Visible & Infrared Survey Telescope for Astronomy

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Document Title:	**Technical Specification for the Telescope Structure Work-Package**
Document Number:	**VIS-SPE-ATC-01000-0006**
Issue:	**4.0**
Date:	**4 March 05**

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Change Record

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
1	28/02/02	All pages	Released for feedback.
2	02/05/02	All pages	Second Issue
3	21/02/03		Update for Contract
		3.2	Clarification that M1 Handling Equipment is not part of this contract
		4.1	Addition of ICD Telescope to IR Camera Services, update issue AD03 and AD04
		4.2	Update issue AD25 & AD28, correct drg ref for AD23
		4.3	Update issue AD40
		4.5	Update issue AD80
		5.3	Update top level product tree
		5.4.1	Max integration duration 30 min.
		5.5	Rewording to allow alternative Control Hardware location.
		6.1	Remove reference to Europe
		6.4.3	ESO preferred temperature sensor specified
		6.4.4	ESO preferred anemometer specified
		6.5	Removal of non applicable ref to hydrostatic bearing
		7.5	Ref added to AD07
		7.6	Rewording to allow alternative Control Hardware location.
		7.10	Removal of non applicable information ref Hydrostatic bearings
		8.1.1.2	Max mass for maintenance lift reduced to 9 tonnes
		8.4.1 c & d	Clarification that structural deformations due to thermal operation loads is over any 30 minute period.
		8.5.2	Provisional Acceptance changed to Preliminary Acceptance
		8.6.2	Form of Controller to be used
		9.2.1	Update of azimuth bearing requirements
		9.3	Update of azimuth cable wrap requirements
		9.5	Update of altitude bearing requirements
		10.3.5	Removal of 'Range of Adjustment' from table 12.
		10.3.6	Removal of 'Range of Adjustment' from table 13.
		10.3.8	Removal of 'Range of Adjustment' from table 15.
		10.4.2	Correct ref to RD03
		10.4.3 f & g	Relaxation of accuracy requirement for force measurement to $\leq \pm$ 2.0 N TBR footnote and definition of range for accurate measurement.
		10.4.4 c	Change FDR to PDR
		10.4.4 i & e	Rms applies to supports and definers, removal of non applicable information

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
		10.4.4 l & m	Inclusion of axial support lateral force requirements TBR
		10.4.5 i & j	Relaxation of accuracy requirement for force measurement to ≤ ± 10.0 N and definition of range for accurate measurement.
		10.4.6	Removed non applicable information on force balancing
		10.4.6 b	Correct axial to say lateral support loads & change FDR to PDR
		10.4.6 e	Clarification of sector geometry
		10.4.6 l	Rms applies to supports and definers
		10.5.3	Cassegrain cable wrap SCP
		10.6 f	Removed non applicable information on M2 Baffle
		11.1.3	Update to include velocity feed forward & removal of PI type velocity loop.
		11.1.4.1	Update motor requirements
		11.1.4.2	Update requirements for motor continuous torque
		11.1.5	Update requirement for motor power amplifiers
		11.1.6	Requirement c) TBR
		11.1.7	Update requirements for velocity measurement
		11.1.8.1 & 11.1.11	Update to include option for non mechanical alternative to end stop. Axis limits Table 17 TBR except for Operational and Alt software limit. See footnote.
		11.1.10	Update to allow for lower brake deceleration
		11.1.11	Insert cross reference to 11.1.8.1 for alternatives to mechanical end stops.
		111.12	Removed the word maximum
		11.2.4	Update requirements for Lateral Support Control
		13.1	Designed to perform over lifetime
		13.3.1.4	Replacement of Azimuth Bearing
		13.4	CE Requirement clarified
		13.4.11	Inclusion of word independent
		13.4.12	Telescope parked position interlock signal TBR
		14.1.4	Inclusion of Acceptable Earthquake Hazards
		14.2	Inclusion of metric components and ISO standards
		14.4	EMC Requirements TBC
		14.5	Product to be as per requirements of ISO 9000:2000
		15	Update of requirements for Technical Documentation.
		16.3	Inclusion of sections 11.2.1, 12.7, 13.4.1& 15 in Verification Matrix. Verification Plan when approved by VPO will supersede Verification Matrix.
4.0	4 Mar 05		Update on review of TBR and TBC items
		6.4.3	Resolution of PT 100 sensor ≤ 0.1 deg C & ≤ 0.2 deg C repeatability over 2 month period.
		6.4.5	Signal Conditioning and acquisition electronics for 5 additional PT100's on the Telescope Structure, 4 additional PT100's on the M1 Mirror and 6 additional miscellaneous sensors on the M1.

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
		8.1.1.2 a)	Telescope total mass < 100 tonnes (Design Goal < 95 tonnes)
		8.1.1.2 c)	Maximum installation mass 35 tonnes
		8.6.1.2	Telescope Dynamic Response – First Locked rotor frequency ≥ 11.4 Hz
		8.6.2	Azimuth, Altitude and Cassegrain Rotator Axes dynamic response was removed at update to Issue 3.0
		9.1.2 c)	Altitude Axis Alignment 0.5 mm
		9.4.1	Fork Azimuth Floor localised loading 1 Tonne over 70 x 40mm area with deflections of floor elements such as beams, girders and bracings as per requirements of ISO 14122 Safety of Machinery – Permanent means of access to machinery Part 2 Working Platforms and walkways.
		10.3.2	Telescope tube alignment sequence Contractor propose at FDR
		10.4.3	Axial definer accuracy of force measurement ≤ ± 2.0 N dependent upon the accuracy of VPO spec'd equipment
		10.4.4 l)	Non-repeatable lateral force at axial support piston ≤ 0.35 N rms
		10.4.4 m)	Repeatable lateral force at axial support piston ≤ 4.5 N rms
		10.4.5	Lateral definer frictional torque in linkage ≤ 0.15 Nm Non-Repeatable & ≤ 1.5 Nm Repeatable
		10.4.6	Lateral support frictional torque in linkage ≤ 0.15 Nm Non-Repeatable & ≤ 1.5 Nm Repeatable
		10.6	Combined stiffness of vanes and M2 system as per TBR Value
		10.7	M1 Mirror Removal sequence Contractor proposal at FDR
		11.1.6	Encoder measurement accuracy before compensation < Requirement removed as is covered by 11.1.6 b).
		11.1.8.1	Axis limits – nomenclature and positions updated
		11.1.9	Table 18 Further axes lockouts as per TBR values, Azimuth Lockout #2 45 deg (SE)
		11.1.10	Maximum braking deceleration values as per TBR values
		11.1.11	Removal of requirement for end stops on all axes – justification required as per 11.1.8.1.
		11.2.4	Lateral support control bandwidth requirements > 2 Hz
		12.1.1 d)	M1 dummy tolerance on Centre of Gravity position ± 10 mm
		12.1.1 f)	M1 dummy radius of curvature of the underside ± 10 mm
		12.2.1	M2 System dummy tolerance on Centre of Gravity position ± 10 mm
		12.3	M2 Electronic Cabinet dummy tolerance on Centre of Gravity position ± 10 mm
		13.4.12	Telescope parked position interlock to be provided by VRSI
		14.1.1.1	Structural damping factor for modal analysis 0.75%
		14.3.1	Paint for surfaces around optical beam – Lord Chemical Products Aeroglaze Z306 – Matt Finish.
		14.4	Electromagnetic Compatibility to be in accordance with IEC 61000 family of standards Introduction of table of pass fail criteria and design goals for EMC testing.
		14.7	Removal of all TBR and TBC Items

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks

Table of Contents

1 SCOPE

VISTA (Visible and Infrared Survey Telescope for Astronomy) is a survey telescope, which will be installed at ESO's Cerro Paranal Observatory, on a peak roughly 1.5 km North East of the Very Large Telescope. ESO's Cerro Paranal Observatory is in the Atacama Desert of Northern Chile on a peak roughly 1.5km North East of the Very Large Telescope.

This Technical Specification covers performance, design, verification, operational, maintenance and installation requirements of the VISTA Telescope Work.

The requirements are directly applicable to the Contractor who will be appointed to design, manufacture, verify and install the telescope structure.

2 Acronyms and Abbreviations

Altitude Angle	Angle above Horizon
CANbus	Controller Area Network Bus
COSHH	Control of Substances Hazardous to Health
COTS	Commercial Off The Shelf
ESO	European Southern Observatory
ICD	Interface Control Document
LCU	Local Control Unit
LEMP	Lightning and Electro Magnetic Pulse
LRU	Line Replaceable unit
M1	Primary Mirror
M2	Secondary Mirror
MLE	Maximum Likely Earthquake
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
OBE	Operating Basis Earthquake
PCB	Printed Circuit Board
PI	Proportional and Integral (Control)
PTV	Peak to Valley
PWM	Pulse Width Modulation

RMS	Root Mean Square
SCP	Standard Connection Panel
TBC	To be Confirmed, but requires further verification or agreement.
TBD	To be Determined
TBR	To be Reviewed
TCS	Telescope Control System
VISTA	Visible and Infrared Survey Telescope for Astronomy
VLT	Very Large Telescope
VPO	VISTA Project Office
wrt	With Respect To

TN-S Power System with the main earthing terminal of the installation connected to the earthed point of the source of energy.

3 Definitions

3.1 Contractor

The term *Contractor* refers to the Company entrusted with the task of design, manufacture and verification and installation of the Telescope Work Package.

3.2 System Definition

The following technical terms will be used throughout this specification with the meaning herein:

Telescope Work Package	The object of this specification as defined in Section 5.3; Comprising the Telescope Structure, M1 Cell, Cassegrain Rotator, Control Hardware, Service and Test Equipment, Factory Service and Test Equipment and Test Equipment and all supporting documentation
Telescope Structure	The structure comprising the Ground Interface, Azimuth Drive, Fork, Altitude Drive, Telescope Tube and Cable Wraps
Telescope Tube	The structure comprising the Centre Section, M1 Cell, Cassegrain Rotator, Trusses, Top end ring and Vanes
M1 Cell	The structure supporting the M1 Primary Mirror comprising: Cell Structure, Axial and Lateral Supports including load cells, actuators and local electronics, Axial and Lateral definers,

	Earthquake restraint and all necessary service connection points
Cassegrain Rotator	The rotary drive system interfacing between the M1 Cell and VISTA instrumentation comprising: rotator bearing, rotator drive and encoder systems, rotator cable wrap and instrument mounting flange
Sub-assembly Control System	The control electronics and embedded software that interface to the electromechanical hardware for the following sub-assemblies: Azimuth Drive, Altitude Drive, M1 Support and Cassegrain Rotator.
Local Control Unit	VME/VxWorks based computer system *(not part of this contract)* which controls the Sub-assembly Control System
Telescope Control System	The external control system that controls the Local Control Units described in this document. *(The Telescope Control System is not part of this contract.)*
VISTA Control System	The external software based system that controls the equipment described in this contract - it comprises the Telescope Control System, LCUs and other components *(the VISTA Control System is not part of this contract)*
IR Camera	The IR Camera is the IR science instrument. *(The IR Camera is not part of this contract.)*
Visible Camera	The Visible Camera is the visible wavelength science instrument. *(The Visible Camera is not part of this contract.)*
Test Camera	The Test Camera is a commissioning instrument that has a subset of the functions of the Visible Camera. *(The Test Camera is not part of this contract.)*
M2 System	The collective term for M2 mirror and the sub-systems utilised to mount and align it. The major sub-systems are the M2 Assembly, being the M2 Mirror in its support frame and the M2 Unit being the alignment system. *(The M2 System is not part of this contract.)*
M1 Handling Equipment	The device(s) used to remove the M1 through the telescope centre section using the Enclosure Crane. *(The M1 Handling Equipment is not part of this contract.)*
Altitude Axis, Altitude Angle	The Altitude Axis is defined as the axis of rotation of the telescope tube. Altitude angle is the angle of the telescope tube

wrt the horizon Altitude zero is when the telescope tube points to horizon, increasing to +90º at Zenith

Azimuth Axis, Azimuth Angle	The Azimuth Axis is defined as the axis of rotation of the telescope forks. Azimuth Angle is zero when the telescope is South pointing and increases towards east.
Arcsec	To avoid confusion, the unit of measurement arcsec is defined as an arc second on the sky
Axial	An Axial tolerance or measurement is defined as being in the direction of the telescope optical axis, that is in the + Z direction
Radial	A Radial tolerance or measurement is defined as being orthogonal to the telescope optical axis.
Accuracy	In theory, the difference between a reported parameter and its true value. In reality, the difference between a reported parameter and the parameter value as measured by an external system with a calibrated accuracy higher than the system under test. Accuracy shall include repeatability between measurements.
Resolution	For measurement, the minimum possible measurable and repeatable change in a reported parameter due to discretisation, noise or other factors. For example, the grating marks in an encoder define its resolution. For performance, the minimum possible measurable and repeatable change in a controlled parameter. For example, friction or deadband in a position controlled system may not allow actual movements as small as the resolution of the position sensor.

3.3 Reference Frame Definition

The co-ordinate system requirements detailed in AD43 shall be applied for all analyses and drawings. Local co-ordinate systems linked to the telescope may be defined by agreement with the VPO, taking into account the requirements of AD43. All local co-ordinate systems shall be defined either by reference to a previously defined co-ordinate system or with respect to physical datums.

3.4 Definition of Requirements Under Development

At present, a certain number of parameters defining the Telescope Work Package have to be considered provisional. Such parameters will be fixed before signing the Contract for the supply of the Telescope Work Package or at a later stage to be mutually agreed between the VPO and Contractor. These parameters which are still provisional are labelled with TBR, TBC or TBD.

TBR	To Be Reviewed: a requirement specified to meet the VISTA top-level requirements, but might over-constrain the design. The Contractor shall investigate the requirements labelled TBR during the preliminary design phase. The findings of these investigations shall be used in further development of the requirements.
TBD	To Be Defined: a requirement to be developed and agreed between the VPO and the Contractor by an agreed date.
TBC	“To be confirmed”: a requirement that is correct with the current design information. To be confirmed by the VPO at an agreed date

A summary table of TBC, TBD and TBR items will be found in Section 17.

4 Applicable and Reference Documents

The documents listed in Sections 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6 of the exact issue stated, form a part of this Technical Specification to the extent specified herein.

In the event of a conflict between this Technical Specification and the Statement of Work AD40, the content of the SOW shall be considered as a superseding requirement.

In the event of conflict between any other applicable document and the content of the Technical Specification, the present specification shall be considered as a superseding requirement.

In this context the term *document* includes *drawings.*

4.1 Interface Control Documents

Table 1: Interface Control Documents

AD	Title	Document No.	Issue
AD01	Interface Control Document between the Electro-mechanical Hardware and the VISTA Control System	VIS-ICD-ATC-01000-0007	1.0 03 May 2002
AD02	Interface Control Document between M1 Mirror and M1 Cell	VIS-ICD-ATC-02000-03000	2.0 31 January 2002
AD03	Interface Control Document between the Telescope Structure and the M2 System	VIS-ICD-ATC-01000-05000	3.0 19 June 2002
AD04	Interface Control Document between the Instrument mount to Cameras	VIS-ICD-ATC-04000-06000	3.0 21 November 2002
AD05	Interface Control Document between the Telescope Structure and the Enclosure	VIS-ICD-ATC-01000-10000	1.0 02 May 2002
AD06	Interface Control Document between the Telescope Structure and the Site Development	VIS-ICD-ATC-01000-09000	1.0 01 May 2002
AD07	Interface Control Document Telescope to IR Camera Services	VIS-ICD-ATC-01000-04020	1.0 21 November 2002

AD08 to AD20 intentionally left blank

4.2 Interface Control Drawings

Table 2: Interface Control Drawings

AD	Title	Document No.	Issue
AD21	Azimuth track interface to Telescope pier	VIS-DWG-ATC-01010-09031	A 19 April 2002
AD22	Primary Mirror interface to Mirror Cell	VIS-DWG-ATC-02000-03000	A 31 January 2002
AD23	Telescope structure interface to M2 System	VIS-DWG-ATC-01000-05000	A 01 May 2002
AD24	Telescope interface to M1 handling equipment	VIS-DWG-ATC-01000-02040	A 23 April 2002
AD25	Mechanical interface with Cassegrain focus instruments	VIS-DWG-ATC-06000-04000	B 16 October 2002
AD26	Telescope interface to instrument handling equipment	VIS-DWG-ATC-01000-06130	A 23 April 2002
AD27	Telescope interface to M2 Unit handling equipment	VIS-DWG-ATC-01000-05030	A 23 April 2002

AD28	Instrument interface to telescope	VIS-DWG-ATC-06000-01000	B 16 October 2002

AD29 to AD39 intentionally left blank

4.3 Applicable Documents

Table 3: Applicable Documents

AD	**Title**	**Document No.**	**Issue**
AD40	Statement of Work for the Telescope Work Package	VIS-SOW-ATC-01000-0005	2.0 21 February 2003
AD41	Acceptance Procedure Electrical Safety and EMC	VLT-VER-ESO-10000-0958	2.0 01 March 1996
AD42	VLT Requirements for Safety Analyses	VLT-TRE-ESO-00000-0467	1.0 27 July 1993
AD43	VLT specification: Basic Telescope Definitions	VLT-SPE-ESO-10000-0016	2.0 07 March 1992
AD44	VLT Environmental Specification	VLT-SPE-ESO-10000-0004	6.0 12 November 1997
AD45	LCU Location and Cable Wrap Schedules	VIS-SPE-ATC-01000-0011	2.0 13 February 2003
AD46	Service Connection Point Technical Specification	VLT-SPE-ES0-10000-0013	4.0 16 February 1997
AD47	VLT CANopen Specifications	VLT-SPE-ESO-10000-2772	1.0 18 March 2002.
AD48	EMC and Power Quality Specification - Part 1	VLT-SPE-ESO-10000-0002	2.0 11 March 1992
AD49	EMC and Power Quality Specification - Part 2	VLT-SPE-ESO-10000-0003	1.0 05 February 1992
AD50	Construction requirements of the VLT Observatory Infrastructures/Buildings/Enclosures related to EMC	VLT-SPE-ESO-12000-0262	1.0 01 July 1992
AD51	VLT Electronic Design Specification	VLT-SPE-ESO-10000-0015	5.0 06 March 2001

AD52 to AD59 intentionally left blank

4.4 Applicable Drawings

AD	Title	Document No.	Issue
AD60	Telescope interface to Enclosure	VIS-DWG-ATC-01000-10000	A 24 April 2002
AD61	Telescope observing aperture	VIS-DWG-ATC-10010-0051	A 24 April 2002
AD62	Telescope truss configuration	VIS-DWG-ATC-01000-0002	A 23 April 2002
AD63	Telescope Azimuth floor	VIS-DWG-ATC-01000-0003	A 23 April 2002
AD64	M1 Mirror axial support	VIS-DWG-ATC-03020-0001	A 24 April 2002
AD65	M1 Mirror lateral support	VIS-DWG-ATC-03030-0001	A 24 April 2002
AD66	M1 Mirror earthquake restraints	VIS-DWG-ATC-03010-0006	A 01 May 2002
AD67	Telescope Interface to M2 Baffle	VIS-DWG-ATC-01000-05050	A 01 May 2002
AD68	Telescope Structure Forbidden Zone	VIS-DWG-ATC-01000-0004	A 01 May 2002

AD69 to AD79 intentionally left blank

4.5 Safety and Standards

Note: In lieu of DIN standards equivalent national standards or European directives may be used subject to the approval of the VPO.

