Visible & Infrared Survey Telescope for Astronomy

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1	16/7/01	Major Rewrite	Incorporate comment from Systems Review, elimination of Statement of Work type requirement
2	26/9/01	All	Complete Rewrite

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Acronyms and Abbreviations

ADC	Atmospheric Dispersion Corrector
ALARP	As Low As Reasonably Possible
Altitude Angle	Angle above horizon
BOB	Broker for Observation Blocks
Canbus	Controller Area Network Bus
COSHH	Control of Substances Hazardous to Health
CCD	Charge Coupled Device
CCS	Central Control Software
CWL	Central Wavelength
DRP	Design Reference Program
DVD	Digital Versatile Disc
EED	Encircled Energy Diameter
EMU	Electromechanical Unit
ESO	European Southern Observatory
FIERA	Fast Imager Electronic Readout Assembly
FITS	Flexible Image Transfer System
FMEA	Failure Mode Effect Analysis
FWHM	Full Width at Half Maximum
HVAC	Heating Ventilation and Air Conditioning
HW	Hardware
ICD	Interface Control Document
IRACE	Infra Red Array Control Electronics
IWS	Instrument Workstation
LCU	Local Control Unit
LEMP	Lightning and Electro Magnetic Pulse
LTO	Linear Tape Open
LN_2	Liquid Nitrogen
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
OCDD	Operational Concept Definition Document
OPD	Optical Path Difference
OB	Observation Block
OHS	Observation Handling Software

OS	Observation Software
P2PP	Phase 2 Proposal Preparation
PCB	Printed Circuit Board
PP	Peak to Peak
PTV	Peak to Valley
RMS	Root Mean Square
SCP	Standard Connection Panel
SRD	Science Requirements Document
SW	Software
TBC	To be Confirmed, but requires further verification or agreement.
TBD	To be Determined
TCS	Telescope Control System
T_0	Predicted minimum observing air temperature
VCS	VLT Control System
VISTA	Visible and Infrared Survey Telescope for Astronomy
VPO	VISTA Project Office
VTS	VISTA Technical Specification
WFE	Wave Front Error
WS	Workstation
ZD	Zenith Distance (i.e. 90deg – altitude angle)
Zenith Blind Spot	Area around zenith that the telescope **cannot** track in azimuth

NOTE Where numerical values of deviations are given, unless they are qualified (e.g. by rms), they are to be taken as maximum absolute values.

1 SCOPE

1.1 General

The purpose of this Technical Specification is to define the high level technical requirements for the VISTA telescope (Visible and Infrared Survey Telescope for Astronomy). VISTA is a survey telescope which will be installed near the location of ESOs Very Large Telescope, in the desert of Atacama, in the North of Chile.

The specification covers the performance, the design, the testing and the operational requirements of VISTA. It is not the purpose of this specification to establish all the detailed technical requirements necessary for the procurement of the single subsystems, but rather to define the overall system architecture and performance, and outline the major subsystem requirements.

The System Requirements, which can be directly related to the Science Requirements Document (SRD) – AD 01, are covered in Section 4. Common engineering requirements to the overall system are also included in this section.

The subsystem characteristics and requirements, which are considered to be necessary for the fulfilment of the System Requirements are covered in Section 5. Many sub-system requirements are application specific. Specifications have been derived from the VISTA conceptual design. As the detailed design and manufacture progresses, some requirements may need modification.

Operational concepts as described in the OCDD (AD 02) are convolved into the specification where appropriate to expand SRD requirements. The OCDD will be used as a reference source in making systems decisions and operational trade-offs.

1.2 Explanatory notes

While translating the requirements of the SRD (AD 01) into System Requirements, the following guidelines have been used:

- Requirements contained in the SRD (AD 01) and are translated into engineering requirements only if they constitute a Technical Specification.
- The requirements detailed in the Technical Specification shall be quantifiable and verifiable.

2 Applicable and Referenced Documents

2.1 Applicable Documents

The following documents of the exact issue shown form a part of this Technical Specification to the extent specified herein. In the event of conflict between the documents referenced and the content of the present specification, the content of the present specification shall be considered as a superseding requirement.

2.1.1 Science Requirements Documents

Reference	Document title	Doc Number	Date
AD 01	VISTA Science Requirements Document (SRD)	VIS-SPE-VSC-00000-0001 issue 2	26.10.00
AD 02	Operational Concept Definition Document (OCDD)	VIS-SPE-VSC-00000-0002 issue 1	28.03.01

2.1.2 ESO Documents

AD 03	Basic Telescope Definitions	VLT-SPE-ESO-10000-0016-issue 3	(TBD)
AD 04	VLT Environmental Specification	VLT-SPE-ESO-10000-0004 issue 6	12.11.97
AD 05	Instructions to perform Earthquake analyses for VLT instruments and similar equipment	VLT-SPE-ESO-10000-1853, issue 1	09.06.99
AD 06	Service Connection Point Technical Specification	VLT-SPE-ES0-10000-0013 issue 4	16.02.97
AD 07	VLT Software Requirements Specification	VLT-SPE-ESO-10000-0011 issue 2	30.09.92
AD 08	EMC and Power Quality Specification - Part 1	VLT-SPE-ESO-10000-0002, issue 2	11.03.92
AD 09	EMC and Power Quality Specification - Part 2	VLT-SPE-ESO-10000-0003, issue 1	05.02.92
AD 10	Construction requirements of the VLT Observatory Infrastructures/Buildings/Enclosures related to EMC	VLT-SPE-ESO-12000-0262, issue 1	01.07.92
AD 11	VLT Electronic Design Specification	VLT-SPE-ESO-10000-0015, issue 5	06.03.01
AD 12	Acceptance Procedure Electrical Safety and EMC	VLT-VER-ESO-10000-0958, issue 2	01.03.96
AD 13	VLT Requirements for Safety Analyses	VLT-TRE-ESO-00000-0467, issue 1	27.07.93

Note: Documents AD13 to AD19 intentionally blank

AD 20	VLT-Programming Standards	VLT-PRO-ESO-10000-0228 issue 1	10.03.93
AD 21	LCU Common Software User Manual	VLT-MAN-SBI-17210-0001 issue 3.6	01.03.01
AD 22	VLT Instrumentation Software Specification	VLT-SPE-ESO-17212-0001 issue 2	12.04.95
AD 23	VLT Instrument Common Software Specification	VLT-SPE-ESO-17240-0385 issue 2.1	15.07.96

AD 24	Data Interface Control Document	GEN-SPE-ESO-19400-0794 issue1.1	25.11.97
AD 25	Telescope Control System User Manual	VLT-MAN-ESO-17230-0942 issue 1.6	12.10.99
AD 26	Broker for Observation Blocks User Manual	VLT-MAN-ESO-17220-1332 issue 1.5	06.03.01
AD 27	Central Control Software User Manual	VLT-MAN-ESO-17210-0619 issue 1.9	30.10.98
AD 28	Final Layout of VLT Control LANs	VLT-SPE-ESO-17120-1355, Issue 1.2	12.01.99

Note: Documents AD 29 - AD 30 intentionally blank

2.1.3 Interface Control Document

AD 31	Interface Control Document between the Paranal infrastructure and VISTA (possibly only Power Distribution System of Paranal) (TBC)	ICD TBD	TBD
AD32	ICD between VLT Control System and Observation Handling System	VLT-ICD-ESO-17240-19200 issue 1.2	17.05.99

Note: Documents AD 33 to AD 39 intentionally blank

2.1.4 Safety and Standards

Note: In lieu of DIN standards equivalent national standards or European directives can be used upon approval from the VPO.

AD 40	VISTA Project Safety Management Plan	VIS-PLA-ATC-00001-0019	24.9.01
AD 41	Eurocode No.8 Structures in seismic regions--Design- Part 1	Commission of the EC Report EUR 12266 EN 1988	1988
AD 42	Recommendations for calculating the effect of wind on constructions, European Convention for Constructional Steelwork	ECCS Technical Committee 12-wind, report no. 52, 2nd edition	1997
AD 43	General principles for the Safety Design of Technical Products	DIN 31000 (1979-03) including DIN VDE 31000-2 (1987-12)	1979, 1987
AD 44	Safety of machinery - Electrical equipment of machines - Part 1: General requirements	EN 60204-1:1997	1997
AD 45	Protection against electrical shock – Common aspects for installation and equipment	IEC 61140	1997-11
AD 46	Electrical installation of buildings	IEC 60364	2001
AD 47	Safety of information technology equipment	IEC 60950, 3rd edition	1999-04
AD 48	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests	IEC 60664-1, Ed. 1.1	2000-04
AD 50	Hydraulic fluid power -- General rules relating to systems	ISO 4413:1998 , 2nd edition	1998
AD 51	Electromagnetic Compatibility (EMC) including Electromagnetic Pulse (EMP) and lightning Protection – Programme and Procedures –	VG 95 374 Part 4	

	Procedures for Systems and Equipment"		
AD 52	COSHH Regulations	Framework Directive98/24/EC	1999

2.2 Reference Documents

Reference documents provide background information for use as appropriate.

Reference:	Document title:	Doc Number	
RD 01	Interface Control Document Between Telescope Structure and M2 Unit	VLT-ICD-ESO-11310-11210, issue 3	14.07.94
RD 02	IRACE Design Description	VLT-TRE-ESO-14100-1654, Issue 2.0	31.08.98
RD 03	Reflecting Telescope Optics II	Wilson, R, N. ISBN 3-540-60356-5 Springer-Verlag	1999

3 Description of VISTA

3.1 General

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. The available field of view will be approximately 2 degrees diameter in the Visible and 1.6 degrees diameter in the infrared. It will be used to undertake pre-planned key observation programmes rather than a single large uniform sky survey. This will be carried out in various wave-bands at fainter magnitudes than those produced by the current generation of survey telescopes.

Being a wide field telescope the optical design has been optimised together with the design of the cameras. The cameras are positioned at the Cassegrain focus and are provided with integrated dedicated field correctors. The design is based on the following considerations.

- To achieve the desired field of view, image quality and image plate scale, the telescope optics must deliver an ~f/3 beam.
- The Cassegrain focus has been used requiring an ~f/1 primary mirror.
- There is no re-imaging in the cameras and in particular no cold-stop in the IR camera.

VISTA will be located at ESO's Cerro Paranal Observatory, on a peak roughly 1.5 km North East of the VLT site (Figure 1). The elevation is approximately 2500m above sea level.

ESO staff will carry out the operation and maintenance of VISTA. VISTA will, therefore, comply with the design and operational standards and policies in force at the site. The telescope will be operated from the existing VLT Control Building and use existing electrical power generation.

VISTA will be equipped with dedicated operation and maintenance facilities. The telescope will be mounted in an enclosure on the selected peak. The peak will be levelled to provide a suitable area for foundations and vehicular access. The enclosure will consist of a rotating dome and a basement area. This will include provision for primary mirror washing and coating (protected silver or aluminium) and a maintenance and storage area for the cameras. Some of these functions will be housed in an auxiliary building, others in the telescope basement. The enclosure will provide environmental protection to the telescope during operation and standby conditions. Thermal conditioning will be provided in the enclosure for minimising temperature differences between the night ambient temperature and the telescope structure and optics. A preliminary outline of VISTA at its location is shown in Figure 2.

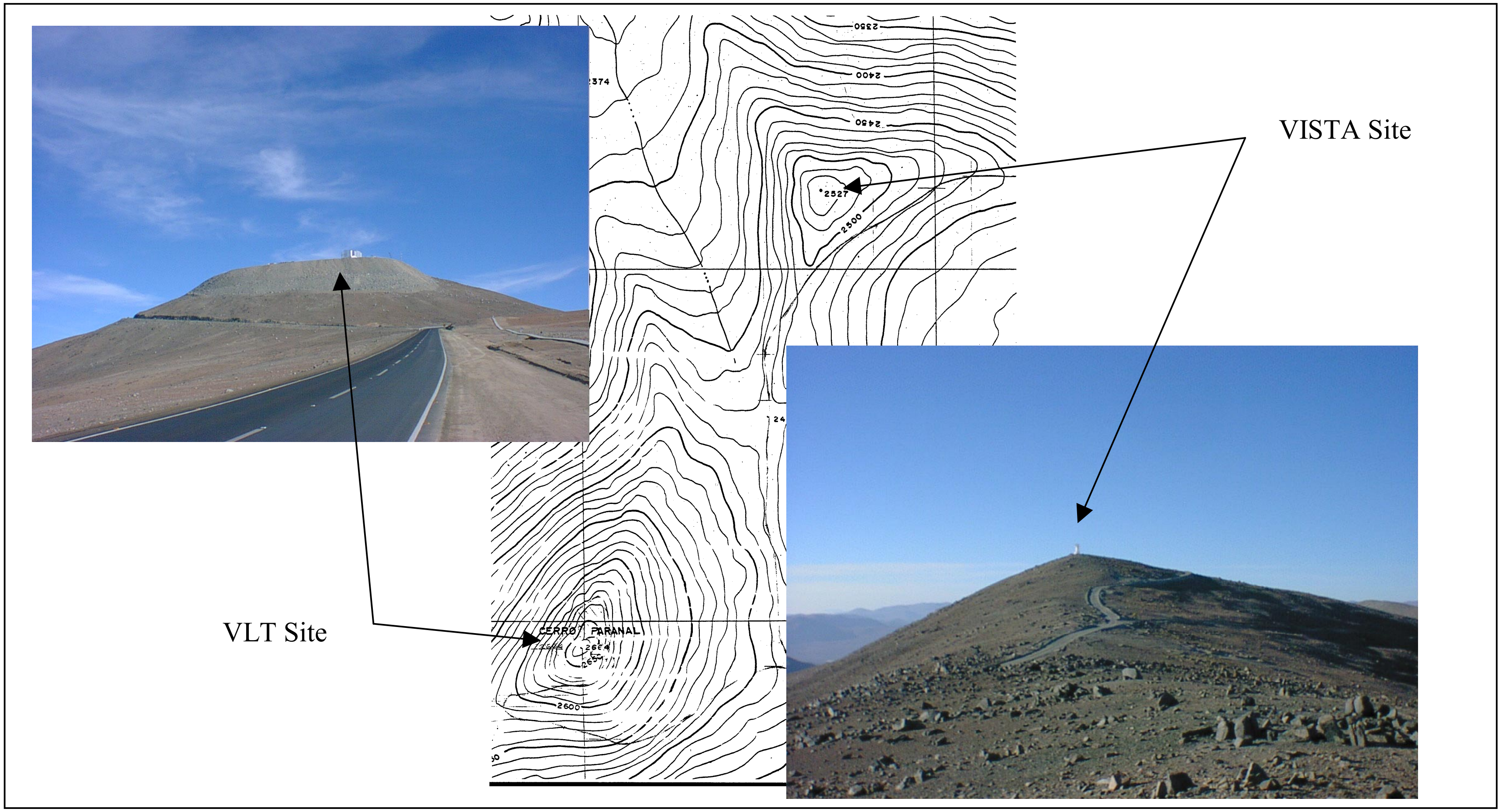

Figure 1 VLT and VISTA Site

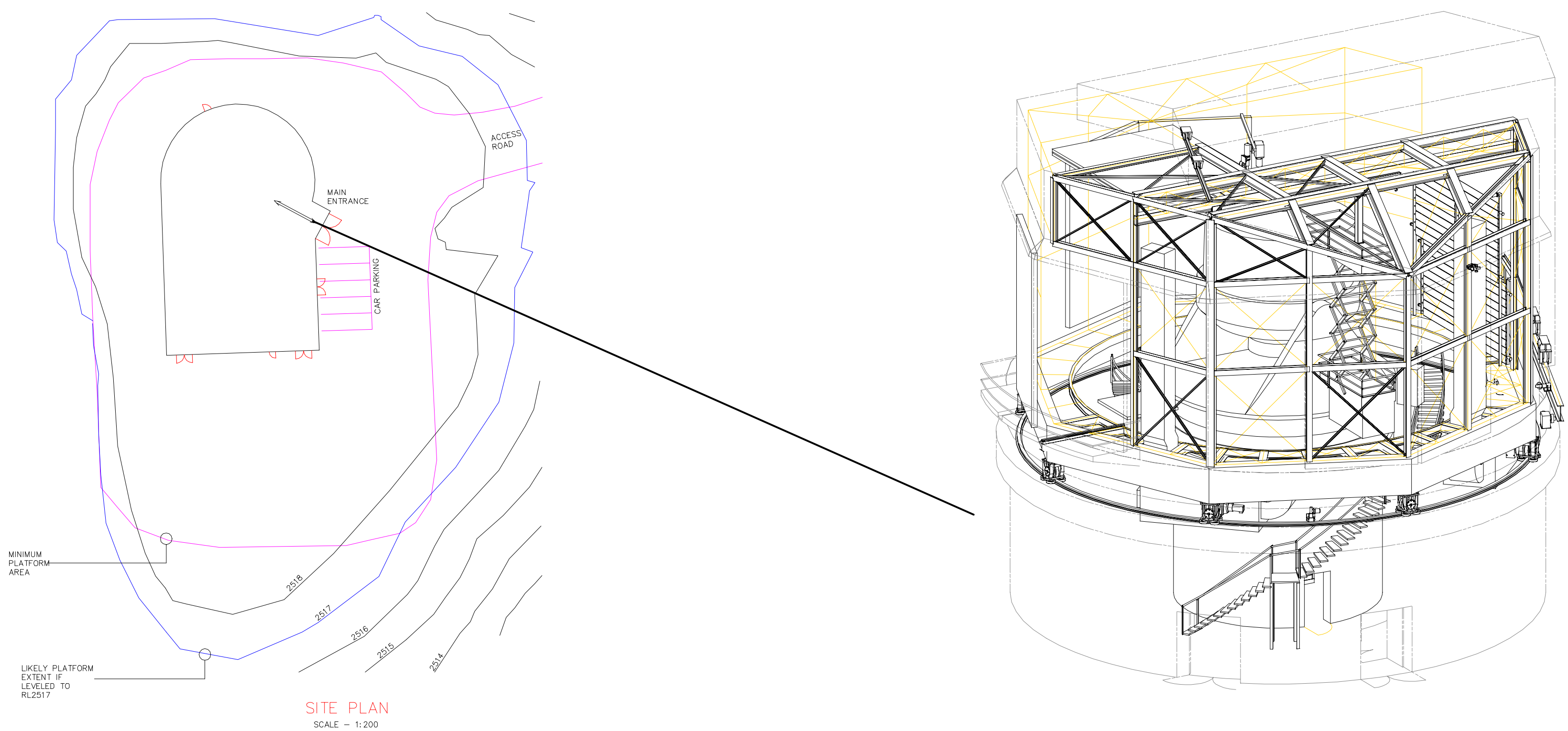

Figure 2 VISTA Site and Enclosure (preliminary)

3.2 Telescope Structure

The telescope structure is based on an Alt/Azimuth mount with the altitude axis above the primary mirror. The telescope fork consists of a welded steel structure that rotates around the azimuth axis by means of hydrostatic bearings and an azimuth track. Direct drive motors and tape encoders are used to control this axis. The base of the fork has a platform for access to the M1 Cell and to the camera. The tube is based on a Serrurier truss design mounted to a centre-section. The centre-section supports the magnets of the direct drive altitude motors. A top end ring connects the upper ends of the trusses and interfaces the spiders connecting to the M2 Unit. The altitude axis is mounted on bearings at each side of the fork, either mechanical or hydrostatic.

The M1 Cell interfaces directly to the centre-section of the telescope. The mirror is supported by means of axial and lateral supports in addition to lateral and axial restraining points. During installation the M1 Cell is brought below the centre-section by a carriage and lifted to the centre-section with dedicated handling equipment. The selected camera is then attached to the Cassegrain rotator mounted at the bottom of the M1 Cell. Figure 3 shows the general layout of the Telescope.

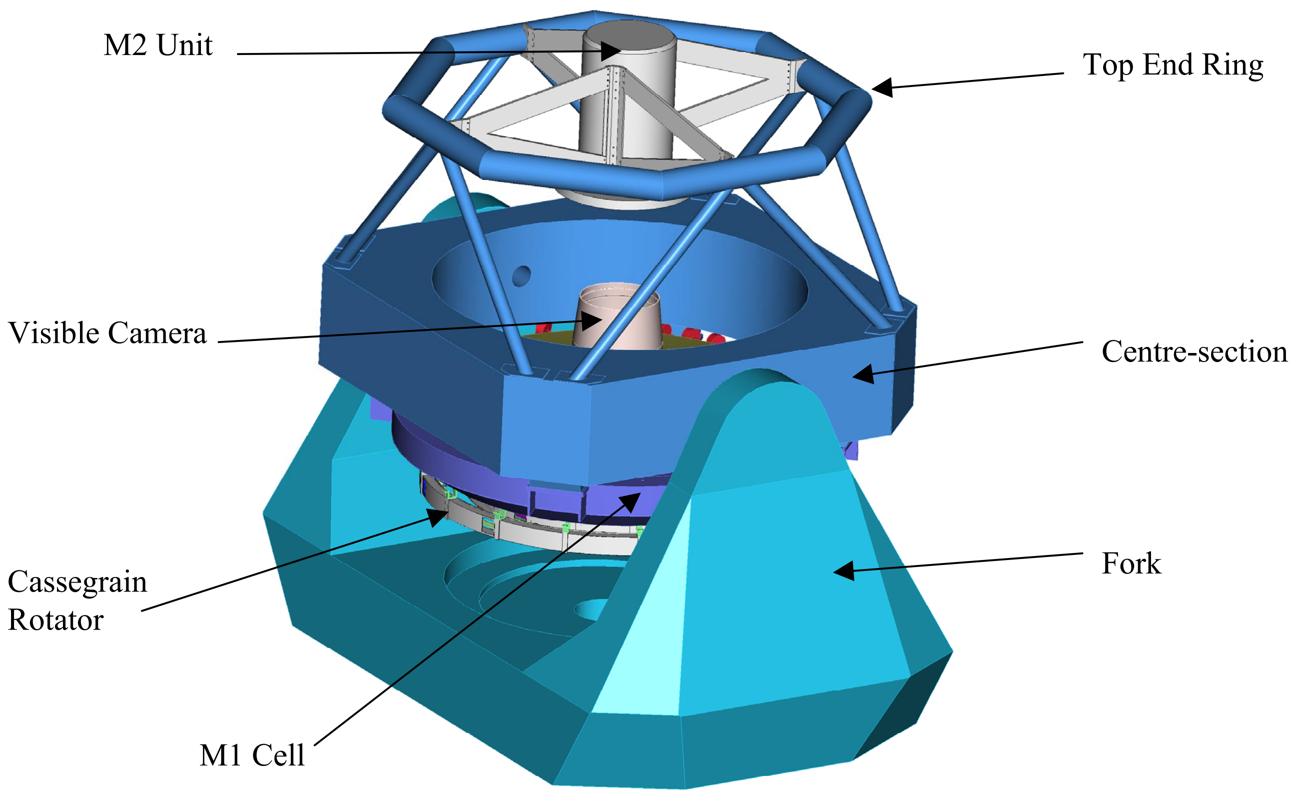

Figure 3 General view of the VISTA Telescope

3.3 Optical Characteristics

VISTA will be a quasi-Ritchey-Chretien telescope with a Cassegrain focus. The design is based on a f/1, 4m primary mirror, in the form of a deformable meniscus and a rigid light-weighted secondary mirror of approximately 1.24 m diameter. The required image quality is obtained by means of a field corrector physically included in each of the two cameras.

Each camera is equipped with wavefront sensing devices to measure the image quality and to determine the individual optical aberrations. This allows active corrections of the primary mirror shape, as well as focussing and collimation of the secondary. Each camera is equipped with annular baffles with the IR camera baffle being situated within the IR cryostat. In addition, a fixed baffle is mounted around the secondary mirror in order to stop light from the sky being seen from around the edge of M2.

3.4 Cameras

Either of two exchangeable cameras, one operating in the visible and one in the IR wave bands, can be mounted at the Cassegrain focus at any one time. Camera changes are carried out by means of dedicated handling equipment which is used to mount the selected camera to a common mounting flange. The cameras will have provisions for balancing, in order to limit the need for re-balancing of the telescope after each camera change.

3.4.1 Visible Camera

The Visible camera interfaces to the Cassegrain rotator by means of a mounting flange. A lens barrel extends from the mounting through the primary mirror hole. The barrel keeps the corrective optics, including the Atmospheric Dispersion Corrector (ADC), aligned accurately. It also supports a baffle for controlling stray light. On the lower side of the mounting there is a shutter mechanism, filter mechanism and focal plane assembly. The focal plane assembly is contained within the cryostat along with the guiding and wavefront sensors. The field of view of the science detectors is approximately 2 deg^2. There will be up to fifty 2Kx4K three side buttable CCD detectors with a pixel size of approximately 0.24 arcsec. Figure 4 shows the general layout of the Visible Camera.

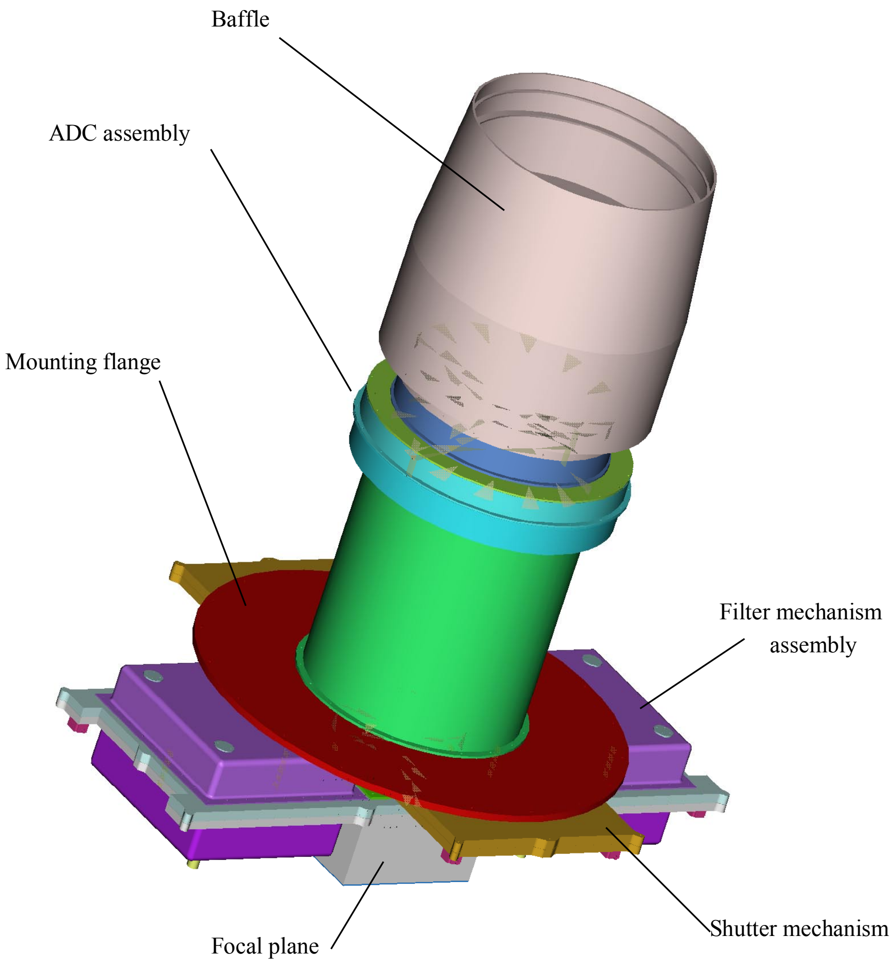

Figure 4 General view of the Visible Camera

3.4.2 Infrared Camera

The IR camera is based on the use of a cold baffle. This is necessary due to the f/3 design, image quality requirements and the field of view. The direct imaging produces excellent uniformity of image quality across the field.

A cold baffle is mounted around the inside of the vacuum vessel. This limits the field of view so that only cold surfaces or reflections of cold surfaces are visible from the focal plane. It also limits the heat load on the cryostat by reflecting heat back towards the cryostat window. This latter function is achieved by a number of curved surfaces inside the baffle which have coatings reflective at wavelengths longer than 3 μm. Extensive modelling of this system shows it has a performance comparable to a cold-stop design. The camera is composed of 4 main assemblies. The vacuum vessel with its integral cryogenic baffle, the focal plane unit with the IR detectors, the guiding, focus and wavefront sensor hardware, and a filter wheel with associated mechanism.

The focal plane can accommodate up to sixteen 2kx2k non-buttable IR detector arrays spaced by ~ 90% of the detector width. The cryogenic baffles limit the field-of-view of the detectors off the optical axis and reduce the thermal load contribution from the cryostat window. Figure 5 shows the general layout of the Infrared Camera.

