary Equipment, the Consortium shall demonstrate by ad-hoc testing the maintainability of the product. The maintainability demonstration shall verify and validate the following, as a minimum:

- Troubleshooting techniques as detailed in the Maintenance Manual
- Maintenance tools and equipment
- MTTR values and maximum allocated time (where applicable), both for corrective and preventive /predictive maintenance actions
- Corrective, Preventive and Predictive maintenance procedures and instructions
- Software routines used for maintenance, if applicable

[R-VLT-689] D/A/ / During the Design phase, the predicted MTTR value of the System shall be assessed by analysis.

15.5 Thermal Verification Requirements

[R-VLT-691] D/A/ /T The requirements on surface temperature shall be verified by:

1. thermal analysis during the design phase
2. test in representative conditions during acceptance testing using
   a. infrared camera to provide overview and estimates of temperatures
   b. local temperature measurement with appropriate accuracy for critical cases

[R-VLT-692] D/A/I/ The requirements related to heat dissipation power shall be verified by:

1. Analysis summarized in the form of a heat dissipation power budget
   a. during the design phase using as-designed parameters
   b. at acceptance using as-built configuration and measured parameters (e.g., electrical power consumption)

15.6 Vibration Verification Requirements

[R-VLT-694] D/A/ /T The vibration requirements (section 8.13.1) shall be verified by a combination of analysis and testing. The instrument team shall identify and characterize all possible vibration sources, and by analysis estimate the interface forces in amplitude and frequency defined in section 8.13.1.

[R-VLT-695] / / /T The characterization of vibration sources by test shall consider the following:

- Under operational conditions, e.g., mechanical boundary condition, coolers, pumps electronic racks in nominal operation.
- Measurements with duration of at least 30 seconds with sampling of at least 300Hz shall be performed.
- Each measurement set (same condition) shall be repeated at least ten times and an average over 30 sec shall be constructed.
- A spectral analysis of the measured data (averaged data) shall be performed, e.g., PSD (Power Spectral Density) shall be estimated.

[R-VLT-696] /A/ / The analysis and modeling shall consider the following conditions:

- The model shall be representative of operational boundary condition.
- The model shall be representative of the specified frequency range.
- The damping factor of 0.75% shall be assumed. Larger damping values shall be approved by ESO based on justification from the instrument team.

[R-VLT-697] /A/ / The post processing of the measured and estimated values shall consider the following:

- Minimum third-octave bands shall be used for frequency band RMS estimation with frequency bands defined using the standard "Acoustics -- Preferred frequencies" ISO 266:1997: 1000Hz as the central frequency corresponding to the 30th band.
- The RMS in each band shall be estimated from the band-pass filtering of the temporal signal and to be crosschecked with the integral of PSD in the respective bands.

15.7 Data Flow Verification Requirements

[R-VLT-699] / / /T AD25 shall apply for all Data Flow Verifications delivered by the instrument builders.

15.8 Welding Verification Requirements

[R-VLT-701] / / /T The quality and load capability of weld seams shall be verified according to the processes defined in RD27.

15.9 Bonding Verification Requirements

[R-VLT-703] / / /T Any structural bonding or bonding to optical substrates shall be qualified before manufacturing.

[R-VLT-704] / / /T Qualification shall apply to materials, process, and procedure and provide at least 3-sigma confidence that the complete set of concerned bondings will collectively withstand the critical load combinations within the specified lifetime and environment.

[R-VLT-705] D/ / /T Test results and test specimens shall be delivered to ESO with the concerned elements of the instrument. The test procedure and the design of the test setup, if any, shall also be delivered to ESO.

[R-VLT-706] / / /T Bonding samples shall be glued in parallel with the bonded parts and delivered with the instrument, in quantities sufficient to allow periodic (typically, yearly) destructive tests throughout the lifetime of the instrument.

15.10 Workmanship Verification Requirements

[R-VLT-708] / /I/ Proper workmanship shall be verified by in-process and final inspections.

15.11 EMC and Safety Verification Requirements

[R-VLT-710] / /I/T Verification of EMC- and Safety-related requirements shall be according to Sec. 4 of AD22.

16. Annex 1

[INFO-VLT-712] This section provides the list of ADs and RDs from the old Instrument Control System standards and New Generation Controller standard for the purpose of instruments currently in construction.

[R-VLT-713] D/ /I/T The VLT-Instrumentation Software Specifications AD48 shall be applicable to all instrument following the old VLT SW standard.

[R-VLT-714] D/ / / The following list of documents shall be applicable for all instruments using the old NGC controller and can be provided under request by ESO:

NGC - Detector (VLT)	New General Detector Controller Infrared Detector Control Software - User Manual	ESO-044406
NGC - Detector (VLT)	NGC Safety Compliance Assessment	ESO-250730
NGC - Detector (VLT)	NGC Power Supply - User Manual	ESO-044444
NGC - Detector (VLT)	NGC User Manual	ESO-044440
NGC - Detector (VLT)	NGC Shutter and TIM interface	ESO-044439
NGC - Detector (VLT)	NGC - New General Detector Controller - Safety and Hazard Analysis	ESO-044438
NGC - Detector (VLT)	NGC-LCU Interface Software - User Manual	ESO-044412
NGC - Detector (VLT)	Fanless Front-end Electronics NGC	ESO-257865
NGC - Detector (VLT)	New General Detector Controller Optical DCS - User manual	ESO-044405

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