AD80	VISTA Project Safety Management Plan	VIS-PLA-ATC-00001-0019 Issue 2.0, 12 April 2002
AD81	Eurocode No.8 Structures in seismic regions-Design- Part 1	Commission of the EC Report EUR 12266 EN 1988
AD82	Recommendations for calculating the effect of wind on constructions, European Convention for Constructional Steelwork	ECCS Technical Committee 12-wind, report no. 52, 2nd edition
AD83	"General Principles for the Safety Design of Technical Products"	DIN VDE 1000 (1979-03)
AD84	"Safety of machinery - Electrical equipment of machines - Part 1: General requirements"	IEC 60204-1 (2000-05) Consolidated Edition 4.1 (incl. amendments)
AD85	"Protection against electric shock – Common aspects for installation and equipment"	IEC 61140 (2001-10) Edition 3.0

AD86	"Electrical installations of buildings - Part 1: Fundamental principles, assessment of general characteristics, definitions"	IEC 60364 (2001-08) Edition 4.0
AD87	"Information technology equipment – Safety - Part 1: General requirements"	IEC 60950-1 (2001-10) Edition 1.0
AD88	"Insulation co-ordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests"	IEC 60664-1 (2000-04) Consolidated Edition 1.1 (incl. amendments)
AD90	"Hydraulic fluid power - General rules relating to systems"	ISO 4413:1998 Edition 2
AD91	"Electromagnetic compatibility (EMC) including Electromagnetic Pulse(EMP) and lightning protection; programme and procedures; procedures for systems and equipment"	VG 95374-4 (1992-11)

4.6 Reference Documents

Reference documents provide background information for use as appropriate.

RD	Title	Document No.	Issue
RD01	VISTA Project Overview	VIS-TRE-ATC-00000-0004	1.0 25 September 2001
RD02	Overview of the Telescope	VIS-TRE-ATC-01000-0017	1.0 02 May 2002
RD03	Reflecting Telescope Optics II, R.N.Wilson (Springer 1999)	ISBN 0941-7834	

5 Description of VISTA

5.1 VISTA Project

VISTA is a 4m diameter telescope dedicated to carrying out imaging surveys of the southern sky. It will be capable of operating in either the visible or infrared by means of two dedicated, Cassegrain mounted, exchangeable cameras.

An overview of VISTA is provided in RD01.

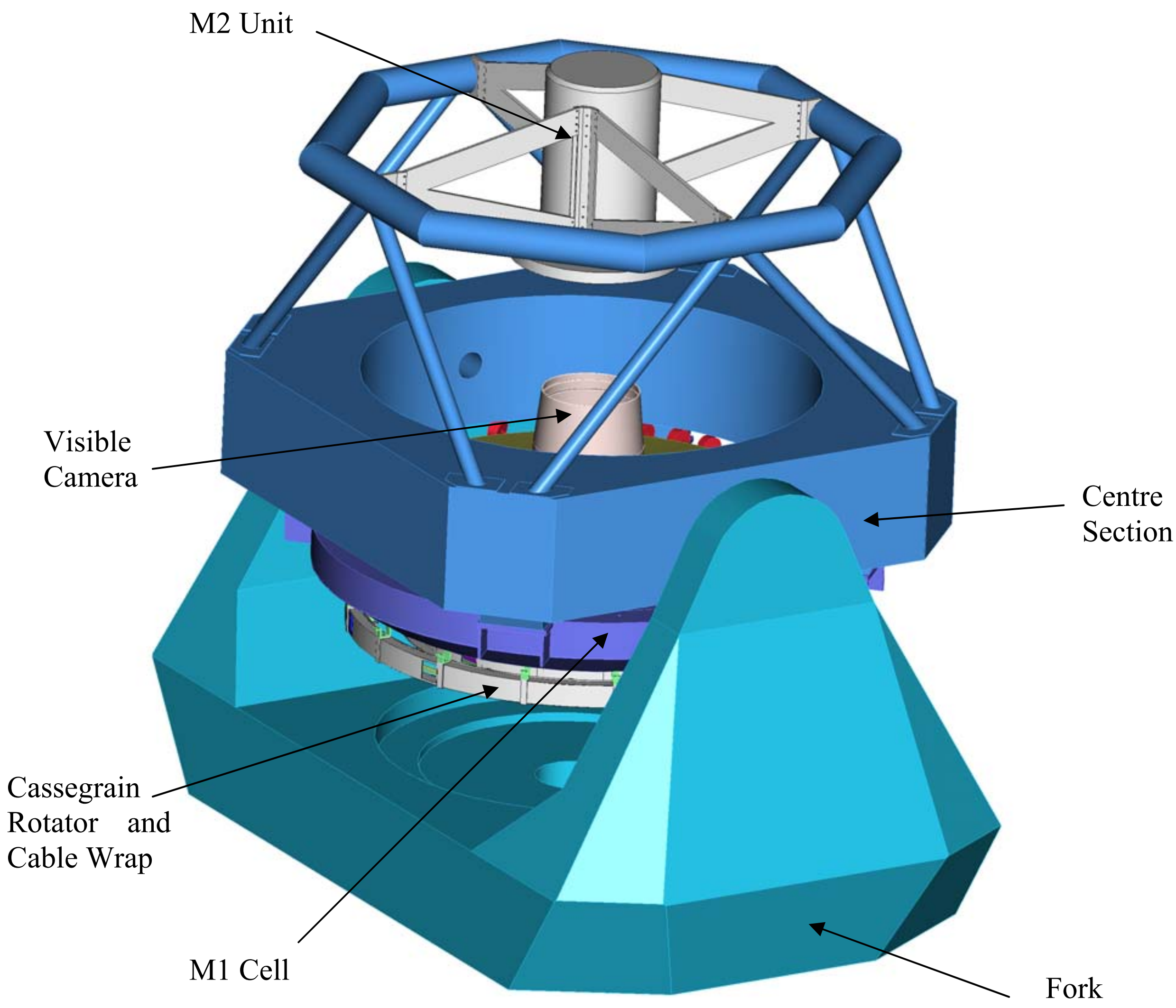

Figure 1 General view of the VISTA Telescope Concept (For Information Only)

5.2 Telescope Conceptual Design

An overview of the VPO's baseline conceptual design for the telescope is provided in RD02. The baseline conceptual design was developed during Phase 'A' of the VISTA project. The principal objective of this work was to provide the basis for cost estimates and project planning to facilitate a judgement on the feasibility of meeting the scientific objectives within the financial and time constraints. The conceptual design work has also been used for the preliminary definition of space envelopes and interfaces between the various work packages.

The optical design has been frozen and contracts will be placed for the M1 Mirror and M2 Assembly before issue of the Telescope Work Package Contract. Outwith the constraints imposed by the contracts for the M1 Mirror and M2 Assembly and subject to meeting the requirements of this Specification, the Contractor will be given free reign to develop their own solutions to suit their experience and capabilities.

Note: RD02 ***is included for information only. Tenderers are free, at their own risk, to use any or all aspects of this design. It should be noted that it is a proof of concept design and the detail design has not been developed to a significant level. Use of the conceptual design will not remove the responsibility of the Contractor to meet the requirements.***

5.3 Top Level Product Tree

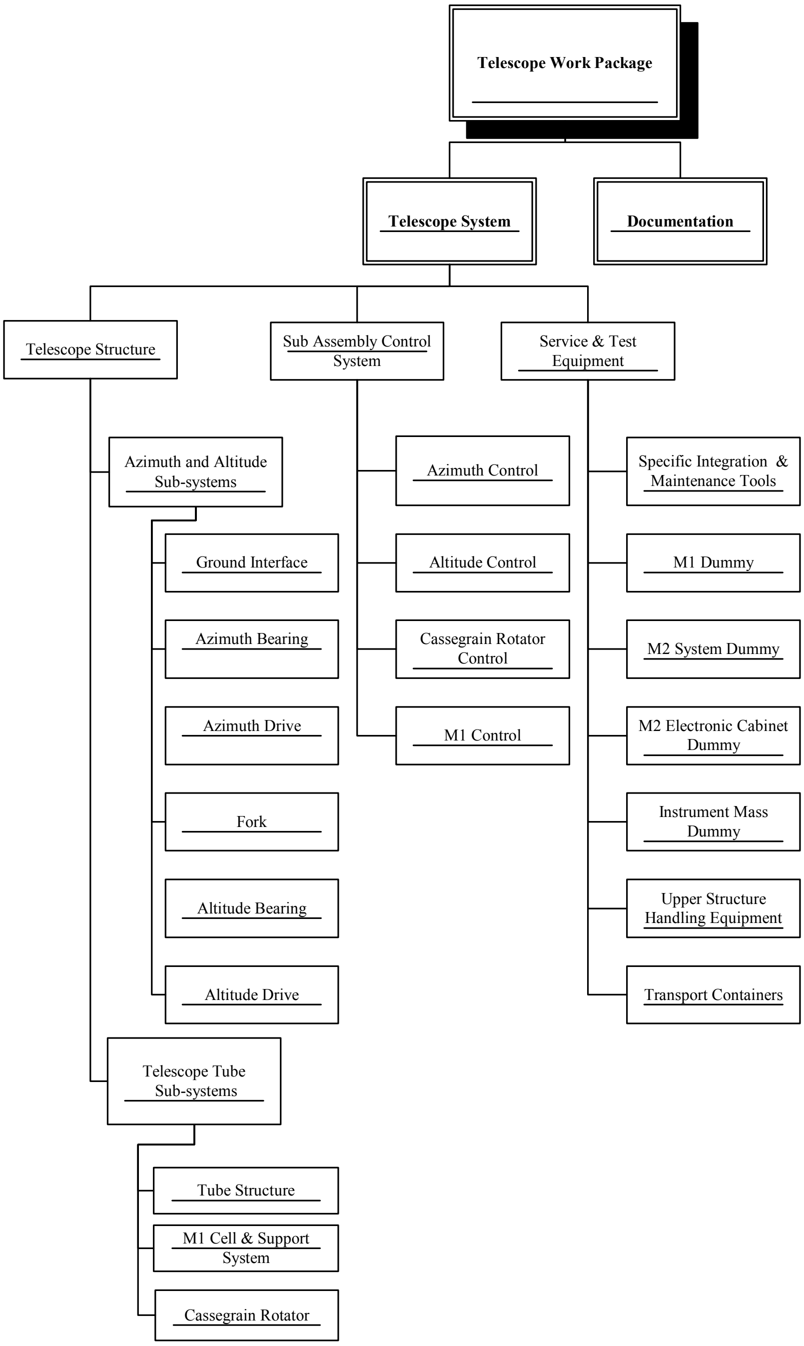

Figure 2 Top Level Product Tree

The Telescope Work-Package is divided into the sections as defined within the Top Level Product Tree in Figure 2.

The Work-Package consists of the Telescope System and the supporting documentation, which relates to both technical and the project aspects. The Telescope system is further sub-divided into Telescope Structure, Sub-assembly Control System and Service and Test Equipment.

Descriptions for the Telescope Structure and Sub-assembly Control System are provided in Section 3.2. The Service and Test equipment is required to carry out routine and on-site set-up, testing and servicing. This includes dummy equipment masses to allow removal of the selected components for testing/servicing while maintaining the Telescope balance and also initial testing of the telescope performance. Also included are the transport containers and component handling equipment for routine service operations.

5.4 Description of the Operational Scenario

5.4.1 Observation Modes

During normal night-time science observations, first the telescope will be pointed at a science target. Blind pointing will usually be sufficient, but occasionally a small correction may be applied using the autoguider measurement of a star with known position. After reaching the target position the three telescope axes will be tracked to follow the sidereal motion due to the Earth's rotation (occasionally a small component of 'non-sidereal tracking' angular velocity may be demanded, e.g. for solar system targets). The normal mode will be closed-loop tracking, with error correction signals applied to the altitude and azimuth axes using measurements (at around 10 Hz) of a star from the autoguider. On a timescale of ≈3 minutes small corrections will be applied to the M2 alignment, using an error signal from the on-instrument curvature sensors and/or look-up tables. The M1 mirror alignment is maintained through an active support system.

When observing a science field with the IR Camera, typically once per minute a small telescope pointing offset of 10 arcsec on sky will be applied: this is to move the sky image relative to the detectors, which aids removal of artefacts in later processing.

Longer slews between science targets, typically between 3 degrees and 45 degrees on sky, will be demanded typically hourly but can be as frequent as 10 minutes. Targets will most commonly be at Altitude angles between 80 to 50 degrees, but occasionally as low as 20 degrees. Azimuth angles may be at any angle. The maximum expected integration duration will be 30 minutes.

5.4.2 Additional Operational Modes

Further to observation mode, the following operational modes shall be implemented:

5.4.2.1 Start-up

Start-up is carried out prior to the commencement of the night-time observation mode. It entails taking the telescope from the daytime standby mode to the night time *observation* mode and carrying out any required tasks to ensure that the telescope is correctly configured for optimum observation performance.

5.4.2.2 Shut-down

Shut-down is executed at the end of each observing night or more generally when the observation is stopped. It consists of bringing the telescope from the night time *observation* mode to the *daytime standby* mode and performing all necessary actions to ensure a safe configuration of the telescope regarding adverse weather conditions.

5.4.2.3 Daytime Standby

The daytime standby mode is the mode when the telescope is used neither for observation nor for maintenance (typically during daytime). Typically the telescope will be parked at an altitude of 20 degrees and South pointing. This parked position should be modified by a small random offset in order to avoid flat spots building up in bearings and or drives.

It provides a safe configuration of the telescope against environmental aggression and provides the required thermal conditioning to keep the telescope to the expected minimum temperature of the next night.

All equipment is switched off except those functional units that are required for thermal stability, basic communication with the workstation and re-activation. The power supplies and amplifiers for all drive systems are switched off. All brakes shall be in a power-off failsafe engaged conditions.

The duration of the daytime standby mode is typically 10 to 14 hours depending on the Chilean seasons.

5.4.2.4 Test Mode

The test mode involves moving the telescope to find a bright star and then use the Shack-Hartman Sensor or Curvature Sensor to measure and re-calibrate if necessary the M1 support system. It may be necessary to take the telescope into Test Mode at the any point during the observation period due to deterioration of the image quality.

5.4.2.5 Emergency Modes

The emergency modes correspond to all situations when a failure and/or sudden adverse conditions occur and could potentially cause personal injury or damage to part or the entire telescope. In these eventualities, all necessary functions shall be provided to bring the telescope to a safe configuration in a minimum of time.

5.4.2.6 Maintenance Mode

The Maintenance Mode denotes any condition where the telescope sub-systems may be under engineering control but not necessarily under high level software control.

5.4.3 Operation of Equipment

VISTA will be operated by ESO staff and will be designed to be compatible with the operational procedures employed at Paranal. The telescope will be operated remotely from the VLT Control Room. The operator will control all telescope and camera functions, including selecting and queuing the observations, performing calibrations, and responding to changing conditions and unexpected events.

5.4.4 Access to VISTA

Routine engineering access to the VISTA enclosure and telescope will only be possible during the day. During observing, the telescope building will not be staffed.

5.5 VISTA Control System

The VISTA telescope, cameras and other systems will be controlled by VME computers known as Local Control Units (LCU's). These will be located in the VISTA Enclosure and several will be mounted on the telescope structure (approximate locations of telescope mounted LCU's are defined in AD45, alternative locations may be mutually agreed during Preliminary Design). LCU's integrated by the VPO for telescope control shall reside in the telescope drive electronics cabinets. The LCU's will be controlled by the TCS. The Telescope Work Package Hierarchy is shown in Figure 3.

The LCU's will be connected to Unix workstations located in the VLT Control Building by a Local Area Network. Workstations or terminals will be available in the VISTA Enclosure for local engineering control, but these will not be used operationally.

LCU's will control the telescope axes (altitude, azimuth and Cassegrain rotator) and M1 Cell described in this document *(LCU hardware and software are not part of this contract)*. LCU hardware and software will be integrated with the hardware after Preliminary Acceptance, as defined in the SOW AD40. The interface with the VISTA Control System is defined in AD01.