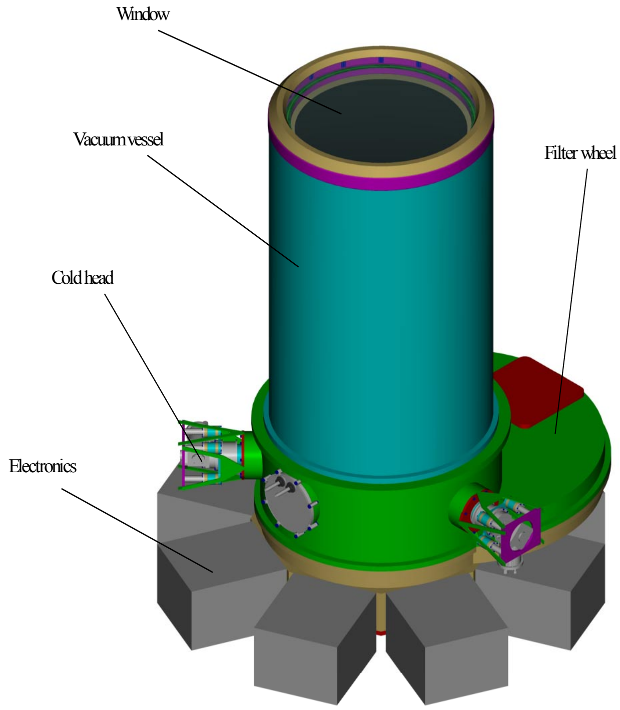

Figure 5 General view of the IR Camera

3.5 Enclosure

The VISTA telescope enclosure will be designed to harmonise visually with the existing facilities at the site. It is based on a rotating part (dome) having its azimuth floor at the same level as the telescope and a fixed part in concrete (basement) with a mezzanine floor at the level of the azimuth track and hydrostatic bearing of the telescope for maintenance purposes. The rotation of the dome will be independent from that of the telescope, in order to guarantee flexibility for maintenance and internal motion. The foundation of the enclosure will be separate from that of the telescope to minimise vibration transmission during rotation.

The rotating dome will be a steel frame structure clad with panels providing insulation from the external environment. A number of wheel supports will be placed on a rail fixed to the basement. The wheels will carry the load of the dome and will also drive its rotation. The observing slit is generated by two L shaped doors moving parallel to the side of the enclosure. Ventilation doors and wind screens are provided for control of ventilation to achieve good thermal performance. A flat field facility is included in the dome. During the day, temperature in the dome is controlled in order to maintain the telescope and the mirrors at the expected night temperature. A view of the enclosure layout is given at Figure 2 on page 16.

3.6 Maintenance Facilities

An auxiliary building is located adjacent to the enclosure. The location of the building and specifically its direction has been chosen taking into account the predominant wind direction in order to minimise the disturbance to the wind flow during observation. This building and parts of the Enclosure Basement are utilised for maintenance and support functions.
This will include the primary mirror coating plant, capable of coating in protected silver or aluminium, the washing and stripping facilities of the primary mirror, a maintenance area for the instruments and a local control workstation. The secondary mirror can be coated in the VISTA coating plant.
Housed within the Auxiliary Building are the power sub-station, containing the medium to low voltage transformer, switching gear and other necessary functions. Handling and hoisting facilities will be included for the various foreseen operations. Figure 6 shows the Basement and Auxiliary Building layout.

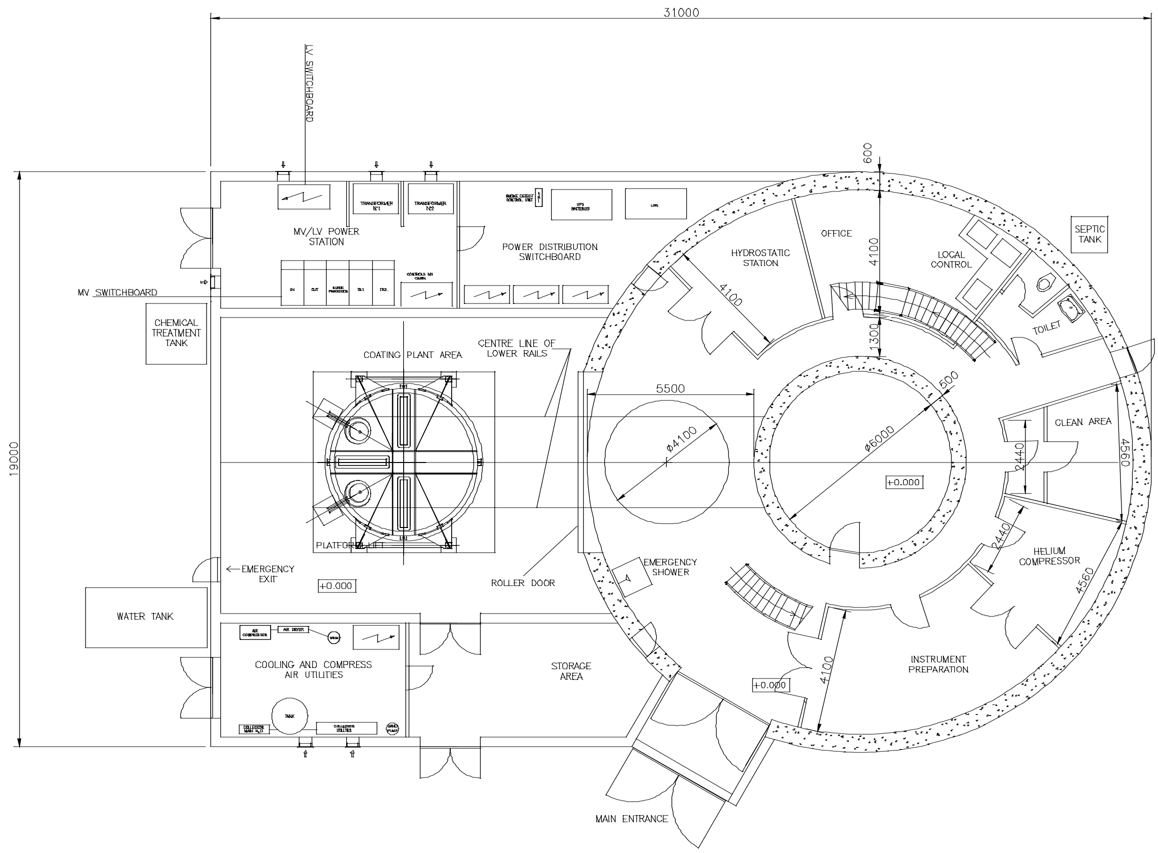

Figure 6 Cross Section of Basement and Auxiliary Building (preliminary)

3.7 Description of the Operational Scenario

3.7.1 Operation of Equipment

VISTA will be operated by ESO staff and is designed to be compatible with the operational procedures employed at Paranal. The telescope will be operated 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. A visiting astronomer may also be present.

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

3.7.2 Observation Submission and Execution

For all normal operations, VISTA will be queue scheduled. Observations will be specified in advance, using a tool similar to ESO's Phase II Programme Preparation tool (P2PP), based on Observation Blocks (OB), and adapted to assist the definition of survey observations. The VISTA operator will control the queuing and the execution of the observation blocks. Observation Blocks will be automatically translated into commands to the various telescope and camera subsystems. Also, visiting astronomers will make use of Observation Blocks.

For particular events where a rapid reaction is needed, e.g. in response to a gamma ray burst, it will be possible to have observations made at short notice.

3.7.3 Data Handling

Data, both science and calibration, will be stored to disk as FITS files containing not only the detector data but also headers containing keywords that fully describe the data. Observation and engineering logs will be generated.

Final data reduction will be performed in Europe. Because of their volume, typically 400 GB per night, the data will be transferred on physical media, for archiving. Final data reduction is not part of the VPO's responsibilities and is therefore not covered by this specification.

Data will be reduced at the observatory to the extent sufficient for assessing the quality of the data before the start of the next night's observing. In addition, real time diagnostics and monitoring of observing conditions will be employed.

It will also be possible for a visiting astronomer to analyse data in near real-time, by copying data to a work station not interfering with the observing process.

4 System Requirements

4.1 *Context*

The requirements described in this section refer to the system as a whole and not its component subsystems. They describe what the system does, how it interfaces to the external world and what it delivers. It does not describe how these requirements are met or how the system is implemented. However some assumptions are necessarily made about how VISTA is designed.

Diagrammatically, the context of VISTA is illustrated in Figure 7. The principal input is observations requests, acted upon by inputs from the operator and, if present, visiting astronomer. The principal output is data including both science observations and calibrations. Also output are the observing and engineering logs. Site interfaces exist for power and networking. VISTA will make use of the VLT site monitor data.

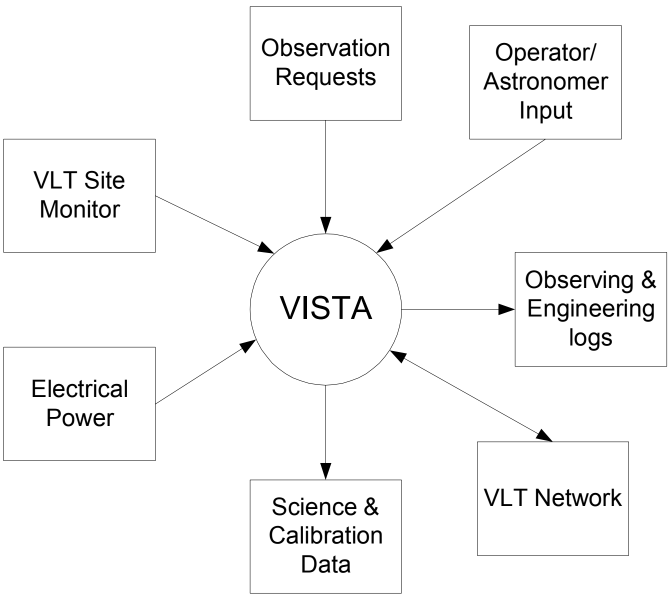

Figure 7 Context of VISTA showing externals.

4.2 *VISTA System Tree*

A System Tree of the hardware and software of VISTA, covered by this specification is given in Figure 8.

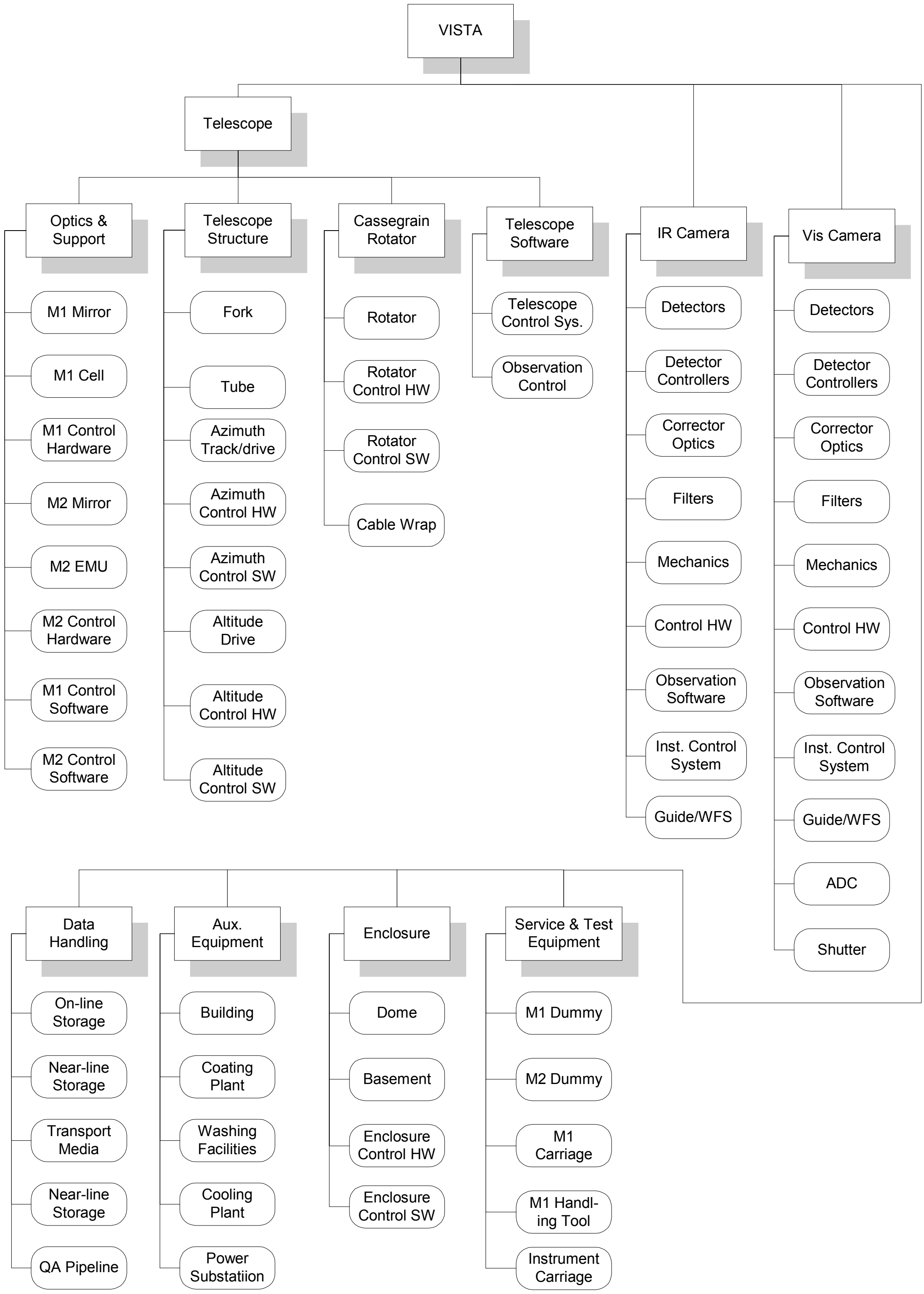

Figure 8 VISTA System Tree

4.3 Environmental Conditions

4.3.1 General

The equipment shall comply with the requirements defined in the VLT Environmental Specification (AD04), unless specifically amended by the requirements defined herein. This document describes the overall environmental conditions to be expected in operation, maintenance, storage at the Chilean site and transportation from Europe.

4.3.2 Transportation Environment

The transportation environment defined under Section 4.1 of AD04 is applicable.

4.3.3 Installation Operation Maintenance Environment

The transportation environment defined under Section 4.2 of AD04 is applicable except for what specified herein.

4.3.3.1 Natural Temperature

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

Operational temperature range 0 to 15 °C

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. It is defined as:

Functional temperature range -5 to 25 °C

4.3.3.2 Natural Wind

Operational wind speed

VISTA shall be able to operate within its nominal performances, achieving the SIQ defined in Section 4.9, for external wind speed up to v = 18 m/s. For wind speed above this value observation shall be stopped and the dome closed.

Survival wind speed

Each subsystem of VISTA shall be dimensioned for the relevant expected wind speed, taking into account the requirement of Section 4.2.9.1 of AD04 including possible accidental condition. In case that the Enclosure cannot be closed, parts of the telescope may be exposed to stronger wind than the operational wind speed.

Unless otherwise substantiated by proper design and/or analysis the survival wind speed to be used for the dimensioning of equipment inside the VISTA enclosure shall be v = 36 m/s.

The survival wind speed to be used for the dimensioning of buildings and external facilities shall be as per AD04, section 4.2.9.1.

4.3.3.3 Earthquakes

Two design earthquakes are defined by the requirement of AD04 section 4.2.14: The Operating Basis Earthquake (OBE) and the Maximum Likely Earthquake (MLE).

The excitation characteristics to be used are defined in Section 8.1.1.4 (Earthquake Analyses).

For the purpose of hazard evaluation (Section 7.4.1.2) the OBE and MLE shall be classified as Hazards Probability Levels B and C respectively.

4.4 External Interfaces

4.4.1 Power Distribution

The interface of VISTA to the Power Distribution System of the Cerro Paranal Observatory is defined by applicable document AD31. (TBC)

4.4.2 Local Area Network

Local Area Networks shall comply with ESO standards, as defined in applicable documents AD11 and AD28, and shall interface to the Observatory's Local Area Network as defined in these documents.

4.5 Reference Frame Definition

The co-ordinate system requirements detailed in AD03 shall be applied to all levels of VISTA. Local co-ordinate systems linked to telescope, telescope assemblies and other parts of VISTA may be defined as necessary, taking into account the requirements of AD03.

4.6 Telescope Aperture

1. The telescope shall have a primary mirror of diameter ≥ 4m.

2. The diameter of the equivalent clear aperture, taking into account the telescope pupil at the secondary mirror shall be ≥ 3.7m.

4.7 Wavelength Coverage

VISTA shall be capable of operating over the wavelength range 350 nm to 1000nm with the Visible Camera and 1.1 microns to 2.30 microns with the IR Camera (goals 1.0 micron to 2.45 micron).

Table 1 shows the nominal central wavelength (CWL) and bandwidths for the main filters anticipated [1, 2].

Band	U_L	B	g'	V	r'	i'	z'	Z_{IR}	J	H	K_S	K
Nominal CWL (μm)	0.375	0.44	0.48	0.55	0.62	0.76	0.90	1.05	1.22	1.65	2.16	2.18
Nominal Bandwidth FWHM(μm)	0.05	0.10	0.14	0.08	0.14	0.15	0.14	0.10	0.24	0.29	0.28	0.41

Table 1 VISTA Nominal Filter Passbands

4.8 Sky Coverage

4.8.1 Zenith Distance

1. The system shall operate and meet its specifications at zenith distances:

    - 2º to 67º in the azimuth range of South ±30º
    - 2º to 60º at all other azimuths

2. In the U_L band operation below a zenith distance of 60º is not required.

The region within 2º radius of the zenith is referred to as the zenith blind spot.

4.8.2 Visible Camera Field

1. The Visible Camera shall provide an available field of ≥ 2.05° diameter. This shall be unvignetted compared to the centre of the field, except for the outermost 10% by radius, which may be vignetted by up to 5% compared to the centre of the field.

2. The plate scale shall be ≥ 48 μm/arcsec.

3. The Visible Camera shall employ pixels of size of ≤ 0.28 arcsec.

[1] Z_{IR} & K are not SRD (AD 01) requirements

[2] The actual filter characteristics will be defined prior to specification for tendering

4. At least 80% of a rectangle on the focal plane of size 341x285mm shall be viewed by the science detectors of the Visible Camera. The dimensions of this rectangle may be modified such that its area is not reduced and its diagonal dimension is not increased.

4.8.3 IR Camera Field

1. The IR Camera shall provide an available field of ≥ 1.6° diameter. This shall be unvignetted compared to the centre of the field, except for the outermost 10% by radius, which may be vignetted by up to 5% compared to the centre of the field.

2. The plate scale shall be within the following values: 54.5 ≤ plate scale ≤ 60 μm/arcsec.

3. The IR Camera pixel size shall be within the following values: 0.30 arcsec ≤ pixel size ≤ 0.33 arcsec.

4. Using no more than 4 telescope pointings, the IR Camera shall observe a contiguous area of the sky ≥ 1.6 deg^2. This will be achieved using 16 detector arrays of approximate size 2k x 2k pixels on a 90% spacing.

4.9 System Image Quality

System Image Quality (SIQ) involves all system parameters including detector size and sampling, optical system image quality (including design and manufacturing errors), defocus, closed loop tracking error, guiding, misalignment, dome seeing, flexure, filter errors and thermal expansion, but not the free atmosphere seeing. For VISTA the SIQ is defined as SIQ= max (50%EED, 80%EED/1.54).

The figures in this section refer to the inner 90% (by radius) of the field of view. The SIQ in the outer 10% (by radius) may be degraded by no more than 10%.

The SIQ requirements shall be met for external wind speed ≤ 14 m/s. For wind speed higher than 14 m/s the SIQ shall not be degraded by more than 15%.

4.9.1.1 SIQ Visible Channel Requirements

The following Visible Camera SIQ requirements shall be met for an exposure of duration up to 30 minutes:

1. SIQ ≤ 0.4 arcsec, airmass ≤ 1.3, over bands B to z*'* (TBC at B)[1]

2. SIQ ≤ 0.4 arcsec x $(\text{airmass}/1.3)^{0.6}$, airmass > 1.3, over bands B to z*'*

3. SIQ ≤ 0.7 arcsec, airmass ≤ 1.3, at U_L

[1] The visible camera design is undergoing re-optimisation for filter location and the B band SIQ estimate is currently (26/09/01) up to 5% (50% EED) and 15% (80% EED) above specification near the centre of the field. Further optimisation prior to fixing optical prescriptions will be performed to reduce this.

4. The quadrupole of the telescope PSF after convolution with a circular Gaussian of 0.45 arcsec FWHM, and measured within the resulting 90% EED shall be ≤ 10% (averaged across the detector field of view) and ≤ 15% at any point across the detector field

5. The gradient in the (vector) PSF quadrupole after convolution shall be ≤ 3% across the width of any detector (width is ~ 8 arcminute) (TBC).

6. In U_L band the system shall deliver a SIQ ≤ 0.7 arcsec over the field of view covered by the detector at airmass ≤ 1.3.

Note: airmass = 1/cos(ZD), e.g. ZD = 40° gives airmass =1.3.

4.9.1.2 SIQ IR Channel Requirements

The following IR Camera SIQ requirements shall be met for an exposure of duration up to 30 minutes:

1. SIQ ≤ 0.5 arcsec, airmass ≤ 1.3, over bands J to K_s

2. SIQ ≤ 0.5 arcsec x $(airmass/1.3)^{0.6}$, airmass > 1.3, over bands J to Ks.

4.10 Astrometry

To achieve the Astrometric budget, requirements 4.10.1 & 4.10.2 apply.

4.10.1 Stability of the Visible and IR focal planes

4.10.1.1 Co-planarity

1. The pixels within the detector arrays shall be contained within two planes spaced by 50 µm across the focal plane.

2. The tilt relative to the focal plane of any one detector array shall remain stable within 0.0125 deg.

4.10.1.2 Thermal Expansion

Differential thermal expansion across the focal plane, leading to distortion of the array during operation shall be ≤ 4.5 µm.

4.10.1.3 Flexure

Differential flexure across the focal plane shall be
≤ 3 µm laterally
≤ 30 µm axially

4.10.1.4 Distortion

The centre of the pincushion distortion pattern shall remain stable relative to the focal plane within a circle of $\leq$ 180 µm radius.

4.10.2 Neutral Density Filter

A 'sandwich' filter, consisting of a Sloan r' passband + 3 mag neutral density, shall be provided for astrometric purposes[1].

4.11 Photometry

No explicit photometric requirements are defined in this document, but technical parameters are specified to ensure that the photometric requirements in the SRD can be achieved. These requirements are listed in Table 2.

Photometric Requirement	VTS Section
Basic Stability	
Shutter Timing	4.15
Detector and Controller non-linearity	5.2.7, 5.3.6
Detector and controller gain	5.2.7, 5.3.6
Flat field	5.6.5.8
Filter	
Opaque Filter	5.2.3, 5.3.2
Filter Stability	5.2.4 (5,6)
Positional accuracy	5.2.4, 5.3.3
Transmission stability measurement	5.10.3
Other	
Readout noise pickup test	6.1.8
Slew rotator when tracking open loop	5.1.17.5
Multi shutter operation during one exposure	5.2.5
Dome light tightness	5.6.5.2
Offset focus	5.1.18.1

Table 2 Photometric Requirements

[1] For astrometric calibrations, it will sometimes be necessary to be able to observe bright standards (R ~15) from a highly accurate catalogue, e.g. UCAC or FAME, for 30 second exposures without saturation.

4.12 Sensitivity

4.12.1 Sky Brightness Definitions

Values for sky brightness are assumed in the specifications of background and scattered light levels. These design values are:

1. The intrinsic dark sky brightness is assumed to be as follows:

Band	U_L	B	g’	V	r’	i’	z’	J	H	Ks
mag's/sq. arcsec	22.0	22.7	22.2	21.9	20.8	19.8	18.5	16.0	14.1	13.0

2. The intrinsic sky brightness at Full Moon is assumed to be as follows:

Band	U_L	B	g’	V	r’	i’	z’	J	H	Ks
mag's/sq. arcsec	17.0	19.5	19.0	20.1	19.8	19.1	17.8	16.0	14.1	13.0

4.12.2 Throughput

The System Throughput includes the effects of optics, filters and detectors, but not those of the atmosphere or degradation from dust or reflectivity decay of mirrors. The System Throughputs below make assumptions regarding the choice of detectors. The CCDs are assumed to be of the deep depletion, Astro Process, mid-band coated type. The IR arrays are assumed to be PACE devices (Note, Specifications for MBE devices are not yet available, but should be superior).

Under these assumptions[1], the System Throughput at each band using mirrors coated with protected silver shall be equal or greater than:

Band	U_L	B	g’	V	r’	i’	z’	J	H	Ks
System Throughput	0.035	0.32	0.40	0.41	0.38	0.31	0.20	0.22	0.33	0.36

4.12.3 Scattered Light

1. Light scattered from a 1st magnitude object 1.5° from the centre of the field shall not contribute >50% additional light over and above the dark night sky background.

2. For the Visible Camera, in any filter, the contribution to detector background from ‘locally scattered’ light, in any passband, shall not exceed 20% of the ‘natural sky’

[1] Note: - the requirements in the SRD are not met for U_L and B, but are exceeded at some other passbands, particularly H and K_S.

background (including moonlight scattered in the atmosphere) at angles ≥ 45˚ from Full Moon; and shall not exceed 50% at angles 25˚ - 45˚ from the Full Moon.

3. For the IR Camera, the contribution to detector background from 'locally scattered' light, in any filter, shall not exceed 5% of the 'natural sky' background at any angle ≥ 25˚ from the Full Moon; and it should not exceed 50% of the natural sky value at angles 15˚ - 25˚ from the Full Moon.

4.12.4 IR Thermal Rejection

1. To achieve a comparable performance to a cold stop IR camera, the effective emissivity of the system shall not be more than a factor of 1.3 higher than a perfectly baffled system (TBC).

4.12.5 Ghosting

Ghosting is defined as image artefacts caused by multiple reflections of objects in the field of view.

For both the Visible and IR Cameras:

1. Ghosting with up to two unwanted reflections shall not generate any images with diameter ≤ 75 arcsec.

2. From an 6^{th} magnitude star at any point in the field, the proportion of detector pixels in the focal plane that receive ghost flux exceeding 50% of the dark sky background shall be ≤ 0.1%.

4.12.6 Light Leakage

The cameras will be designed such that light leakage (being any light bypassing the science filters) shall be designed out and the maximum permissible increase in background from this source shall be 0.1%.

4.12.7 System Noise Characteristics

The power spectrum of the system noise shall be such that coadding images measured through a broad band filter shall improve the S/N as $(\text{time})^{0.5}$ between 15 minutes and 16 hours to within 10%.

4.13 Target Acquisition

4.13.1 Accuracy

4.13.1.1 Definition

In the context of target acquisition, the pointing accuracy is defined as that achievable in open-loop (i.e. without guiding) after correction with a suitable pointing model based on an appropriate catalogue.

4.13.1.2 Absolute Pointing

Absolute pointing accuracy shall be ≤ 3 arcsec rms[1].

4.13.1.3 Offset Pointing

Offset pointing is that achieved by moving a certain distance from a known accurate position.

1. For offsets of up to 2° on the sky in any direction, the relative pointing accuracy shall be ≤ 2″ (95% confidence).
2. For offsets where the guide star remains on the autoguider CCD, the relative pointing accuracy shall be ≤0.5 pixel (95% confidence).

4.13.1.4 Re-Acquisition

It shall be possible to reacquire objects across the field, previously observed at the same airmass, to the same position in the detector focal plane as before to an accuracy of <1 pixel (95% confidence).

4.13.2 Acquisition Time

Target acquisition speed defines the maximum time to acquire a new object and start tracking open loop. It includes motions of both the telescope mount and the enclosure. It does **not** include filter change, detector read-out or shutter overheads.

1. It shall be possible to acquire a target up to 60° from the previous position within 45s.
2. It shall be possible to acquire a target up to 15° from the previous position within 30s.
3. It shall be possible to acquire a target up to 2° from the previous position within 10s.
4. It shall be possible to acquire a target up to up to 10 arcmin from the previous position within 6s.
5. It shall be possible to acquire a target up to up to 2 arcmin from the previous position within 3s.
6. It shall be possible to acquire a target up to up to 20 arcsec from the previous position within 2s.

4.14 Tracking

4.14.1 Open Loop Tracking

Open loop tracking is defined as the image drift whilst not auto-guiding.

1. Open-loop tracking shall be accurate to within ≤0.2 arcsec over 15 seconds.
2. Open-loop tracking shall be accurate to within ≤0.5 arcsec over 5 minutes.

[1] This will be achieved by use of a pointing model

3. It shall be possible to track open-loop, objects moving at non-sidereal rates of 1 arcsec/s. The size of the zenith blind spot may be increased by 25% radius for non-sidereal tracking at the maximum rate and proportionally for lesser rates.

4.14.2 Closed Loop Tracking

1. Closed loop tracking is that performed whilst auto-guiding. Closed loop tracking performance is not defined explicitly, since it is one of the contributors to the SIQ (Section 4.9).
2. The autoguider shall be operational within 1 second of acquisition unless a further offset on the guide detector is required. If a further offset is necessary, the autoguider shall be operational within 5 seconds.

4.14.3 Non-sidereal Tracking

It shall be possible to track objects moving at up to 2 arcsec per minute relative to the sidereal rate. The additional tracking error shall not degrade the SIQ by more than 10%.

4.15 Exposure Requirements

4.15.1 Exposure Length

It shall be possible to make exposures of any duration specified between 1s (0.5s goal) and 1 hour.

4.15.2 Exposure Accuracy

1. The duration of exposures shall be within 0.1s or 1% of that requested, whichever is the larger.
2. The duration of the exposure at any point in the field shall be recorded to an accuracy of 0.01s or 0.25%, whichever is the larger (TBC).