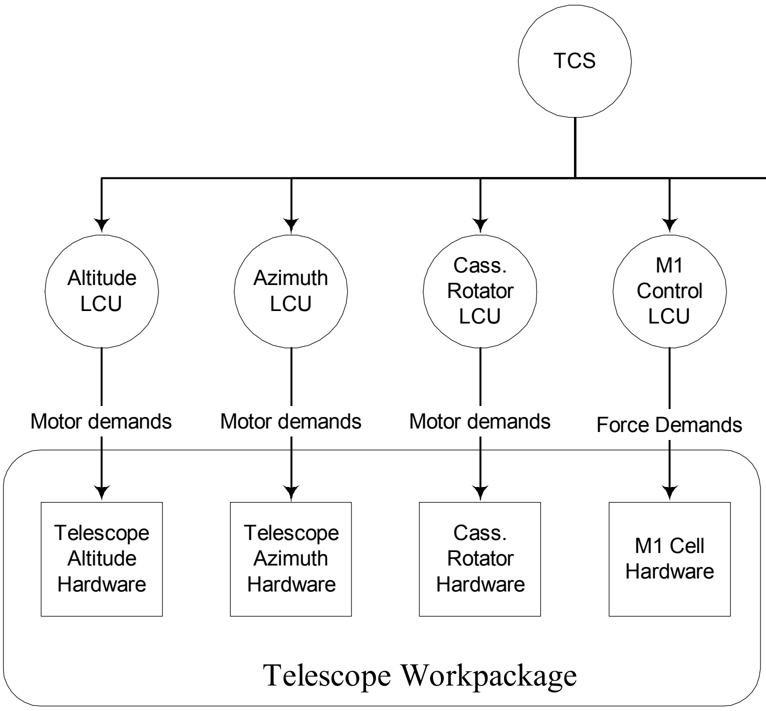

Figure 3 Telescope Control Hierarchy.
(Arrows show the direction of control; other data flow in both directions.)

6 Environmental Requirements

6.1 General

The equipment shall comply with the requirements defined in the VLT Environmental Specification AD44, unless specifically amended by the requirements defined herein. AD44 describes the overall environmental conditions to be expected in operation, maintenance, storage at the Chilean site and transportation.

6.2 Transportation Environment

The transportation environment defined under Section 4.1 of AD44 is applicable. The Telescope Work Package components should be capable of withstanding rapid changes in atmospheric pressure as would be experienced in an aircraft cargo hold or transportation from sea level to the Paranal Observatory.

6.3 Installation/Operation/Maintenance/Survival Environment

The installation/operation/maintenance/survival environment defined under Section 4.2 of AD44 is applicable except for what is specified herein.

6.3.1 Natural Temperature

6.3.1.1 Definitions

Operational temperature range is defined as the ambient air temperature under which all performance requirements shall be met.

Functional temperature range is defined as the ambient air temperature under which it shall be possible to operate the system although with degradation of performance.

6.3.1.2 Requirements

a) Operational temperature range 0 to 15 °C

b) Functional temperature range -5 to 25 °C

6.3.2 Humidity

The site humidity is defined in AD44. All design must take into account the effects of low humidity on site particularly with respect to provision for anti-static protection as defined in AD51.

6.3.3 Sand and Dust

The design of both mechanical and electrical components shall take into account sand and dust particulate matter, which may be encountered either during transportation or installation/operation of the Telescope Work Package. Typical data concerning the particulate matter is contained in AD44.

6.3.4 Elevation above Sea Level

The Paranal Observatory is 2630 m above sea level with a nominal atmospheric pressure of 750 mb. The design of both electrical and mechanical components shall take into consideration all effects of operating at such an elevation above sea level.

All systems using radiative cooling or forced air heat exchange must be appropriately de-rated for altitude as defined in AD51.

Due to the elevation above sea level, the need to increase separation of *exposed* electrical tracks/conductors by a factor of x1.07 is described in AD41.

6.3.5 Exposure to Ultra-Violet Radiation

The Paranal Observatory is 2630 m above sea level with a corresponding reduction in UV protection. AD44 defines the UV exposure on Paranal. All systems exposed to UV must be appropriately designed for such exposure as defined in AD51.

6.3.6 Natural Wind

6.3.6.1 Definitions

Internal operational wind speed is defined as the wind speed inside the enclosure averaged over 30 minutes, within which VISTA shall operate within its nominal performance. This will be achieved by operation of the enclosure wind-blind and doors.

Survival wind speed is defined as the maximum wind speed for which each subsystem of VISTA shall be dimensioned, taking into account the requirement of Section 4.2.9.1 of AD44 including possible accidental conditions. In the event that that the enclosure cannot be closed, parts of the telescope may be exposed to stronger wind than the operational wind speed. No damage is permitted to the telescope structure at this wind speed.

6.3.6.2 Requirements

a) Internal operational wind speed 9.0m/s average, 2.0 m/s rms, with spectrum defined in section 14.1.1.2.
b) Survival wind speed 36 m/s maximum.

6.3.7 Earthquakes

6.3.7.1 Definitions

Two design earthquakes are defined by the requirement of AD44 section 4.2.14: the Operating Basis Earthquake (OBE) and the Maximum Likely Earthquake (MLE).

An OBE is an earthquake of moderate size but with a high probability of occurrence during the lifetime of the telescope, while a MLE is an earthquake of large magnitude but with a lower probability of occurrence.

6.3.7.2 Requirements

The design shall be verified by analysis using the excitation characteristics defined in Section 14.1.1.5 and must meet the requirements of Section 14.1.2.

6.4 Environmental Control and Monitoring

6.4.1 Enclosure Air Conditioning

The Enclosure Air Conditioning System will maintain the predicted ‘at sunset’ ambient temperature to within 0^{o}C to + 2^{o}C.

6.4.2 Control of Heat Sources

Any system connected to an external energy source or conveying fluids shall meet the following requirements:

a) Systems above primary mirror level shall not have a surface temperature which differs more than +1.5°C / -3°C from the operational ambient air. This shall assume 0 m/s wind speed within the open dome and the telescope pointing to zenith. This requirement shall be met with ambient air variation of +/- 0.5°C.

b) Systems below primary mirror level shall not have a surface temperature which differs more than +1.5°C / -5°C from the operational ambient air. This shall assume 0 m/s wind speed within the open dome and the telescope pointing to zenith. This requirement shall be met with ambient air variation of +/- 0.5°C.

c) No individual heat source or sink or shall transfer > 100 W to or from the ambient air.

d) No dispersed system of heat sources or sinks or shall transfer > 200 W to or from the ambient air.

e) Active cooling shall use coolant as specified in AD05.

6.4.3 Temperature Sensors

Temperature sensors shall be provided at various locations on the telescope for monitoring and calibration purposes. As a minimum, sensors shall be provided to measure the temperature of:

a) the top-end ring

b) the trusses (one per structural member)

c) the centre section

d) the mirror cell

Temperature sensors shall be type PT100. Resolution of PT 100 sensor ≤ 0.1 deg C & ≤ 0.2 deg C repeatability over 2 month period.

6.4.4 Anemometers

Anemometers shall be provided on the telescope for monitoring and calibration purposes. Signal conditioning and acquisition electronics shall conform to AD51 and interface to the LCU's as specified in AD01.

a) As a minimum, anemometers shall be located with 1 on M2 Unit, 2 on centre-section facing down to mirror, fore and aft.

Anemometers shall be type 1086M with RS485 interface as manufactured by UK firm GILL.

6.4.5 Additional Sensors

Signal conditioning and acquisition electronics shall conform to AD51 and interface to the LCU's as specified in AD01. Signal conditioning shall be provided for:

a) sensors specified in section 6.4.3.

b) sensors specified in section 6.4.4.

c) 5 additional PT100 temperature sensors (not provided by the contractor) on the Telescope Structure.

d) 4 additional PT100 temperature sensors (not provided by the contractor) on the M1 Mirror.

e) 6 additional miscellaneous sensors (not provided by the contractor) on the M1 Mirror

6.5 Vibration and Noise

The effects of Vibration and noise on the telescope performance shall be kept to a minimum through good engineering practice and operational considerations such as isolation of vibration sources from the telescope and not operating the enclosure air conditioning plant during observation modes.

The components of the Telescope Work Package shall be designed such that there is no vibration or noise source attached to or connected to the telescope without adequate damping.

7 Interface Requirements

7.1 Interface between Telescope Structure and Pier

The interface to the pier is described in AD06 and AD21.

The interface will be developed by the Contractor in consultation with the VPO during the preliminary design phase.

The site development contractor will supply and anchor the interface base-plates in the concrete pier acting for the VPO taking into account requirements for operational and accidental loading. The Contractor will provide initial results of the earthquake analysis with the reaction forces at the interface, as specified in the SOW AD40.

7.2 Interface between M1 Mirror and M1 Cell

The interface between M1 Mirror and M1 Cell support system is described in AD02. Interface control drawing AD22 prescribes the dimensions and tolerances of the interface and provides the centre of gravity co-ordinates of M1 together with its inertia features.

The interface between the M1 Mirror and the M1 Cell Earthquake restraints is shown in AD66.

This interface is with equipment that will be under contract before placing the Telescope Work Package Contract.

7.3 Interface between Telescope Tube and M2 System

AD03 and AD23 are applicable to this interface. The interface will be agreed between the Contractor and the VPO during the preliminary design phase.

7.4 Interface between Telescope Tube and M2 Baffle

The interface between the Telescope Tube and the M2 Baffle is prescribed in AD67. Neither the M2 Baffle or its vanes are part of this contract.

7.5 Interface between Cassegrain Rotator and Cassegrain Focus Instruments

The mechanical interface between the Cassegrain Rotator and the Cassegrain focus instruments (Cameras) is prescribed in AD04 and AD25.

AD28 provides the centre of gravity co-ordinates of the cameras along with inertial features.

Services required for the IR camera are prescribed in AD07

Note: To avoid re-balancing the telescope between camera changeovers, the Visible, IR and Test cameras will be adjusted to have the same balance torque relative to Altitude Axis.

7.6 Interface between Telescope Work Package and Control Hardware

The Interface to VISTA Control System (azimuth, altitude, M1 support, M2 Unit, Cassegrain rotator, instrument, auxiliary services) is defined in AD01 together with the extent of supply and responsibility by the Contractor.

LCU's shall be co-located with the Contractor supplied control hardware, in Contractor supplied electronic cabinets. Likely locations of these cabinets are identified in AD45. If these locations are unsuitable, alternative locations shall be discussed during the preliminary design phase and mutually agreed. Note that in the event of an alternative position being proposed and agreed, the additional cabling requirements and subsequent effect on cable wrap sizing and design shall be the Contractor's responsibility.

The contractor supplied cabinets for co-location of the contractors control hardware and the LCU's shall be thermally conditioned if they are located as per AD45 or elsewhere in the enclosure above the level of the azimuth floor. If located below the level of the azimuth floor then the enclosure air conditioning system will be active during observing and it is then necessary to ensure the cabinet has the facility (e.g. ventilation fans) to maintain the equipment within the cabinet at the appropriate operating temperature. Initial estimate of the thermal load due to this equipment shall be supplied at PDR.

7.7 Interface between Telescope Structure and M1 Mirror Handling Equipment

The interface between the Telescope Structure and the M1 Mirror Handling Equipment for removal of the M1 Mirror by dome crane is defined in AD24.

This interface will be developed by the Contractor in consultation with the VPO during the preliminary design phase.

7.8 Interface between Telescope Structure and Camera Handling Equipment

The interface constraints with camera handling equipment are provided in ICD drawing AD26.

Note: The telescope is horizon pointing when mounting a camera onto the Cassegrain rotator.

7.9 Interface between Telescope Structure and M2 System Handling Equipment

7.9.1 M2 Unit

The top-end vane configuration shall allow removal of the M2 Unit, using the dome crane (after removal of the M2 baffle and M2 assembly). This operation shall be performed utilising the enclosure crane after the trusses, top end ring and M2 Unit have been removed from the centre section and placed adjacent to the telescope. The M2 Unit handling interface constraints are defined in AD27.

7.9.2 M2 Assembly

The telescope trusses shall be configured to allow access for the M2 Assembly and for the use of the M2 Assembly Handling Equipment. The space requirement for this operation is shown in AD62.

Note: The telescope is horizon pointing when removal and replacement of the M2 Assembly takes place.

7.10 Interface between Telescope Structure and VISTA Enclosure Services Systems

Services that interface with the Telescope Work Package deliverables (e.g. power and coolant) are located within the enclosure and auxiliary building. AD05 defines these interfaces.

8 System Requirements for the Telescope Work Package

8.1 Physical Characteristics

8.1.1 Mass

8.1.1.1 Definitions

The *telescope total mass* is defined as the total mass of the parts belonging to the Telescope Work Package, excluding service and test equipment and including additionally the following systems:

a) M1 mirror mass: refer to AD02

b) M2 System mass: refer to AD03

c) Camera mass: refer to AD04

d) Cables and cooling pipes and external electronic cabinets on the telescope structure for the M2 System and instruments.

The *maximum mass for lifting during maintenance* is defined as the limit on the mass of parts or sub-assemblies including all handling devices, slings, etc. to enable them to be lifted within the capacity of enclosure crane.

The *maximum mass for installation* is defined as the limit on the mass of parts or sub-assemblies including all handling devices, slings, etc. to enable them to be lifted into the enclosure during installation by an external crane.

8.1.1.2 Requirements

a) telescope total mass	< 100 tonnes (Design Goal < 95 tonnes)
b) maximum mass for lifting during maintenance	< 9 tonnes
c) maximum mass for installation	< 35 tonnes

8.1.1.3 Mass Balance

a) There shall be provision for the addition of masses on the M1 cell and top-end to enable the balancing of the telescope around the altitude axis.

b) Balance masses shall allow balancing such that the residual torque around the altitude axis is ≤ 200 Nm in any orientation of the Telescope Tube.

c) The Contractor shall maintain a mass balance spreadsheet.

d) Provision shall be made to include a trim weight system for the fine tuning of the telescope tube balancing.

8.1.2 Design Volume and Constraints

The Requirements with respect to the Design Volume and constraints are:

a) The telescope structure shall be within the space envelope defined in AD60

b) The vignetting of optical beams shall be avoided by any mechanical part with the exception of the top-end vanes AD68.

c) The fraction of the annular aperture within diameters of 4340 and 1500 mm obstructed by the vanes shall be less than or equal to 1.5% of the area.

d) All parts or sub-assemblies shall be designed so that they can be manoeuvred into the enclosure, during installation, by an external crane, through the observing aperture of the enclosure as defined in drawing AD61.

8.2 Angular Coverage

8.2.1 Definition

Angular Coverage is defined as the range of altitude, azimuth and Cassegrain rotator angles within which VISTA shall operate and meet its performance requirements. The angular ranges are defined in accordance with the system of co-ordinates and the origin in accordance with the Basic Telescope Definitions AD43.

The *Zenith Blind Spot* is defined as the area around zenith (≤ 4.0° diameter) that the telescope is not required to track in azimuth.

8.2.2 Operating Angular Coverage Range Requirements

a) Altitude operating angular coverage	88º to 20º
b) Azimuth operating angular coverage	+135º to -315º
c) Cassegrain rotator operating angular coverage	+180º to -360º

Note: Due to maintenance requirements, extended ranges are required where the performance requirements are inapplicable (see section 11.1.8.1).

8.3 Operating Angular Velocity and Acceleration Requirements

When manoeuvring between targets, it shall be possible to control angular velocities and accelerations within the ranges shown in Table 4 (including zero).

Table 4: Range Maximums for Velocities and Accelerations

	Azimuth	Altitude	Cassegrain Rotator
velocity	±2.0 °/s	±2.0°/s	±3.6°/s
acceleration	±0.5 $°/s^2$	±0.5 $°/s^2$	±1.0$°/s^2$

8.4 Telescope Pointing

8.4.1 Pointing Definitions

The *quasi-static pointing error* is defined as the differential pointing error on-axis after rotation of the telescope axes through various specified angles (additional off-axis error is limited by the Cassegrain Rotator Requirements, Section 10.5.2). It includes, but is not restricted to:

a) encoder accuracy and mounting imperfections

b) axis misalignment and runout

c) structural deformation resulting in misalignment between the drive encoders and the tube axis under gravity and thermal operational loads over any 30 minute period.

d) structural deformation resulting in misalignment of the optical surfaces with respect to the tube axis under gravity and thermal operational loads over any 30 minute period.

Quasi static pointing error excludes the telescope tracking errors and wind effects.

8.4.2 On Axis Pointing Requirements

a) Quasi static pointing error is specified for several range combinations of the telescope axes in Table 5.

b) Quasi static pointing error is defined as the cumulative worst case combinations of azimuth and altitude error.

c) The Contractor shall build and maintain a quasi static pointing budget as specified in the SOW AD40. Parameters outwith the scope of this technical specification will be supplied as required.

Table 5 : Quasi Static Pointing Error

Azimuth Range (up to)	Altitude Range (up to)	Quasi Static Pointing error at Cassegrain focus (expressed in arcsec rms on the sky)	
		Total	Non-repeatable
0.17 deg	0.17 deg	<0.1	<0.1
2 deg	2 deg	<0.5	<0.25
60 deg	60 deg	<8.0	<0.5
360 deg	n/a	<15.0	<1.0

8.4.3 Field Rotation Requirements

Cassegrain requirements wrt to field rotation are detailed in section 10.5.2

8.5 Telescope Tracking

8.5.1 Tracking Definitions

The *Open Loop Tracking Mode* is the continuous pointing of the telescope at a moving stellar object using its theoretical trajectory. It involves the continuous motion of the telescope axes and Cassegrain rotator. Tracking at low non-sidereal rates is also required.

Open-loop tracking accuracy is defined as the rms angular error between the demanded target position and the actual target position, excluding the mean offset over the given timescale. This applies when moving all axes up to and at the tracking velocities and accelerations defined in Table 6 and including any required transitions through zero velocity.

Table 6: Tracking Velocities and Accelerations

	Azimuth	**Altitude**	**Cassegrain Rotator**
tracking velocity	± 2.327 mrad/s	± 0.082 mrad/s	± 2.327 mrad/s
tracking acceleration	± 0.048 mrad/s^2	± 0.0025 mrad/s^2	±0.048 mrad/s^2

The open-loop tracking error of the telescope structure includes, but is not limited to:

a) windshake effects including buffeting and structure excitation

b) motor torque errors (cogging and ripple)

c) bearing friction variation

d) encoder error

e) Accuracy must consider the worst case combinations of azimuth, altitude and rotator error.

f) Bearing errors, which may lead to incorrect determination of errors.

Other errors (such as the low-spatial frequency errors of the pointing model and bearing errors) are assumed to be corrected.

8.5.2 Tracking Requirements

a) Tracking shall be verified with a Contractor supplied control system at time of Preliminary Acceptance.

b) Open-loop tracking shall be accurate to within 0.10 arcsec rms over 15 seconds

c) Open-loop tracking shall be accurate to within 0.25 arcsec rms over 5 minutes

d) The Contractor shall build a telescope open-loop tracking budget as specified in the SOW AD40.

8.6 Telescope Dynamic Performance

8.6.1 First Telescope Locked Rotor Frequency

The design of the telescope structure and of its parts shall be driven by considerations of achieving a high first locked rotor frequency of the system.

8.6.1.1 Definition

The *first locked rotor frequency* is defined for the purposes of FEA dynamic modelling in the context of this work package:

1. With coupling of the degrees of freedom in the direction of relative motion of the stators and the respective rotors of the Altitude, Azimuth and Rotator drives.
2. With all parts of the drive chain modelled including the attachment to the structure.
3. With the mass and inertial properties of the M1 Mirror as specified in ICD drawing AD22
4. With the mass and inertial properties and stiffness of the M2 System as specified in ICD AD03
5. Including compliance of the bearings of the Altitude, Azimuth and Rotator axes.
6. Assuming that the pier is rigid

8.6.1.2 Requirement

First locked rotor frequency $\geq$ 11.4 Hz

8.6.2 Azimuth, Altitude and Cassegrain Rotator Axes Dynamic Response

The pointing and tracking requirements in sections 8.4 and 8.5 shall be tested using a control system of the type described in Section 11.1.3. The control parameters used by the vendor for the telescope Azimuth, Altitude and Cassegrain axes shall be supplied to the VPO for inclusion in their LCU software (not in contract).

9 Requirements for the Altitude and Azimuth Sub-Systems

In the event of conflict between any sub-system specification and systems requirements in Section 8 the system requirement shall be considered as a superseding requirement.

9.1 Altitude and Azimuth Axis Alignment

9.1.1 Azimuth Axis Alignment

a) The Azimuth axis shall be aligned to the local vertical within 0.15 mrads.
b) The Azimuth axis shall be concentric to the telescope pier such that there is satisfactory load transfer into the pier and foundations.
c) the Azimuth cable wrap shall be concentric to the azimuth axis.

9.1.2 Altitude Axis Alignment

a) The altitude axis shall be perpendicular to the azimuth axis to within 0.15 mrads.
b) The altitude axis and shall have a horizontal offset of less than 0.5 mm to the azimuth axis.
c) The axis of the centre section when zenith pointing shall be concentric to the azimuth axis to within 0.5 mm.

9.2 Azimuth Bearing

The azimuth bearings support the telescope fork axially, restrain it radially and resist overturning moments. The bearing conceptual design assumes a hydrostatic axial bearing and rolling element radial bearing configuration; however, alternative bearing designs are acceptable provided they meet the pointing, tracking and dynamic requirements.

A trade-off study may be requested if alternative systems are proposed.

a) The use of hydrostatic bearings or other bearing types of equivalent system performance is required to support the axial component of the load.

b) The radial component of the load shall be supported either by hydrostatic bearings or by rolling element bearings.

c) Flexure in the bearing, e.g. through variation in support load must be included in the pointing and tracking error analysis.

9.2.1 Azimuth Bearing Requirements

The bearing implementation must meet the pointing, tracking and dynamic requirements:

The Azimuth Bearing requirements are:

a) Static and dynamic friction torque shall allow the performance in section 8.4 and 8.5 above to be achieved over the life of the telescope.

b) Earthquake restraints shall be provided.

c) In case of failure of the oil supply no damage shall occur.

d) The system shall be designed to minimise flooding in the event of a leak.

e) If the oil temperature is such that the thermal levels outlined in section 6.4.2 are exceeded then the system shall be equipped with an oil cooling heat exchanger connected to the enclosure cooling circuit.

f) Provisions shall be made in the design of the bearing and in the oil collection and return system to avoid oil contamination.

g) Status of Lubrication system shall be reported back to the azimuth LCU.

h) In the event that rolling element bearings are utilised, they shall be sealed to prevent ingress of dirt or water or egress of oil.

9.3 Azimuth Cable Wrap

a) The cable wrap shall be mounted on the fork below the azimuth floor.

b) The cable wrap shall exceed the azimuth angular range of travel (see section 11.1.8.1) by a margin of 5° beyond the telescope end-stops.

c) The cable wrap shall have capacity for permanent installation of all services for the telescope, including the M2 Unit and the IR, Visible and test cameras and all LCU's mounted on the telescope (see AD45).

d) If the torque effect experienced by the azimuth drive due to the cable wrap affects the drive capability to meet the pointing, tracking and dynamic requirements then it shall be equipped with a dedicated drive system and shall be synchronised with the Azimuth Drive. The effect of the residual torque experienced by the Azimuth Drive shall be included in the pointing and tracking error.

e) The wrap shall be interlocked to the main Azimuth Drive to prevent damage to the cable wrap from differential motion or drive failure.

9.4 Telescope Fork

The telescope fork comprises all systems between the azimuth drive system and the altitude drive system. The conceptual design assumes a direct drive motor for the altitude drive.

The stiffness of the fork shall be such that:

a) The first locked rotor requirement is met 8.6.1.2.

b) The stiffness and alignment requirements for the azimuth and altitude bearings are maintained.

9.4.1 Fork Azimuth Floor

A continuous azimuth floor attached to the fork shall be provided meeting the following floor requirements:

a) The level and diameter of the azimuth floor is prescribed in ICD AD63

b) general loading : 10 kN/m^2

c) localised loading: 1 Tonne over 70 x 40mm area with deflections of floor elements such as beams, girders and bracings as per requirements of ISO 14122 Safety of Machinery – Permanent means of access to machinery Part 2 Working Platforms and walkways.

d) The azimuth floor shall include access panels to allow access to equipment inaccessible from the enclosure.

e) Part of the fork azimuth floor shall be removable to allow the M1 mirror to be lowered through an aperture in the enclosure floor into the basement of the enclosure as shown in AD63.

f) The azimuth floor shall provide a safe working surface for inspection and maintenance access to components on the M1 cell and cameras.

g) The floor finish shall be antistatic and shall consist of:

- PVC conductive flooring, or similar and approved.
- Copper grid for the connection between PVC parts and with the steel structures.

9.5 Altitude Bearings

The Altitude bearings support the telescope tube axis radially and restrain it axially. The bearing conceptual design utilised a hydrostatic bearing configuration, alternative bearing designs are acceptable provided they meet the pointing, tracking and dynamic requirements. A trade-off study may be requested if alternative systems are proposed.

The altitude axis shall make use of two bearings, one at either side of the fork.

The bearing implementation must meet the pointing, tracking and dynamic requirements:

The Altitude Bearing requirements are:

a) Minimum stiffness shall be determined by dynamic requirements.

b) Alignment of Axis see Section 9.1

c) The bearing system shall provide restraint against earthquake loads.

d) In the event that rolling element bearings are utilised, they shall be sealed to prevent ingress of dirt.

9.6 Altitude Axis Cable Wrap

a) A cable wrap system shall be implemented on the altitude axis. One or more wraps shall be mounted adjacent to the trunnions on the centre-section. The wraps shall be driven by the main altitude axis and the variable torque loading from the wrap must be taken into account. Any frictional contribution from the cable wrap must be included within the Pointing and Tracking Budget.

b) The cable wrap shall have capacity for permanent installation of all services for the telescope, including the M2 Unit, the IR Camera, Visible Camera, Test Camera and the different LCU's mounted onto the telescope tube (see AD45).

10 Requirements for the Telescope Tube Sub-Systems

10.1 General Requirements

a) In the event of conflict between any sub-system specification and systems requirements in Section 8 the system requirement shall be considered as a superseding requirement.
b) The optical performance of VISTA is entirely dependent on two differential displacement and alignment tolerances. The first is the relative alignment of the M2 Mirror with respect to the M1 Mirror. The second is the relative alignment of the M1 Mirror and Cassegrain Rotator.
c) The design of the tube structure shall be driven by consideration of stiffness and deflection, limitation of hysteresis and limitation of aerodynamic torque. Wherever possible circular structural cross-sections shall be used to minimise wind drag forces.

10.2 Telescope Tube Structural Performance

To achieve the necessary tolerances, the M2 system will be equipped with a five axis adjustable mount. This can readily remove repeatable errors. Non-repeatable error sources can be corrected using on-instrument wavefront sensors but with a significant time latency (≈ 3 min).

10.2.1 M2/M1 Differential Displacement

a. The differential error requirements for the M1 Mirror and M2 Mirror Alignment are specified in Table 7.

b. Repeatable error is considered as varying with the relevant gravity component of the altitude angle and therefore the maximum allowable differential over the operating range is given.

c. Analysis of the differential displacement should treat the M1 Mirror as a rigid body and incorporate the stiffness of the M2 System as specified in AD03.

Table 7: M2/M1 Differential Displacement

Altitude Range	Max Axial (Focus)		Max Radial (De-centre)		Max Tilt	
	Repeat	Non-Repeat	Repeat	Non-Repeat	Repeat	Non-Repeat
Any 1°	n/a	1 μm	n/a	2 μm	n/a	1 μrad
Any 10°	n/a	4 μm	n/a	7 μm	n/a	3 μrad
88° to 20°	270 μm	10 μm	200 μm	20 μm	40 μrad	10 μrad

10.2.2 M1 Mirror/Cassegrain Rotator Differential Displacement

Differential movement between the M1 Mirror and the Cassegrain Rotator can be partially compensated by movement of the M2 mirror. The most critical residual is the tilt error.

a) The differential displacement requirements for the M1 Mirror and the Cassegrain Rotator shall not exceed those specified in Table 8.

b) Repeatable error is considered as varying with the relevant gravity component of the altitude angle and therefore the maximum allowable differential over the operating range is given.

c) Analysis of the differential alignment should treat the M1 Mirror and IR Camera as rigid bodies.

Table 8: M1/Cassegrain Rotator Differential Displacement

Altitude Range	Max Axial (Focus)		Max Radial (Lateral)		Max Tilt	
	Total	Non-Repeat	Total	Non-Repeat	Total	Non-Repeat
Any 1°	n/a	2 μm	n/a	2 μm	n/a	1 μrad
Any 10°	n/a	7 μm	n/a	7 μm	n/a	3 μrad
88° to 20°	35 μm	20 μm	30 μm	20 μm	20 μrad	10 μrad

10.3 Alignment Requirements of Telescope Tube Sub-Systems

10.3.1 Principal Datum for Alignment of the Telescope Tube

The datums for alignment of the telescope tube shall be

i. the axis of rotation of the Cassegrain Rotator

ii. the plane of the Instrument Mounting Flange of the Cassegrain Rotator

iii. These datums are termed instrument interface hereafter

10.3.2 Telescope Tube Alignment Sequence (Telescope Contractor to propose at FDR)

The following alignment sequence is assumed in generating the subsystem tolerances. Other sequences can be adopted but where these impact the alignment tolerance build-up, this can only be by agreement with the VPO:

1. The Cassegrain Rotator is mounted to the rotator to mirror cell interface.
2. The axial and lateral mirror supports are aligned radially with respect to the rotator to mirror cell interface axis.
3. The dummy primary mirror is fitted and aligned with respect to the instrument interface.
4. The mirror supports are aligned axially to the dummy mirror interfaces.
5. The mirror cell is mounted on the telescope centre section.
6. The vanes are mounted to the dummy M2 unit and mounted on the top end ring.
7. The trusses complete with the top end ring are mounted to the centre section.
8. The vanes are adjusted to align the dummy M2 to the instrument interface.
9. Subsequent to alignment adjustments and testing of the system, the M1 Mirror, M2 Unit and M2 Assembly are fitted.
10. Final alignment of the M1 with respect to the instrument interface is completed.
11. The test camera is fitted to the instrument interface and aligned to the Cassegrain axis of rotation.

10.3.3 Cassegrain Rotator Alignment to M1 Cell

The interface between the Cassegrain Rotator and the M1 Cell is considered fixed on final assembly. This interface defines the whole alignment reference system and should the rotator require dismounting the alignment sequence will require checking and if necessary adjustment.

The interface of the Cassegrain Rotator to the M1 Cell shall have factory installation adjustment capabilities to compensate for all manufacturing tolerances to achieve the alignment tolerances specified in Table 9:

Table 9: Cassegrain Rotator to M1 Cell Alignment Requirements

Cass Rotator to M1 Cell	Initial Alignment	Repeatability of Installation
Axial	±0.5 mm	±0.1 mm
Radial	±0.5 mm	±0.1 mm
Tilt	±0.1 mrad	±0.05 mrad

10.3.4 M1 Mirror Supports to the Cassegrain Rotator

Other than the axial adjustment of the lateral supports and tangential definers, the M1 Mirror Support shall meet the alignment requirements of Table 10.

Table 10: M1 Mirror Supports to the Cassegrain Rotator

M1 Mirror Support to Cass Rotator	Initial Alignment	Repeatability of Installation
Axial	±0.5 mm	±50 µm
Radial	±0.2 mm	±50 µm

The axial alignment of the lateral supports and tangential definers shall be adjusted with respect to the M1 Primary mirror to meet the requirements of Table 11.

Table 11: M1 Mirror Lateral Support and Tangential Definer Axial Alignment

M1 Mirror Supports to M1 Mirror	Range of Adjustment	Initial Alignment	Repeatability
Axial	±3.0 mm	±0.1 mm	±50 µm

10.3.5 M1 Cell Alignment to Telescope Centre Section

The attachment point of the M1 Cell to the telescope centre-section shall have factory installation adjustment capabilities to compensate for all manufacturing tolerances to achieve the alignment tolerances specified in Table 12:

Table 12: M1 Cell to Centre Section Alignment Requirements

M1 Cell to Centre Section	Initial Alignment	Repeatability
Axial	±0.5 mm	±200 μm
Radial	±0.5 mm	±200 μm
Tilt	±0.1 mrad	± 50 μrad

10.3.6 M1 Alignment to the Cassegrain Rotator

The M1 alignment with respect to the Cassegrain Rotator is a critical systems performance alignment. This alignment is achieved by adjustment of the axial and lateral definers of the M1 support system. The requirements for this adjustment are defined in Table 13.

Table 13: M1 Mirror to Cassegrain Rotator Alignment Requirements

M1 Cell to Centre Section	Initial Alignment	Repeatability
Axial	±50 μm	±50 μm
Radial	±50 μm	±50 μm
Tilt	± 10 μrad	± 10 μrad

10.3.7 M2 Alignment with respect to the Top End Ring

The top-end ring shall have provision at the ends of the vanes to allow initial site installation alignment of the M2 System. The system provided shall have adjustment capabilities to compensate for all manufacturing tolerances plus the allowances below for positioning of the M2 System to achieve the alignment tolerances specified in Table 14.

Table 14: M2 Vanes Alignment with respect to the Top End Ring

Vanes to Top End Ring	Range of Adjustment	Initial Alignment	Repeatability
Axial	±3.0 mm	±1.0 mm	±0.5 mm
Radial	±3.0 mm	±1.0 mm	±0.5 mm
Tilt	±0.5 mrad	±0.1 mrad	±0.1 mrad

10.3.8 Telescope Truss Alignment to the Centre Section

While not a critical systems performance requirement, this is the interface that is split to allow removal of the M1 Mirror from the M1 Cell for coating. Repeatability of the alignment of this interface is therefore more stringent than the vanes or centre-section.

The alignment tolerances for the telescope truss are specified in Table 15.

Table 15: Telescope Truss Alignment to the Centre Section

M1 Cell to Centre Section	Initial Alignment	Repeatability
Axial	±1.0 mm	±0.1 mm
Radial	±1.0 mm	±0.1 mm
Tilt	±0.1 mrad	± 20 µrad

10.3.9 Cassegrain Rotator Interface to Cameras

The rotator shall have a mounting surface with features to ensure repeatable assembly of the cameras with the interface requirements defined in AD04 and AD25.

10.4 M1 Cell Sub-System Requirements

10.4.1 General Description

The M1 Cell Sub System supports the M1 and through the Cassegrain rotator also provides the mounting interface for the cameras. The M1 Cell Sub Systems consists of, but is not limited to the following:

a) M1 Cell which supports the axial and lateral M1 support system and definers. The Cassegrain rotator and cable wrap are mounted onto it. The M1 Cell is mounted onto the telescope centre section.

b) Axial and Lateral Definers which provide the position location for the M1 relative to the M1 Cell

c) Axial and lateral support of the M1 Mirror using axial and lateral supports which provide the reaction forces necessary to maintain the M1 Mirror in position against gravity, wind loads and force errors arising from the supports themselves.

d) The Cassegrain rotator onto which the operational camera is mounted and the cable wrap for the required camera services.