4.15.3 Time Stamping

The absolute timing of each exposure shall be recorded so as to permit reconstruction of the absolute UT of mid-exposure at each pixel to ≤ 0.1 s

4.15.4 Exposure Rate and Readout

4.15.4.1 Visible Camera

Using the Visible Camera it shall be possible to start an exposure within 40s of the completion of the previous exposure (assuming no reconfiguration is required).

4.15.4.2 IR Camera

Using the IR Camera, it shall be possible to start an exposure sequence within 5s of the completion of the previous exposure sequence (assuming no reconfiguration is required).

4.15.4.3 Multiple Readouts per IR Exposure

Using the IR Camera, it shall be possible to execute and process, prior to data storage, multiple readouts per exposure. At least two such modes are anticipated:

1. Double correlated sampling where the array is reset and a first read is performed followed by a second read after a predetermined delay. Subtracting the first read from the second gives the data frame.
2. Read/reset/read sequences as defined in AD 02.

During an exposure it shall be possible to perform individual read-outs at the rate of one every 10s.

4.15.4.4 Rapid Sequence of IR Exposures

1. Using the IR Camera and looking at the same point on the sky through the same filter, it shall be possible to execute a sequence of exposures such that the delay between completing one exposure within the sequence and starting the next shall be ≤ 1s.

2. It shall be possible to perform data acquisition and store IR exposures within a sequence at a rate of one every 10s (raw data) or 20s (coadded or NDR data).

3. The number of exposures within a sequence shall be defined in advance.

4.16 Data Handling

4.16.1 Stored Data

4.16.1.1 Visible

1. Data from the Visible Camera shall be stored in their raw form without any processing.

2. Using the Visible Camera it shall be possible to perform data acquisition and store exposures at a sustained rate of one exposure per minute over 14 hours. (This is a requirement on data acquisition and storage alone).

4.16.1.2 IR

It shall be possible to store data from the IR Camera in any of the following forms:
1. Raw data with or without differencing, 2 bytes/pixel
2. Coadded, 4 bytes/pixel
3. Coadded read-reset-read sequence, 4 bytes/pixel

Any set of data shall be stored in one form only.

Using the IR Camera it shall be possible to perform data acquisition and store exposures at a sustained rate of one exposure per 10s over a period of 14 hours. (This is a requirement on data acquisition and storage alone.)

4.16.2 Writing to Disk

1. The system shall ensure that adequate free disk space is available to store the data when an exposure is initiated, so long as the maximum data volume per night as stated in Sections 4.15.4.1 and 4.15.4.2 is not exceeded. If adequate disk space cannot be made available, e.g. due to an equipment or operational failure, the exposure shall not be initiated.

2. It shall be possible to store data to disk whilst concurrently moving the telescope and reconfiguring the camera.

4.16.3 Archiving

All science and calibration exposures shall be stored to disk with adequate meta data to allow subsequent full data reduction.

All exposures shall be stored in the format compliant with ESO's Data Interface Control Document (AD24).

4.16.4 Transport

The system shall write data to media as agreed with ESO.

4.16.5 On-line Storage

Data from the previous 2 nights shall be stored on-line. On-line storage is defined as storage accessible without physical exchange of media.

4.16.6 Near-Line Storage

Data from the previous 30 nights shall be stored near-line, e.g. an optical disk or tape autoloader. Near-line storage is defined as that which allows data to be retrieved within 10 minutes of its request and without manual handling of media. It shall be possible to submit batch requests for retrievals from near-line storage.

4.16.7 Data Quality Assessment

1. The quality of data shall be assessed automatically by noon the following day.

Data assessment shall comprise metrics including the following:

a) bad pixel identities
b) dark currents
c) system noise
d) representative point spread functions
e) photometric zero points
f) sky brightness levels

2. Data assessment shall properly take account of non-operational detectors, both individual pixels or entire detector arrays.

4.16.8 Local Data Reduction

1. The VISTA system shall allow visiting astronomers to read and process data from VISTA within 10 minutes of their being acquired by means of a local workstation. This shall not interfere with the observing process (including data acquisition, pipeline data reduction and data archiving) either in functionality or performance.

2. A workstation shall be provided for use by visiting astronomers.

3. Use of the workstation shall not impact the performance of VISTA's data acquisition, pipeline data reduction and data archiving processes. (SRD 7.7/1)

4. Authorised personnel shall be able to install new application software for use by visiting astronomers, provided it can be compiled and run on the specific hardware and complies with any constraints imposed by ESO. (SRD 7.7/1, 7.1/5)

5. Subject to any necessary authorisation, a visiting astronomer may be allowed to use their own computer system. It shall be possible to export data from VISTA to this computer system, if it complies with a predefined specification, but this computer system shall not have any other access to VISTA data or control systems.

4.17 Thermal Control

Any systems capable of introducing thermal seeing effects must fulfil the following requirements:

1. Systems above primary mirror level shall not have a surface temperature which differs more than +1.5°C / -3°C from the ambient air. This assumes 2m/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.
2. Systems below primary mirror level shall not have a surface temperature which differs more than +1.5°C / -5°C from the ambient air. This assumes 1m/sec 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.
3. All concentrated heat sources generating > 100 W shall be cooled.
4. Dispersed heat generating systems with combined heat sources of 200 W shall be actively cooled.

4.17.1.1 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 on the telescope structure, the M1, M1 Cell and the M2 Unit.
In addition air temperature at the M2 Level and at the M1 level shall be measured.

5 VISTA Subsystem Characteristics and Requirements

The following sub-system requirements define specific design data, characteristics and performance that apply to the various assemblies and major parts of VISTA. They are complementary to the requirements of Section 4 of this Technical Specification.

Many sub-system requirements are application specific and have been derived from the VISTA conceptual design. As the detailed design and manufacture progresses, some requirements may need modification. In the event of conflict between the contents of this section and the requirements of Section 4, Section 4 requirements shall take precedence.

5.1 Telescope Requirements

5.1.1 General Characteristics

The VISTA design is based on a 4 metre class "Alt-Az" telescope with a camera mounted at the Cassegrain focus. The use of an f/1 primary mirror allows for a telescope tube of short dimensions. The mounting of the camera onto the Cassegrain field rotator is carried out with the telescope horizon pointing. This contributes to shorten the length of the fork and lower the altitude axis position. These features enable the telescope to be extremely compact with high fundamental natural frequencies.

The telescope is based on active optics. The active elements used in order to control the wavefront are the primary and secondary mirror. The primary mirror is a meniscus of low expansion material, approximately 170 mm thick. Its optical shape is controlled by means of 84 axial force actuators located in the M1 Cell. The secondary mirror is a light-weighted mirror whose position can be actively controlled along 5 axes for focusing, correction of decentre, coma and fine alignment. In order to keep the image quality within the specified requirements, image analysis will be performed and the corresponding force pattern on M1 and positions of M2 will be adjusted.

The telescope will rotate around the azimuth axis by means of direct drive motors mounted at the base of the fork, and hydrostatic bearings. The base of the fork will also constitute the azimuth platform. This protects the azimuth hydrostatic bearings and track. It will also be used for the installation and removal of the M1 Cell and the cameras.

The altitude axis will comprise of two bearings mounted on the fork structure. The tube interfaces the altitude bearings through trunnions mounted on a centre-section. Serrurier trusses, mounted onto the centre-section will support the top ring. The M2 Unit will be mounted on 4 spiders, equipped with alignment capability. Due to the squat nature of the telescope and the balancing requirement, the mirror cell will be rigidly connected to the centre-section.

For maintenance purposes the telescope tube will be locked in a horizontal position (e.g. camera exchange or M2 maintenance) or vertical position (e.g. M1 Cell mounting) by means of manual locking pins.

The design will be optimised to attain equilibrium with the ambient temperature. Heat sources will be cooled and flushing of the primary mirror will be achieved through openings at the level of the M1 Cell.

5.1.2 Telescope Design Volume

The available design volume allocated for each telescope work-package shall be defined by space envelope drawings. Figure 9 shows a simplified view from such a drawing.

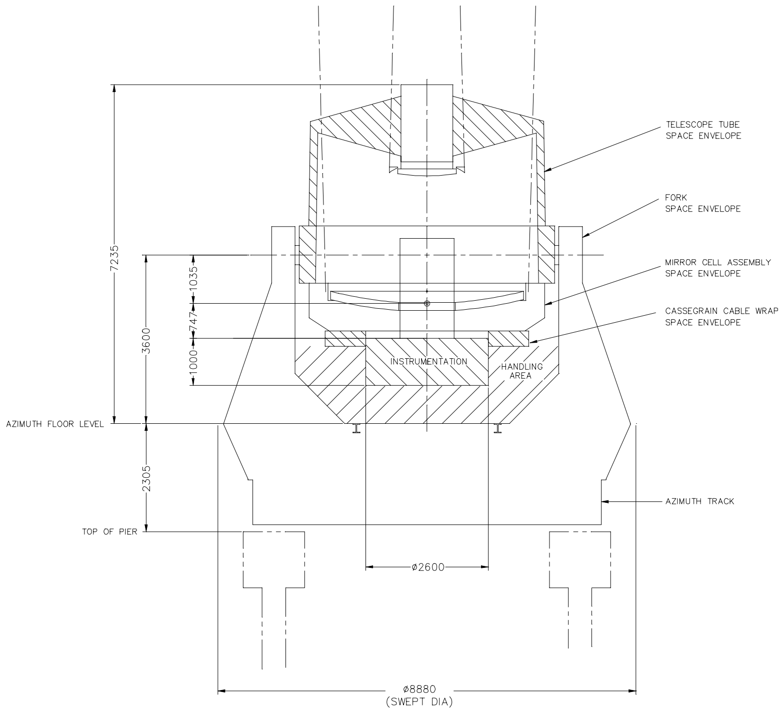

Figure 9 VISTA Preliminary Telescope Design Volume

5.1.3 Telescope Mass

1. The expected masses of the telescope in operational conditions are:

- Total telescope mass (above pier)	105 tonnes
- Moving mass on Azimuth axis	90 tonnes
- Moving mass on Altitude axis	45 tonnes
- Moving mass on Cassegrain Rotator	3.5 tonnes

2. The mass of the heaviest sub-assembly to be lifted during maintenance shall not exceed the capacities of the enclosure crane (10 tonne-TBC)
3. There shall be provision for the addition of masses on the cell and top-end to enable the balancing of the telescope.

5.1.4 Telescope Dynamic Performance

The design of the telescope and of its parts shall be driven by considerations of achieving a high eigenfrequency of the system. The minimum requirement of the locked rotor frequency is:

- First locked rotor frequency (Alt, Azimuth) ≥ 12 Hz

The locked rotor frequency is computed assuming that the stator and the rotor of the axis controlled are locked.

The values above do not take into account the effect of the telescope pier. They do take into account the azimuth track and the hydrostatic bearings.

5.1.5 Telescope Optics Requirements

The VISTA telescope is based on a quasi-Ritchey Chretien design with a large field of view and an undersized secondary representing the stop of the optical train. The residual third order spherical aberration for on-axis images introduced in the two-mirror design is compensated for by the field corrector lenses located in the cameras. Figure 10 shows the telescope optical layout.

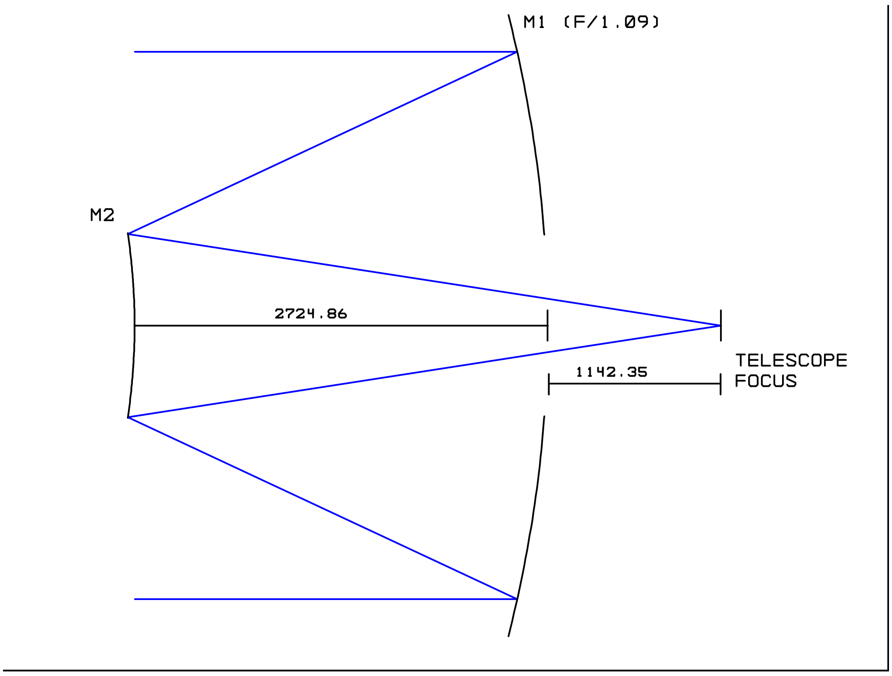

Figure 10 View of the telescope Optical Layout

The baseline telescope optical parameters are defined as follows:

- Focal length: ~12 m
- Entrance pupil diameter: ~3.7 m
- Primary mirror focal ratio: ~1.09

- Telescope focal ratio: ~3.2
- Back focal distance: ~1142.3mm
- Plate scale: ~58µm/arcsec
- Obscuration diameter (defined by M2 baffle): ~1.6 m

5.1.5.1 Optical Design Data

The baseline nominal characteristics of M1 and M2 are described in Table 3

Components	Radius of Curvature (mm)	Conic Constant K	Clear Aperture Diameter (mm)	Separation (mm)
M1	8094.22	-1.129792	4020.0	-2724.86 M1/M2
M2	4018.81	-5.548792	1240.6	3867.21 M2/focal plane

Table 3 Optical design data for M1 and M2

5.1.6 M1 Blank Characteristics

The M1 mirror blank will be constituted by a machined meniscus. Possible materials to be used for the blank manufacturing are: Zerodur, Astrosital, and Corning ULE™ Titanium Silicate low expansion material ("ULE"). The concave surface will be machined aspherical, close to the mirror final figure, in order to shorten the polishing time.

The major geometrical parameters of the blank are as follows:

- Nominal outside diameter of the blank 4100 mm
- Tolerance on nominal diameter (out of roundness) ± 0.5 mm
- Diameter of centre hole 1200 mm
- Concentricity of centre hole with outer diameter 0.5 mm
- Nominal thickness 170.5 mm
- Radius of convex surface ≈ 8.3 m
- Surface finish (concave surfaces, edges) D76

Preliminary values of residual stresses (compressive) are:

- Mean absolute value: 10 nm / cm
- Maximum absolute value: 20 nm / cm

Coefficient of Thermal Expansion (CTE) $0 \pm 0.05 \cdot 10^{-6}$ /K
Homogeneity of thermal expansion coefficient in the blank: $\leq 0.02 \cdot 10^{-6}$ /K

5.1.7 M1 Mirror Optical Characteristics

The primary mirror of VISTA is an active mirror. The optical specification takes into account the active optics correction capability of the system. This specification covers:

Low spatial frequency errors:
These are the errors that can be removed from the final figure of the M1 mirror by use of the active optics capability of the system.

High spatial frequency errors:
These are the residual surface errors after removal of the low spatial frequency errors defined above.

5.1.7.1 M1 Mirror Optical Prescription

The parameters herein are based on a blank of 4100 mm outer diameter.

- Useful external optical diameter 4020 mm
- Useful Internal optical diameter 1250 mm
- Radius of curvature at vertex (at T=10 °C) 8094 mm ±20 mm
- Conic constant K $-1.129792+1.455\cdot10^{-5}\cdot(R_{measured}-8094) \pm 5\cdot10^{-4}$

The specification on the radius of curvature and on the conic constant may be obtained taking into account the provision for correction allowed under the following section .

5.1.7.2 Low Spatial Frequency Errors

Low spatial frequency errors are defined as follows:

- The first 8 (TBC) natural modes of the M1 mirror;
- The curvature error
- The conic constant error.

Active axial forces may be added to or subtracted from the nominal fraction of mirror weight at each axial support location in order to remove the low spatial frequency errors from the measured wavefront.

The maximum allowable active force at each point for correction of the low spatial frequency error is +/-60 N. (TBC)

5.1.7.3 High Spatial Frequency Errors

High spatial frequency errors are the residual wavefront errors after removal of the low spatial frequency errors defined above.

The high spatial frequency errors are defined as rms slope error of the wavefront and shall be ≤ 0.06 arcsec rms.

5.1.7.4 Microroughness

The micro roughness of the polished surface shall be random and ≤ 2nm.

5.1.7.5 Interface to the M1 Cell

The axial and lateral interfaces to the M1 Cell are realised by means of bonded Invar pads. The lateral pads (24) will have a recess where the rods of the lateral supports of the M1 will be attached. The interface design will only be able to transmit push forces to the mirror back.

The basic principles and layout of the interface between the primary mirror and the M1 Cell is described in Figure 11. Additional interface points may be defined for the lateral restraints.

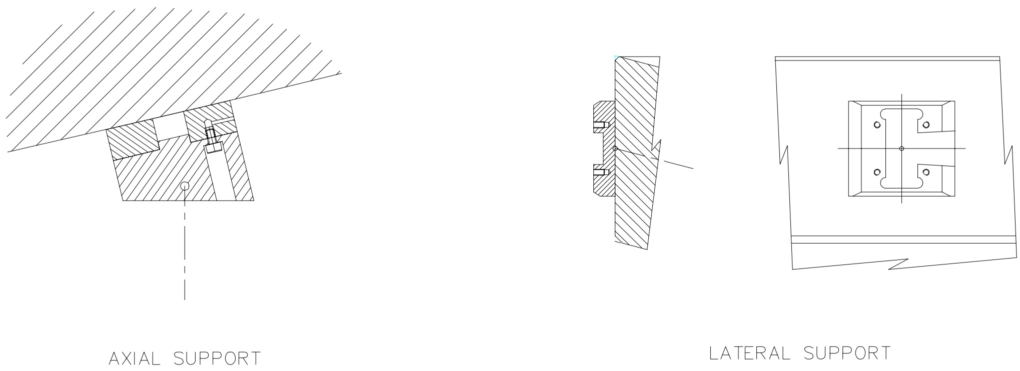

Figure 11 Primary Mirror and Interfaces

5.1.7.6 Polishing requirements

The primary mirror shall be polished on a support system equivalent to the final support system. The support system shall have the same geometry and interfaces as in the final support system of the M1 Cell, in order to have the same print-through as in the telescope.

The support system shall be equipped with remotely adjustable active force supports, equipped with load cells whose final accuracy shall be ≤1N.

The verification of the Optical Performance Requirements shall be done with the M1 mirror pointing at zenith with the mirror on the polishing support system.

5.1.8 Secondary Mirror Assembly

5.1.8.1 M2 Optical Design Characteristics

- External diameter (also physical diameter) 1241 mm
- Useful Internal diameter 520 mm
- Radius of curvature at vertex $R_{M2} = 4018.81 \pm 2$ mm
- Conic constant K_{M2} $-5.548792 - 0.00101 \cdot (R_{M2measured} - 4018.81) \pm 0.001$[1]

The mirror will be polished up to the external rim, except for a small chamfer to avoid chips (typically 0.25mm).

[1] This value includes the accuracy of measurement

5.1.8.2 M2 Optical Quality

The specification applies to the mirror after integration on its support system, over any operational orientation. The VISTA telescope will be equipped with an active primary mirror able to correct low spatial frequency errors caused by the secondary mirror. Therefore the optical specification of M2 distinguishes between passive and an active quality.

1. Optical quality in Passive mode

The optical quality in Passive Mode includes all surface errors with the exception of curvature and conic constant. (Active optics correction not in operation). The optical quality is expressed in terms of the rms slope error of the mirror surface. The requirement for the optical quality is:

The rms slope error of the wavefront after removal of the curvature error (focus) and of the conic constant error (third order spherical aberration) shall be ≤ 0.35 arcsec rms.

2. Optical quality in Active Mode:

The optical quality in active mode includes only the high spatial frequency errors, which are the residual surface errors which are not removed by the active optics system. The high spatial frequency errors are those remaining after subtraction of:

- the curvature error (focus),
- the conic constant error,
- the first 8 (TBC) natural modes of the VISTA primary mirror.

The high spatial frequency errors are defined as *rms slope error of the wavefront*. The requirement is:

The rms slope error of the wavefront shall be ≤ 0.15 arcsec rms**.**

5.1.8.3 Micro Roughness

The micro roughness of the polished surface shall be random and ≤ 2nm

5.1.8.4 M2 Assembly Mechanical Characteristics

1. The mirror blank will be of lightweighted Zerodur or similar ultra low expansion glass or ceramic.
2. The mass of the mirror shall be ≤ 150 kg.
3. The M2 assembly comprises the M2, M2 supports, M2 Cell and safety back-up supports.
4. The first eigenfrequency of the M2 assembly rigidly supported at the M2 Electromechanical Unit interface is expected to be ≥120 Hz.
5. The connection between the mirror and the cell shall be done with rigid supports (rather than astatic levers) in order to guarantee sufficient stiffness and low hysteresis. The baseline number of support points is 3. If additional support points are needed to obtain the optical quality they may be realised with additional non-constraining (e.g. spring) devices.
6. Thermal effects on the mirror figure shall be considered.

7. The connection between the support system and the mirror substrate shall be optimised for safety. Bayonet type of connections, secured against opening are preferred (epoxy bonding or other) on image quality and stress shall be studied.
8. A safety backup support system shall be included in the M2 Assembly to prevent the mirror or major part of it from falling in case of failure. Under normal operation the safety backup support shall not influence the mirror performance.
9. The M2 Cell will be used for interfacing the M2 Electromechanical Unit and for all handling operations.
10. Features for the safe and convenient handling of the mirror shall be provided.
11. The M2 Mirror will be provided with a flat area at the centre and a cross hair for alignment purposes.
12. All items permanently attached to the mirror shall be compatible with high vacuum applications.

5.1.9 Telescope Structure

The telescope structure is composed of the following main assemblies:[1]

Azimuth axis part:

- Azimuth track and bearings
- Azimuth drive system
- Cable wrap
- Fork, including azimuth floor
- elevation bearings
- elevation drive system

Telescope Tube structure

- Centre-section
- Cable drape
- Serrurier struts
- Top ring
- Spiders

Limit switches and other safety provisions are provided in the system to define the rotational limits and limit hazards in case of errors or malfunctions. Figure 9 (page 40) shows the preliminary design volumes.

5.1.9.1 Azimuth track and bearings

The azimuth bearing supports the telescope axially and restrains it radially. Hydrostatic bearings shall be implemented for both the axial component and the radial component of the load. The baseline number of axial bearings is 6. The bearings will be located below shoes mounted on the bottom of the fork, whose location is optimised for stiffness. The number of

[1] (The M1 Cell, the M2 unit and the instrument mount are treated separately)

radial bearings will be determined during the detailed design. The radial bearing shall be preloaded.

The general requirements are:

- Diameter of Track (TBC) — centre line of bearings @6000mm
- Stiffness hydrostatic bearings — driven by telescope first frequency
- Friction (stick, and slip at max tracking speed) — ≤ 120 Nm
- Earthquake restraints shall be provided.
- The hydrostatic system shall be designed in a manner that dampens pressure fluctuations and maintains the film thickness to an accuracy better than 10 microns.
- In case of failure of the oil supply no damage shall occur to the track or the hydrostatic pads.
- Provisions shall be taken for avoiding oil contamination.

5.1.9.2 Cable wrap

The cable wrap will be mounted on the yoke below the azimuth floor. The cable wrap constitutes the limit to the azimuth axis rotation. The cable wrap shall be equipped with a dedicated drive system and shall be synchronised with the telescope azimuth axis.

The angular position of the cable wrap shall be slaved to the azimuth drive.

The cable wrap shall have capacity for permanent installation of all services for the telescope, Cassegrain rotator, IR and Visible cameras.

5.1.9.3 Telescope Fork and Base

1. The telescope forks and base comprise all systems between the azimuth drive systems and the altitude drive system.
2. The dimension of the fork shall be compatible with the allowable design volumes Figure 9 (page 40)
3. The stiffness of the fork shall be such that the variation in the altitude thrust hydrostatic bearing oil film thickness shall be less than 10 microns and the variation in the direct drive air gap shall be less than 0.1 mm. Should roller bearings be utilised for the altitude axis, this requirement applies to the thrust bearing compliance.
4. The fork will be optimised for best stiffness/mass performance.
5. The forks and base shall allow easy access to bearings, encoders and all components of the drives.
6. A continuous azimuth floor at level –2565 (TBC) with respect to the primary mirror pole and diameter 8880 (TBC) meeting the floor loading defined in Section 5.6.4 shall be mounted from the base structure.
7. The azimuth floor shall include provision for support, guiding and locking in position of the primary mirror and camera handling carts.
8. The azimuth floor shall provide a safe working surface for inspection and maintenance access to components on the mirror cell and instrument mount and camera.

5.1.9.4 Altitude bearings

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

- Minimum stiffness compatible with dynamic requirements.
- Friction torque ≤ 150 Nm
- The bearing system shall provide restraint against earthquake loads.

5.1.9.5 Telescope tube

The allowable design space of the telescope tube is defined in Figure 9 (page 40)

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 rounded sections shall be used.

The design shall be based on a centre-section, interfacing the M1 Cell and the altitude bearings and four Serrurier trusses.

The top ring shall be mounted to the Serrurier trusses through flanged connections

The M2 Unit shall be supported on spiders. Their location shall be coincident with the location of the vertex of the telescope tube Serrurier trusses.

The maximum thickness of the spiders shall be 32 mm. Cables and insulated coolant tubes shall be run in channels above the spiders without further obstruction of the optical path.

5.1.9.6 Telescope tube structural performance

Dynamic performance: compatible with first locked rotor frequency and first free rotor frequency.

Static deflection of the Telescope Tube: The change in deflection in the range 0 – 70 degrees zenith distance shall not exceed the values in Table 4. This assumes that the M1 Cell and the M2 Unit are rigid.

Components	Max Displacement Y (Lateral)	Max Displacement Z (Focus)	Max Tilt (about X)
M1 vertex	160µm	450 µm	16 arcsec
M2 vertex	660 µm	500 µm	17 arcsec

Table 4 Maximum Static Deflection of Telescope Tube

5.1.9.7 Altitude Axis Cable Drape

A cable drape system shall be implemented on the altitude axis. One or more drapes shall be mounted adjacent to the trunnions on the centre-section. The drapes shall be driven by the main altitude axis and the torque loadings from the drape must be taken into account.

The cable drape system shall have capacity for permanent installation of all services for the telescope, Cassegrain rotator, IR and Visible cameras.

5.1.9.8 Adjustment and balancing

The top ring shall have provision at the ends of the spiders to allow initial alignment (in plane, along the optical axis and in tilt of the secondary mirror assembly. The typical alignment capabilities are:

- Along the optical axis +/-10 mm
- In plane +/- 5 mm
- resolution 0.05 mm

The top-end ring shall have provision for telescope balancing.

The attachment point of the M1 Cell to the telescope centre-section is expected to have the following adjustment capabilities:

- Along the optical axis +/-3 mm
- In plane +/- 2 mm
- Resolution 0.05 mm

5.1.10 Alt/Az Axis Control

5.1.10.1 Reuse of ESO Software

The altitude and azimuth axes shall be controlled from separate LCU's, running identical software to the VLT axis control system. This software shall be configured to VISTA's specific requirements.

5.1.10.2 TCS Interface

The Axis Control System shall be controlled by the TCS, using the same interface definition as used on the VLT, modified in detail only if necessary.

5.1.10.3 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.

5.1.10.4 Control Algorithms

The control algorithms shall be as implemented and documented in ESO software release.

It is anticipated the algorithm will uses 3 position controllers, switched into use as the position error reduces, using square root, polynomial and PI compensation techniques. An inner velocity loop with PI compensation will also be used.

If necessary, notch filtering and low-pass elements may be used to compensate for structural resonance.

5.1.10.5 Position measurement

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.

The measurement accuracy of the encoders shall be sufficient for the system to meet the position accuracy of the telescope.

1. The encoders' measurement accuracy after compensation shall be < 0.1 arcsec rms.

2. Resolution of the encoders shall be < 0.01 arcsec.

5.1.10.6 Velocity Measurement

The velocity signal will be obtained by digital differentiation of the position measurement data.