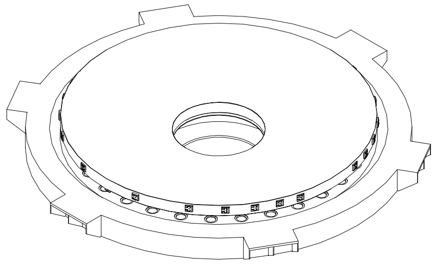

Figure 4 M1 Cell Sub-System (for information only)

10.4.2 M1 Cell Requirements

a) The M1 Cell and support system shall meet the stability and alignment requirements defined in Sections 10.2 and 10.3.

b) The M1 Mirror shall be supported by means of a distributed axial and lateral support system.

c) The interface between the supports and the M1 mirror is detailed in AD02.

d) The axial support system shall comprise active axial supports in contact with pads on the base of the mirror. There are 84 supports arranged in four rings, with 120 degrees symmetry. 81 supports are astatic force actuators as defined in Section 10.4.4. Three supports shall be position definers providing location in the X rotation, Y rotation and Z translation directions as defined in Section 10.4.3.

e) By changing the force pattern applied to the mirror by the axial supports it shall be possible to modify the mirror figure. The support forces shall be servo controlled. A load cell shall be used to measure the force applied by each axial support.

f) The system shall be addressed from the M1 Cell LCU as described in Section 11.2.

g) The lateral supports shall produce a system of forces whose distribution approximates to the Schwesinger solution (RD03). There shall be 24 nominally equally loaded lateral supports acting on M1 circumference. The supports shall be astatic force actuators as defined in Section 10.4.6.

h) Three lateral definers, tangential to the M1 Mirror circumference, shall provide location in the X translation, Y translation and Z rotation directions as defined in Section 10.4.5.

i) The mirror shall be protected against earthquakes by safety devices ensuring that the mirror stresses will be always lower than the limit specified in Section 14.1.2.

j) There shall be provision for safe and convenient access to the primary mirror supports, electrical and mechanical services, electronic controls and any other maintainable equipment mounted on or in the cell with the M1 in place and M1 cell attached to the Centre section.

k) The M1 Cell shall have provision for attaching telescope balancing weights.

10.4.3 Axial Definer Requirements

The Axial Definer System shall meet the following requirements after initial alignment of the support system as defined in Section 10.3.4.

a) Three position definers shall be arranged in accordance with the dimensions and tolerances specified in ICD drawing AD22.

b) Range of Adjustment — +/-3 mm

c) Adjustment Step Size — ≤25 µm

d) If the axial definer mechanisms are not accessible for manual adjustment from external to the M1 Cell then provision must be made for remote adjustment.

e) Each axial definer shall incorporate a load cell.

f) Accuracy of force measurement — ≤ ± 2.0 N [1]

g) Range over which accuracy of force measurement required — 5 to 900 N

h) Each axial definer shall be equipped with force limiting devices to prevent over-stressing the mirror.

i) Limiting force of each axial definer — 1700 N

j) Minimum stiffness of each axial definer (wrt altitude axis) — $\geq 30\text{x}10^6$ N/m

10.4.4 Axial Support Requirements

a) Each active support shall incorporate a load cell and the force generated shall be controlled in an individual closed loop.

b) 81 force actuators shall be arranged in accordance with the dimensions and tolerances specified in ICD drawing AD02.

c) The position of the supports will be optimised by the VPO following metrology of the M1 blank to minimise the surface errors generated by the axial support loads. This may result in minor changes to the dimensions specified in AD22. Such changes shall not result in structural modifications to the M1 Cell. The VPO will inform the Contractor of any such changes prior to the Preliminary Design Review.

d) The force actuators used in the conceptual design were "frictionless" pneumatic cylinders using rolling element diaphragm seals (Bellofram™ [2]). The requirements in this section relating to the force actuators were defined based on the components used within the conceptual design. If an alternative proposal for the force support system is made then the requirements of this section shall form the basis of the proposal.

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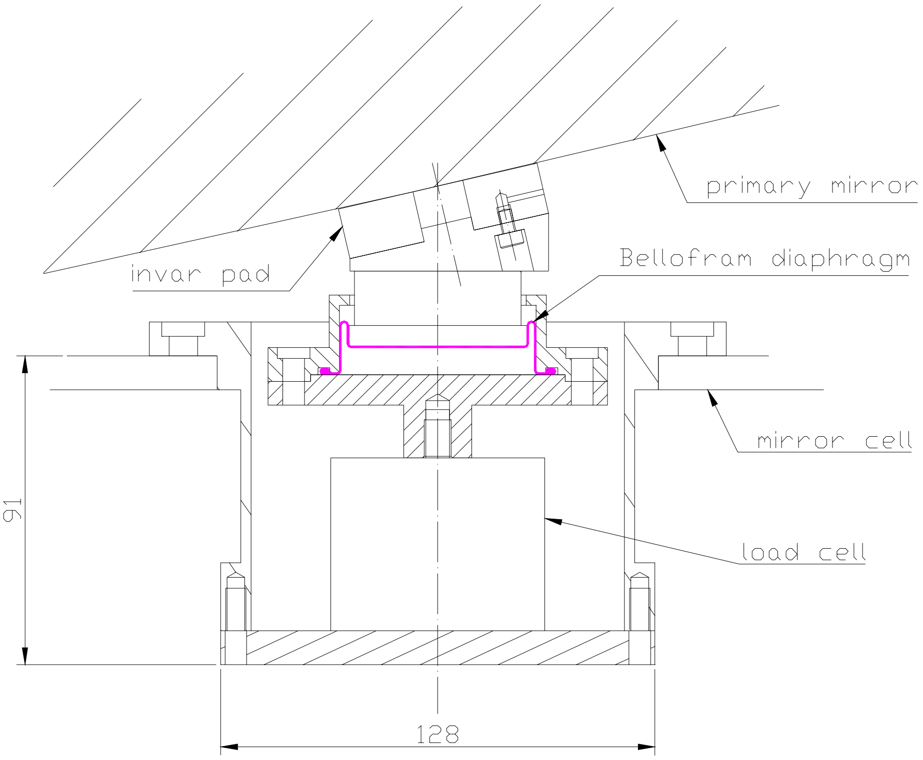
[1] Requirement dependent upon customer specified equipment

[2] Bellofram is a trademark of Marsh Bellofram Corporation



e) Range of Travel ≥ ± 2.0 mm

f) Actuator Force Range 5 to 900 N

g) Absolute accuracy, individual support ≤ ± 2.0 N maximum error

h) RMS error of all supports and definers at any instant < 0.6 N r.m.s.

i) Load Cell Resolution ≤ 0.5 N

j) Closed loop force control demand bandwidth (-3dB) ≥ 3 Hz

k) Update rate for demanded forces Fi ≤ 20 ms

l) Non-repeatable lateral force at piston ≤ 0.35 N rms

m) Repeatable lateral force at piston ≤ 4.5 N rms

10.4.5 Lateral Definer Requirements

The Lateral Definer System shall meet the following requirements after initial alignment of the support system as defined in Section 10.3.4.

a) Three lateral definers shall provide location in the X translation, Y translation and Z rotation directions only.

b) Each lateral definer shall incorporate a load cell. The measured forces shall be used to control the lateral supports in a closed loop to balance gravity, wind and axial supports residuals in the Y-translation and Z-rotation directions. X-direction residual force shall be reacted solely by the definers.

c) Each lateral definer shall incorporate a safety device to limit the load that it can apply to the mirror.

d) The linkage of each lateral definer shall incorporate manual length adjustment for alignment of the primary mirror.

e) If the lateral definer mechanisms are not accessible for manual adjustment from external to the M1 Cell then provision must be made for remote adjustment.

f)	Range in the lateral plane	+/-1 mm	
g)	Resolution of Adjustment	≤ 0.020 mm	
h)	Total stiffness in Y direction	≥ $1.2\text{x}10^{8}$ N/m	
i)	Accuracy of force measurement	≤ ± 10.0 N	
j)	Range over which accuracy of force measurement required	- 100N to +100N	
k)	Maximum force limiter setting per definer	5000 N	
l)	Max frictional torque in linkage	Non-repeatable	≤ 0.15 Nm
		Repeatable	≤ 1.5 Nm

10.4.6 Lateral Supports Requirements

a) There shall be 24 force actuators, providing lateral support, arranged in accordance with the dimensions and tolerances in AD02.

b) The position of the supports will be optimised by the VPO following metrology of the M1 blank to minimise the surface errors generated by the lateral support loads. This may result in minor changes to the dimensions specified in AD22. Such changes shall not result in structural modifications to the M1 Cell. The VPO will inform the Contractor of any such changes prior to the Preliminary Design Review.

c) The force actuators used in the conceptual design were “frictionless” pneumatic cylinders using rolling element diaphragm seals (Bellofram™ [1]). The requirements in this section relating to the force actuators were defined based on the components used within the conceptual design. If an alternative proposal for the force support system is proposed then the requirements of this section shall be applied.

d) The force demands on the mirror shall be 12 push only below and 12 pull only above the M1 mirror.

[1] Bellofram is a trademark of Marsh Bellofram Corporation

e) For control purposes the force actuators shall be divided into 2 sectors, one on the lower left and upper right side and one on the lower right and upper left side of the mirror viewed along the positive z axis as shown in Figure 5.

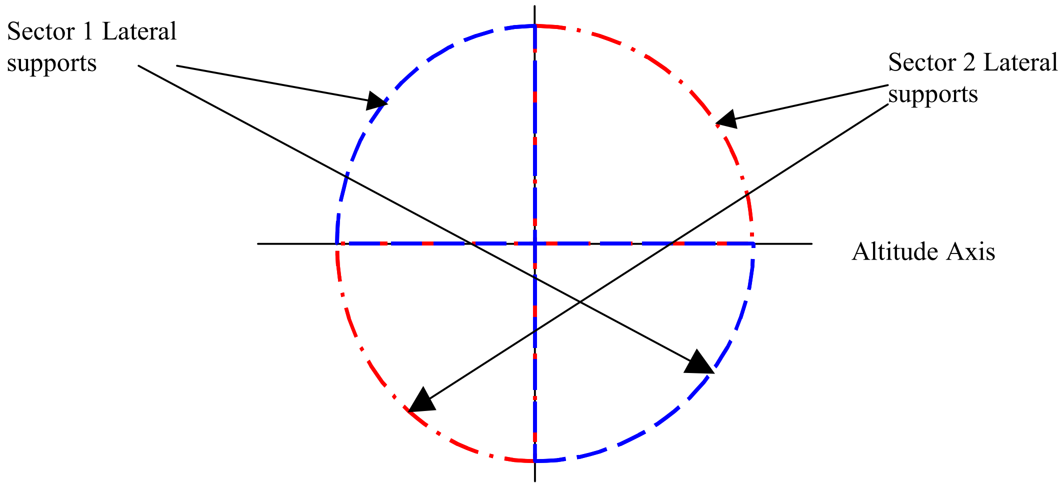


Figure 5 Lateral Support Sectors

f) The linkage in the supports shall use low-friction rolling element bearings in the pivots.

g) The linkage of each force actuator shall incorporate manual length adjustment to set the pneumatic piston at mid-travel following alignment of the primary mirror.

h) The supports shall ensure easy disconnection for mirror removal and repeatable assembly without re-adjustment.

i) The supports shall stow safely following disconnection to prevent accidental damage during removal and replacement of the primary mirror.

j)	Force range		10 to 2700 N
k)	Absolute accuracy, individual support		+/-10 N maximum
l)	Absolute accuracy, all supports and definers at any instant		≤ 3.0 N r.m.s.
m)	Resolution		≤ 1.5 N
n)	Max frictional torque from linkage at mirror periphery	Non-repeatable	≤ 0.15 Nm
		Repeatable	≤ 1.5 Nm
o)	Closed loop bandwidth (-3dB)		> 1 Hz

10.4.7 Earthquake and Maintenance Restraints

a) Earthquake restraints shall limit the movement of the primary mirror axially and laterally.

b) The stresses induced by the earthquake and maintenance restraints shall not exceed the values specified in section 14.1.2.

c) Resilient rest pads, which may form part of the earthquake restraint system, shall be provided to support the mirror axially when the air supply is disconnected for any reason.

d) Resilient rest pads, which may form part of the earthquake restraint system, shall be provided to support the mirror laterally off zenith when the air supply is disconnected for any reason.

e) To secure the primary mirror axially outside the operational altitude axis range (i.e. in the maintenance range beyond sky coverage) clamps shall be applied to hold the mirror against the rest pads. These pads shall be pneumatic actuated and designed to clamp the mirror in the failsafe condition.

f) Conceptual design for earthquake restraint is shown in AD66.

10.4.8 M1 Cell Thermal Requirements

10.4.8.1 Cooling of Heat Sources

a) See section 6.4.

10.4.8.2 Thermal Conditioning of Primary Mirror

a) The primary mirror temperature will be regulated by means of the air conditioning system in the enclosure.

b) The design of the telescope (telescope structure and M1 Cell) shall accommodate openings for flushing the primary mirror in operation:

- Area of ventilation apertures through the mirror cell > 3 m^2
- Area of ventilation aperture between the top of the mirror and a level 1m above > 2m^2

c) The outer diameter of the mirror shall be exposed for ventilation except where absolutely necessary for the lateral supports, earthquake restraints, etc.

10.5 Cassegrain Rotator

The Cassegrain rotator is the interface between the Camera and the telescope. It provides the following functions:

- Camera mounting
- cable wrap providing camera services

- field de-rotation

10.5.1 Cassegrain Rotator Bearing

The Cassegrain rotator shall be provided with a rolling element bearing. The rotator shall be designed in conjunction with the mirror cell to ensure that bearing performance is:

- Axial run out ≤ 0.02mm
- Radial run out ≤ 0.02mm
- Maximum friction torque ≤250 Nm

Rolling element bearings shall be sealed to prevent ingress of dirt.

10.5.2 Cassegrain Rotator Tracking Requirements

Cassegrain Rotator Range	Total	Non-Repeat
Any 45 deg	N/A	6 μrads
Up to 360 deg	150 μrads	45 μrads

Table 16 Cassegrain Rotator Tracking Requirements

10.5.3 Cassegrain Rotator Cable Wrap

a) The Cassegrain cable wrap shall be mounted below the M1 Cell and shall carry services from the M1 Cell to the IR and Visible Camera.

b) The angular position of the cable wrap shall be slaved to the rotator to minimise loading on the Cassegrain rotator drive:

c) The cable wrap shall be equipped with a dedicated drive system and shall be synchronised with the rotator azimuth axis. The effect of the residual torque experienced by the Azimuth Drive shall be included in the pointing and tracking budgets and measures.

d) The cable wrap shall exceed the rotator angular range of travel (see section 11.1.8.1) by a margin of 5° beyond the end-stops.

e) The wrap shall be interlocked to the main Rotator Drive to prevent damage to the cable wrap from differential motion or drive failure.

f) Cables and services shall be as specified in ICDs AD04 and AD07.

g) Services provision to IR Camera will be from a SCP (free issue to Contractor from VPO) mounted on the cassegrain cable wrap inner ring as detailed in AD07.

h) The cable wrap shall be designed to allow access to the cell for maintenance; should removal of the cable wrap be necessary to access any LRU (see section Maintenance Approach 13.3.1) within the cell then the cable wrap shall be designed for rapid removal and replacement.

10.6 Vanes

The general requirements for the vanes are as follows:

a) The M2 System shall be supported on vanes. Their attachment points shall be coincident with the location of the vertex of the telescope tube Serrurier trusses (see AD23).

b) The interface features with M2 System are defined in AD03.

c) Two vanes will have channels for cables and coolant as defined in AD03.

d) Thickness of the vanes in the optical path is defined in AD03.

e) The combined stiffness of the vanes and M2 System in the telescope tube axial direction shall be greater than 1.3×10^8 N/m.

10.7 M1 Mirror Removal (Telescope Contractor to Propose at FDR)

The Contractor will be responsible for developing the M1 Mirror removal sequence from the Mirror Cell for coating. The following M1 Mirror removal sequence is assumed in generating the subsystem tolerances. Other sequences can be adopted by agreement with the VPO. The removal sequence has specific handling equipment associated with it, some items being Contractor supply. In the event the Contractor proposes alternative handling scenarios, any additional handling equipment shall be provided.

The sequence is:

a) The telescope tube is horizon pointed.

b) The M2 Assembly and the Camera are removed. (Handling equipment **is not** part of this Contract)

c) The dummy M2 Assembly and instrument mass are substituted.

d) The telescope is zenith pointed.

e) The systems above the centre section are removed in one operation (see AD24). (Handling equipment **is** part of this Contract)

f) The M1 Lateral Supports and Radial Definers are disconnected from the M1 Mirror.

g) The M1 mirror is extracted through the centre section as shown in AD24. (Handling equipment **is not** part of this Contract)

11 Mechanism Control

11.1 Altitude, Azimuth and Cassegrain Rotator Axis Control

Unless otherwise stated the requirements for axis control apply to the Azimuth, Altitude and Cassegrain Rotator drive axes.

11.1.1 Axis Control

The altitude, azimuth and rotator axes shall be controlled from separate LCU's. ***Neither the LCU software nor the LCU hardware is part of this contract.***

The electrical interfaces from the LCU's to the hardware are defined in AD01. Although the LCU's will not be connected to the hardware until after Preliminary Acceptance, as defined in AD40, provision shall be made for mounting and interfacing them.

11.1.2 Software/Hardware Interface

The interface between VISTA hardware and the Axis Control System shall be defined at the level of hardware signals delivered by VME interfaces in the LCU, see AD01.

11.1.3 Control Algorithms

It is required for ease of subsequent integration with LCU software (not in contract) that the control algorithms far all axes shall use PI-type position loops and velocity feed-forward if needed.

Additional notch filtering and low-pass elements may also be used for resonance and noise filtering as required.

11.1.4 Motors

11.1.4.1 Requirements

a) The motors shall be equipped with sensors (Hall effect or equivalent) independent from the on axis position encoder to provide the motor position signal for commutation.

b) The motors shall be capable of providing twice the continuous torque necessary to drive the rotator under the worst-case operational conditions.

11.1.4.2 Continuous Torque

The motors shall provide a low-ripple torque sufficient to enable the telescope pointing and tracking requirements under all normal conditions.

11.1.5 Power Amplifiers

The motor power amplifiers shall have sufficient bandwidth to enable the telescope pointing and tracking performance using the position and velocity bandwidths provided by the vendor for section 8.6.2.

11.1.6 Position Measurement

a) Position information shall be derived from precision encoder tapes or integrated encoder sub-assemblies, using vendor-supplied calibration software to increase resolution and reduce systematic errors.

b) The measurement accuracy of the encoders shall be sufficient for the system to meet the position accuracy of the telescope (pointing and tracking requirements).

In addition to (b) above

c) Requirement removed as is covered by 11.1.6 b) above..

d) Resolution of the Altitude and Azimuth encoders shall be < 0.01 arcsec.

e) Resolution of the Rotator encoder shall be < 0.015 arcsec

f) Encoder read-out delay shall be less than 1 ms.

g) Multiple read heads shall be incorporated into Azimuth, Altitude and Cassegrain rotator axis to take into account short term or random translation errors.

11.1.7 Velocity Measurement

a) The velocity signal closing the axis loop in the LCU may be obtained by digital differentiation of the position measurement data.

b) A hardware based measurement of velocity shall also be implemented. This shall be used for system start-up and over-speed sensing for safety purposes. It shall not depend on any software operation. A system using frequency measurement or timing of the encoder outputs is suggested. The error in this velocity signal shall be <10% of maximum speed.

c) Detection of overspeed shall cause the brakes to be applied.

11.1.8 Altitude, Azimuth and Cassegrain Rotator Angular Range

Unless otherwise stated the requirements for axis control apply to the Azimuth, Altitude and Cassegrain Rotator drive axes.

11.1.8.1 Altitude, Azimuth and Cassegrain Rotator Limits

Each axis shall be equipped at both ends with a set of limit switches and end-stops. The axis limits are specified in Table 17.

Operational limits. Operational limits are software protections that are programmed in the LCU controlling the axis. They shall decelerate the telescope to a complete stop within the maintenance range. It shall be possible to drive the telescope out of a software limit under TCS control or drive at a reduced speed to the software limit in maintenance mode (see section 11.1.8.2.)

Software Limits:

a. Switch - LCU Software switch on position signal
b. Action - LCU software commanded motor deceleration to complete stop.
c. Reset – LCU software command out of software limit towards operational limit.

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Vicinity Limits:

a. Switch - Mechanical cam actuated.
b. Action –
    i. Axis motors remain active and axis automatically backs-out of the limit condition.
    ii. Fault reported to the LCU through contacts open.
c. Reset – Done automatically

Pre-Interlock Limits:

a. Switch - Mechanical cam actuated.
b. Action –
    i. Axis Brakes applied - axis deceleration under brake torque to complete stop.
    ii. Axis motors are disabled (remove motor enables[1]).
    iii. Fault reported to the LCU-through contacts open.
c. Reset – backing out of the limit has to be done from the Limit Override momentary switch (inside the appropriate Power Drive Unit) by continuously depressing the switch until the limit clears.

Interlock Limits:

a. Switch
    i. Altitude axis – Mechanical lever arm actuated switch
    ii. Azimuth & Cass axis – Lanyard Switch.

[1] When the motor (controller) enables are removed, the high-current motor armature signals to the motors are removed and the brakes are set. The motor controllers are still supplied with utility power but the motor controller's output voltage to the motors is zero.

b. Action -
   i. Switch toggles a Shunt Trip Circuit Breaker connecting Mains Power to the axis motor controllers.
   ii. Failsafe brakes are set on removal of power – axis deceleration under brake torque to complete stop.
   iii. Fault is reported to the LCU-fed contacts open.
c. Reset - Recovery of the limit can only be done by manually (physically) moving the structure and clearing the Interlock Limit.

Altitude Axis only -Buffer placed beyond interlock limit in case of out of balance incident. This is not applicable for azimuth and cassegrain as structural interference not possible.

The *maximum safe speed* is defined as 2 times the maximum velocity, as defined in Table 4, Section 8.3.

Safe alternatives to mechanical end stops may be suggested by the vendor and used at the discretion of the VPO. Justification for the manner of implementation of these limits shall be clearly laid out in the Safety Case Document as required in AD40.

The *maintenance region velocity* is defined in Section 11.1.8.2.

Table 17: Axis Limits

Limit	Azimuth	Altitude	Rotator
Operational limit	+135° , -315°	20° , +88°	+180° , -360°
Software Limit [1]	+136° , -316°	0° , +90°	+184° , -364°
Vicinity Limit [2]	+140° , -320°	-1° , +91°	+188° , -368°
Pre-Interlock Limit	+141° , -321°	-2° , +92°	+189° , -369°
Interlock Limit	+142° , -322°	-3° , +93°	+190° , -370°
Altitude Buffer	n/a	-5.8° , +96.8°	n/a

[1] Software Limit positions are provided for information as LCU's are not part of this contract.
[2] Limit positions beyond software limit must be consistent with the system deceleration properties.

11.1.8.2 Maintenance Conditions

In maintenance mode it shall be possible to drive the Altitude Axis out with the operating limits under local engineering control at a reduced velocity of 0.5°/s (maintenance region velocity). The drive amplifiers shall be hardware velocity limited within this range.

In maintenance mode it shall be possible to drive all axes to the interlock limits under local engineering control at a reduced slew rate to verify the correct functioning of the interlock system.

11.1.9 Axis Lockout

1. Pins shall be provided which will prevent rotation about the azimuth, altitude and rotator axes caused by motor torque, unbalance due to disassembly or MLE external loading.
2. Use of a locking pin shall disable the relevant axis drive.
3. The pins shall have provision to be tagged out i.e. an engineer can lockout the pin preventing unauthorised removal.
4. Locking pin positions specified in Table 18 shall be used for orientation of the telescope for mirror and camera handling operations.
5. Accuracy of position 0.05 deg.

Table 18: Lockout Positions

Drive	**Lockout #1**	**Lockout #2**	**Further Lockouts**
Azimuth	+0°	+45°	-180°
Altitude	+0°	+90°	+20°
Rotator	+0°	+180°	90° and 270°

11.1.10Brakes

Brakes shall be provided on all axes. Brakes shall be failsafe, in the engaged condition, in the event of power failure. The systems shall be equipped with status detection capability for interlock purposes. The systems shall be capable of preventing rotation about the axis when the telescope is not in use, stopping the rotation in emergency or when limit switches are actuated from the maximum safe speed. The brake systems shall have the capacity to resist the maximum motor torque combined with survival wind loading.

Angular deceleration during braking shall be within the range given in table Table 19 below.

Table 19: Braking deceleration range

Drive	Minimum	Maximum
Azimuth	4°/s^2	60°/s^2
Altitude	8°/s^2	60°/s^2
Rotator	16°/s^2	120°/s^2

Lower angular braking decelerations will be considered such that the telescope is capable of reaching a stand still prior to engaging the end stop limit. The justification for lower than specified braking deceleration shall be clearly laid out in the Safety Case Document as required in AD40.

11.1.11End Stops

End stops, where provided, shall be capable of stopping the rotation in emergency from the maximum safe speed. The end stops shall have the capacity to resist the maximum motor torque combined with survival wind loading.

The maximum allowable angular decelerations are given in table Table 20 below.

Table 20: End Stop deceleration

Drive	Maximum
Azimuth	60°/s^2
Altitude	60°/s^2
Rotator	120°/s^2

For alternatives to mechanical End Stops see section 11.1.8.1.

11.1.12Auxiliary Drives

An auxiliary drive system shall be provided on the altitude axis. This shall be a manual drive with suitable gearing to allow the telescope to be driven with an out of balance load of 1000 Nm with respect to the altitude axis. The auxiliary drive shall be interlocked to disable the main altitude drives and brake when used.

11.2 M1 Control

11.2.1 Context

The relationship between the systems described in this document and external systems is illustrated in Figure 3. This section specifies the M1 Control Hardware, which includes valves, load cells and controllers connected to one or more buses. The M1 Cell Control Hardware will be controlled by the M1 LCU (not in contract) itself controlled by the TCS (not in contract).

The M1 Cell control hardware is shown in more detail in Figure 6, which shows the axial support hardware. The M1 LCU shall receive information from each axial support at up to 50 Hz and will then generate a new force demand vector at the same rate. Devices connected to the bus(es), for each support shall close the loop between the measured force and the valve demand.

In the case of the lateral hardware, there is no local force control loop around each individual support and so the LCU will close loops using the lateral definer load cells as inputs and the valve demands as outputs. Note that the valves are assumed to have self-contained electronics and pressure sensors providing a local pressure control loop. Additional electronics may be required to send and receive data from the LCU.

The M1 Cell control hardware shall also control the 2 groups of 12 lateral supports. It shall read the corresponding 3 load cells of the lateral position definers.

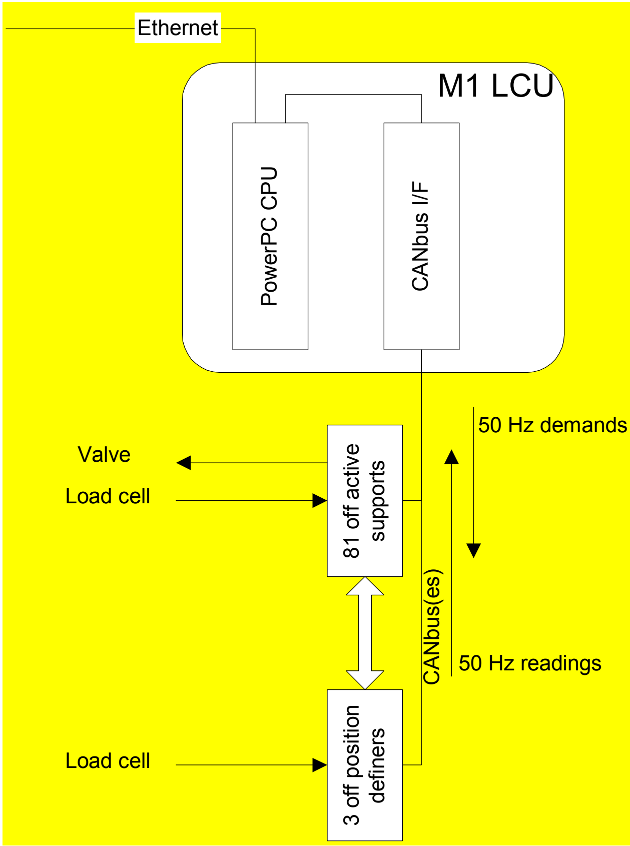

Figure 6 Control of the axial supports by the M1 LCU (not in contract).

11.2.2 General Requirements

a) The hardware listed in Section 11 shall be controlled or monitored by control hardware supplied by the Contractor. This hardware comprises the 81 active axial supports, the 3 axial position definers, the 2 groups of 12 lateral supports and the 3 lateral position definers. Note that the number of lateral valves required will depend on the specific tube lengths and cylinder volumes used and so this is left for the vendor to design, such that the required overall 1 Hz control bandwidth is obtained. The minimum number of valves shall be 2 and the maximum 24.

Table 21 Hardware controlled or monitored by the M1 LCU.

Device	No. off	Controlled
Axial support load cells (inc. 3 definers)	84	
Axial support valves	81	Yes
Lateral load cells (3 definers)	3	
Lateral valves	2-24 in 2 groups	Yes

b) The control hardware in a) shall be commanded and monitored by the M1 LCU (not in contract).

c) The control hardware shall be connected to the M1 LCU (not in contract) using an appropriate number of CANbuses and using the CANopen protocol. The specifications of the CANbuses, the CANbus devices and the CANopen protocol are defined in AD47.

d) The number of CANbuses shall be minimised, such that all the requirements of this specification shall be met, including but not limited to: response time, physical distances and EMC.

e) The control hardware should comprise analogue electronics or COTS controllers without any custom embedded software. If the control hardware includes embedded software, provision shall be made for maintaining and updating this software. Justification shall be made for using any embedded software and approval obtained from the VPO.

f) If equipment is not listed in AD47 or AD51, details and justification shall be submitted to the VPO for approval.

g) All signals generated and received shall be made available to the LCU for monitoring purposes.

h) The interface between the LCU and the hardware shall be defined in AD01.

i) Where times are specified below for the transmission of data, these times shall include the receipt of any commands from the LCU necessary to trigger the transmission of data, e.g. multiple data request telegrams or a single synchronisation telegram (the synchronisation method is preferred).

11.2.3 Axial Support Control Requirements

a) The control hardware shall be able to transmit to the M1 LCU all 84 axial load cell readings within 8 ms.

b) The control hardware shall be able to transmit to the M1 LCU all 81 valve settings within 1 s.

c) The control hardware shall be able to receive and act upon a new set of 81 axial force demands within 8 ms.

d) The control hardware shall close the force loop at each axial support, by reading the load cell and controlling the valve. The 3 dB bandwidth of this loop shall be ≥ 3Hz.

e) It shall be possible to reconfigure the control hardware so that, instead of responding to force demands, it shall respond to valve demands within the same time interval. (This reconfiguration is not required to be remotely controlled).

11.2.4 Lateral Support Control Requirements

a) The control hardware shall be able to transmit to the M1 LCU all 3 load cell readings within 30 ms.

b) The control hardware shall be able to transmit to the M1 LCU all measured valve settings within 1 s.

c) The control hardware shall be able to receive a new set of valve demands from the LCU and apply them to the pressure control valves in less than 30 ms from transmission of the demands by the LCU.

d) The transfer function between the demanded air pressure and the actual air pressure (for demand changes of less than 5% of full scale) in a lateral support group of 12 actuators shall have a -3dB frequency of > 2 Hz.

12 Service and Test Equipment

12.1 M1 Mirror Dummy

12.1.1 M1 Dummy Mirror Requirements

The *M1 Mirror dummy* is a representation of the M1 assembly, defined in Section 12.1.2. The dummy construction is at the discretion of the Contractor but shall have the following characteristics and interfaces:

a) AD22 provides the centre of gravity co-ordinates, mass and moments of inertia of the M1 mirror.

b) mass	(tolerance ±5 %)
c) moments of inertia	(tolerance ±5 %)
d) the centre of gravity	(tolerances ± 10 mm)
e) external diameter:	4.1 m
f) radius of curvature of the under-side:	8.25 m (tolerance ± 10 mm)

g) Lateral support and definer interfaces.

h) The real axial interfaces to the M1 mirror are realised by means of bonded pads and wedges. To be fully representative of this interface the dummy shall be fabricated with surfaces positioned as specified in ICD drawing AD22.

i) The M1 dummy shall have interfaces for handling as specified in AD02 M1 Mirror

j) Features in or adjacent to the bore to allow alignment fixtures to be installed with a repeatability of 0.05mm.

12.1.2 M1 Mirror Assembly

The M1 mirror assembly *(which is not part of this work package)* comprises:

a) the M1 mirror;

b) the bonded axial support Invar pads;

c) axial support pad wedges;

d) The bonded lateral support Invar pads.

e) Lateral definer pads

12.2 M2 System Dummy

12.2.1 Requirements

The *M2 System dummy* is a representation of the M2 System, defined in Section 12.2.2 in terms of mechanical interfaces, mass properties and stiffness with the following requirements:

a) The shape of the M2 System dummy shall be representative of the M2 Unit outer shell and the M2 Mirror Assembly.

b) mass (tolerance±5%)

c) centre of gravity (tolerance ±10 mm)

d) The interface with the telescope vanes shall conform to ICD drawing AD23.

e) ICD drawing AD23, centre of gravity co-ordinates, mass and moments of inertia of the M2 System.

f) ICD AD03 provides the stiffness of the M2 unit presented at the mechanical interface to the telescope structure.

12.2.2 M2 System

The M2 System comprises:

a) the M2 mirror and its cell;

b) the M2 mechanisms used to adjust the position of the M2 mirror;

c) A mechanical structure interfacing with the top-end vanes.

12.3 M2 Electronic Cabinet dummy

The *M2 Electronic Cabinet Dummy* is a component having the same mass and centre of gravity position as the real M2 Electronic Cabinet.

a) The shape of the M2 Electronic Cabinet Dummy is at the discretion of the contractor

b) mass (tolerance±5%)

c) centre of gravity (tolerance ± 50 mm)

12.4 Instrument Mass Dummy

12.4.1 Definition

The *Instrument Mass dummy* is a component fully representative of the heaviest instrument in terms of mechanical interfaces, mass properties and stiffness.

12.4.2 Requirements

a) The mechanical attachment to the rotator is to be in accordance with the Cassegrain Rotator to Instrument ICD drawing AD25.

b) ICD drawing AD25 specifies centre of gravity co-ordinates, mass and moments of inertia of the Instrument.

c) ICDs AD04 provides the maximum point loading by the instrument at the mechanical interface.

12.5 Specific Integration and Maintenance Tools

The contractor shall provide all Custom or Special tools not obtainable through normal purchasing practise but necessary to do the integration and the maintenance on site of the Vista Telescope structure.