5.1.10.7 Motors

1. The motors shall be of the direct-drive type.
2. The system shall have sufficient margin between its rated output torque and the computed maximum torque for operational and survival. The margin shall be sufficient for operating the telescope also in case of failure of 1/3 of the motors.
3. The <u>preliminary</u> characteristics for the Azimuth axis are:

- Number of stators	6 (TBC)
- Nominal torque	> 10 kNm
- Cogging torque	≤ 2% of max torque
- Ripple torque	≤ 2% of torque

4. The <u>preliminary</u> characteristics for the Altitude axis are:

- Number of stators	6 (TBC)
- Nominal torque	> 6 kNm
- Cogging torque	≤ 2% of max torque
- Ripple torque	≤ 2% of torque

5.1.10.8 Telescope Angular Range

The angular ranges are defined in accordance with the system of co-ordinates and the origin as per AD 03 (Basic Telescope Definitions)

5.1.10.8.1 Kinematic ranges

Azimuth axis

- Azimuth zero	South, increasing towards East
- Azimuth angular range	+135° to - 315°

Altitude axis (limited by hard stops)

- Altitude zero	Tube pointing to horizon
- Altitude angular range (End stop)	-1° to +90.5° (TBC)

5.1.10.8.2 Operational conditions

Zenith Blind Spot (Tracking)	≤ 4.0° diameter
Azimuth	
- Azimuth range (SW limit)	+130° to -310°
- maximum Azimuth tracking velocity	480 arcsec/s
- maximum Azimuth tracking acceleration	10 arcsec/s^2
- maximum Azimuth slew velocity	2.0°/s
- maximum Azimuth slew acceleration	0.5°/s^2
Altitude	
- Altitude range (SW limit)	+20° to +88°
- maximum Altitude tracking velocity	17 arcsec/s
- maximum Altitude tracking acceleration	0.5 arcsec/s^2
- maximum Altitude slew velocity	2.0°/s
- maximum Altitude slew acceleration	0.5°/s^2

5.1.10.8.3 Maintenance conditions

The telescope shall be able to enter into the full kinematic range in maintenance mode. Between the SW operational limit and the end stops there shall be additional limits (Software limits, hardware proximity switches and interlock stops). End stop shall be provided with damping characteristics to limit the acceleration of the structure.

5.1.10.9 Telescope Limits

1. Software Limits. Software limits shall decelerate the telescope to a complete stop before it reaches the hardware switch.
2. Hardware Limits. In the event that the telescope reaches the hardware switches, the latter shall actuate the brakes such that the telescope can be decelerated from maximum velocity to a complete stop before it reaches the end stops.
3. End Stops. Cushioned end stops shall be capable of decelerating the telescope from maximum velocity to a complete stop without damage to the telescope.

5.1.10.10 Telescope Lockout

Locking pins shall be provided which will prevent rotation about the azimuth axis caused by motor torque, unbalance due to disassembly or reasonable external loading. The locking pins will be part of the Telescope Interlock System. The pins shall have provision to be locked out. The locking pin positions shall be used for alignment of the telescope with the mirror and camera handling equipment.

5.1.10.11 Brakes

Brakes shall be provided both on altitude and azimuth axes. The systems shall be equipped with status detection capability for interlock purposes. The systems shall be capable to prevent rotation about the axis when the telescope is not in use; stopping the rotation in emergency; or when limit switches are actuated. The brake systems shall have the capacity to resist the maximum motor torque combined with survival wind loading.

5.1.10.12 Auxiliary drives

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

5.1.11 Primary Mirror Cell

The primary mirror cell has the function to support the primary mirror, and to provide an attachment to the Cassegrain rotator and cable wrap.

The primary mirror will be kinematically supported by means of a distributed axial and lateral support system. The axial support system is comprised of 84 active axial supports, connected to the mirror by flexural or similar de-coupling device. The 84 supports will be disposed in 4 ring as per Figure 12**.** Three axial definers will be used out of the 84 supports.

By changing the force pattern applied to the mirror back, by the axial supports, it is possible to modify the mirror figure. The supports are servo controlled. A load cell is used to guarantee the accuracy of the force produced and applied to the mirror. The system will be addressed by a specific bus from the M1 Cell LCU.

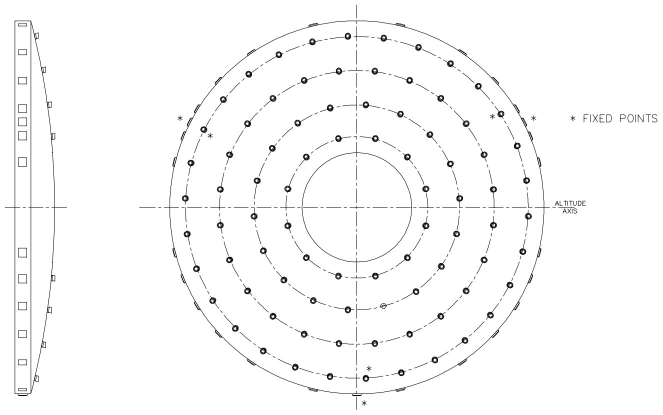

Figure 12 Primary Mirror Support Layout

The lateral supports are distributed according to the Schwesinger solution[1]. There will be 24 lateral supports acting at the external rim. The baseline solution for the lateral supports is to use pneumatic force actuators based on rolling membranes.

The actuator system is astatic, requiring the mirror position in the lateral plane to be defined by means of three lateral definers equipped with load cells.

The mirror will be protected against earthquakes by safety devices ensuring that the mirror stresses will be always lower than the limit specified in Section 8.

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.

The cell shall have provision for telescope balancing. The general characteristics and performance of the M1 cell are defined in Sections 5.1.11.1 to 5.1.11.5.

5.1.11.1 Design Space Envelope

The design space envelope cell is approximately five metres in diameter and 0.6 metres deep (Figure 12).

5.1.11.2 M1 Cell Stability Requirements w.r.t M1

The primary mirror shall be held stable in the M1 Cell within the following limits:

<u>M1 Position stability under gravity</u> (zenith to horizon)

Along the optical axis	≤0.25 mm
Lateral plane	≤0.25 mm
Tilt	≤10 arcsec

[1] RD 03 Section 3.4.3

Position adjustment of M1

Range along the optical axis	+/-1.5 mm
resolution	≤0.05 mm
Range in the lateral plane	+/-1 mm
resolution	≤0.020 mm
Tilt range	+/-10 arcsec
resolution	≤0.5 arcsec

5.1.11.3 Axial Support Requirements

There are 84 axial supports disposed in four rings, with symmetry of 120 degrees of which 81 are active and three are position definers.

Each active support shall incorporate a load cell and the force generated shall be controlled in an individual closed loop. Various solutions may be adopted. Typical examples are a pneumatic support using bellofram membranes (Gemini, UKIRT) or a motorised spring loaded device (ESO VLT).

The axial definer supports shall be equipped with force limiting devices to prevent over-stressing the mirror in case of system malfunction. Each axial definer shall incorporate a load cell. The required value of force in each definer shall be controlled in closed loop to ensure that the gravity and external axial loads are equally applied to all 84 supports. External moment loads will be resisted by generation of additional support forces. These will be proportional to the pitch circle radius of the support and the sine of its angular position with respect to the moment.

Performances

- Force Range	0 to 900 N
- Absolute accuracy	± 1.5 N (TBC)
- Repeatability	± 0.2 N (TBC)
- Minimum step	± 0.5 N
- Limiting force of axial definers	5000 N
- Minimum stiffness of axial definers	30.10^6 N/m

5.1.11.4 Lateral Supports Requirements

There shall be 24 lateral supports in a Schwesinger style arrangement on the periphery of the mirror. The position of the supports shall be optimised to minimise the surface errors generated by the lateral support loads.

The baseline design is a double acting (push-pull) pneumatic rolling diaphragm sealed pneumatic cylinder. Tangential links, lateral definers, shall provide the lateral component of kinematic location. The lateral definers shall incorporate load cells. The measured forces shall be used to control the lateral supports in a closed loop to balance gravity and external lateral loads.

The supports shall ensure easy disconnection for mirror removal and repeatable assembly.

Lateral supports Performance

- Force range (push or pull) 0 to 2700 N
- Absolute accuracy +/-5 N
- Resolution 0.8 N

Lateral definer performance

- Total stiffness $1.2 \cdot 10^8$ N/m
- Resolution of force measurement 0.5 N
- Maximum force limiter setting 5000 N

The linkage between the mirror and supports shall use low-friction rolling element bearings in the pivots. The performance shall be such that

- Max frictional torque in the linkages at mirror rim ≤150 Nmm

5.1.11.5 Requirement for the Cassegrain Interface Flange

Position stability under gravity (0° to 70°zenith distance) with respect to the attachment flange to the telescope centre section.

- Vertical direction 0.5 mm (TBC)
- Lateral plane 0.15 mm
- Tilt 15 arcsec
- Planarity (static) 20 µm

Differential deflection between the Cassegrain flange and the primary mirror vertex shall not exceed 0.3 mm (TBC).

The Cassegrain flange shall have provisions for ensuring repeatability of the mounting of the Cassegrain rotator.

5.1.12 M1 Cell Thermal requirements

5.1.12.1 Cooling of heat sources

The total heat transferred to the ambient air by heat generating sources below the primary mirror shall not exceed 300 W.

5.1.12.2 Thermal Conditioning of Primary Mirror

Active cooling of the primary mirror is not anticipated. The primary mirror temperature will be regulated by means of the air conditioning system in the enclosure. The design of the telescope (telescope structure and M1 Cell) shall accommodate openings for flushing the primary mirror in operation.

5.1.13 M1 Control

5.1.13.1 TCS Interface

The M1 Control System shall run on an LCU controlled by the TCS, using the same interface definition as used on the VLT, modified in detail only if necessary.

5.1.13.2 Hardware Interface

Hardware shall be controlled via signals transmitted from the M1 LCU on one or more Canbus (TBC).

5.1.14 M2 Electromechanical Unit

5.1.14.1 Functional Description

The M2 electromechanical unit (EMU) function is to support the secondary mirror and to maintain its position in a controlled manner. It shall be equipped with its own drives, sensors and electronics.

The baseline EMU consists of:

A rigid <u>mechanical structure</u> connected to the telescope spiders by means of bolted metallic flanges having the function of physically supporting and containing the other assemblies. The stiffness shall be sufficient to minimise the effects transmitted to the kinematics by the gravity loads originating at the interface with the spiders. The housing shall be cylindrical in order to reduce the wind drag. To access the assemblies inside the housing for maintenance and test, removable covers and ports shall be utilised.

A <u>focusing mechanism</u> consisting of a servo-controlled actuator generating a movement of the M2 mirror along the telescope axis. During observation it shall be possible to move the M2 mirror in discrete steps under the command of the Telescope Control System.

A <u>centring mechanism</u> constraining the movement of the mirror on an ideal sphere centred on the M2 centre of curvature. During observation it shall be possible to move the mirror in discrete steps under the command of the Telescope Control System in order to maintain the optical alignment of the telescope.

A <u>slow tip-tilt mechanism</u> shall adjust the mirror around two axes orthogonal to the mirror optical axis close to the mirror pole.

A <u>Sky baffle</u> to obstruct an annular region of the sky around the secondary mirror.

The Control System consisting of the Local Control Unit and all the electronic hardware and software (including Power supply) used to control and monitor the operation of the M2 EMU, and to interact to the Telescope Control Software. If necessary, and reasonably justified, an external electronic cabinet, to be positioned at the telescope centre-section may be used to house bulky components (example: power supply).

The thermal control system is used to cool heat sources in order to guarantee safe operation and to avoid heat losses to the ambient air.

5.1.14.2 Interface Requirements

Interface to the telescope structure

The mechanical interface with the telescope structure shall be designed and manufactured in such a way to allow a good reproducibility of position of the M2 EMU after dismounting and re-mounting. In particular it requires:

- Rigid body position repeatability +/- 100 microns in all directions
- Rigid body tilt +/-40 arcsec

The fluid, power and communication interfaces between the telescope and the M2 EMU shall make use of the standard Service Connection Point as defined in AD 06**.** The SCP shall be mounted at the telescope centre-section. Power, fluid and communication lines shall be routed in channels along the spiders. If additional connectors are used, they shall be located either in the shadow of the M2 EMU (or M2 Baffle) or in the shadows of the spiders.

An example of a possible I/F design with the telescope structure is given in RD01.

Handling Interface

The M2 EMU shall be equipped with hoisting I/F points in order to be handled in horizontal position with the enclosure crane

5.1.14.3 Co-ordinate Systems

The co-ordinate system applicable to the M2 Unit shall follow the requirements of AD 03. In particular a specific co-ordinate system called the Body co-ordinate system may be defined according to the rules of AD 03, with reference to the altitude axis. The position of the mirror in the M2 EMU shall be defined in the M2 Body co-ordinate system.

5.1.14.4 M2 EMU physical Characteristics

Typical dimensions of the M2 EMU will be:

- Height 1600 mm :
- Outiside Diameter 1100 mm (without M2 Baffle)

No parts of the M2 EMU shall be visible from the camera except the M2 Baffle.

The total mass of the M2 EMU (without cables on spiders, external electronic cabinet , cooling pipes etc.) shall not exceed 1750 kg (TBC)**.**

5.1.14.5 Requirements on M2 Mirror Positioning

The requirements below represents the baseline performance expected for the M2 EMU mechanisms.

Focusing

Focussing is defined as displacement of the mirror along the axis of the M2 EMU

- Focusing range (centred on nominal position): ± 4 mm
- Minimum speed (continuous mode) 0.05 mm/sec

- Absolute accuracy ≤ 10 µm (TBC)
- Minimum step response
  - amplitude ≤ 2.5µm (TBC)
  - differential accuracy ≤ 1 µm
  - settling time ≤ 3 sec

Centring

Centring is the movement of the mirror on a sphere centred around the mirror centre of curvature (located at 4018.8 mm from mirror vertex). It requires:

- Centring range (centred on nominal position): +/- 3 arcmin
- Minimum speed in continuous mode 0.05 arcmin/sec
- Absolute accuracy ≤ 3 arcsec
- Minimum step response
  - amplitude ≤ 0.5 arcsec (TBC)
  - differential accuracy ≤ 0.2 arcsec
  - settling time ≤ 3 sec

Tilt Requirements

The fine adjustment mechanism of the tilt of the mirror shall have the following performances:

- Location of tilt axes plane 0 to 300 mm from M2 vertex
- Tilt range (remotely adjustable) +/- 1 arcmin (TBC)
- Residual adjustment accuracy ± 0.15 arcsec

Independence of Stage

A complete kinematic separation between the focusing and centring and tilt is desirable but it may be difficult to achieve. The final M2 specification will set limits on the cross coupling between the kinematic stages, both the repeatable ones (which may be calibrated by look-up table) and the random ones.

5.1.14.6 M2 Mirror Position Stability

The typical values of position stability of the M2 mirror with respect the M2 EMU are reported here.

Stability of M2 under changing gravity loads (Zenith to 70 degrees)

- X-Y plane ≤ 120 µm (TBC)
- Z direction ≤ 50 µm (TBC)
- Tilt (X-Y plane) ≤ 12 arcsec

Stability of M2 mirror during operation

- X-Y plane ≤ 3 µm/3 minutes (TBC)
- Z direction ≤ 0.5 µm/3 minutes (TBC)
- Tilt (X-Y plane) ≤ 0.25 arcsec/3 minutes (TBC)

5.1.14.7 M2 Baffle Requirements

A fixed reflective annular baffle is placed around the secondary mirror. Its main purpose is to block out the sky background seen by the IR camera between the inner edge of the primary mirror and the edge of the cryostat window. It has a spherical surface; the radius of curvature is chosen such that any point on the IR focal plane sees a cold surface (inside the cryostat) reflected in the baffle. This helps to reduce the overall background in the IR instrument.

The M2 baffle contributes to the control of stray light in the visible camera. The majority of the stray light control in the visible camera is provided by the instrument baffle and the design of the enclosure opening.
Figure 13 shows the M2 Baffle layout.

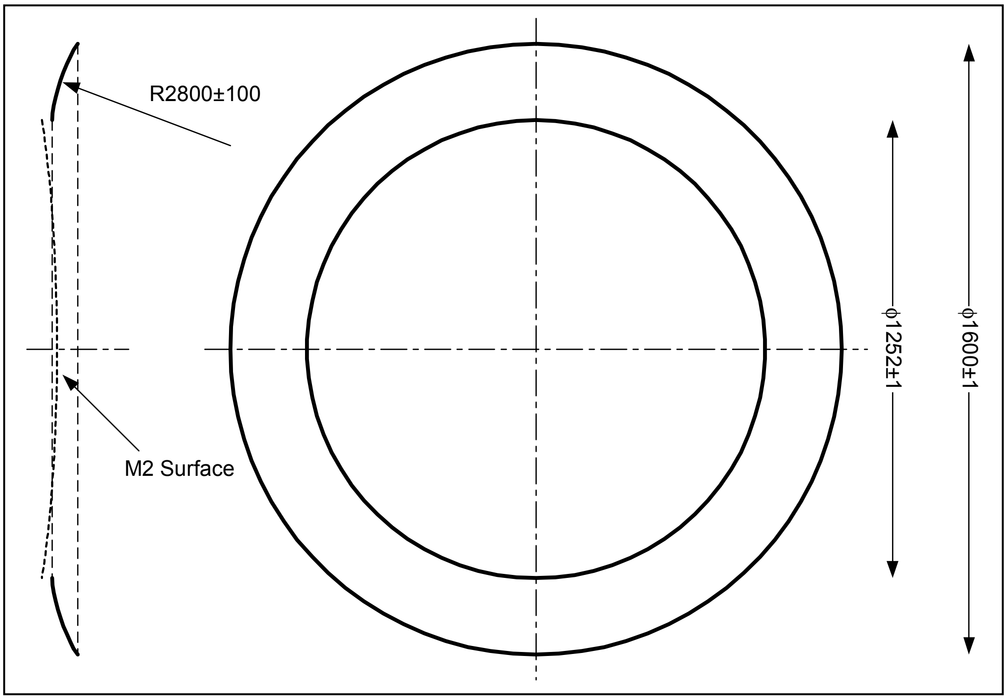

Figure 13 M2 Annular Baffle

The requirements on the M2 baffle are:

– Lower surface (pointing at M1)	Specular reflectivity >95% (2-2.5µm) Surface roughness <1µm RMS Gold plated (or equivalent)
– Upper surface (pointing at sky)	Maxorb foil (or equivalent)

– Outer edge	Sharp edge
– Concentricity with M2	±1mm
– Baffle temperature control	Not required

5.1.15 M2 Control

5.1.15.1 TCS Interface

The M2 Control System shall run on an LCU controlled by the TCS, using the same interface definition as used on the VLT, modified in detail only if necessary.

5.1.15.2 Hardware Interface

Hardware shall be controlled via signals transmitted from the M2 LCU. By agreement with ESO, the M2 control may be achieved by the LCU CPU sending demands via a serial interface to a Delta Tau PMAC multi-axis controller card mounted in the VME backplane of the LCU.[1]

5.1.16 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

5.1.16.1 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 predictable. Rolling element bearings will be sealed to prevent ingress of dirt.

- Axial run out	≤ 0.05mm
- Radial run out	≤ 0.05mm

5.1.16.2 Cassegrain Rotator Interface

The rotator shall have a mounting surface with features to ensure repeatable assembly on the primary mirror cell:

- Axial repeatability	≤ 0.05mm rms
- Radial repeatability	≤ 0.05mm rms
- Tilt repeatability	≤ 15 micro radians rms

The rotator shall have a mounting surface with features to ensure repeatable assembly of the cameras:

[1] This will have a similar interface as used in the VLT Auxiliary Telescopes System

- Axial repeatability ≤0.05mm rms
- Radial repeatability ≤0.05mm rms
- Tilt repeatability ≤15 micro radians rms

5.1.16.3 Cassegrain Cable wrap

The Cassegrain cable wrap is mounted below the mirror cell and carries services from the M1 cell to the rotator, IR and visible cameras. The Cassegrain cable wrap drive motors shall be brushless DC servo motors with resolver, brake and reduction gearbox.

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

Residual torque loading on the rotator shall be: ≤ 100Nm (TBC)

The range of travel of the cable wrap shall be greater than the end stop on the Cassegrain rotator (see 5.1.17.11) to avoid damage in the event of overrun.

Cables and services shall be terminated at each end at a Service Connection Point as defined in AD 06.

The cable wrap shall be designed to allow access to the cell for maintenance.

5.1.17 Cassegrain Rotator Control

5.1.17.1 Reuse of ESO Software

The rotator axis shall be controlled from LCU(s), running identical software to the VLTs Rotator Control System. This software shall be configured to VISTAs specific requirements.

5.1.17.2 TCS Interface

The Rotator Control System shall be controlled by the TCS, using the same interface definition as used on the VLT, modified in detail only if necessary.

5.1.17.3 Software/Hardware Interface

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

5.1.17.4 Control Algorithms

The control algorithms shall be as implemented and documented in ESOs software release.

5.1.17.5 Slew When Tracking Open-Loop

It shall be possible, as a specific implementation, to slew the rotator while tracking the telescope open-loop.

5.1.17.6 Performance

The Cassegrain Rotator angle is defined as zero degrees, with the telescope azimuth angle of zero (South) and the altitude angle 90 (Zenith pointing) and increasing to the east.

With the Cassegrain rotator at zero degrees it shall be possible to orientate the camera focal plane to the cardinal compass points.

The values of the performance parameters will be typically:

- The range of Cassegrain rotation +135° to -405°
- Tracking velocity maximum 480 arcsec/s
- Tracking acceleration maximum 10 arcsec/s^2
- Slew velocity maximum 3.6°/s
- Slew acceleration maximum 1.0°/s^2
- Tracking error < 0.5 arcsec rms

5.1.17.7 Position measurement

1. The control system shall comprise a precision tape encoder, a direct drive motor, an angular velocity measurement device.

2. The measurement accuracy of the encoders shall be sufficient to allow the rotator system to meet its requirements. The resolution of the encoders will typically be < 0.015 arcsec.

5.1.17.8 Velocity Measurement

The velocity signal will be obtained by digital differentiation of the position measurement data

5.1.17.9 Motors

The motors shall be of the direct drive type.
The maximum rotator motor torque will be ≥2.5 kNm. (TBC)
The combined effect of ripple and cogging will typically be less than 1% of the maximum torque.
The motors shall be capable of providing twice the torque necessary to drive the rotator under the worst-case operational conditions.

5.1.17.10 Brakes

Brakes shall be provided which capable of preventing rotation when the telescope is not in use and stopping the rotation in emergency or when hardware limit switches are actuated. The brakes shall have the capacity to resist the maximum motor torque.

5.1.17.11 Limit switches and end stops

Limits and end stops will operate relative to the cable wrap to prevent damage to the latter. Software limits shall decelerate the rotator to a complete stop before it reaches the hardware switch.

Hardware limit +139° to -409°

In the event that the rotator reaches the hardware switches the latter shall actuate the brakes such that rotator can decelerated from maximum velocity to a complete stop before it reaches the end stops.

End Stop +143° to -413°

Cushioned end stops shall be capable of decelerating the rotator from maximum velocity to a complete stop without damage to the rotator, cable wrap or camera.

5.1.17.12 Safety locking

The Cassegrain rotator shall be capable of manual lockout. The locking pins will be part of the Telescope Interlock System.

5.1.18 Guiding and Wavefront Sensing - Telescope Requirements

5.1.18.1 Telescope Feedback Requirements

VISTA requires a number of sensors to control telescope pointing and image quality. This is driven by a number of factors:

- A guide sensor is required in order to achieve the required closed loop tracking accuracy. This is integrated into the telescope pointing control system.
- The use of an active primary mirror means that there has to be some method of measuring the wavefront error, so this can be corrected
- The adoption of the f/1 primary mirror design leads to very tight tolerances on the collimation and focus of the secondary mirror. These tolerances are difficult to be met by passive methods, so some form of active control of M2 is required. Therefore a sensor is needed to produce the required error signals.
- The large field of view of VISTA means that maintaining image quality simultaneously over the field is not straightforward. To separate the effects of field dependant astigmatism (produced by errors in the secondary mirror position) and primary mirror astigmatism, two wavefront sensors at opposite sides of the field are required.

- An additional requirement is that disruption to surveys has to be avoided. This means that functions which have to be carried out in parallel with observations cannot disrupt these observations.
- It must be possible to deliberately maintain an offset defocus of M2 during specific observations.

5.1.18.2 Sensor Implementation

Three types of sensor are used to achieve the required functions. These are:

Autoguider – A single fixed CCD, providing a fast measurement of the position of a guide star. The autoguider runs continuously in parallel with science observations.

Curvature Sensor – These are fixed sensors, and use pairs of CCD's to measure wavefront error from intra- and extra-focal images of stars. They are used to measure low order wavefront errors, typically defocus, coma, astigmatism and trefoil. They run continuously, in parallel with science observations.

Shack Hartmann Sensor – This is a fixed sensor, mounted off axis outwith the science field. It is used to measure wavefront errors to a high enough order to fully characterise the system. It is used to provide calibration and checking of the system. It is used only periodically, outwith science observations. It requires a telescope offset to point the star at the sensor.

5.1.18.3 Sensor Location

The design for the VISTA telescope and instruments has no intermediate focal plane - both instruments are implemented with field correctors. Therefore, the sensors for guiding and wavefront sensing are integrated into the cameras.

5.2 *Visible Camera*

The Visible Camera mounts at the Cassegrain focus of the telescope and is based on a field corrector optical design similar to existing wide field optical cameras. The design has a large field of view and resolution commensurate with the very large focal plane that will be used.

The main assemblies of the Visible Camera are the lens barrel assembly, the filter mechanism assembly, the shutter mechanism assembly, the focal plane unit assembly, and the baffle assembly. These main assemblies are described in more detail in the following paragraphs, Figure 14 shows a cross sectional view of the baseline design.

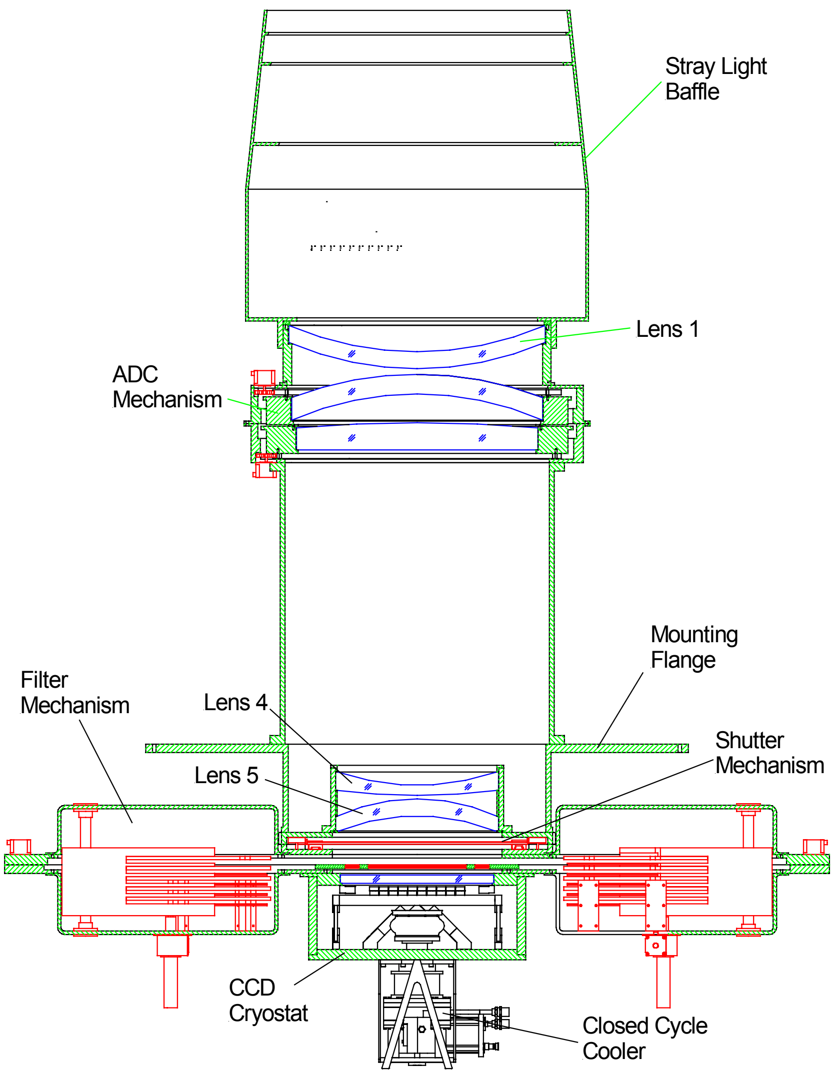

Figure 14 Visible Camera Cross Section

The approximate dimensions and mass of the camera will be:

Height ~ 2.8m	Length ~1.8m
Width ~ 2.7m	Mass ~2100kg

To avoid re-balancing the telescope between camera changeovers, the Visible and IR cameras will be adjusted to have the same balance relative to the Cassegrain interface.

5.2.1 Visible Camera Optics

5.2.1.1 Visible Camera Optical design characteristics

- Unvignetted Field of view	2.13 degrees (diagonal)
- Wavelength coverage	350-1020 nm
- Plate scale	58.80 µm/arcsec

5.2.1.2 Visible Camera Optical layout

The optical components required for the Visible Instrument are a fused silica lens(L1), an Atmospheric Dispersion Corrector (ADC, made of 2 cemented doublets of BK7 and N- LLF6), two fused silica lenses (L4 and L5) , strip filters , and a fused silica window.
All the surfaces are spherical except the last lens L5 which is aspheric and located on the concave surface to control the astigmatism in the design.
The optical layout in Figure 15 shows the ray-tracing of the on and off-axis rays and Table 5 the telescope and optical data.

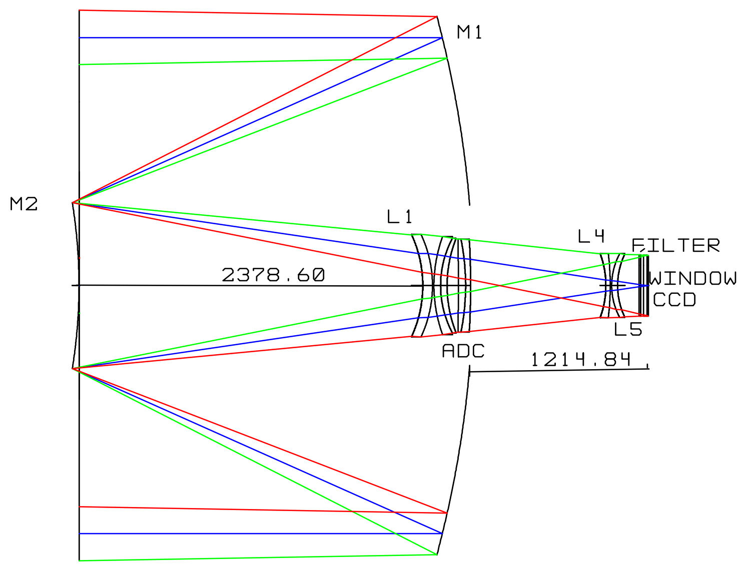

Figure 15 Optical Layout of Telescope and Visible Camera

Components	Radius (mm)	Conic K	Clear Aperture (mm)	Separation (mm)
M2				2378.60
L1	-967.43 -963.80	- -	754.6 762.8	67.0 10.0
ADC 1	1148.03 804.29 1023.35	- -	731.3 706.5 697.5	45.87 45.00 78.31
ADC 2	-29254.03 -1884.34 -6171.69	- -	694.62 692.28 685.83	50.00 34.81 935.87
L4	-733.36 -2129.49	-	475.77 479.02	30.00 10.00
L5	538.46 578.78	even asphere	477.58 467.14	41.05 148.18
Filter	Plano Plano	- -	458.33 457.72	10.00 20.00
Window	Plano Plano		455.96 454.44	25.00 10.00
CCD Detector		-	453.61	

Table 5 Nominal Optical Data of Telescope and Visible Camera

5.2.2 Lens Barrel Assembly

The lens barrel assembly comprises the ADC mechanism sub-assembly, the main mounting barrel of the camera, the remaining optical elements of the field corrector (in their lens mounts) and the camera mount.

The ADC mechanism comprises the ADC lenses, the housing for mounting the lenses, the motors and the mechanism controller. The ADC lenses are a pair of large doublet lenses with small wedge angles in the lens elements. The lenses counter rotate around the optical axis to provide the required atmospheric correction. The complete ADC assembly is attached to the lens barrel. A DC servo motor is used to move the lenses and hold them in position. The angular accuracy to which the ADC lenses have to be aligned is 1°.

The mounting barrel provides the main structural mounting of the camera. The remaining elements of the field corrector (in their housings) are located in this barrel. The other main assemblies of the camera (filter mechanism, shutter mechanism and focal plane unit) are mounted to the barrel.

The camera mount is part of the lens barrel assembly and forms the mechanical interface between the camera and the Cassegrain rotator (which is situated on the telescope).

The lens barrel also contains internal annular baffles to control stray light. The surfaces of these baffles are treated with an absorbing coating.

5.2.3 Filters.

Seven sets of science filters sufficient to cover the focal plane, an ND + r' sandwich filter and an opaque "filter" shall be provided for use in the Visible camera. The science filters will cover the following wavebands: U_L, B, g', V, r', i', z'.

The opaque filter shall be housed in a duplicate filter holder and in all physical dimensions conform to the science filter design.

No observational sensitivity degradation shall result from changing the filter in the beam.

5.2.4 Filter Mechanism Assembly

The filter deployment mechanism consists of two carousel boxes that will be used to deploy ten or more science filters (including the opaque filter). Each filter holder includes a unique machine readable identifier.
When a filter is selected for an observation, a screw jack moves the appropriate stack of filters vertically until the correct filter is in line with a catchment device. The selected filter is removed from the stack and positioned accurately in the optical path by means of a linear slideway. A proximity switch is used to detect the datum position for both vertical and horizontal movement.

The requirements for the filter mechanism are:

1. The filters shall be positioned in the optical path to better than 100µm horizontally and better than 500µm vertically.
2. It shall be possible to change a filter with one from the opposite carousel within 25s.
3. It shall be possible to exchange a filter with one from the same carousel within 60s.
4. It is highly desirable to exchange filters whilst reading out detectors without adding readout noise or light leaks.
5. The filter mechanism housing shall be designed in such a manner to preclude dust and prevent absorption of water vapour into the filters (e.g. positive pressure system).
6. Removing or inserting filter holders within a carousel will not disturb other filters.

5.2.5 Shutter Mechanism Assembly

A shutter mechanism is used to provide accurate control of the exposure time of the CCD arrays, and to enable the arrays to be blanked off from light. The mechanism consists of two large carbon fibre panels, a pair of linear slideways to support the panels, and two DC servo motors each driving a single panel via a toothed belt. Proximity switches or equivalent devices shall be used to indicate the datum position and end of travel for each panel. The motors provide a constant velocity of each panel across the optical path. The shutters are shaped to allow the autoguider to be exposed without exposing the science arrays to direct illumination.

The requirements on the shutter are:

1. Exposure timing must meet the requirements of Section 4.15
2. The overhead to observing from the operation of the shutters shall be ≤ 4s per exposure.
3. The shutter must allow exposure of the autoguider CCD with less than 50% vignetting without exposing the science array.
4. It is highly desirable to allow exposure of the curvature sensors without exposing the science array.
5. It shall be possible to take 'multi-exposure' i.e. one exposure with many operations of the shutter for diagnostic purposes.

5.2.6 Flexure

Tilt of the instrument focal plane due to internal flexure shall be less than 30 arcsec (TBC)

5.2.7 Focal Plane Unit Assembly

The focal plane unit assembly contains the CCD detectors, the detector controller, the cryostat and window the detector pre-amps and circuitry, the closed cycle cooler, temperature sensors, cabling and connectors. The focal plane unit also contains all of the hardware (optics, CCD detectors and mechanical mounts) for the autoguider and wavefront sensors.

Figure 16 shows a layout of the current design for the focal plane. The gap between the active areas of the large strips of CCD's is shown as 20mm. This allows separate filters for each strip of CCD's to be used.

The unvignetted field of view of the current optical design (2.13 degrees diameter) is shown, together with the total field covered by the CCD's (2.15 degrees).

Detector and controller non-linearity must be ≤ 3% before calibration. Detector and controller gain should vary by ≤ 2% peak to valley across the full range of operating temperatures.

Electrical Crosstalk between any pair of pixels separated by ≥ 10 pixels shall be less than 5 $x10^{-5}$ (goal 1 $x10^{-5}$) (TBC).

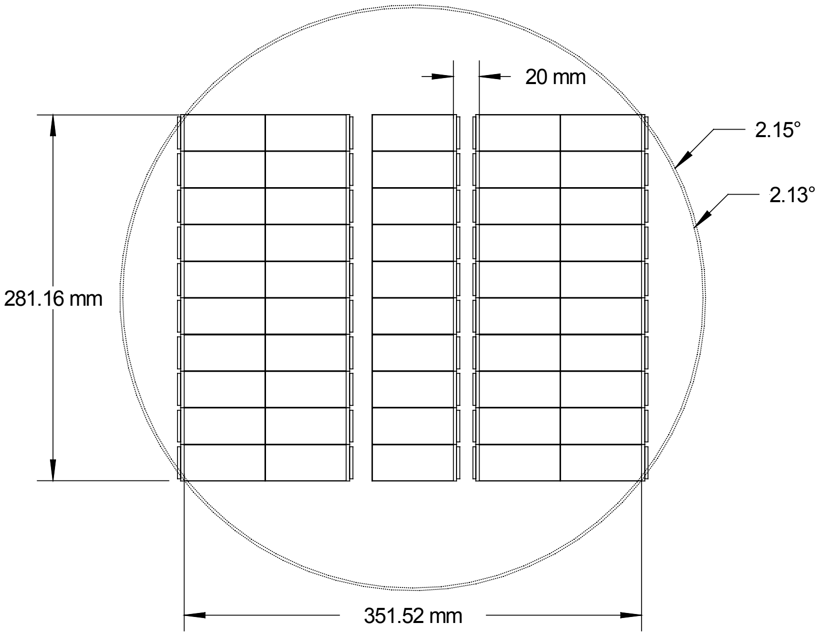

Figure 16 Visible Camera – Indicative CCD Layout

5.2.7.1 CCD Detectors

The following Visible Detector specifications form the baseline for the VISTA visible camera.

1. Wavelength Range. The wavelength range of operation shall be between 350-1020nm.
2. Pixel Size. The pixel size shall be between 12 microns and 16 microns.
3. Readout Noise and Rate. The readout noise shall be not more than 10 electrons per pixel at all readout rates between 250 - 500 kpix/sec. The readout noise shall not be more than 6 electrons per pixel at a readout rate of 150 kpix per sec.
4. Number of Devices and Filling Factor. Sufficient devices shall be supplied and the physical package size shall be such, to satisfy all of the following:
5. The devices can tile a rectangle of size 341 mm x 285 mm, (or a different rectangle of equal area and not greater diagonal to the preceding one) such that at least 80% of the area of the rectangle shall consist of active pixels; and
6. The largest gap between active pixels in at least one of the x and y directions shall not exceed 2 mm.
7. Physical Flatness. Each individual chip should be flat to better than 12 microns peak-to-valley.
8. Full Well. The full well shall be at least 90 000 electrons/pixel.
9. Defects. The total area of 'linear' defects (averaged over all supplied devices) shall be ≤ 1% of pixels. The total area of 'spot' defects should be ≤ 0.1% of pixels. Any square of 100x100 pixels should not contain more than 15% defective pixels.
10. Linearity. ADUs per electron shall be linear to better than 3% between 5% and 90% of

full-well.

11. Charge Transfer Efficiency: The CTE shall be ≥ 99.999%.
12. Chip Binning. It shall be possible when desired to read the devices with 2x2 pixel on-chip binning.
13. Fringing: Fringing shall be minimised. Detailed specification TBC.

5.2.7.2 Detector Controller

1. The Visible Camera shall use ESO FIERA Detector Controllers to acquire data from the CCDs. These systems will be provided by ESO and are expected to include:
    - 5 off Detector Head Electronics
    - 5 off quad preamps
    - 5 off power supplies
    - 5 off Sparc LCUs
    - power supplies
    - cabling
    - mounting hardware
    - software

2. The front end of the FIERA equipment shall be mounted on the camera and the backend in the VISTA enclosure.

3. Each FIERA Sparc LCU shall be connected to the Visible Camera Instrument Workstation via a 155 Mbps ATM connection (or superseding technology if agreed with ESO) as defined in applicable documents AD11 and AD28.

4. The practicality of anti-bleeding clocking with the FIERA controller will be investigated.

5.2.7.3 Detector Cryostat and Window

The detector cryostat provides the mechanical mounting of all the components of the focal plane unit. It includes an optically transparent window to allow light to reach the detectors.
The cryostat temperature is maintained at a constant temperature in the range 150-190K by means of a temperature controller (included in the detector controller). A closed cycle cooler provides the necessary cooling power. Temperature sensors are included in the cryostat to provide an input signal to the temperature controller.

5.2.8 Visible Camera Guiding and Wavefront Sensing

In the visible camera, all sensors are integrated into the focal plane unit. This removes the need for additional cooling of CCD detectors.
The autoguider is required to operate continuously whilst the shutter is passing across the science arrays. It is also desirable to operate the curvature sensor before exposure of the science arrays. This is achieved using a specially shaped shutter, incorporating a ‘notch’. The notch allows the shutter to be partially opened, exposing the autoguider and curvature sensors without exposing the science detectors.

To minimise the number of additional filters required, the autoguider CCD is mounted adjacent to one set of curvature sensor CCDs.
The shows the concept for the incorporation of the sensors into the visible camera. Each sensor is located around the science focal plane, using the corrected field produced by the optics.

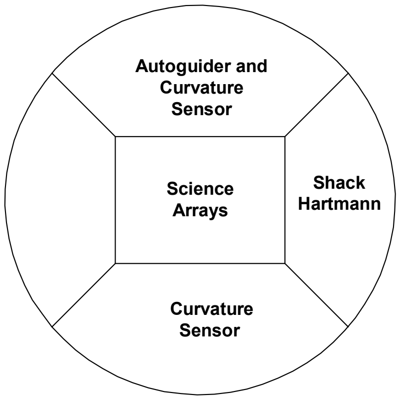

Figure 17 Visible Camera – Sensor layout (Not to scale)

Sample rate	10Hz
Field of view	63 $arcmin^2$
Waveband	550-700nm
CCD type	2K x 2K
CCD pixel size	<15µm
Location and format	In focal plane, separate filter (in filter holder), fixed CCD

Table 6 Visible Camera Autoguider Requirements

Sample rate	Once per minute
Integration time	30 seconds
Averaging	Previous 3 measurements to remove atmospheric effects
Defocus	± 1mm
Field of view	≥ 35 arcmin^2
Waveband	550-700nm
CCD type	2K x 2K
CCD pixel size	<15µm
Location and format	In focal plane, separate filter (in filter holder), 2x fixed CCD's

Table 7 Visible Camera Curvature Sensor Baseline Requirements

Lenslet format	12 x 12 (TBC)
Waveband	550-700nm - same as visible curvature sensor
CCD type	512 x 512
Dynamic range	6 arcsec
Spot separation	6 arcsec
Pinhole size	5 arcsec diameter
Pixel scale	<0.2 arcsec/pixel
Location and format	In focal plane, Separate filter
Calibration source	In instrument, beamsplitter

Table 8 Visible Camera Shack Hartmann Requirements

Figure 18 & Figure 19 show how the sensors are incorporated into the camera.

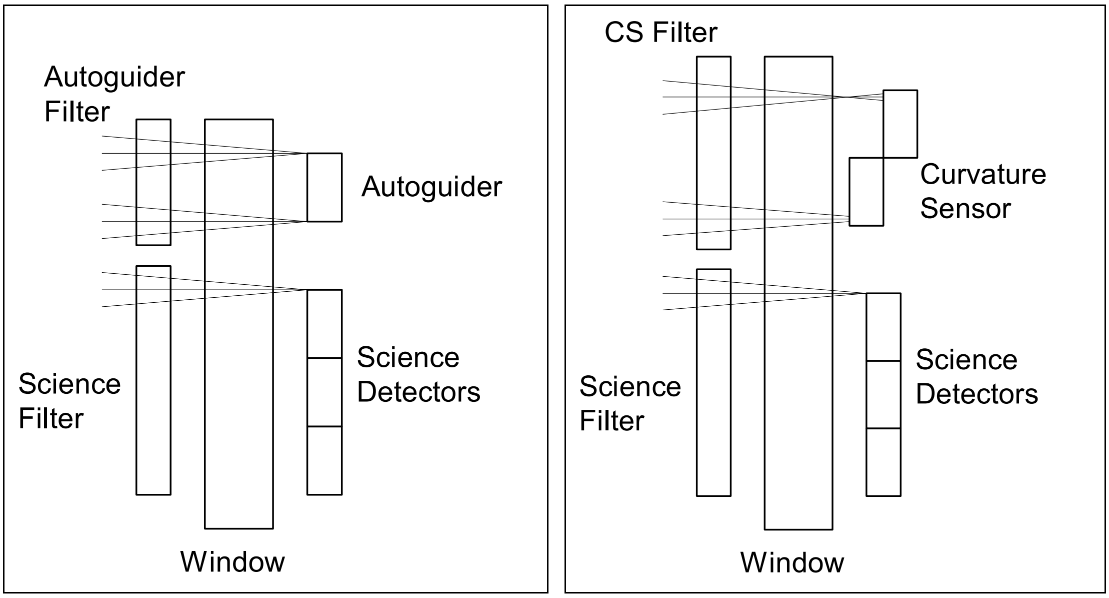

Figure 18 Visible Autoguider, Visible Curvature Sensor

(Figure 18 & Figure 19 are not to scale)

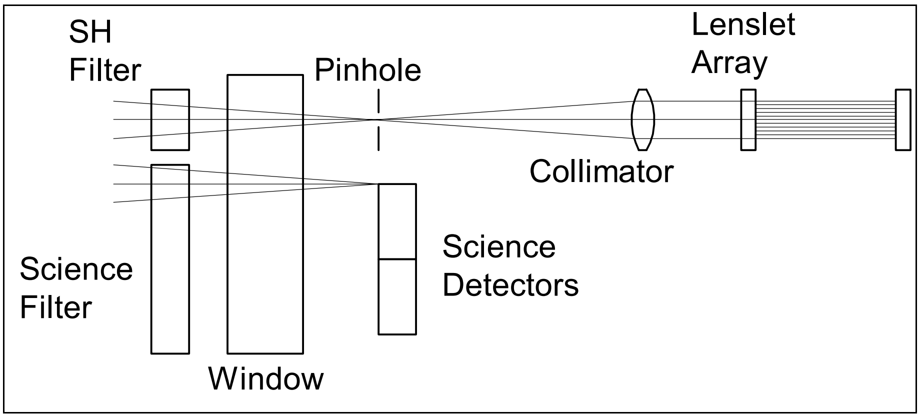

Figure 19 Visible Shack Hartmann Sensor

5.3 *IR CAMERA*

The IR Camera is based around an array of 16 IR detector arrays. It has a three element field corrector optical unit mounted above the focal plane, giving a corrected field of view of 1.65° diameter. A cold baffle design is used to control stray light.

Initial operating temperatures are achieved by means of a pre-cool with LN_2 thereafter closed cycle cooler(s) are used to maintain operating temperature. Filters are placed in the optical path to control the pass band of light falling on the detector arrays.

The main assemblies of the IR camera are the filter mechanism assembly, the camera structure assembly and the focal plane unit assembly. The main assemblies are described in more detail in the following paragraphs. Figure 20 shows a cross sectional view of the IR camera baseline design.

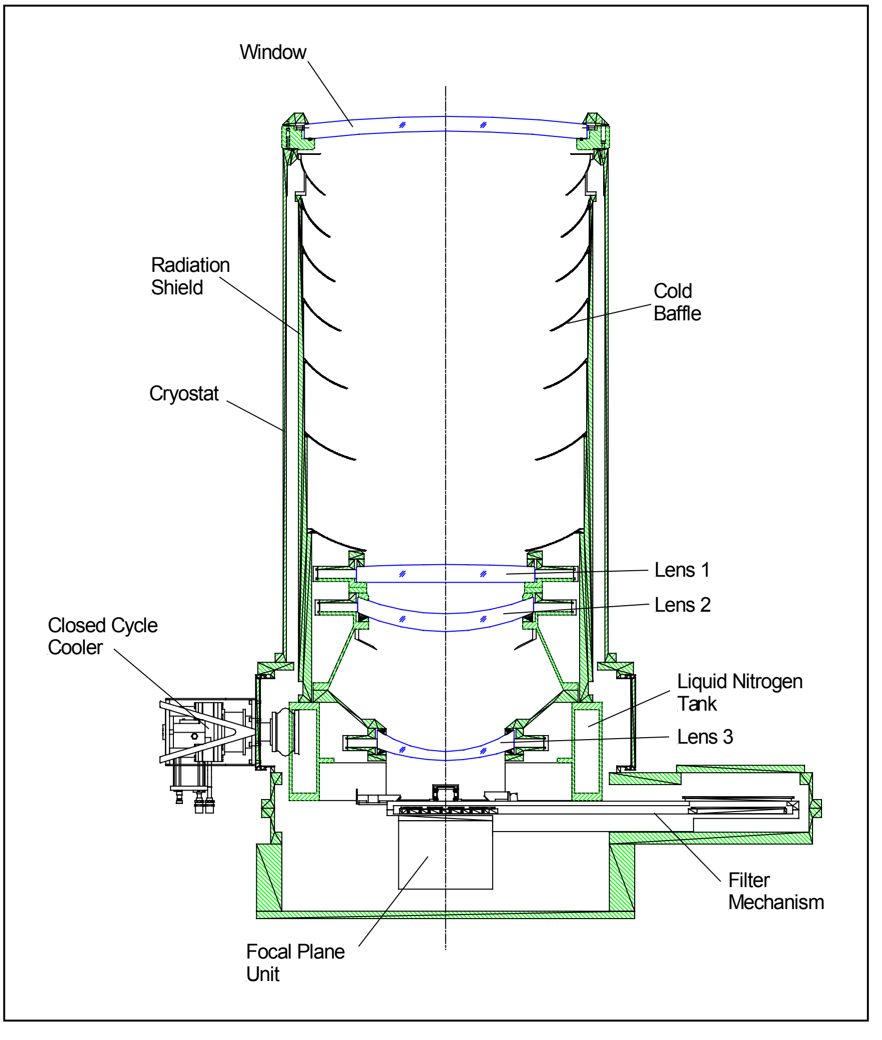

Figure 20 VISTA IR Camera with Cryogenic Baffle

The approximate dimensions of the camera are:

Height	~ 2.85m
Diameter	~ 2.6m.
Mass	~ 2700kg.

To avoid re-balancing the telescope between camera changeovers, the Visible and IR cameras will be adjusted to have the same balance relative to the Cassegrain interface.

5.3.1 Infrared Camera Optics

5.3.1.1 Infrared Camera Optical design characteristics

- Unvignetted field of view — 1.65 degrees (diagonal)
- Wavelength Range — 0.95-2.3 µm Z (IR), J, H, K_{short}
- Plate scale — 58.52 µm/arcsec

5.3.1.2 Infrared Camera Optical Layout

The optics required in the IR camera are a cryogenic window, three Infrasil corrector lenses and IR square filters placed in front of the detector array. The optical layout shows the ray-tracing of three positions in the sky: on–axis (green line)and the ± 0.825 degrees (blue and red lines).

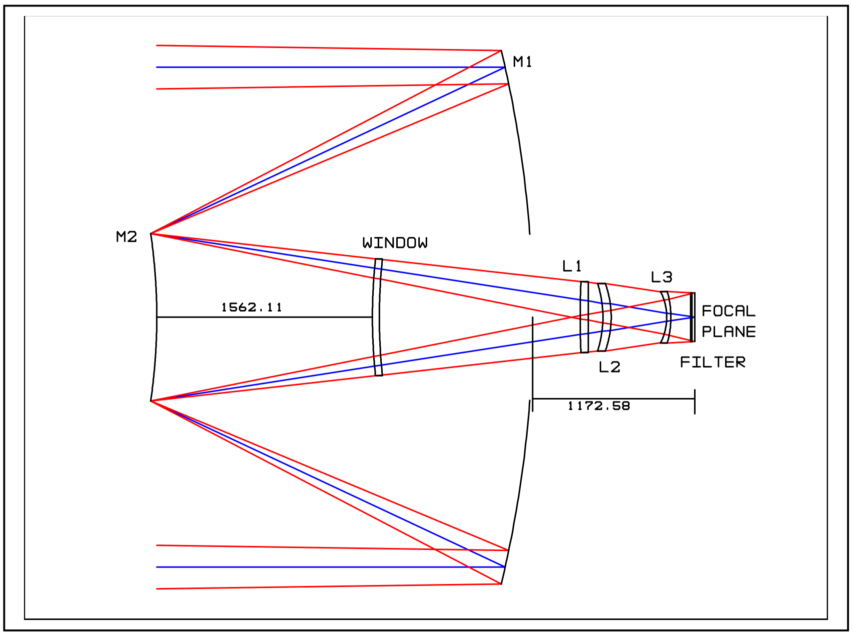

Figure 21 Optical Layout of Telescope and IR Camera

5.3.1.3 Baseline Infrared Camera Optical Design Data

Components	Radius (mm)	Conic K	Clear Aperture (mm)	Separation (mm)
M2				1562.11
Window	4050.0 4000.0	- -	862.0 850.6	50.0 1454.7
L1	6029.18 Plano	- -	520.0 510.0	60.0 105.0
L2	-794.11 -723.13	- -	492.0 493.2	60.0 402.6
L3	-394.49 -672.98	even asphere -	370.0 375.0	30.0 143.0
Filter	Plano Plano	- -	354.0 353.1	10.0 20.0
IR Detector	Plano	-	350.8	

Table 9 Nominal Optical Data of Telescope and IR Camera

5.3.2 IR Filters

Three science filters sufficient to cover the focal plane, and an opaque filter shall be provided for use in the IR camera. The science filters will cover the following wavebands: J, H, and Ks.

The opaque filter shall be housed in a duplicate filter holder and in all physical dimensions conform to the science filter design.

5.3.3 Filter Mechanism Assembly

The filter mechanism comprises the IR filters, the mechanism to place the filters in the optical path and the mechanism controller. The conceptual design consists of sixteen individual filter pieces (one per detector array) mounted in a filter holder. This filter holder is mounted on the filter wheel as one single item. The filter mechanism can accommodate up to eight filter holders (seven science + one opaque) at any time. Each filter holder includes a unique machine readable identifier. The filter holders are accessible via a port on the filter wheel housing. This allows filters holders to be changed without complete disassembly of the entire camera.

Deployment requirements for the filter wheel are:

1. It must be possible to move to adjacent filters within 25s.
2. It must be possible to move to any other filter within 60s.

3. It must be possible to position the filters in the optical path to better than 100µm horizontally and 500µm vertically.

5.3.4 Camera Structure Assembly

The Camera structure comprises of the cryostat, the closed cycle coolers, the lenses and lens mounts, the cryogenic baffles and the autoguider and wavefront sensors.

5.3.4.1 Cryostat

The cryostat is attached to the interface flange of the Camera and has a hollow annular bench that is used to hold LN_2 during pre-cooling. Once the cryostat reaches operating temperature, the temperature is maintained by closed cycle coolers.

The design will use up to three closed cycle coolers to keep the cryostat at operating temperature. One of the coolers shall be fitted with a second stage to cool the science detector focal plane assembly.

5.3.4.2 Lens Mount

The four lenses required for the IR optical design are mounted in individual cells. The first forms the cryogenic window whilst the other three cells are combined to form a barrel which mounts directly to the main bench of the cryostat.

5.3.4.3 Cryogenic Baffle

The cryogenic baffle has two prime functions, the first is to limit the field-of-view of the detectors off the optical axis and the second to reduce the thermal load contribution from the cryostat window. The baffles consist of a series of seven (TBC) ellipsoidally contoured aluminium annuli that fit inside the upper section of the cryostat and are located between the cryostat window and the first lens. The extent and location of the baffles is defined by the intersections of rays from the edge of the cryostat window and the cone of light defining the limit of the field of view from the edges of the cryostat window to the edges of the detector array. This results in a system of baffles such that no point on the detector array can see any scattered light from the cryostat wall.

The ellipsoidal figure on the baffles is designed to reflect light back out the cryostat window. The baffle surfaces facing the window are treated with a special coating which absorbs light at the science wavelengths and reflects above ~3µm. This has a number of benefits, it reduces the heat load on the cryostat considerably and it helps to keep the window warm, reducing the risk of condensation and frosting on the window.

5.3.5 Flexure

Tilt of the instrument focal plane due to internal flexure shall be less than 30 arcsec (TBC)

5.3.6 Focal Plane Unit Assembly

The focal plane module shall be used to hold, cool and protect the IR detector arrays and their associated circuit boards, electronics and cables. The conceptual design is for sixteen detectors to be used with a separation between detectors of 90% of the active width. The detectors are mounted such that piston and tilt relative to the focal plane can be adjusted during assembly. They are connected to PCBs using pin grid arrays which are needed due to the depth of the detector housing. A flexi-rigid PCB design where the flexible section lies along one edge of the PCB next to the detector will be used to route the detector array outputs and to supply analogue biases and digital clocking signals. Over-voltage and electro-static discharge protection circuitry shall be used to protect the detectors.

Detector and controller non-linearity must be ≤ 3% before calibration. Detector and controller gain should vary by ≤ 2% peak to valley across the full range of operating temperatures.

Electrical Crosstalk between any pair of pixels separated by ≥ 10 pixels shall be less than 5×10^{-5} (goal 1×10^{-5}) (TBC)

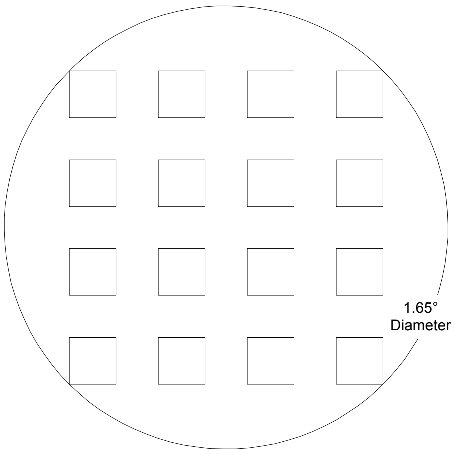

Figure 22 Proposed IR detector array layout

5.3.6.1 IR Detectors

The following IR Detector specifications form the baseline for VISTA.

1. Wavelengths of Operation. The required wavelengths of operation shall be 1.0 to 2.31 microns
2. Quantum Efficiency. The QE of the best 90% of pixels shall be: J > 38%, H > 47%, Ks > 47% (Z_{IR} will be best effort).
3. Format The IR detectors shall have an array of 2048 x 2048 pixels active pixels
4. Pixel Size. Pixel size shall be between 12-20 microns
5. Read Noise. Detector and controller read noise over a period of 1 minute shall be < 32 electrons.
6. Read-out Time. The maximum acceptable read time shall be 1 second at maximum well depths. The well depth is defined as the number of electrons giving a response non-linearity of 5%.
7. Defects. The number of bad pixels shall be less than 1% (4.10^4). These shall not be

clustered in groups larger than 500 pixels.