12.6 M1 Mirror Removal Sequence

The M1 Mirror Removal Sequence is defined in Section 10.7.

12.7 Transport Containers

The contractor must provide all the containers necessary to transport all the Telescope Work Package sub-assemblies in safe condition to the site taking into account the transportation environment as defined in AD44.

13 Reliability Maintainability and Safety Requirements

13.1 Telescope Lifetime

VISTA shall be designed for a minimum lifetime of 25 years of operation at the level of performance prescribed by this specification, comprising an average 12 hours of observation and 12 hours of stand-by per day.

13.2 System Reliability

13.2.1 Overall Availability

The system shall be designed and manufactured in order to ensure that the total non-scheduled down time does not exceed 2 nights per year.

13.2.2 Specific Reliability Requirements

A Failure is defined as an event causing complete loss of observing capability and which cannot be recovered by corrective maintenance (including fault identification) in less than 4 hours.

The telescope including the M1 cell and support system shall be designed for a Mean Time Between Failures (MTBF) of 3 years.

As a general rule, a high reliability shall be enforced in the design and manufacturing process by appropriate methodology and review.

13.3 Maintainability Guidelines and Requirements

13.3.1 Maintenance Approach

ESO will operate VISTA and perform the on-site maintenance. Therefore the maintenance philosophy to be considered during the design of VISTA is the one established by ESO at the Cerro Paranal Observatory. The major elements of this philosophy are as follows:

The maintenance work load and therefore manpower at the Chilean site shall be minimised and shall be limited as far as possible to preventive maintenance tasks.

Maintenance work shall be performed at system level and by exchange of module (Line Replaceable Units, LRU's) when practical.

1. LRU's are defined as units which can easily (i.e. without extensive calibration, etc) be exchanged by maintenance staff of technician level, and that can be easily shipped to a suitable ESO repair location, or to an industrial supplier for repair.

2. This concept implies that spare LRUs must be available at the observatory.

3. Standardisation of equipment, fully applicable to VISTA is given in applicable documents AD46 and AD51, covering Service Connection Points and Electronic components. As a general design guideline the VISTA telescope structure design should make use of standard equipment already selected by ESO for the VLT.

Three different category of maintenance shall be considered:

1. Predictive Maintenance

2. Preventive Maintenance

3. Overhaul

13.3.1.1 Predictive Maintenance

Predictive maintenance is "condition driven" preventative maintenance. Instead of reliance on life-time statistics, predictive maintenance uses direct monitoring of off the system performance or condition. Typical examples are testing of gearbox oil for bearing deterioration or monitoring of drive currents for change in loading characteristics. The Contractor shall define the predictive maintenance tasks applicable to this work package.

13.3.1.2 Preventive Maintenance

Preventive maintenance actions shall be planned with a frequency of:

a) Every month for inspections and relatively simple actions of less than 4 hours in total;

b) Multiple of 6 months for other actions with a maximum of 12 hours every 6 months.

The preventive maintenance tasks shall be accomplished by two trained technicians with a minimum of special equipment or tools. The Contractor shall define the preventive maintenance tasks applicable to his work package.

13.3.1.3 Overhaul

Overhaul is defined as special preventive maintenance operation during which the equipment is not operational and observing time is lost. Overhaul involves removal of the equipment from the telescope and partial or total disassembly. Limited overhauls for VISTA lasting up to 48 hours can be undertaken during the periodical re-coating of the primary mirror, provided they do not impact the coating process.

Overhauls which would require the loss of more than 3 observing nights shall not take place more often than every 3 years. The Contractor shall define the overhaul tasks applicable to his work package.

13.3.1.4 On-Site Repair/Corrective maintenance

On site repair is normally limited to the in-situ exchange of line-replaceable units (LRUs). The faulty LRU will be sent to the ESO repair location or to an industrial supplier for repair.

As a general rule, an LRU replacement or other repair activity shall be accomplished by a maximum of two trained technicians with a minimum of special equipment or tools in a maximum time of 4 hours. Exceptions to this rule will be by agreement with ESO. The Contractor shall define a list of spare parts and propose this list to the VPO. The spare parts will be the subject of a specific contract.

Provision shall be made for the removal and replacement of the azimuth bearing as an LRU without the dismantling of the Telescope upper structure.

13.4 Safety

The safety of the VISTA Project is of paramount importance and therefore should be given appropriate attention during all phases of the contract. The requirements with respect to Safety for the VISTA Project are contained in AD80. The following list is simply to be intended as a reminder of such requirements and not a waiver to AD80.

All commercially available equipment to be used shall bear a CE mark stating compliance with the applicable European Directives. Equipment shall comply with its IEC product or product-family standard as required by section 4.2.1.1 of AD51.

13.4.1 Hazard Risk Acceptance Criteria

The Contractor shall perform a hazard analysis in accordance with that required in AD80.

13.4.2 General Safety Requirements

The general principles of safety design of technical products defined in AD83 and AD84 shall be applied.

13.4.3 Earthquake Hazard

For the purpose of hazard evaluation the OBE and MLE shall be classified as Hazard Probability Levels B and C respectively as defined in AD80.

13.4.4 Mechanical Safety

A minimum safety margin of 1.5 with respect to sigma 0.2% has to be used in the design of all those mechanical components, which in case of a failure lead to an Unacceptable or Undesirable hazard risk.

Transport, lifting, hoisting devices and similar equipment shall be approved by an officially recognised independent verification agency.

13.4.5 Protection against electric shock and other hazards

13.4.5.1 Introduction

The low-voltage electrical installations of the VLT Observatory are designed and erected according to AD86 (IEC 60364 Electrical Installation of Buildings); their system earthing is TN-S.

13.4.5.2 Safety Compliance

In order to achieve protection against electric shocks and other hazards, the parts belonging to the Contractor supply shall be designed and erected in compliance with the applicable documents AD84 (EN 60204-1), AD85 (IEC 61140) and AD86 (IEC 60364)

13.4.5.3 Electrical and Electronic Equipment

Electrical and electronic equipment to be installed onto VISTA shall comply with AD86, taking into account the VLT Observatory altitude.

Information Technology Equipment to be integrated into VISTA shall comply with AD87 (IEC 60950)

13.4.5.4 Bond Corrosion

In order to prevent bond corrosion, pairing of dissimilar metals shall be avoided where possible. Should joints between dissimilar metals be essential, the metals in direct contact shall exhibit the lowest possible combined electrochemical potential (in any case below 0.6 V) and the anodic member of the pair shall be the larger in size of the two.

13.4.6 Hydraulic Safety

Any hydraulic systems shall be designed in accordance with AD90.

13.4.7 Pneumatic Safety

Any compressed air piping, including connections of compressed air system shall be designed in accordance with AD83.

13.4.8 Cooling System Safety

Cooling systems shall be designed in accordance with AD83.

13.4.9 Software Safety

Any computer software failure or failures shall not lead to an unacceptable or undesirable hazard risk.

13.4.10 Handling, Transport and Storage Safety

The design of telescope work package shall incorporate all means necessary to preclude or minimise hazards to personnel and equipment during assembly, disassembly, test, transport, transport on site and short/long term storage of VISTA and/or parts thereof.

13.4.11 Operational Safety

None of the following cases shall lead to an unacceptable or undesirable hazard risk

- One or two independent hardware failures
- Partial or complete loss of energy supplied to the VISTA or subsystems of it
- Emergency braking of the telescope tube
- OBE or MLE earthquakes
- Wind loads.

13.4.12 Safety Interlock System

Interlocks shall be implemented wherever necessary to prevent a dangerous situation or to respond to a dangerous situation. Dangerous situations include hazards both to personnel and to equipment.

a) The number and position of interlocks within the scope of the Telescope Work Package shall be defined during the design phase in accordance with AD51.

b) It will be necessary to externally activate interlocks within the scope of the Telescope Work Package to prevent dangerous interaction between components from different work packages. An example of this would be interlocking the Telescope Structure with the enclosure crane such that the telescope cannot be operated unless the enclosure crane is in its parked position. These interfaces will be confirmed at T/0 + 2 months.

c) It will also be necessary to interlock the Telescope in its parked position with the enclosure opening operation. To facilitate this, the Telescope contractor shall provide hardware dependent signaling of the Telescope in its parked position.

14 General Requirements for Design and Construction

14.1 Requirements for Analyses

14.1.1 Structural Analyses: General

All Finite Element analyses necessary for the verification of the design and the performance of the Telescope Work Package shall be performed with a numerical code agreed with the VPO. The structural model shall be sufficiently detailed to provide an accurate description of the quantities under study (stiffness, displacements, stress and frequencies, etc.).
The analysis error due to mesh density shall be ≤ 10%.

14.1.1.1 Modal Analysis

Modal analysis shall be performed in order to obtain accurate information concerning the eigenfrequencies and the eigenmodes of the various subsystems, as required. The number of degrees of freedom shall be such as to have a good representation of the frequency range required. Boundary conditions must be correctly represented.

Structural damping factor to be considered is 0.75%.

14.1.1.2 Wind Loading Dynamic Response

The telescope shall operate to specification with ambient wind conditions represented by the following Von Karman spectrum:

> S(f) = 4*sigma^2*(L/U) / [1 + 70.8*(f*L/U)^2]^(5/6)
> Where
> S(f) = wind spectral density (m/s)^2/Hz
> sigma = rms wind velocity = 2.0 m/s rms
> U = mean wind velocity = 9.0 m/s
> L = scale of turbulence = 0.6 m
> f = frequency in Hz"

FE Post processing of the modal analysis results (random vibration analysis) shall be performed at the internal operational wind speeds together with the above wind power spectra.

The results shall be used together with control systems simulations to verify that the tracking and pointing requirements will be met. Alternatively the mass normalised eigenmodes from the FE analysis may be used as states in the control system simulation.

14.1.1.3 Gravity Load Analysis

The effect of gravity shall be taken into account by means of FE analysis.

14.1.1.4 Wind Stress Analysis

Dynamic and static wind stress analyses shall be performed.

The effect of the wind to be expected during operational conditions or survival conditions shall be verified by means of a finite element analysis.

The wind load application method shall follow the methods of applicable document AD82.

14.1.1.5 Seismic Analysis

<u>General</u>

The seismic analyses shall be based on the modal response spectrum technique. The design response spectra for OBE and MLE are given in AD44. The applicable percentage of critical damping to be used is:

- 1 % for OBE for the telescope and its subsystems (Page 31 of AD44)
- 1 % for MLE for the telescope and its subsystems (Page 25 of AD44)
- 3 % for OBE for the buildings, pier and enclosure (Page 33 of AD44)
- 5 % for MLE for the buildings, pier and enclosure (Page 33 of AD44)

For the verification of specific scenarios, where the equipment is in a configuration which is used only occasionally (for example M1 mirror in coating plant), a reduced Response Spectrum may be used (MLE_{LR}). In particular this is covered by the curve of AD44

- MLE_{LR}: Mirror Maintenance 1%, q=1.0, B1 (Page 45 of AD44)

The model used and the number of dynamic degrees of freedom shall be such that an accurate modal response is obtained up to a frequency of 35 Hz. The model shall include the foundations and the interface to the ground.

The Square Root Sum of the Square method (SRSS) shall be used in order to combine the contribution of the various modes. The three spatial components of the response shall be combined according to the provisions of Chapter 6 of the Eurocode 8, Part 1.

14.1.2 Stress Verification Criteria and Limits

The design of the telescope structure shall be such that

a) under any circumstances, condition or process, the *maximum principal tensile stress* in the M1 and M2 substrates do not exceed:
   - 5 MPa under any circumstances
   - 3 MPa for any period > 24 hours

b) The stresses and loads are within the limits permitted by the Applicable Documents and any regulations in force at the contractor's premises and at the telescope site. In the absence of any such requirements in the case of metallic parts the maximum allowable stresses shall be:

Case	Criteria	Limit & Safety Factor
Operational Loading	Mechanical Stress in Mechanism	Manufacturers recommendation or Fatigue limit/2 (See Footnote1)
	Mechanical Stress	Fatigue limit/1.5
Short Term Accidental Loading	Mechanical stress in mechanisms	Manufacturers recommendation or Fatigue limit/1.2 (See Footnote)
	Mechanical stresses	0.2% Proof Stress/1.5 (metallic parts)
Survival Loading	Mechanical Stress	0.2% Proof Stress/1.2, Ultimate Tensile Stress/1.5 (metallic parts)

1 Manufacturers Recommendations have precedence

14.1.3 Load Combinations

The load combinations for verification of stresses, displacement and the performances under the specified conditions, shall take into account the sum of the relevant individual load cases applicable to the subsystem or part under examination. It is the Contractors responsibility to define the plausible worst case combinations. The Load combinations shall include but are not limited to the following:

<u>Operational Loading (Optical Performance)</u>

a) Gravity(+88^{o} Altitude) + Differential Thermal Expansion(Operational) + Wind (Operational) +Telescope Dynamic Loads(Operational)

b) Gravity(+20^{o} Altitude) + Differential Thermal Expansion(Operational) + Wind (Operational) +Telescope Dynamic Loads(Operational)

c) Gravity(+50^{o} Altitude) + Differential Thermal Expansion(Operational) + Wind (Operational) +Telescope Dynamic Loads(Operational)

<u>Operational Loading (Stress)</u>

d) Gravity(-2^{o} Altitude) + Differential Thermal Expansion(Functional) + Wind (Operational) +Telescope Dynamic Loads(Operational)

e) Gravity(+92^{o} Altitude) + Differential Thermal Expansion(Functional) + Wind (Operational) +Telescope Dynamic Loads(Operational)

<u>Short Term Accidental Loading</u>

f) Gravity(-4^{o} Altitude) + Differential Thermal Expansion(Functional) + Wind (Operational) +Telescope Dynamic Loads(Emergency Braking against end-stops)

g) Gravity(+94^{o} Altitude) + Differential Thermal Expansion(Functional) + Wind (Operational) +Telescope Dynamic Loads(Emergency Braking against end-stops)

h) Gravity(-4^{o} Altitude) + Differential Thermal Expansion(Functional) + Wind (Operational) + OBE

i) Gravity(+94^{o} Altitude) + Differential Thermal Expansion(Functional) + Wind (Operational) + OBE

<u>Survival Loading</u>

j) Gravity(+94^{o} Altitude) + Wind (Survival)

k) Gravity(-4^{o} Altitude) + Wind (Survival)

l) Gravity(+94^{o} Altitude) + Wind (Operational) + MLE

m) Gravity(-4^{o} Altitude) + Wind (Operational) + MLE

Note: In addition to the above all specific component or sub-assembly load cases shall be identified and specified including all handling loads both for installation and for routine testing/service.

14.1.4 Acceptable Earthquake Hazards

Acceptable hazards in the event of an earthquake applicable to load combinations h, i, l and m are defined in Table 22.

Earthquake Type	Acceptable Hazard	Not Acceptable Hazard
OBE	None	Minor system damage Major system damage System Unrecoverable Severe injury or death
MLE	Minor system damage Major system damage	System Unrecoverable Severe injury or death

Table 22: Acceptable Earthquake Hazards

Note: Each case of damage under MLE categorised as an Acceptable Hazard to be agreed with VPO.

<u>Minor System Damage</u> is defined as any damage that can be repaired by site personnel without any support from industry and/or the system is up to three weeks out of operation.

<u>Major System Damage</u> is defined as a system that can be recovered but extensive industrial support is necessary and/or the system is out of operation for more than three weeks.

<u>System Unrecoverable</u> is defined as damage permanently effecting the operational characteristics of the Telescope and M1 Mirror.

Severe Injury is defined as partial permanent disability of human beings.

14.1.5 Requirement for Safety Analyses

Safety analyses will be performed following best practice to meet the requirements within AD42.

14.1.6 Electromagnetic Compatibility Analysis

An electromagnetic compatibility (EMC) analysis may be used for VISTA as a method of verification of specific EMC requirements instead of tests.

In this case, the analysis shall be performed with the procedure and goals standardised by AD91. Similar reference standards may be used as an alternative subject to the approval of the VPO.

14.2 Material Parts and Processes

a) All components except pipework fittings shall be metric. Non metric components or parts may be used only if there is no metric equivalent. A Request For Waiver shall be submitted for these items.
b) AD51 lists ESO preferred electro-mechanical components.
c) Welding shall be carried out in accordance with applicable ISO Standards.
d) Major welded components of the VISTA telescope shall be stress relieved. The process used shall be in accordance with applicable ISO Standards.
e) Steel plate and sections used shall be of metric dimensions and to international material standards.

14.3 Painting/Surface Treatment

The design, manufacturing and assembly of the Telescope Work Package shall take into account possible corrosion of components and use a preservation scheme appropriate to the specified environment and duty.

14.3.1 Paints

The VISTA telescope tube structure shall be covered with low emissivity (≤ 20%) diffuse aluminium paint or aluminium foils.

The surfaces around the optical beam shall be painted with matt black paint (e.g. Aeroglaze Z306 from Lord Chemical Products)

14.3.2 Surface Treatments

All Surfaces shall be treated against corrosion. In this case, the bonding requirements specified in AD86 shall be met.

14.4 Electromagnetic Compatibility

14.4.1 General

14.4.1.1 Intra-system Electromagnetic Compatibility

VISTA shall exhibit complete electromagnetic compatibility among the parts, components, devices, apparatus and equipment of which it is composed (intra-system electromagnetic compatibility).

No malfunction, degradation of performance or deviation from specified parameters is admitted because of lack of intra-system electromagnetic compatibility.

14.4.1.2 Inter-system Electromagnetic Compatibility

Minimisation of the electromagnetic interference between VISTA and its environment shall be a concern in the design and manufacture of VISTA (inter-system electromagnetic compatibility). In order to achieve inter-system electromagnetic compatibility, VISTA shall comply with the EMC requirements set by the IEC 61000 Standards and shall reference the applicable limits contained in documents AD48and AD49.