8. Dark Current. The detector dark current shall be < 8 e/s per pixel.
9. Remnant Image Artefacts. The decay time constant τ shall be < 100s.
10. Maximum dT/dt. Detectors shall be capable of surviving a temperature gradient of 8 degrees per hour.
11. Image smearing. The maximum allowed pixel charge smearing shall be less than 1%.
12. On-chip Glow. The on-chip glow shall be less than 8 e/s per pixel everywhere.
13. Physical Flatness. The arrays shall be flat to within 12 microns peak-to-valley.
14. Non-linearity. Non-linearity shall be less than 5% up to 150,000 electrons well depth.

5.3.6.2 Detector Controller

1. The IR Camera shall use a 512 channel ESO IRACE Detector Controller (RD 02) to acquire data from the detector arrays. This system will be provided by ESO and is expected to include
   - 5 off VME crates
   - 4 off ESO backplanes
   - 36 off 16 channel AQ modules
   - 16 off Clk/bias modules
   - 1 off sequencer
   - 17 off GIGA interface modules
   - 8 off DMA interface modules
   - 4 off Sun workstation
   - modifications to distribute 'start conversion' signals
   - power supplies
   - cabling
   - mounting hardware
   - software

2. The front end of the IRACE equipment shall be mounted on the camera and the backend in the VISTA enclosure.

3. Each IRACE Sun workstation shall be connected to the IR Camera Instrument Workstation via a 155 Mbps ATM connection (or superseding technology if agreed with ESO) as defined in applicable documents AD11 and AD28.

5.3.6.3 Detector Pre-amps and Circuitry

The detector pre-amps shall be located as close to the detectors as practicable in order to keep the connection run to the detectors as short as possible.

5.3.6.4 Temperature Sensors, Cabling and Connectors

The IR detectors are cooled to approximately 70K. Active temperature control shall be used to ensure that the detectors are kept at the optimum operating temperature. This is achieved using temperature sensors and diode heaters controlled from the detector controller. The filters, lenses and baffles operate at a higher temperature of between 150K -190K.

5.3.7 IR Camera Guiding and Wavefront Sensing

In the IR camera, all sensors are fed by pick-off mirrors, and are located around the detector array on the filter mechanism housing. This allows the CCD detectors to be maintained at the higher temperature required for their correct operation.
Figure 23 shows the concept for the incorporation of the sensors into the IR camera. Each sensor is located around the science focal plane, using the corrected field produced by the optics.

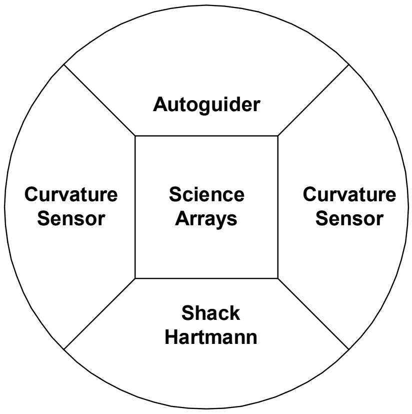

Figure 23 IR Camera – Sensor Layout (not to scale)

Sample rate	10Hz
Field of view	63 arcmin^2
Waveband	720-920nm
CCD type	2K x 2K
CCD pixel size	<15µm
Location and format	In focal plane, separate filter (in filter holder), fixed CCD

Table 10 IR Camera Autoguider Requirements

Sample rate	Once per minute
Integration time	30 seconds
Averaging	Previous 3 measurements to remove atmospheric effects
Defocus	± 1mm
Field of view	≥35 arcmin^2
Waveband	720-920nm
CCD type	2K x 2K
CCD pixel size	<15µm
Location and format	In focal plane, separate filter (in filter holder), 2x fixed CCD's

Table 11 IR Camera Curvature Sensor Baseline Requirements

Lenslet format	12 x 12 (TBC)
Waveband	720-920nm – same as IR curvature sensor
CCD type	512 x 512
Dynamic range	6 arcsec
Spot separation	6 arcsec
Pinhole size	5 arcsec diameter
Pixel scale	<0.2 arcsec/pixel
Location and format	Pick off mirror, Separate filter
Calibration source	In instrument, beamsplitter

Table 12 IR Camera Shack Hartmann Requirements

Figure 24 & Figure 25 show how the sensors are incorporated into the camera.

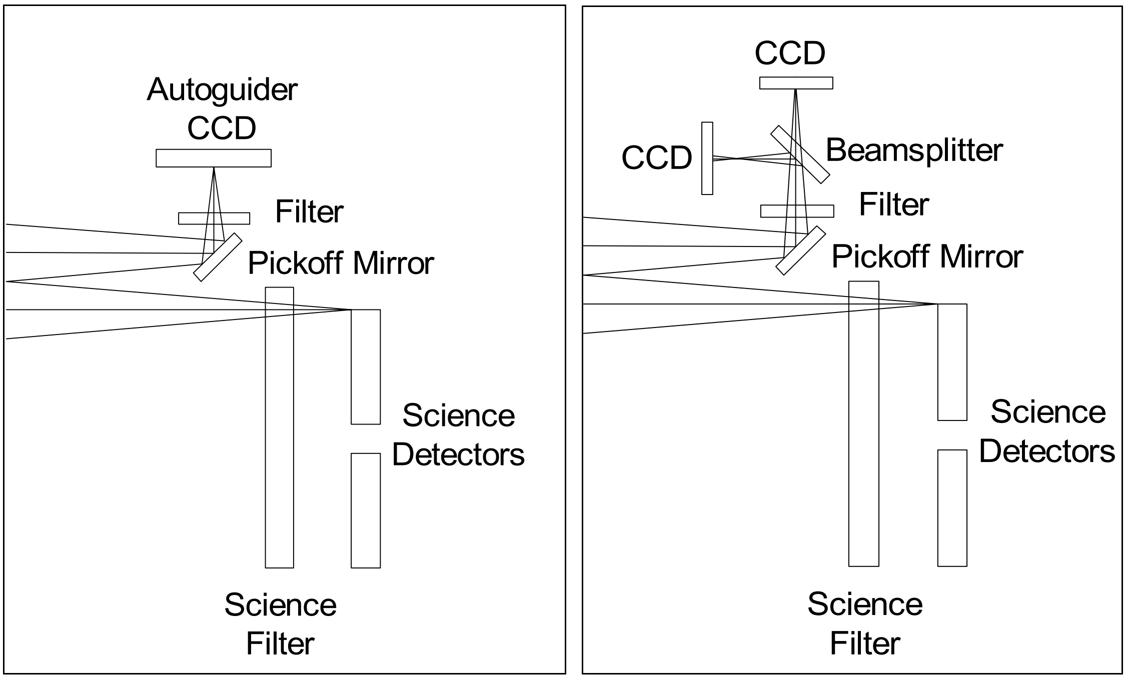

Figure 24 IR Autoguider & IR Curvature Sensor

(Figure 24 & Figure 25 *are not to scale)*

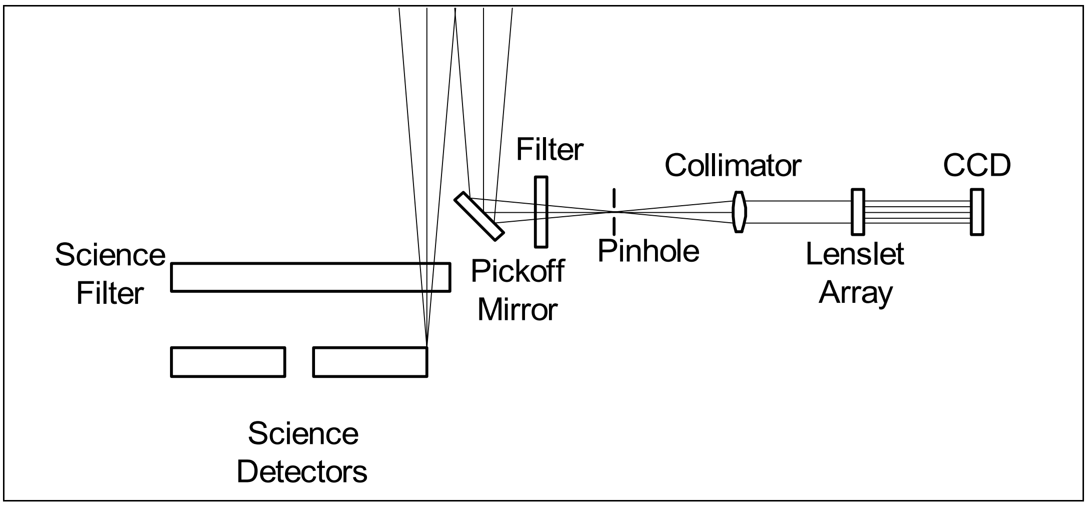

Figure 25 IR Shack Hartmann Sensor

5.4 Control

5.4.1 Hardware Architecture

5.4.1.1 LCU Hardware

Where software is required to control hardware directly or is required to have deterministic performance, it shall run on a VME/VxWorks based computer system conforming to the requirements and constraints of an ESO LCU AD11.

5.4.1.2 Unix Hardware

Where software is not required to control hardware directly or to have deterministic performance, it shall run on a Unix workstation conforming to the requirements and constraints of an ESO workstation AD 11. (In this context a workstation may actually be a server not used directly by a human operator.)

5.4.1.3 Location of Computing Equipment

1. All LCUs shall be located in the VISTA telescope enclosure, which will also contain any X terminals required for engineering work.
2. All workstations shall be located in the Cerro Paranal Control Building. In the Control Room, VISTA will share a console (an open plan work area) with the VST. This console shall accommodate all keyboards, screens and, where appropriate CPUs and storage, necessary for the Telescope Operator to control VISTA and its cameras. Within the Control Building, some VISTA equipment will also reside in other computer rooms.
3. A local control workstation will be situated in the office in the Enclosure Basement.

5.4.1.4 Local Area Networking

VISTA's computing equipment, both in the Telescope Enclosure and the Control Building, shall be interconnected using media and equipment that complies with ESO standards (AD 28). These standards require that fibre optics are used to connect equipment, except in special circumstances where copper may be used.

5.4.2 Software Architecture

5.4.2.1 Infrastructure

All software shall use ESOs infrastructure Common Control Software AD 27 and LCU Common Software AD 21 and shall not duplicate functionality contained in these systems.

5.4.2.2 Control Hierarchy

The control hierarchy of the principal systems comprising the VISTA Control System is illustrated in Figure 26. Within the telescope software, the hierarchy of the TCS and its subsystems is shown in Figure 27.

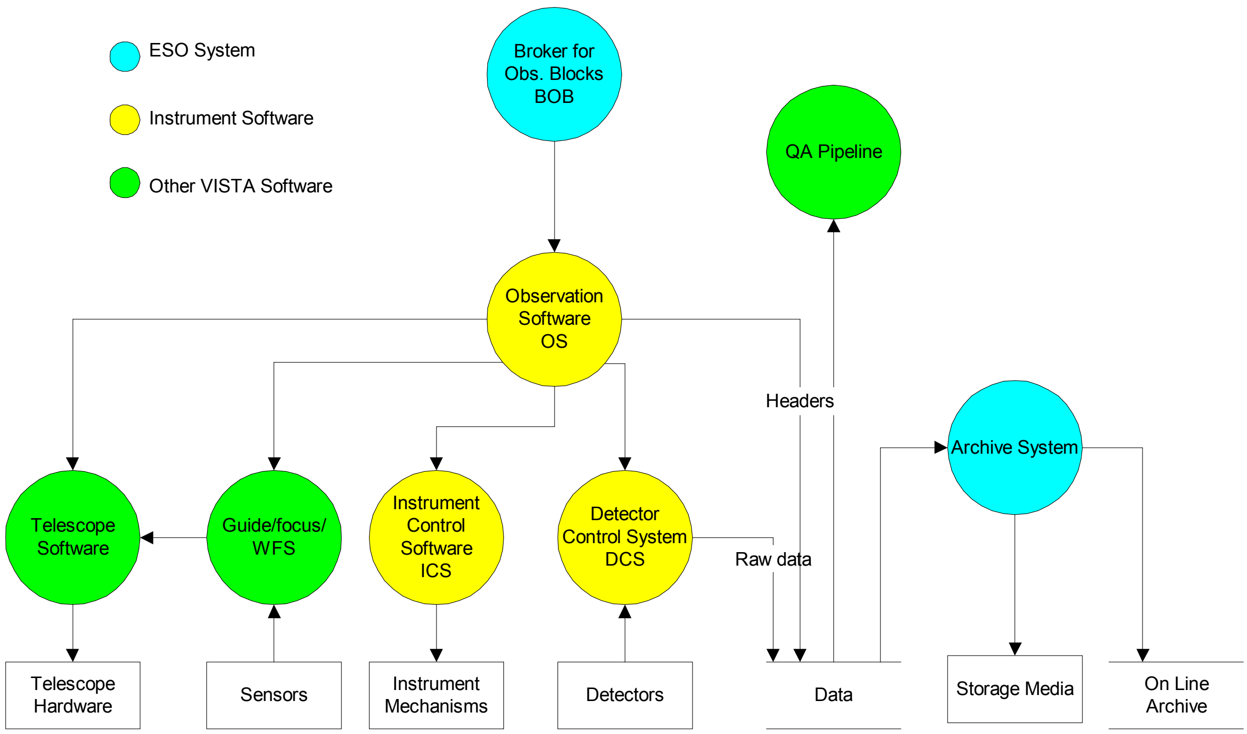

Figure 26 Control hierarchy of the principal VISTA software systems.

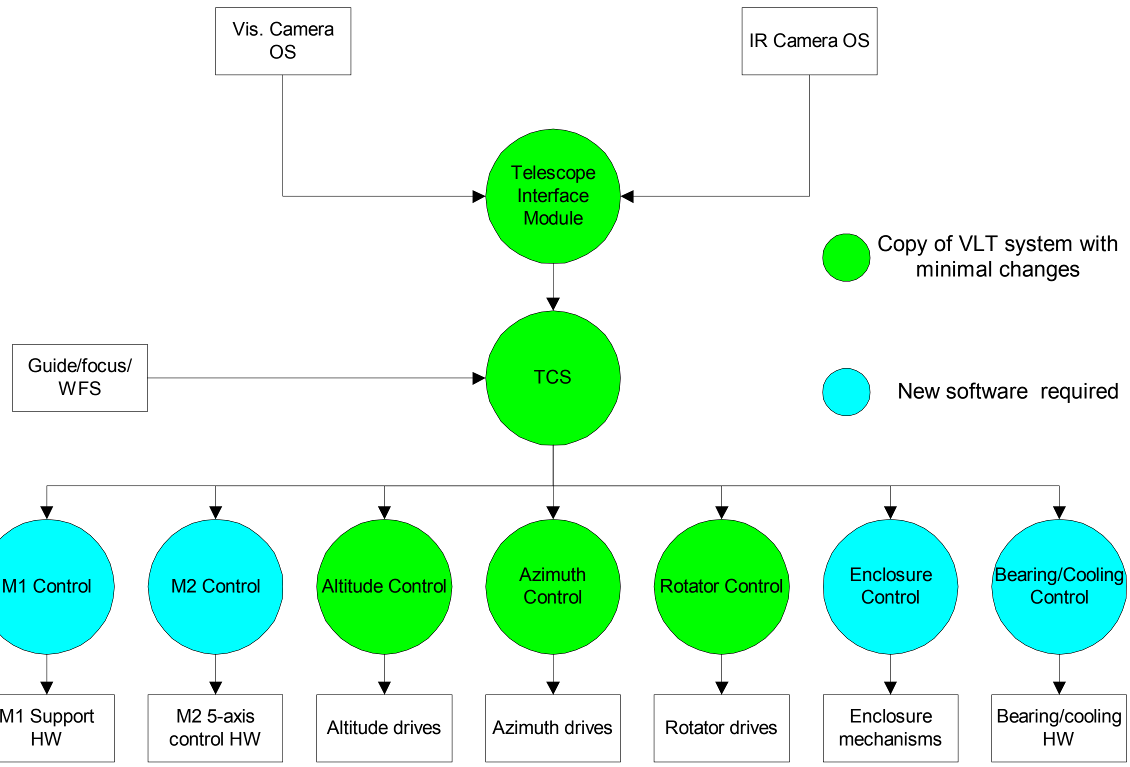

Figure 27 Control hierarchy of the TCS and its subsystems.

5.4.3 Telescope Control System

5.4.3.1 Functionality

1. The Telescope Control System (TCS) shall not control any hardware directly but shall control other software systems that do control hardware. In normal operations, the TCS shall be controlled by the Observation System (OS) of whichever VISTA camera (Visible or IR) is mounted on the telescope.

2. The VISTA TCS and its subsystems shall provide the functionality as defined in AD 25 with the following differences:

    a) There shall be no Adaptive Optics.
    b) There will be no M3.
    c) There will be no M2 chopping.
    d) Guide signals shall be external inputs to the TCS and shall be generated by the camera on the telescope.
    e) Focus and other active optics corrections shall be external inputs to the TCS and shall be generated by the camera on the telescope.
    f) Selection of guide stars shall be the responsibility of the Instrument Software (TBC).

5.4.3.2 Reuse of ESO Software

VISTA's TCS software shall be a copy of the VLT TCS AD 25, modified where necessary by ESO.

5.4.3.3 External Inputs

The TCS shall accept external inputs from whichever VISTA camera is mounted on the telescope to control guiding, focus and wavefront sensing.

5.4.4 Observation Control

5.4.4.1 Reuse of ESO Software

High level observation control at the Cerro Paranal site shall be performed using standard ESO VLT software, configured for VISTA use. This shall include software schedulers and the Broker for Observation Blocks AD 26. The Broker for Observation Blocks shall pass commands to VISTAs Instruments' Observation Systems (Section 5.4.5).

5.4.4.2 Hardware Requirements

Observation control software shall run on the User Workstation or other workstation as agreed with ESO.

5.4.5 Instrument Control

5.4.5.1 Components

1. Instrument Control comprises the Instrument Software and the hardware necessary to run it. Separate systems shall be provided for each instrument i.e. the Visible Camera and the IR Camera.

2. The Instrument Software shall comply with the VLT Instrument Software Specification AD 22. It shall include:
   - Observation Software
   - Instrument Control Software
   - Detector Control Software
   - Observer Support Software
   - Maintenance and Verification Software

5.4.5.2 Interfaces

1. Interfaces shall comply with the corresponding interfaces on the VLT including
   a) Observation Handling Software AD 31
   b) Archive System AD 33
   c) TCS AD 25

2. The Instrument Software shall receive commands from the Broker for Observation Blocks (Section 5.4.5).

5.4.5.3 Hardware Requirements

Separate hardware shall be provided for each of the IR Camera and the Visible Camera. This hardware shall be sufficient to run the software and will include:

- Instrument workstation
- Instrument control LCU
- Detector Control System
- Any networking equipment necessary to allow these systems to communicate with each other
- Storage (see Section 5.5.1)

5.5 Data Handling

5.5.1 Data Storage

5.5.1.1 Reuse of ESO Software

Science and calibration files shall be stored to disk and catalogued using ESOs On Line Archive system Software. This ESO software shall be installed on VISTA hardware and configured for VISTA use.

5.5.1.2 Disk Capacities and Data Rates

The following workstations shall handle VISTA data and shall have access to disk systems with typical capacities and storage rates as indicated in Table 13.

Workstation	Data Capacity	Storage Rate
Visible Camera Instrument	0.8 TB	24 MB/s
IR Camera Instrument	0.8 TB	54 MB/s
Data Handling	1.6 TB	14 MB/s
Archive	2.8 TB	14 MB/s
User	0.8 TB	14 MB/s
Pipeline	1.6 TB	14 MB/s

Table 13 Workstations that handle instrument data.

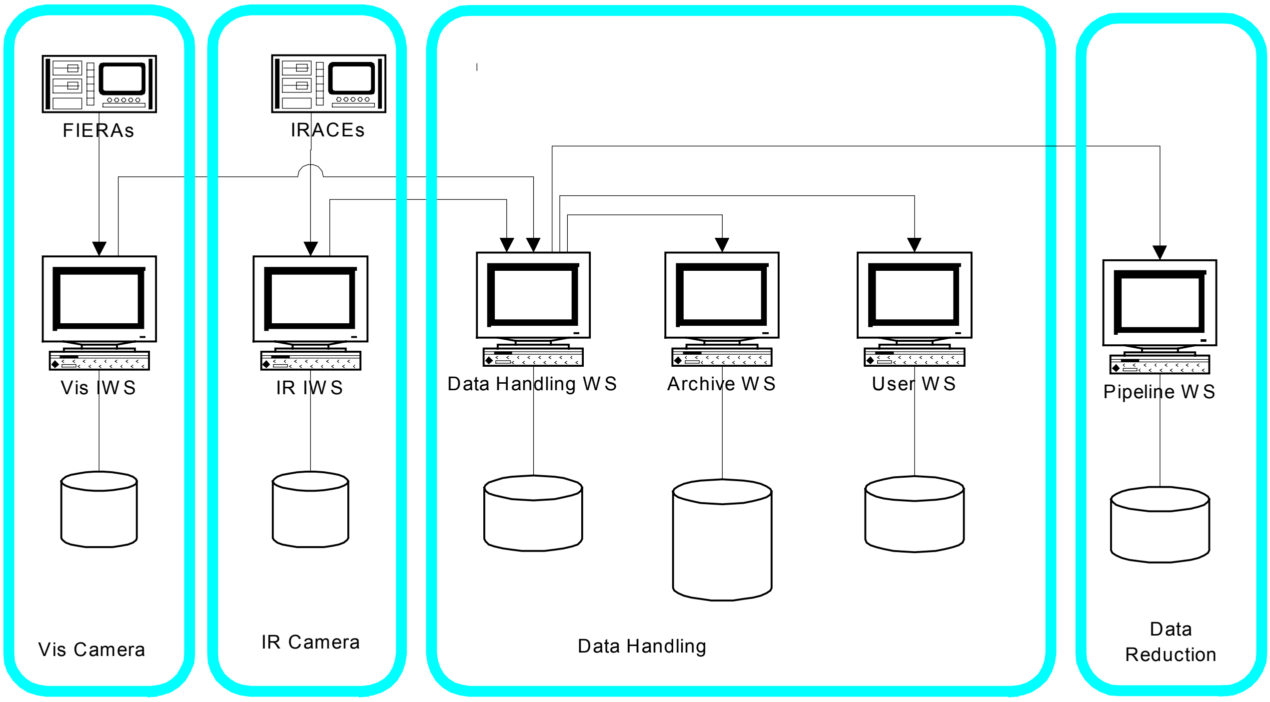

Figure 28. Flow of data from the detector controllers to disk.

These disk systems shall be RAID disks, of a type acceptable to ESO, attached to a single workstation. The storage technology and architecture may be different to that described in this document, if agreed mutually by ESO and the VPO, e.g. to take advantage of new technology.

These workstations exist as discrete entities in the VLT architecture adopted by VISTA. ESO and VISTA may decide that software functionality may be distributed across fewer workstations, in which case the disk capacities required will reduce accordingly.

The dataflows between these systems is illustrated in Figure 28 and specified in the following sections.

5.5.1.3 Visible Camera Instrument Workstation

1. The Visible Camera Instrument Workstation (IWS) shall store data received from the FIERA detector controllers. It shall be capable of storing to disk a single exposure from all the CCDs within 40s of the initiation of the data transfer.

2. The Visible Camera IWS shall transfer data to the Data Handling Workstation at a sustained rate of up to 14 MB/s concurrent with data acquisition.

5.5.1.4 Infrared Camera IWS

1. The Infrared Camera IWS shall store data received from the IRACE detector controllers. It shall be capable of storing to disk a single exposure from all the IR arrays within 5s of the initiation of the data transfer.

2. The IR Camera IWS shall transfer data to the Data Handling Workstation at a sustained rate of up to 14 MB/s concurrent with data acquisition.

5.5.1.5 Data Handling Workstation

1. The Data Handling WS shall store data received from the Visible and IR Camera IWSs at a sustained rate of up to 14 MB/s. It shall be able to receive data from both IWSs concurrently.

2. The Data Handling WS shall transfer data to the Archive WS, the User WS and the Pipeline WS, each of these data flows being able to handle a sustained data rate of 14 MB/s concurrently.

5.5.1.6 Archive Workstation

The archive WS shall store data received from the Data Handling WS at a sustained rate of up to 14 MB/s.

5.5.1.7 User Workstation

The User WS shall be able to store data received from the Data Handling WS at a sustained rate of up to 14 MB/s.

5.5.1.8 Pipeline Workstation

The Pipeline WS shall be able to store data received from the Data Handling WS at a sustained rate of up to 14 MB/s.

5.5.2 Near Line Storage

1. The Archive WS shall be able to store 12 TB of data on near line media. The choice of near line media be agreed with ESO by a date consistent with the start of science observations. Possible media are DVD, other optical disk, LTO, other tape media and magnetic disks.

2. The Archive WS shall be able to store data to the near-line storage media at a sustained rate of 7 MB/s.

5.5.3 Data Transport

1. The Archive WS shall write data to transport media at a sustained rate of up to 14 MB/s.

2. The choice of transport media shall be agreed with ESO by a date consistent with the start of science observations. (Possible media are DVD, other optical disk, LTO, other tape media and magnetic disks.)

5.5.3.1 Data Format

1. Science and Calibration data shall be stored in FITS format, conforming to the specifications in the Data Interface Control Document AD 24.

2. The FITS headers shall contain all ancillary data necessary to characterise the data fully and to allow complete data reduction subsequently to be performed.

5.5.4 Quality Assessment

1. Data shall be reduced sufficiently to assess the quality of the data by noon following the night on which the data were acquired. Quality assessment data shall include as a minimum:

   a) bad pixel identities
   b) dark currents
   c) system noise
   d) mean point spread function
   e) photometric zero points
   f) sky brightness

2. Software shall be provided to alert the operator of any quality assessment metrics that are not within a predefined acceptable range.

3. Trends of metrics shall be displayed graphically.

4. Metrics shall be logged for subsequent analysis.

5. Details of quality assessment shall be defined in VISTA Instrument Software Requirements.

5.6 *Enclosure*

5.6.1 Purpose of the Enclosure

An enclosure is required for three purposes.

1. To provide a safe environment for the telescope, protecting it from extreme weather conditions.
2. To maintain a stable operating environment through thermal control, stray light control and wind attenuation.
3. To facilitate the operation of the telescope by providing infrastructure for the telescope.

In achieving these functions, the enclosure must not be detrimental to telescope operation, i.e. no function of the enclosure must degrade telescope performance.

5.6.2 Definitions

The Enclosure consists of the sub-systems shown in Figure 29, comprising:

- The Dome: consisting of the rotating portion of the Enclosure providing access to and environmental protection of the Telescope.
- The Basement: consists of the static portion of the enclosure providing foundations and support for the Dome and access to maintenance systems below the level of the telescope azimuth floor.
- HVAC system: Heating, Ventilation and Air Conditioning of the Dome and Basement and Auxiliary Building
- Enclosure Control System
- Power.

A schematic diagram of the Enclosure is shown at Figure 30 and a cross section of the Basement and Auxiliary Building in Figure 31.

5.6.3 Aesthetics

The enclosure and basement exteriors will be designed to blend with the existing facilities of the observatory, subject to cost.

5.6.4 General Requirements Applicable to the Enclosure

5.6.4.1 Environmental Conditions

The Enclosure must comply with all environmental conditions specified in AD 04.

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5.6.4.2 Floor Loading:

The preliminary floor loading will be:

1. Rail load 80kN/axle
2. General loading 10kN/m^2
3. Localised loading 50kN/m^2

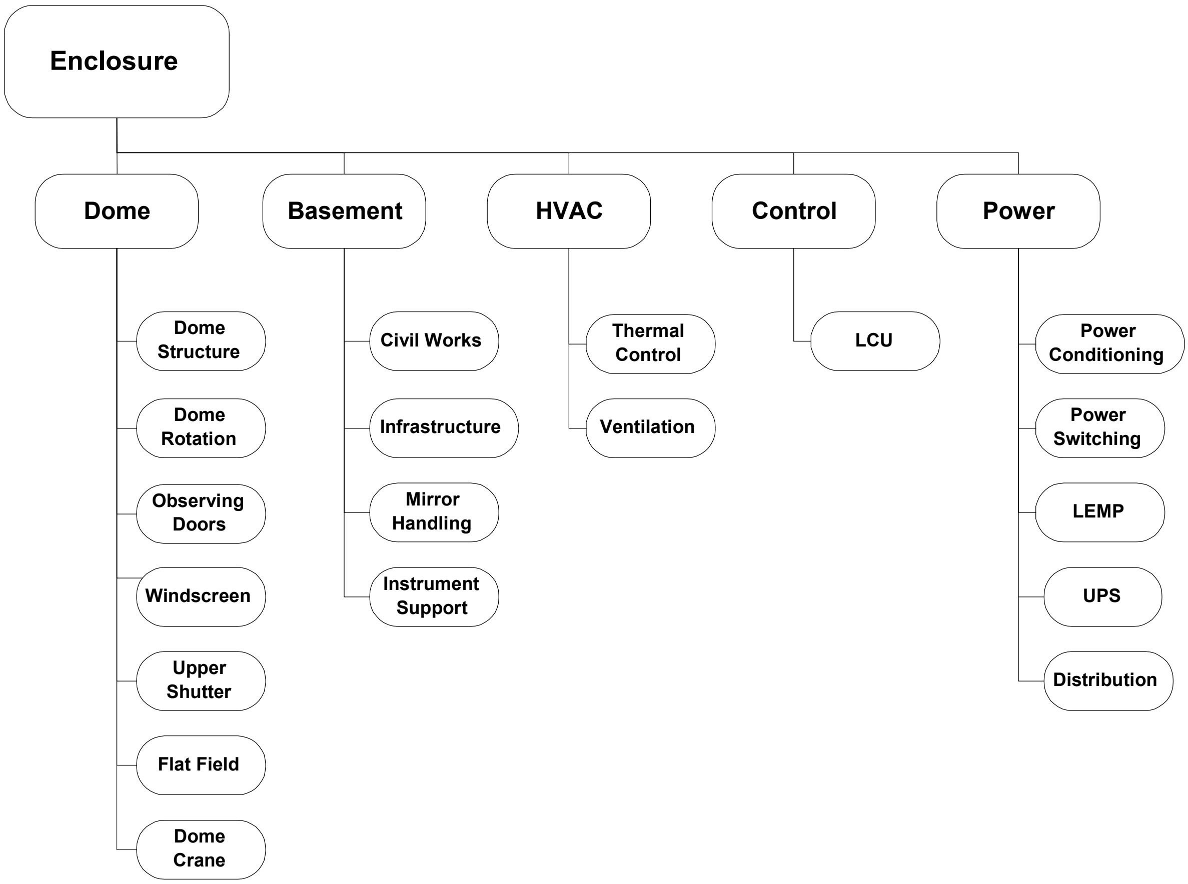

Figure 29 Enclosure Sub-Systems

5.6.4.3 Emergency Lighting

Lighting will be provided to allow safe egress from all parts of the Enclosure and Auxiliary Building. It will be installed to comply with current safety/legislative requirements. Night observing conditions will be taken into account.

5.6.4.4 Protection against Fire

A Fire Alarm system will be provided to ensure the safety of personnel and equipment. It shall be connected via the TCS to the Control Building. Sufficient fire fighting equipment will be fitted to the building in accordance with current regulations.

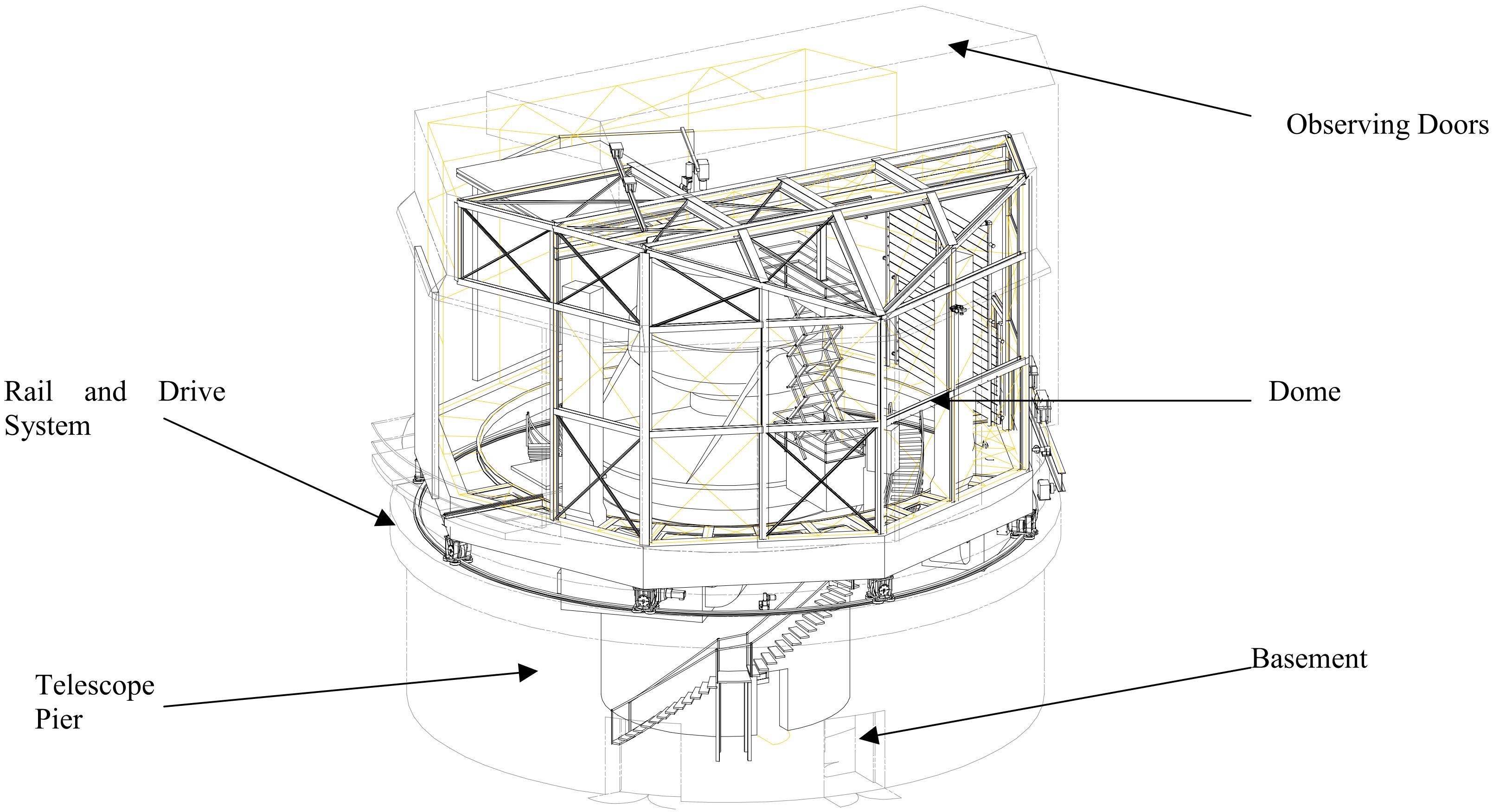

Figure 30 VISTA Enclosure

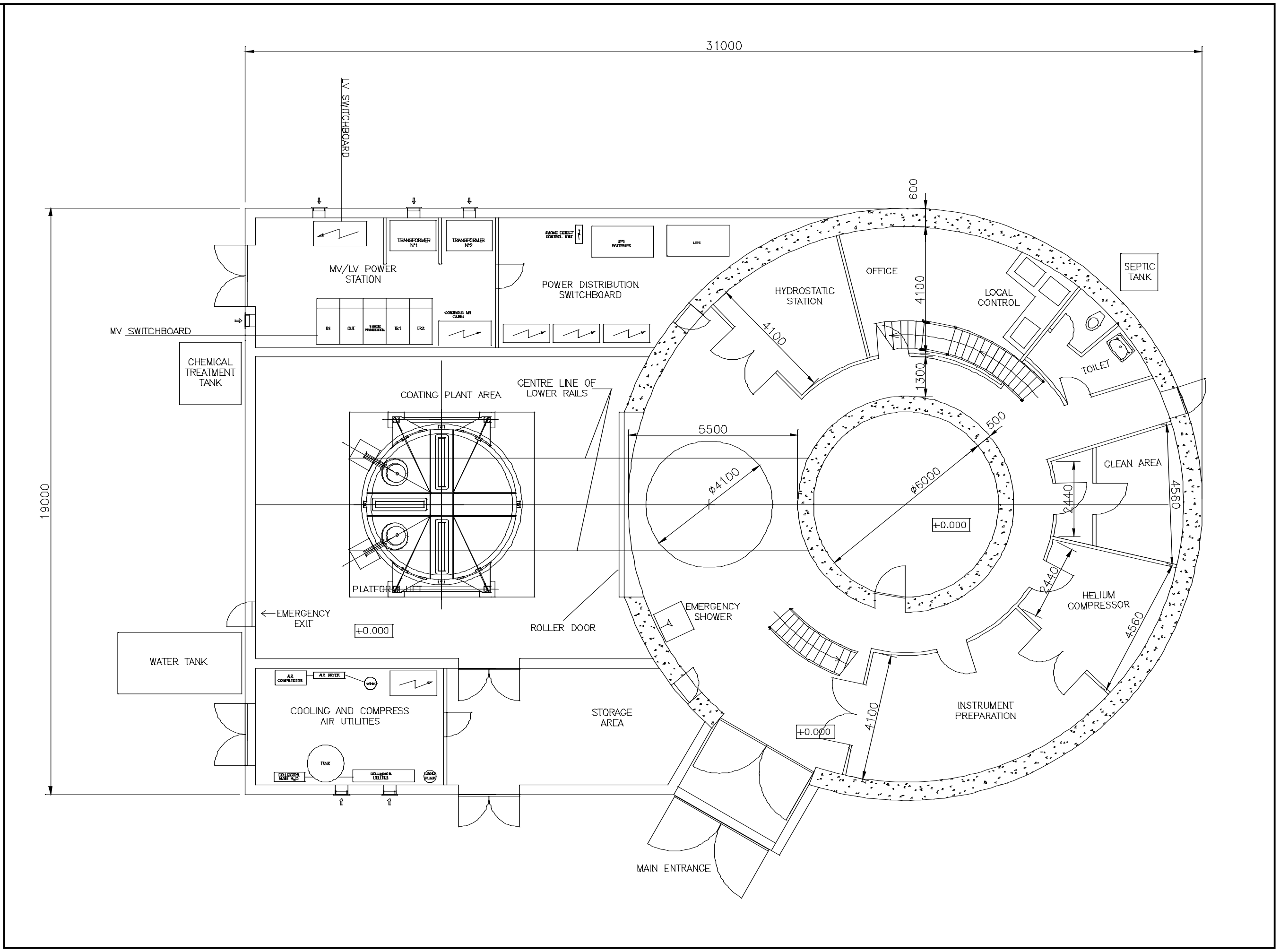

Figure 31: Cross Section of Basement and Auxiliary Building

5.6.5 Dome

5.6.5.1 Steel Construction

1. Steel structures are required throughout the VISTA enclosure, for the rotating part of the enclosure as well as for the roof, the floor, the observing slit door, the doors, staircases and walkways, etc.
2. The steel structures shall consist of all the necessary elements to transmit the different loads from the rotating part through the fixed part to the enclosure concrete structure.

5.6.5.2 Cladding

1. The exterior walls, the roof, and exterior doors of the dome shall be clad with thermally insulating panels, auto-extinguishing type. The mechanical properties of the panels shall comply with the environmental specifications, taking into account the reduced air pressure at the site.
2. The external walls of the enclosure and of the auxiliary building shall be clad with aluminium corrugated sheet (TBC).
3. The cladding system shall have the following characteristics:
   - reduced thermal bridges and continuity of the thermal insulation
4. Water and air-tightness of the enclosure:
   - joints and seals between the cladding panels,
   - joints and seals between the observing slit doors, the ventilation doors, the main mirror door and the enclosure walls and roof.
   - joints and seals between the vertical walls and roof
   - joints and seals between exterior doors and walls
   - the cladding and seals light leakage must be better than 1% of the flat field illumination
5. Bonding of the external metal sheets of the cladding for protection against lightning and lightning electromagnetic pulse (LEMP) in accordance with AD 10. Bonding conductors shall allow good and reliable electrical connections to the structural elements.

5.6.5.3 Observing Slit Door

The observing slit door is composed of bi-parting “L” shaped wings, with the following characteristics:

1. Unvignetted aperture for telescope angles of 0 degrees to 70 degrees zenith distance.
2. The door has a minimum clear aperture of 5400mm.
3. The maximum allowable time for opening is one minute.
4. Open/Closed status indicators will be provided.
5. The doors will be designed for operation in wind speed 20% in excess of operational conditions.

5.6.5.4 Rotation System

The rotation mechanisms shall fulfil the following requirements:

1. sustain all vertical and horizontal dome loads

2. unlimited rotation in any rotation direction (assumes busbar system)
3. minimum slew speed ±2°/s
4. for a zenith blind spot of 4° diameter the maximum angular velocity required for tracking is 480 arcsec/s
5. minimum acceleration: $\pm 0.5°/s^2$
6. provide variable rate of acceleration between 0 and maximum acceleration
7. stop the rotation at maximum speed in less than 5 sec (TBC) in emergency situations
8. allow easy adjustment and assembly during the on-site erection of the enclosure
9. all mechanical parts shall be adequately protected against corrosion

5.6.5.5 Seals

Seals will be provided between the fixed and moveable parts of the building and shutters when closed.

5.6.5.6 Windscreen

An adjustable windscreen will be provided that will track the lower extent of the aperture, providing both ventilation and stray light control.

5.6.5.7 Upper Shutter

An adjustable shutter will be provided that will track the upper extent of the aperture, providing stray light control.

5.6.5.8 Flat Field

A system will be provided to allow Flat Field measurements with the following characteristics:

1. Distance from the M1 Mirror is **not** critical,
2. Repeatability of illumination to ≤ 0.5% is required.
3. The level of illumination of flat field screen should be 100 ± 10 Lux (TBC).

5.6.5.9 Dome Crane

A dome mounted gantry crane shall be provided with the following characteristics:

1. Safe Working Load of 100kN
2. The crane shall be capable of radial access to the azimuth floor
3. The crane shall be capable of reaching the primary mirror handling location(s).
4. During normal operation, the dome will be interlocked to enable rotation only when the crane is in the park location.
5. The dome rotation will have a manual override to allow rotation with the crane in a maintenance location.

5.6.5.10 Maintenance Platform

A moveable maintenance platform will be provided on the azimuth floor. It will be positioned to facilitate servicing of the M2 Unit.

5.6.6 Basement

5.6.6.1 Construction

The basement will be cast in reinforced concrete. The outer wall shall be constructed to support the dome under all design conditions.

5.6.6.2 Access

A mezzanine floor will be provided at a suitable level to access the azimuth track and hydrostatic bearing of the telescope for maintenance purposes.

The basement will incorporate two stairs to access the mezzanine and azimuth floors and to provide emergency exit routes from the enclosure.

5.6.6.3 Vibration

The Telescope Pier will be vibration de-coupled from the Enclosure:

1. Foundations will be cast separately with a gap between the pier and enclosure floor rafts.
2. No equipment will connect between the Telescope Pier and the Basement in such a manner that vibration can be transmitted thorough the coupling.

5.6.6.4 Drainage

The basement floors will be constructed such that spillage or water ingress will drain to a sump with subsequent ducting to an external run-off area.

5.6.6.5 Equipment Housing

The basement will house the following equipment:

1. Oil pump and hydrostatic bearing control equipment
2. He compressors
3. Small clean room
4. Office

5.6.6.6 Primary Mirror Washing Requirements

1. An area in the basement, designated for primary mirror stripping, will be provided with cast in drainage channels leading to an external storage tank.
2. The mezzanine and azimuth floor levels shall provide space above the stripping area for taking the primary mirror from the telescope to the basement.
3. These openings must be covered during normal operation of the telescope with covers meeting the basic floor loading requirements of Section 5.6.4.2.
4. The outer wall will have an access port to the mirror coating facility in the auxiliary building, of minimum dimensions 3m high by 6m wide. This port will be have a roller door or similar to seal the coating chamber area during normal telescope operation.

5. Two parallel rails at 3m (TBC) pitch will be installed between the coating area and the stripping area. These will be recessed into the floor and covered by steel floor plating during normal operation.
6. Safety cabinets shall be provided for storage of stripping and washing materials when not in use.

5.6.6.7 Camera Storage and Support

Facilities to store one camera shall be provided in the basement. These shall include all necessary support to operate the camera remotely from the telescope. It shall be possible to perform minor maintenance activities in this area. For larger engineering tasks, the mirror stripping area shall be utilised.
A facility to support the second camera during a mirror coating shut down shall be provided. This will provide the minimum necessary to maintain the readiness of the camera.

5.6.7 HVAC System

5.6.7.1 Enclosure Temperature Stabilisation

In order to provide the optimum observing conditions, it is required that all internal surfaces of the enclosure have at the start of the night a temperature close to the predicted minimum air temperature (T_o) for that night. Thermal control will be achieved by:

1. Minimising the heat input both from the external environment and from the lower basement area by use of adequate insulation and seals.
2. Air Conditioning the inner volumes, above the azimuth floor during the day and below the azimuth floor level during observing. Cooled air will be distributed throughout the entire volume by means of air outlets distributed along the inner surface, including the upper part of the dome when the dome is locked in its parking position.
3. When the dome is first opened in the evening the surface temperatures above the azimuth floor level shall be $\leq T_o + 2°C$

5.6.7.2 Auxiliary Building

Air Conditioning of the Auxiliary Building will be designed such that the internal air temperature shall be kept at the greater of (T_o)+5°C or 5°C during the day. The area used for coating shall be capable of being heated to 18°C during coating operations.

5.6.7.3 Cooling

A chilled water supply will feed a number of Air Conditioning units. Other secondary chilled water circuits will supply the cooling requirements for all facilities including, hydraulic plant, LCU's, helium compressors and the cooling for the magnetrons.

5.6.7.4 Ventilation Doors

The current implementation foresees three ventilation (double) doors designed in conjunction with the observing doors to allow air flushing of the enclosure. The fully open aperture of these doors is approximately 6m x 6m. Each door shall be capable of independent positioning at closed, half-open or in the fully open position. Appropriate safety barriers and interlocks are provided for each door.

5.6.8 Enclosure Control System

5.6.8.1 Command Interface

The Enclosure Control System shall run on an LCU controlled by the TCS, using the same interface definition as used on the VLT, modified in detail only if necessary.

5.6.8.2 Hardware Interface

Hardware shall be controlled via signals transmitted from the Enclosure LCU. Details of this interface will be defined during detailed design.

5.6.8.3 Manual Control

It shall be possible to operate the various functions of the enclosure through a manual control panel.

5.6.9 Telescope Pier

5.6.9.1 Definition

The Telescope Pier consists of the static portion of the VISTA telescope providing foundations and support for the telescope azimuth bearing.

5.6.9.2 Stiffness

The Pier shall be designed in such a manner that it will not degrade the telescope fundamental natural frequencies by more than 1.5 Hz.

5.6.9.3 Vibration

The Telescope Pier will be vibration de-coupled from the Enclosure:

- Foundations will be cast separately with a gap between the pier and enclosure floor rafts.
- No equipment will connect between the Telescope Pier and the Basement in such a manner that vibration can be transmitted thorough the coupling.

5.6.9.4 Access

The centre of the pier shall be accessible from the basement at ground level. Provision for access to equipment inside the pier (e.g. telescope cable wrap) shall be provided.

5.7 Auxiliary Equipment

5.7.1 Definition

Auxiliary equipment is defined as any ancillary equipment necessary for the operation and maintenance of the VISTA facility.

5.7.2 Equipment Location

Auxiliary Equipment will be housed in the Enclosure Basement, one or more Auxiliary Buildings or Remote from the enclosure. Current planned locations are shown in Table 14, though final location may vary as designs are developed. The Auxiliary Building shall be orientated approximately North–South and will be attached or in close proximity to the Telescope Enclosure Building to the South. The prevailing wind is predominantly from the NW quadrant.

Equipment	Current Location
Mirror Stripping	Basement
Coating Plant	Auxiliary Building
Transformer	Auxiliary Building
Power Distribution	Auxiliary Building
Plant Room	Auxiliary Building
Stores	Auxiliary Building
Computer Facilities	Basement
Office	Basement
Sanitary Facilities	Basement
Camera Support	Basement
He Compressors	Basement
Hydrostatic System	Basement
Heat exchange	Remote

Table 14: Equipment Location Table

5.7.3 Mirror Stripping

5.7.3.1 Washing Facility

An area within the Enclosure basement will be designated for primary mirror stripping and cleaning. A description of this area is contained in Section 5.6.6

5.7.3.2 Water Supply for mirror washing

A supply of de-ionised water will be required for washing the mirror. A 500ltr storage tank will be provided with gravity feed to point of use. De-ionised water will be stored as required. Provisions for water purification will **not** be provided.

5.7.3.3 Mirror Washing

The mirror will be stripped and washed manually.

5.7.3.4 Lighting

Fluorescent lighting will be provided for general illumination in this area. Level of illumination to be 100lux. A higher level of illumination shall be provided for the mirror washing process. This level of illumination shall be 500 lux and shall be achieved by use of metal halide or similar luminaires.

5.7.3.5 Hazardous Material

Hazardous substances will be stored and subsequently disposed of safely in accordance with COSHH requirements (AD 52).

1. Chemical and Flammable materials will be stored in appropriate cabinets.
2. Data sheets will be kept for all substances at a central location on site.

5.7.3.6 Emergency Shower

Shall be provided and available at all times in the event of chemical contamination from, for example spillage whilst undertaking the Mirror Wash process.

5.7.4 Transformer Room *(Power Substation)*

A suitably rated dry resin type transformer and the required Medium Voltage switch gear to step down the Paranal power supply will be provided. It will be installed in a dedicated room within the auxiliary building.

1. The system will be rated to deliver 500 kW.
2. Under normal operating (observing) conditions the peak load will be ≤ 200 kW.
3. When the Mirror is being coated the peak load will be ≤ 250 kW.

5.7.5 Electrical Power Distribution Room

Low Voltage switchgear and distribution panels will be provided. It will be installed in a dedicated room within the auxiliary building. This room will be directly accessible from the Enclosure.

1. UPS power will be provided with a maximum rating of 20 kWh (TBC).

5.7.6 Plant Room

A compressor, air dryer and air receiver will be provided. It is envisaged that this supply will be utilised for the M1 Mirror support system, Coating plant, and general purpose compressed air (Usage requirement 800ltr / min distributed at 8 bar.). **No** provision has been made for air pallet supply. The detailed specification of the quality of the compressed air will be developed during the design phase.
The compressor will be installed in a room within the auxiliary building designated the plant room. This room will house any additional service equipment such as water pumps, heat exchangers etc.

5.7.7 Office/rest area

A small office and document store will be provided. This room will require network, communications and ventilation.

5.7.8 Sanitary Provision

Toilet and washroom facilities will be required.

5.7.9 Heat Exchange

A cooling circuit will be provided for cooling of equipment and air conditioning heat exchange. This circuit will also be utilised in the magnetron cooling system heat exchanger. The chiller will be mounted remotely from the Enclosure to the SE (TBC) charge tanks and boost pumps will be installed as necessary.

5.7.10 Storage

An area within the auxiliary building will be set-up as an equipment store. The auxiliary building design will dictate the size and capacity of this area.

5.7.11 Computing Facilities

Space will be provided for computing facilities not associated directly with hardware e.g. data storage, communications etc. This facility will be housed in the basement.

5.8 Coating Plant

5.8.1 General Description

The Coating Plant will be situated in the auxiliary building immediately adjacent the basement outer wall. The plant consist of two sections, designated the lower and upper vessel. The vessel will be ~5.5m in diameter and 3.0 metres in height and mount all systems necessary for coating the primary mirror and secondary mirror. The control systems including the pumping station, heat exchange, gas supply and magnetron control panel will be housed in the coating plant room.

5.8.2 Coating the Primary Mirror

In brief, the coating process is as follows:

1. Install the primary mirror on the support in the lower vessel, engage earthquake restraints
2. Position lower vessel under upper vessel and close-up
3. Vacuum pump the vessel
4. Inject plasma gas (Ar, N_2)
5. Start mirror rotation
6. Begin magnetron
7. Open shutter for one revolution
8. Close shutter and switch off magnetron

9. Repeat 6 to 8 for additional layers
10. Vent vessel
11. Remove mirror

5.8.3 Lower Vessel

The lower vessel has a rotating whiffle tree arrangement to mount the primary mirror. For safe mounting, earthquake lateral restraints will engage the mirror. The whiffle tree are on a rotating drive which will revolve the assembly and mirror at a pre-determined rate for mirror coating quality.
The lower vessel is mounted on rails, on a 3 metre pitch (TBC), to allow it to be driven into the basement for installation and removal of the mirror.

5.8.4 Upper Vessel

The Magnetron and vacuum systems will be mounted through the upper vessel. The upper vessel is raised on four screw jacks to open the vessel and allow the lower vessel to move on the rail system.

5.8.5 Magnetron

Three magnetrons will be installed in the upper vessel. Each will consist of:

1. Magnetron, water cooled with copper backed targets
2. Water cooled shutter
3. Water cooled mask

Four targets will be provided:

1. Al Target, for testing the system and individual magnetrons
2. Ag reflective coating target
3. NiCr adhesor layer target
4. HfO_2 or similar protective layer target

5.8.6 Vacuum Pumping Equipment

The vacuum will be achieved through a cryo-pumping system. Two cryo-pumps will be installed in the upper vessel with gate valves, one of which will be capable of three position control: closed, fully open and intermediate pumping. The system will be equipped with a roots style roughing pump-set. Pumping will be fully automated.

5.8.7 Power Requirements

Peak demand is estimated to be 60 kW.

5.8.8 Cooling

The vacuum system, magnetrons, masks and shutters will be water cooled. The cooling system will be closed circuit with a heat exchanger connected to the main cooling circuit or in a stand-alone unit.

5.8.9 Plasma Gas

Provision for injection of the plasma gas will be provided. Automatic control of the gas flow rate will be enabled.

5.8.10 Lighting

Fluorescent lighting will be provided for general illumination in this area. Level of illumination to be 100lux. A higher level of illumination shall be provided for the mirror coating process. This level of illumination shall be 500 lux and shall be achieved by use of metal halide or similar luminaires.

5.8.11 Coating Plant Control

A system will be implemented, that will control the coating processes from start-up to shut-down. This process will be automated but will require operator supervision throughout the process.

5.9 Service and Handling Equipment

5.9.1 General

The full requirement for service and handling equipment will be identified during the design phase. The following guidelines will be adopted in provision of service and handing equipment:

1. The dome crane will be the prime lifting facility within the Enclosure
2. Any equipment necessary for safe service and handling will be provided.
3. Any special tools necessary for maintenance will be provided.
4. Sufficient basic tools will be provided for maintenance of VISTA and servicing of the sub-systems.

5.9.2 Lifting Equipment

The dome crane will be utilised for all major lifts. Additional craneage will be supplied as follows:

1. A wall mounted jib crane will be fitted in the camera service area. Capacity 1 tonne.
2. A wall mounted jib crane will be fitted in the area designated for mirror stripping. Capacity 1 tonne.

5.9.3 Basic Handling Equipment

The following basic handling equipment will be provided:

1. Electric Forklift, capacity 1 tonne
2. Manual pallet trolleys, capacity 5 tonne.
3. Slings and shackles as necessary

5.9.4 Special Handling Equipment

The follow are identified as necessary special handling equipment:

1. Mirror cell handling trolley
2. Primary mirror handling tool (nine point whiffle tree lifting frame)
3. M2 handling equipment
4. Camera removal and handling equipment

Some functions may be duplicated and where beneficial, special equipment can be dual purpose.

5.10 Test Equipment

5.10.1 Test Camera

The Test Camera shall be a 'simple' instrument to commission the telescope before the cameras are available. It is not intended as an integrated test facility. It shall be mounted to the Cassegrain rotator in an identical way to the Visible and IR cameras. The telescope will be balanced to the equivalent of the allowable limits of mass and centre of gravity for the science cameras.

The essential features of the wavefront measurement and correction shall be implemented as follows:

1. Measurement of focus and coma terms
2. Other wavefront aberrations measurement for the creation of look-up tables

The wavefront measurements shall be made for various positions in the field: on-axis and 9 off-axis points to characterise the field aberrations. These will be fitted to Zernike modes in an offline PC based analysis package. The results will be used to calibrate the forces required on the active primary mirror M1 and created the force look-up tables

The baseline optical design layout, is shown in Figure 32. The system shall comprise:

1. Field corrector lens (N-BK7, all spherical surfaces, 500mm diameter)
2. Beamsplitter.
3. Two fixed filters (narrow band - 700-710nm).
4. Two lenslets arrays (4x4 for initial set-up and 12x12 for look-up table derivation).
5. Two CCDs (based on Marconi CCD57: 512x512, 13.0 microns pixel): with a fov of 2 $arcmin^2$, one for Shack Hartmann wavefront sensing, and one to measure open loop tracking error.
6. Mounting hardware
7. Computer for operation and analysis. This computer shall be standalone and shall not communicate with other control or computer systems. It need not comply with ESO standards.

5.10.2 Reflectometer

Coating samples shall be measured with a reflectometer.

5.10.3 Filter Transmission Monitor

A monochromator or similar test device for monitoring long-term stability for filter transmission curves shall be provided.