The following sections 14.4.2, to 14.4.4 are highlighted as a reminder of the requirements and not as a waiver to the EMC requirements of IEC 61000.

14.4.2 Electromagnetic Environment

VISTA will be installed, operated and located within the electromagnetic environment specified by AD48.

VISTA shall be considered part of the VLT Observatory. Therefore the general requirement of the VLT observatory are applicable.

For the purpose of this Specification, the requirements applicable to the Telescope Area of the VLT Observatory are to be intended as fully applicable to the VISTA Telescope Area.

As a minimum this entails the following requirements:

a) Earthing and equipotential bonding shall be realised at the VISTA telescope Area

b) The Enclosure and the Auxiliary Building of VISTA shall be designed, built and assembled as to be protected against direct lightning flashes as per the requirements

c) The VISTA telescope including its subsystems and in general all the internal equipment shall be protected against electromagnetic pulse (LEMP). The requirement of the Telescope Area are applicable

d) The electrical and electronic installations of VISTA shall be protected against overvoltages

e) Insulation co-ordination shall be achieved between, on one hand, the Telescope Area electric and electronic installations and on the other hand, the VISTA telescope according to the principals and requirements of national standards, taking into account the altitude of VISTA

f) The VLT power system is expected to provide electric power with the quality specified by Chapter *4. "PERFORMANCE REQUIREMENTS*" of AD 48

14.4.3 Emission

Note. In the present subsection and in the following one *14.4.4*, the term "port" is used according to the definition given by the European Standards CENELEC EN 50 081-1:1992 and EN 50 082-1:1992, viz., "port": particular interface of the specified apparatus with the external electromagnetic environment.

VISTA shall comply with the emission limits specified by IEC 61000. As a minimum this entails the following requirements:

a) Radiated emission

b) Conducted emission (disturbance voltages)

c) Conducted Emission (harmonic currents)

d) Conducted emission (voltage fluctuations)

14.4.4 Immunity

VISTA shall comply with the applicable immunity limits specified by IEC 61000. As a minimum this entails the following requirements

a) Input (and output, if any) AC power ports

b) Control, signal ports

c) Enclosure port

d) Input and output DC power ports (if any)

14.4.5 Acceptance Criteria

Table 23 lays out the acceptance criteria to be used in testing of the VISTA Telescope Work package for Emission and Immunity. The limits applicable to acceptance are those defined under the EN / IEC limits however the limits listed under AD48 & AD49 shall be treated as design goals.

Table 23 : EMC Emission and Immunity Limits

STANDARD	TITLE	EN/IEC LIMITS	AD48 & AD49 LIMITS
EN 50081, Part 2	Electromagnetic Compatibility – Generic Emission Standard Part 2: Industrial Environment **(Class A)**	**CONDUCTED** 0.15 – 0.5 MHz QP 79, AVG 66 dBµV 0.5 – 30 MHz QP 73, AVG 60 dBµV **RADIATED (@ 10 m)** 30 – 230 MHz 39.5 dB(µV/m) 230 – 1000 MHz 46.5 dB(µV/m)	**CONDUCTED** 0.15 – 0.5 MHz 66-56 dBµV QP 0.5 – 5 MHz 56 dBµV QP 5 – 30 MHz 60 dBµV QP **RADIATED (10m)** 30 – 230 MHz 30 dB(µV/m) 230 – 1000 MHz 37 dB(µV/m)
IEC 61000-4-2	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 2: Electrostatic Discharge (ESD) Immunity	**LEVEL 2** 4KV Contact Discharge **LEVEL 3** 8KV Air Discharge	**LEVEL 3** 6KV Contact Discharge 8KV Air Discharge
IEC 61000-4-3	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 3: Radiated Radio-Frequency, Electromagnetic Field Immunity Test	**LEVEL 2** 80 to 1000 MHz 80% AM @ 1KHz 3 V/m	**LEVEL 3** 80 to 1000 MHz 80% AM @ 1KHz 10 V/m
IEC 61000-4-4	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 4: Electrical Fast Transient Immunity	**LEVEL 2** 0.5KV on I/O Signal and Control Lines 1KV on PS Lines	**LEVEL 2** 0.5KV on I/O Signal and Control Lines 1KV on PS Lines
IEC 61000-4-5	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 5: Surge Immunity	**CLASS 2** Line to Earth 1KV Line to Line 0.5 KV	**CLASS 3** Line to Earth 2KV Line to Line 1 KV
IEC 61000-4-6	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 6: Immunity to Conducted Disturbances, Induced by Radio-Frequency Fields	**LEVEL 2** 150 KHz to 80 MHz 3 Vrms 80% Mod.	**Not Specified**
IEC 61000-4-11	Electromagnetic Compatibility – Part 4: Testing and Measurement Techniques – Part 11: Immunity Requirement, Voltage Dips, Short Interruption and Voltage Variation	30% reduction (10ms) 60% reduction (100 ms) >95% reduction (5 sec)	30% reduction,10ms 50% reduction,0.1s >95% reduction,5sec
EN 61000-3-2	Electromagnetic Compatibility Part 3: Limits-Section 2: Limits for Harmonic Currents Emissions (Equipment Input Current <= 16A/phase)	**Class A Limits** Refer to Standard	**Not Specified**
EN 61000-3-3	Electromagnetic Compatibility Part 3: Limits-Section 3: Limitation of Voltage Fluctuations and Flicker in Low Voltage Supply Systems for Equipment with Rated Current <= 16A	**Class A Limits** Refer to Standard	**Not Specified**

14.5 Nameplates and Product Marking

As a general rule the main parts of the VISTA subsystems and all exchangeable units (LRU's) shall be traceable back to the current as built drawing set and therefore to either the design and manufacturing drawings or to the manufacturer of the component.

This shall either be achieved using the manufacturer's product identification details attached to the component or in the case of a Contractor manufactured or fabricated item a nameplate containing the product identification details in accordance with the requirements of ISO 9000:2000.

The nameplates and manufacturer's product identification information shall be visible after installation of the parts or LRU's.

15 Technical Documentation

The technical documentation related to VISTA shall meet the following general requirements:

- The language used shall be English
- Metric SI units shall be used in all delivered drawings, analysis and documentation.
- All documentation shall be delivered on paper as well as in electronically readable format.
- Drawings shall be to ISO 128 standards and delivered on paper as well as in electronically readable format. (Format to be Readable using AutoCad 2000 or otherwise agreed by the VPO).
- Finite Element Models and results as part of analysis shall be delivered also on electronically (Format to be COSMOS/M or otherwise agreed by the VPO)
- Layouts for electronic circuits shall also be provided in electronically readable format. (Format to be Readable using AutoCad 2000 or otherwise agreed by the VPO).

16 Verification and Quality Assurance

This section gives the technical requirements related to the verification to be performed by the Contractor during the course of the project before the Preliminary Acceptance.

Those requirements shall be included in the Verification Plan to be elaborated by the Contractor during the design and development phases and any specific tool required to comply with them shall be identified and designed.

16.1 VISTA Test Philosophy

Several forms of verification activities will take place during the design, manufacture, assembly and integration of the Telescope Work-Package. The Contractor shall define the way he intends to show the compliance of the Telescope Work Package to the requirements in his Verification plan. The Verification plan shall be approved by the VPO.

This shall be done according to the required verification method of the verification matrix hereunder and following a timely process, which will be developed during all the project phases.

Although the Control System (LCU's) is not part of the contract, the Contractor shall develop his own control system, which will be used for the acceptance testing of the telescope work package.

Assembly, integration and test of the telescope structure will be performed in a clean environment and on a stable foundation namely for the frequency and repeatability testing.

16.2 Performance Verification

In addition to the inspections performed as part of quality assurance requirements by the Contractor, the following three methods of verification shall be carried out to show that the requirements are met in accordance with the verification table in Section **16.3**:

16.2.1 Verification by Design

Verification of the design will be carried out during the design phase to ensure that the required performance can be met. This will include the use of Formal Design Reviews.

16.2.2 Verification by Analysis

The performance of the specific item will be demonstrated by carrying out appropriate analysis during the design phase.

16.2.3 Verification by Test

The performance of the specific item will be verified by specific tests.

16.3 Verification Matrix

The following table shows how the requirements listed in Sections 5 to 8 will be verified as a minimum.

Testing should be comprehensive as far as is reasonable practical. It will include one of (or a combination of) the following formats Performance, Functional or Witness/Inspection. The Verification Plan will supersede the verification matrix as given below when approved by the VPO.

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
6 Environmental Requirements				
6.1	General	X		
6.2	Transportation Environment	X		
6.3	Installation/Operation/Maintenance/Survival Environment			
6.3.1	Natural Temperature	X		
6.3.2	Humidity	X		
6.3.3	Sand and Dust	X		
6.3.4	Elevation above Sea Level	X		
6.3.5	Exposure to Ultra-Violet Radiation	X		
6.3.6	Natural Wind	X	X	
6.3.7	Earthquakes	X	X	
6.4	Environmental Control and Monitoring			
6.4.2	Control of Heat Sources	X		
6.4.3	Temperature Sensors	X		
6.4.4	Anemometers	X		
6.5	Vibration and Noise	X		
7 Interface Requirements				
7.1	Interface between Telescope Structure and Pier	X		Inspect
7.2	Interface between M1 Mirror and M1 Cell	X		Inspect
7.3	Interface between Telescope Tube and M2 System	X	X	Inspect
7.4	Interface between Telescope Tube and M2 Baffle	X	X	Inspect
7.5	Interface between Cassegrain Rotator and Cassegrain Focus Instruments	X		Inspect
7.6	Interface between Telescope Work Package and Control Hardware	X		Inspect
7.7	Interface between Telescope Structure and M1 Mirror Handling Equipment	X		Inspect
7.8	Interface between Telescope Structure and	X		Inspect

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
	Camera Handling Equipment			
7.9	Interface between Telescope Structure and M2 System Handling Equipment	X		Inspect
7.10	Interface between Telescope Structure and VISTA Enclosure Services Systems	X		Inspect
8 System Requirements for the Telescope Work Package				
8.1	Physical Characteristics			
8.1.1	Mass	X		
8.1.2	Design Volume and Constraints	X		
8.2	Angular Coverage	X		X
8.3	Operating Angular Velocity and Acceleration Requirements	X		X
8.4	Telescope Pointing	X	X	X
8.5	Telescope Tracking	X	X	X
8.6	Telescope Dynamic Performance			
8.6.1	First Telescope Locked Rotor Frequency	X	X	X
8.6.2	Azimuth, Altitude and Cassegrain Rotator Axes Dynamic Response	X	X	
9 Requirements for the Altitude and Azimuth Sub-Systems				
9.1	Altitude and Azimuth Axis Alignment	X		Inspect
9.2	Azimuth Bearing	X		Inspect
9.3	Azimuth Cable Wrap	X		Inspect
9.4	Telescope Fork	X		
9.4.1	Fork Azimuth Floor	X		
9.5	Altitude Bearings	X		Inspect
9.6	Altitude Axis Cable Wrap	X		Inspect
10 Requirements for the Telescope Tube Sub-Systems				
10.1	General Requirements	X		
10.2	Telescope Tube Structural Performance			
10.2.1	M2/M1 Differential Displacement	X		X

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
10.2.2	M1 Mirror/Cassegrain Rotator Differential Displacement	X		X
10.3	Alignment Requirements of Telescope Tube Sub-Systems			
10.3.1	Principal Datum for Alignment of the Telescope Tube	X		
10.3.3	Cassegrain Rotator Alignment to M1 Cell	X		X
10.3.4	M1 Mirror Supports to the Cassegrain Rotator	X		
10.3.5	M1 Cell Alignment to Telescope Centre Section	X		X
10.3.6	M1 Alignment to the Cassegrain Rotator	X		
10.3.7	M2 Alignment with respect to the Top End Ring	X		
0	Telescope Truss Alignment to the Centre Section	X		
10.3.9	Cassegrain Rotator Interface to Cameras	X		X
10.4	M1 Cell Sub-System Requirements			
10.4.2	M1 Cell Requirements	X		
10.4.3	Axial Definer Requirements	X	X	X
10.4.4	Axial Support Requirements	X	X	X
10.4.5	Lateral Definer Requirements	X	X	X
10.4.6	Lateral Supports Requirements	X	X	X
10.4.7	Earthquake and Maintenance Restraints	X	X	X
10.4.8	M1 Cell Thermal Requirements			
10.4.8.2	Thermal Conditioning of Primary Mirror	X		
10.5	Cassegrain Rotator			
10.5.1	Cassegrain Rotator Bearing	X		X
10.5.2	Cassegrain Rotator Tracking Requirements	X	X	X
10.5.3	Cassegrain Rotator Cable Wrap	X		X
10.6	Vanes	X	X	
10.7	M1 Mirror Removal (Telescope Contractor to	X		X

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
	Propose at FDR)			
11 Mechanism Control				
11.1	Altitude, Azimuth and Cassegrain Rotator Axis Control			
11.1.1	Axis Control	X		X
11.1.2	Software/Hardware Interface	X		X
11.1.3	Control Algorithms	X		
11.1.4	Motors	X	X	X
11.1.5	Power Amplifiers	X		X
11.1.6	Position Measurement	X	X	X
11.1.7	Velocity Measurement	X		X
11.1.8	Altitude, Azimuth and Cassegrain Rotator Angular Range			
11.1.8.1	Altitude, Azimuth and Cassegrain Rotator Limits	X		X
11.1.8.2	Maintenance Conditions	X		X
11.1.9	Axis Lockout	X		X
11.1.10	Brakes	X		X
11.1.11	End Stops	X		X
11.1.12	Auxiliary Drives	X		X
11.2	M1 Control			
11.2.1	M1 Control Context	X		
11.2.2	General Requirements	X		
11.2.3	Axial Support Control Requirements	X		X
11.2.4	Lateral Support Control Requirements	X		X
12 Service and Test Equipment				
12.1	M1 Mirror Dummy	X		Inspect
12.2	M2 System Dummy	X	X	Inspect
12.3	M2 Electronic Cabinet dummy	X		Inspect
12.4	Instrument Mass Dummy	X		Inspect
12.7	Transport Containers	x		Inspect

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
13 Reliability Maintainability and Safety Requirements				
13.1	Telescope Lifetime	X		
13.2	System Reliability			
13.2.1	Overall Availability	X		
13.2.2	Specific Reliability Requirements	X		
13.3	Maintainability Guidelines and Requirements			
13.3.1	Maintenance Approach	X		
13.3.1.1	Predictive Maintenance	X		
13.3.1.2	Preventive Maintenance	X		
13.3.1.3	Overhaul	X		
13.3.1.4	On-Site Repair/Corrective maintenance	X	X	
13.4	Safety	X		
13.4.1	Hazard Risk Acceptance Criteria			Inspect
13.4.2	General Safety Requirements	X		
13.4.4	Mechanical Safety	X		
13.4.5	Protection against electric shock and other hazards	X		X
13.4.5.2	Safety Compliance	X		
13.4.5.3	Electrical and Electronic Equipment	X		
13.4.5.4	Bond Corrosion	X		
13.4.6	Hydraulic Safety	X		
13.4.7	Pneumatic Safety	X		
13.4.8	Cooling System Safety	X		
13.4.9	Software Safety	X		
13.4.10	Handling, Transport and Storage Safety	X		
13.4.11	Operational Safety	X		
13.4.12	Safety Interlock System	X	X	X
14 General Requirements for Design and Construction				
14.1	Requirements for Analyses			

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
14.1.1	Structural Analyses: General		X	
14.1.1.1	Modal Analysis		X	
14.1.1.2	Wind Loading Dynamic Response		X	
14.1.1.3	Gravity Load Analysis		X	
14.1.1.4	Wind Stress Analysis		X	
14.1.1.5	Seismic Analysis		X	
14.1.2	Stress Verification Criteria and Limits		X	
14.1.3	Load Combinations		X	
14.1.4	**Acceptable Earthquake Hazards** **Acceptable hazards in the** event of an earthquake applicable to load combinations h, i, l and m are defined in Table 22.		X	

Earthquake Type	Acceptable Hazard	Not Acceptable Hazard
OBE	None	Minor system damage Major system damage System Unrecoverable Severe injury or death
MLE	Minor system damage Major system damage	System Unrecoverable Severe injury or death

Table 22: Acceptable Earthquake Hazards

Note: Each case of damage under MLE categorised as an Acceptable Hazard to be agreed with VPO.

Minor System Damage is defined as any damage that can be repaired by site personnel without any support from industry and/or the system is up to three weeks out of operation.

Major System Damage is defined as a system that can be recovered but extensive industrial support is necessary and/or the system is out of operation for more than three weeks.

System Unrecoverable is defined as damage permanently effecting the operational characteristics of the Telescope and M1

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	HEADING	DESIGN	ANALYSIS	TEST
	Mirror. Severe Injury is defined as partial permanent disability of human beings. Requirement for Safety Analyses			
14.1.6	Electromagnetic Compatibility Analysis		X	
14.2	Material Parts and Processes	X		
14.3	Painting/Surface Treatment	X		
14.4	Electromagnetic Compatibility			
14.4.1	General			
14.4.1.1	Intra-system Electromagnetic Compatibility	X		
14.4.1.2	Inter-system Electromagnetic Compatibility	X		
14.4.2	Electromagnetic Environment	X		
14.4.3	Emission	X		X
14.4.4	Immunity	X		
14.5	Nameplates and Product Marking	X		
15	Technical Documentation			Inspect

17 Summary of Items TBC, TBD and TBR

TBR
n/a

TBC
n/a

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