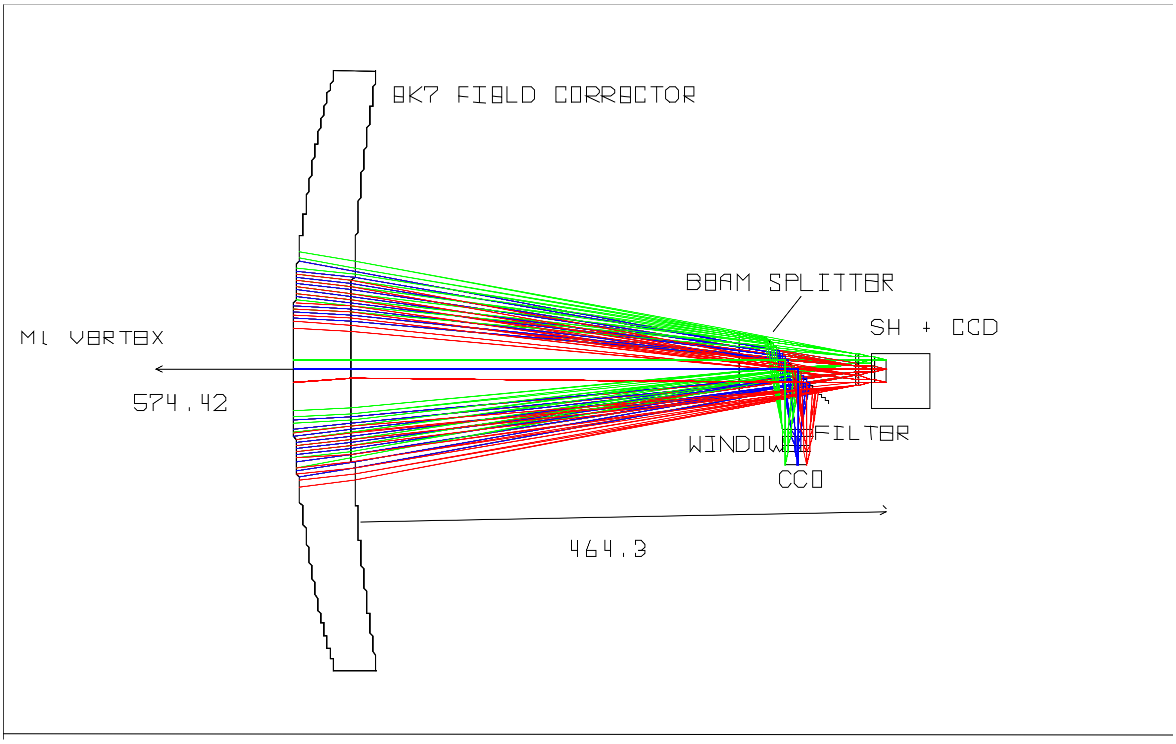

Figure 32 Test Camera Conceptual Layout

6 Operational requirements

6.1.1 Control of Equipment

It shall be possible to operate all equipment, required for observing and normal calibration procedures, from the VLT Control Building.

6.1.2 Independent Operation of Cameras

1. Each camera shall be capable of being operated, maintained and tested without interfering with the other camera.
2. Each camera shall be capable of being operated stand-alone off the telescope.

6.1.3 Calibration Procedures

Calibration procedures shall, where feasible, be implemented in software. These procedures shall:

1. Record all changes so that it is possible to revert to previous calibrations and perform trend analysis.
2. Record all raw data used to generate new calibrations (e.g. FITS files in the archive)
3. Be capable of being initiated and run automatically, whilst remaining under control of the operator.

6.1.4 Observing Modes

1. The normal method of observing shall be queue scheduling, in which observations are completely specified in advance using a tool generating output compatible with P2PP's output.
2. It shall be possible for an observer at the telescope to control observing directly, e.g. by using a tool generating output compatible with P2PP's output.
3. The Telescope Operator shall be able to override any automatic operation, e.g. to perform authorised over-rides. (Within 60 minutes, 10 minute Goal of a suitably authorised request, TBC).

6.1.5 Observing and Engineering Logs

1. All observations, including calibrations, shall be logged.
2. All significant engineering events shall be logged including
   a) telescope motions
   b) camera configurations
   c) faults
3. Logs shall be transmitted during the day following the observations.
4. Logs shall properly take account of non-operating detectors i.e. record that the relevant area of sky has not been observed.

6.1.6 Handling Faults

1. Where feasible, the system shall continue normally to operate in the presence of faults. Such faults may include non-operating detectors.
2. The existence of missing or poor quality data shall be indicated in the data headers.
3. All faults shall be logged. Each log entry shall contain relevant details to help an engineer to diagnose the problem.

6.1.7 Weather Monitoring

1. Weather monitoring data from Paranal Observatory will be incorporated into the science data headers.
2. As a minimum this shall include seeing monitoring, local temperature and wind speed data.

6.1.8 Readout Noise Pickup

It shall be possible to operate any single mechanism during detector readout for noise pickup testing.

7 Reliability Maintainability & Safety Requirements

7.1 Telescope Lifetime

VISTA shall be designed for a minimum lifetime of 15 years of operation, comprising an average 12 hours of observation and 12 hours of stand-by per day.

7.2 System Reliability

7.2.1 Overall Availability

The system shall be designed and manufactured in order to ensure that the non-scheduled down time does not exceed 5% of the observing time.

7.2.2 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.

Major subsystems of VISTA shall be designed for a Mean Time Between Failures (MTBF) of 3 years. As a minimum, this shall apply to the following subsystems:

1. Telescope (including drive and control system)
2. M1 Cell
3. M2 Electromechanical Unit.
4. Enclosure
5. Instruments.

For each of the above subsystems a Failure shall be defined as a fault leading to a loss of observing time of more than 4 hours.

Although MTBF criteria may not be suitable for equipment used only occasionally (example Coating Plant), a high reliability shall be enforced in the design and manufacturing process by appropriate methodology and review.

7.3 Maintainability Guidelines and Requirements

7.3.1 Guidelines for Diagnostic and Maintenance by Software

As a general rule Maintenance procedures shall, where feasible, be implemented in software. These procedures shall:

1. Check performance against predetermined requirements and if necessary alert the operator.
2. Be capable of be initiated and run automatically, whilst remaining under the control of he operator.

3. Log all procedures, whether successful or not.
4. Log relevant data so that trend analysis can be performed.

7.3.2 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, LRUs) when practical.

1. LRUs 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 spares LRUs must be available at the observatory.
3. Standardisation of equipment, fully applicable to VISTA is given in applicable documents AD06 and AD11, covering Service Connection Points and Electronic components. As a general design guideline the VISTA 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

7.3.2.1 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 VPO shall define predictive maintenance opportunities for adoption on site and provide the interfaces necessary for such activities.

7.3.2.2 Preventive Maintenance

Preventive maintenance actions (not including periodic mirror re-coating) shall be planned with a frequency of:
every month for inspections and relatively simple actions of less than 4 hours in total;
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.

7.3.2.3 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. For VISTA limited overhauls 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

7.3.2.4 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.

7.3.3 Monitoring & Test routines

Software routines shall be used to facilitate maintenance and fault detection and location.
As a general rule two monitoring and test levels are to be considered:

1. Monitor level: executed continuously as a background task by the LCUs, shall carry out checks such as:
    - Interlock system
    - power supply level
    - temperatures
    - positions
    - correct execution of commands
    - other variables and signal, as required by the system controlled by the specific LCU.
    - The selection of which parameter has to be monitored (also some not included in the above list) depends on the criticality of the parameter for the overall safety and performance. Monitored parameters shall be stored in the local database to be accessible from the central control software. The list of all parameters being monitored shall be already identified at the design level.

2. Self-test: This will execute on switch-on and at other times. It shall carry out operations such as
    - Checking memory access and communication links
    - Checking the presence of necessary hardware on the LCU bus
    - Exercising any other functions that would be safe to carry out automatically without human intervention (i.e. NOT including any functions that would switch on or move a device that could pose a safety hazard)

3. Diagnostic-test: This will execute additional checks on an individual device or sub-assembly which will test all its functions. This test will ONLY be initiated by the operator or by an engineer, and it is assumed that the operator will be familiar with the test and any safety implications (e.g. stay clear of the telescope while testing the azimuth drive).

7.3.4 Spares

The ranging and scaling of spares shall be defined during the design and manufacture phase. This should be based on standard operating conditions.

7.3.5 Specific Maintainability Requirements

7.3.5.1 In Situ Cleaning

The design of the System shall allow In-situ cleaning of the M1 and M2 mirrors and the camera windows

7.3.5.2 Primary Mirror coating

A complete re-coating operation, by an experienced and rehearsed team, shall not delay science observations by more than 3 nights.

7.3.5.3 Camera Change

1. The time to exchange a camera shall not exceed 8 hours and not demand more than three technicians.
2. It shall be possible to perform all maintenance functions on either camera whilst it is off the telescope, without impacting on the operation of the camera mounted on the telescope.
3. Following a camera change, it should be possible to reach standard operating performance and take sufficient calibration data to calibrate out any systematic changes, using not more than 2 hours of clear night time and 4 hours of additional daylight following the camera change.
4. Following cool down, the cameras shall be capable of meeting the Astrometry stability requirements within 48hrs for the IR Camera and 24hrs for the Visible Camera.

7.3.5.4 Camera Intervention

It shall be possible to change any or all the ‘additional’ IR filters in the IR filter slots within 20 days.

It shall be possible to thermally cycle the IR camera from operating to room temperature and back again in no more than 14 days.

It shall be possible to cycle the Visible camera in 7 days.

It shall be possible to change any or all of the Visible Camera filters within 8 hours.

7.4 Safety

This section describes the general safety philosophy applicable to the VISTA design in order to eliminate or minimise hazards to personnel and equipment during the various phases of the project including assembly, disassembly, test, transport, storage, operation or maintenance. It steps from the requirements of Applicable Document AD40 (VISTA Project Safety Management Plan)

According to the general rules of AD40, non-standard equipment, specifically designed and built for VISTA should be designed to ALARP (As Low AS Reasonably Practicable Requirements), which means that an Hazard analysis based on a probabilistic risk assessment is used to identify hazards, to determine their severity and acceptability. The overall criteria for the review of the Hazards are given here below. Hazards shall be treated in order that they reach ALARP status.

An hazard is considered to have reached the ALARP status when either it is tolerable or a further risk reduction is achievable only with penalties in terms of cost, time and effort disproportionate to the gain obtained.

Risk assessments will be performed in a top down manner to the level necessary to ensure ALARP status has been achieved.

7.4.1 Hazard Risk Acceptance Criteria

7.4.1.1 Hazard Severity

Hazard severity categories are defined to provide a qualitative measure for the mishap classification.

Category	Mishap Definition
CATASTROPHIC	Death or system loss1)
CRITICAL	Severe injury2)", major occupational illness, major system damage3)
MARGINAL	Minor injury, minor occupational illness, minor system damage4)
NEGLIGIBLE	Less than minor injury/occupational illness and minor system damage

Notes: 1) *System loss*: the system cannot be recovered at reasonable costs

2) *Severe Injury*: partial permanent disability of human beings

2) *Major system damage*: the system can be recovered but extensive industrial support is necessary and/or the system is out of operation for more than 3 weeks

3) *Minor system damage*: the system can be repaired without support from industry and/or the system is less than 3 weeks out of operation.

Any failure leading to the loss of primary or secondary mirror shall be considered as "catastrophic".

Any failure leading to loose parts falling on the primary mirror or the camera window shall be considered as catastrophic.

A failure leading to the falling of liquids on the primary mirror shall be classified according to the above mishap classification.

7.4.1.2 Hazard Probability

The probability that a hazard will occur is defined in the following table:

Level	Definition	Description
A	FREQUENT	Likely to occur frequently (≥ 6 times in 25 years)
B	PROBABLE	It will occur several times during 25 years (4-5 times in 25 years)
C	OCCASIONAL	Likely to occur during 25 years (2 to 3 times in 25 yers)
C	REMOTE	Unlikely but possible to occur during the lifetime (typically once in 25 years)
D	IMPROBABLE	So unlikely that the occurrence can be assumed not to be experienced

7.4.1.3 Hazard Risk Category

The following matrix defines the degree of acceptability of the various hazard categories:

Frequency of occurrence	Catastrophic	Critical	Marginal	Negligible
FREQUENT	I	I	I	II
PROBABLE	I	I	II	III
OCCASIONAL	I	II	III	IV
REMOTE	I	II	IV	IV
IMPROBABLE	III	III	IV	IV

Hazard risk index	Assessment criteria
I	Unacceptable
II	Undesirable (ESO decision required)
III	Tolerable with review by ESO
IV	Tolerable

7.4.2 General Safety Requirements

The general principles of safety design of technical products defined in AD43 & AD44 shall be applied.

7.4.3 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.

7.4.4 Protection against electric shock and other hazards

7.4.4.1 Introduction

The low-voltage electrical installations of the VLT Observatory are designed and erected according to AD46 (IEC 60364 Electrical Installation of Buildings); their system earthing is TN-S.

7.4.4.2 Safety compliance

In order to achieve protection against electric shocks and other hazards VISTA and parts of it shall be designed and erected in compliance with the applicable documents AD44 (EN 60204-1), AD 45 (IEC 61140) and AD46(IEC 60364)

7.4.4.3 Electrical and electronic equipment

Electrical and electronic equipment to be installed onto VISTA shall comply with AD45, taking into account the VLT Observatory altitude.

Information Technology Equipment to be integrated into VISTA shall comply to AD47 (IEC 60950)

7.4.4.4 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.

7.4.5 Primary Mirror safety

Under any conditions the maximum principal tensile stress in the primary mirror shall not exceed the following values:

- 6 MPa for a duration shorter than 24 hours
- 3.5 MPa for a duration longer than 24 hours

7.4.6 Hydraulic Safety

Any hydraulic systems shall be designed in accordance with AD50.

7.4.7 Pneumatic Safety

Any compressed air piping, including connections of compressed air system shall be designed in accordance with AD43.

7.4.8 Cooling System Safety

Cooling systems shall be designed in accordance with the electrical safety requirements and AD43.

7.4.9 Software Safety

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

7.4.10 Handling, Transport and Storage Safety

The design of VISTA 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.

7.4.11 Operational Safety

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

- One or two independent operator errors
- One operator error plus one hardware failure
- One or two hardware failures
- One or two software 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.

7.4.12 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. The number and position of Interlocks shall be defined during the design phase in accordance with AD 11.

8 General Requirements for Design and Construction

8.1 Requirements for analyses

8.1.1 Finite Element Structural Analyses

All the Finite Element Analyses necessary for the verification of the performance of the major subsystems of VISTA must be performed with an internationally recognised numerical code. The structural models used shall be adapted to the particular analysis for which they are going to be used and shall be accurate enough to provide a good description of the behaviour of the structure under examination in terms of displacements, stress and frequencies.
The analysis error due to mesh density shall be ≤ 10% in terms of FE internal criteria like the 'Percentage error in energy norm'. Alternatively this type of error can be evaluated by mesh refining. The verification of the accuracy of the modal analysis by experimental methods is in any case the preferred solution.
Analyses used for verification of optical performances (example M2 mirror) shall have a sufficient number of points on the optical surfaces

8.1.1.1 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.

8.1.1.2 Gravity load analysis

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

8.1.1.3 Wind stress analysis

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 AD42.

8.1.1.4 Seismic analysis

General
The seismic analyses shall be based on the modal response spectrum technique. The design response spectra for OBE and MLE are given in AD04. The applicable percentage of critical damping to be used is:

- 1 % for OBE for the telescope and its subsystems (Page 31 of AD04)
- 1 % for MLE for the telescope and its subsystems (Page 25 of AD04)
- 3 % for OBE for the buildings, pier and enclosure (Page 33 of AD04)
- 5 % for MLE for the buildings, pier and enclosure (Page 33 of AD04)

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 AD04

- MLE_{LR}: Mirror Maintenance 1%, q=1.0, B1 (Page 45 of AD04)

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.

Camera analysis
The earthquake analysis of the cameras can either be performed with the general rules above, by physically including them in the model, or, provided that its first natural frequency is sufficiently high by the simplified method (quasistatic analysis) described in AD 05.

8.1.1.5 Load combination Operational Condition

The load combinations for verification of stresses, displacement and in general the performances under operational conditions, shall take into account the sum of the relevant individual load cases applicable to the subsystem or part under examination. This includes but it is not limited to:

- gravity loads (under different conditions)
- wind (operational if applicable)
- Differential thermal expansion (functional, operational)
- operational loads dynamic (example telescope slew, acceleration)
- all specific loading acting on the subsystem or part.

For any subsystem the relevant load cases shall be identified and specified.

8.1.1.6 Load Combination Survival Conditions

As a general rule the verification of the ability of any system to survive accidental loads shall take into account one survival loadcase at the time, in addition to the relevant (functional) operational loads acting on it. As a minimum the accidental loads to be considered are:

- Operating Basis Earthquake
- Maximum Likely Earthquake
- Wind (Survival)
- Telescope Emergency Braking (against hard stops)
- and any specific loadcase that may arise from the particular condition of the system under study (example handling).

8.1.2 Requirement for Safety Analyses

Safety analyses will be performed following best practice to meet the requirements within AD 13.

8.1.3 Control loop design and analysis

Dynamic simulation analysis shall be performed for all the relevant functions and control loop of VISTA. The main purpose of these simulations is to confirm the fulfilment of the different relevant requirements.

As a general rule dynamic simulation should include the effect of non-linear effects like friction, stick-slip, sensor noise, etc. For each of the functions to be controlled the stability margin shall be computed.

8.1.4 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 the following document:

> "Electromagnetic Compatibility (EMC) including Electromagnetic Pulse (EMP) and lightning Protection – Programme and Procedures – Procedures for Systems and Equipment"
> VG 95 374 Part 4

Similar reference standards may be used as an alternative.

8.2 Material Parts and Processes

The selection of material shall be in accordance with the ESO preferred material list. Full details on standard electro-mechanical components are listed in AD11.

The use of non-standard components shall to the possible extent be avoided.

A stress release treatment of the major welded parts of the VISTA telescope shall be applied. The process used shall be agreed by the VPO.

8.3 Painting / Surface Treatment

8.3.1 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. NEXTEL 2010C.10 Black Velvet coating from 3 M Co.):

The telescope spiders and the surface of the M2 Electromechanical Unit shall be covered with low emissivity MAXORB Nickel foil or equivalent.(TBC)

8.3.2 Surface treatments

Unpainted Surfaces shall be treated against corrosion. In this case, the bonding requirements specified in AD 09 shall be met.

8.4 Electromagnetic Compatibility

8.4.1 General

8.4.1.1 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.

8.4.1.2 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 applicable documents AD 08 and AD09.

The following sections 8.4.2, to 8.4.3.6 explicitly highlight the EMC requirements of AD08 and AD09 applicable to VISTA.

8.4.2 Electromagnetic environment (TBC)

VISTA will be installed, operated and located within the electromagnetic environment specified by AD 08 and, therefore, shall comply with the requirements imposed by AD 08.

Definitions:

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

2. For the purpose of this Specification, the requirements applicable to 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 (The following list is simply to be intended as a reminder of such requirements and not a waiver to AD 08)

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

- 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
- 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
- The electrical and electronic installations of VISTA shall be protected against overvoltages
- Insulation coordination 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
- The VLT power system is expected to provide electric power with the quality specified by Chapter *4. "PERFORMANCE REQUIREMENTS*" of AD 08

8.4.3 Emission (TBC)

Note. In the present subsection and in the following one *8.4.3.6*, 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 the AD09. Such compliance entails what is specified by the items.

A further requirement is imposed by item 8.4.3.5 *Disturbance Currents.*

8.4.3.1 Radiated emission

The electromagnetic radiation (radiated field) emitted by VISTA shall comply with the limits imposed by subsection 4.1.2 (resp. 4.1.3) of AD 09.

8.4.3.2 Conducted emission (disturbance voltages)

The terminal voltage emitted by VISTA at its input (and output, if any) AC power ports (AC mains) shall comply with the limits imposed by subsection 4.1.2 (resp. 4.1.3) of AD09.

8.4.3.3 Conducted Emission (harmonic currents)

VISTA shall not emit as its input (and output, if any) AC power ports, harmonic currents in excess of those specified by subsection 4.1.5 of AD09, i.e., of those standardised by IEC 555-2.

8.4.3.4 Conducted emission (voltage fluctuations)

VISTA shall not introduce at its input (and output, if any) AC power ports, voltage fluctuations in excess of the limits specified by subsection 4.1.5 of AD 09, i.e., of those standardised by IEC 555-3.

8.4.3.5 Conducted emission (disturbance currents) (TBC)[1]

VISTA shall not emit at its signal, control, DC power input (DC power output, if any) and other ports, currents exceeding the following values:

40 → 30 dBμA quasipeak (TBC) for $0.15 \leq f \leq 0.5$ MHz
30 → 20 dBμA average (TBC)
linearly decreasing with the logarithm of f

30 dBμA quasipeak (TBC) for $0.5 \leq f \leq 30$ MHz
20 dBμA average (TBC)
(Current probe measurements to be performed with line terminated to reference plane via 150Ω)

8.4.3.6 Immunity (TBC)

VISTA shall comply with the applicable immunity limits specified by the AD 09.

Such a compliance implies immunity to the disturbances detailed in the following. The immunity limits referred to are those specified by the AD09.

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

Disturbances	Immunity limits and performance criteria
Harmonic voltages (individual harmonics and THD)	see item 4.2.2.1 and 4.2.2.2 of AD 09
Voltage fluctuations	see item 4.2.3.1 of AD09
Voltage dips and interruptions	see item 4.2.4.1 and 4.2.4.3 of AD09
Voltage (current) surges	see item 4.2.5.1 of AD09
Fast transient bursts (applied also to PE terminals)	see item 4.2.6.1 of AD09

8.4.3.8 Control, signal ports

Disturbances	Immunity limits and performance criteria
Fast transient bursts	see item 4.2.6.3 of AD09
50 Hz voltage on control/signal lines	see subsection 4.2.1 1 of AD09

[1] This requires detailed discussion with ESO

8.4.3.9 Enclosure port

Disturbances	Immunity limits and performance criteria
Electrostatic discharge – ESD	see subsection 4.2.8 of AD09
50 Hz magnetic field	see subsection 4.2.9 of AD09
Radiated electromagnetic field	see subsection 4.2.10 of AD09

8.4.3.10 Input and output DC power ports (if any)

Disturbances	Immunity limits and performance criteria
Voltage fluctuations	see item 4.2.3.2 of AD09
DC voltage dips	see item 4.2.4.2 of AD09
Voltage (current) surges	see item 4.2.5.2 of AD09
Fast transient bursts	see item 4.2.6.2 of AD09

8.5 Nameplates and product marking

As a general rule the main parts of VISTA subsystems and all exchangeable units (LRUs) shall be tagged with nameplates.

The nameplates shall be visible after installation of the parts or LRUs. The namplate shall contain the following information:

- Part /Unit name
- Drawing number including revision
- Manufacturing month and year
- Name of manufacturer

8.6 Workmanship

These requirements herein shall apply to all entities involved in the design, development and manufacturing of VISTA.

Only methods and procedures which are state of the art or as a minimum best practice in precision mechanics, optics, electric and electronics, hydraulics, design, development and manufacturing shall be used.
Quality assurance activities shall follow the guidelines of ISO 9001-2000 or similar standards.

9 Technical Documentation

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

- The language used shall be English
- Only SI units shall be used with the following exceptions:
  - degree
  - arcminute
  - arcsec
  - hour
  - minute
  - magnitude

  Other exceptions may be agreed between VPO & ESO.
- Drawings shall be delivered on paper as well as in electronically readable format. (Format to be agreed between VPO and ESO)
- Finite Element Models and results as part of analysis shall be delivered also on electronically (Format TBC)
- Layouts for electronic circuits shall also be provided in electronically readable format. (Format TBC)

10 Verification and Quality Assurance

This section shows how the requirements listed in Sections 4 & 5 will be verified. More detailed information will be applied in the sub-system specifications.

10.1 VISTA Test Philosophy

Several forms of verification activities will take place during the design, manufacture, assembly and commissioning of VISTA. These activities will take place in several locations ranging from sub-system manufacturers premises to the commissioning site in Chile.

10.2 Performance Verification

In addition to the inspections performed as part of quality assurance requirements by each supplier, the following three methods of verification shall be carried out to show that the requirements of VISTA are met in accordance with the verification table in Section 10.3:

10.2.1 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.

10.2.2 Verification by Analysis

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

10.2.3 Verification by Test

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

10.3 Preliminary Verification Table

The following table shows how the requirements listed in Sections 4 to 8 will be verified. More detailed requirements will be specified for every specific subsystem, during the design phase.

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
SYSTEM REQUIREMENTS				
4.3.2	Transportation Environment	X		
4.3.3	Installation Operation Maintenance Environment			
4.3.3.1	Natural Temperature	X	X	
4.3.3.2	Natural Wind	X	X	
4.3.3.3	Earthquakes	X	X	
4.4	External interfaces	X		
4.6	Telescope aperture	X		
4.7	Wavelength coverage	X		
4.8.1	Zenith Distance	X		X
4.8.2	Visible Camera Field	X	X	
4.8.3	IR Camera Field	X	X	
4.9.1.1	SIQ Visible Channel Requirements	X	X	X
4.9.1.2	SIQ IR Channel Requirements	X	X	X
4.10.1	Stability of the Visible and IR focal planes		X	
4.10.1.1	Coplanarity		X	
4.10.1.2	Thermal Expansion		X	
4.10.1.3	Flexure		X	
4.10.1.4	Distortion		X	
4.10.2	Neutral Density Filter(s)	X		X
4.12.2	Throughput		X	
4.12.3	Scattered Light		X	X
4.12.4	IR Thermal Rejection	X	X	
4.12.5	Ghosting		X	
4.12.6	Light Leakage	X		X
4.12.7	System Noise Characteristics		X	X
4.13.1	Accuracy *(target acquisition)*			
4.13.1.2	Absolute Pointing		X	X
4.13.1.3	Offset Pointing		X	X
4.13.1.4	Re-Acquisition		X	X
4.13.2	Acquisition Time		X	X
4.14.1	Open Loop Tracking		X	X
4.14.2	Closed Loop Tracking		X	X
4.14.3	Non-sidereal Tracking		X	X
4.15.1	Exposure Length	X		X
4.15.2	Exposure Accuracy		X	X

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
4.15.3	Time Stamping	X		
4.15.4.1	Visible Camera	X		X
4.15.4.2	IR Camera	X		X
4.15.4.3	Multiple Readouts per IR Exposure	X		
4.15.4.4	Rapid Sequence of IR Exposures	X		X
4.16.1.1	Visible *(storage data)*	X		
4.16.1.2	IR *(storage data)*	X		
4.16.2	Writing to Disk	X		
4.16.3	Archiving	X		
4.16.4	Transport	X		
4.16.5	On-line Storage	X		
4.16.6	Near-Line Storage	X		
4.16.7	Data Assessment	X		X
4.16.8	Local Data Reduction	X		
4.17	Thermal control	X	X	(X)
4.17.1.1	Temperature sensors	X		
VISTA SUBSYSTEM CHARACTERISTICS AND REQUIREMENTS				
TELESCOPE REQUIREMENTS				
5.1.2	Telescope Design Volume	X		
5.1.3	Telescope Mass	X		X
5.1.4	Telescope Dynamic Performance	X		X
5.1.5.1	Optical Design Data	X		
5.1.6	M1 Blank Characteristics	X		X
5.1.7.1	M1 Mirror Optical Prescription	X		X
5.1.7.2	Low Spatial Frequency Errors			X
5.1.7.3	High Spatial Frequency Errors			X
5.1.7.4	Microroughness			X
5.1.7.5	Interface to the M1 Cell	X		X
5.1.7.6	Polishing requirements	X		
5.1.8.1	M2 Optical Design Characteristics	X		X
5.1.8.2	M2 Optical Quality		X	X
5.1.8.3	Micro Roughness			X
5.1.8.4	M2 Assembly Mechanical Characteristics	X	X	X
5.1.9.1	Azimuth track and bearings	X	X	X
5.1.9.2	Cable wrap	X	X	
5.1.9.3	Telescope Fork and Base	X	X	
5.1.9.4	Altitude bearings	X	X	X
5.1.9.5	Telescope tube	X		
5.1.9.6	Telescope tube structural performance	X	X	X
5.1.9.7	Altitude Axis Cable Drape		X	
5.1.9.8	Adjustment and balancing		X	
5.1.10.1	Reuse of ESO Software	X		
5.1.10.2	TCS Interface	X		
5.1.10.3	Software/Hardware Interface	X		

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
5.1.10.4	Control Algorithms	X		
5.1.10.5	Position measurement	X		X
5.1.10.6	Velocity Measurement	X		X
5.1.10.7	Motors	X	X	X
5.1.10.8.1	Kinematic ranges	X		X
5.1.10.8.2	Operational conditions	X		X
5.1.10.8.3	Maintenance conditions	X		X
5.1.10.9	Telescope Limits	X		X
5.1.10.10	Telescope Lockout	X		X
5.1.10.11	Brakes	X		X
5.1.10.12	Auxiliary drives	X	X	X
5.1.11.1	Design Space Envelope *(primary mirror cell)*	X		
5.1.11.2	M1 Cell Stability Requirements w.r.t M1	X	X	X
5.1.11.3	Axial Support Requirements	X	X	X
5.1.11.4	Lateral Supports Requirements	X	X	X
5.1.11.5	Cassegrain Interface flange	X	X	X
5.1.12.1	Cooling of heat sources	X		
5.1.12.2	Thermal Conditioning of Primary Mirror	X		
5.1.13.1	TCS Interface	X		
5.1.13.2	Hardware Interface	X		
5.1.14.2	Interface Requirements*(M2 Electromech. Unit)*	X		
5.1.14.4	M2 EMU physical Characteristics	X		
5.1.14.5	Requirements on M2 Mirror Positioning	X	X	X
5.1.14.6	M2 Mirror Position Stability		X	X
5.1.14.7	M2 Baffle Requirements	X	X	
5.1.15.1	TCS Interface	X		
5.1.15.2	Hardware Interface	X		
5.1.16.1	Cassegrain Rotator Bearing	X		X
5.1.16.2	Cassegrain Rotator Interface	X		X
5.1.16.3	Cassegrain Cable wrap	X		X
5.1.17.1	Reuse of ESO Software	X		
5.1.17.2	TCS Interface	X		
5.1.17.3	Software/Hardware Interface	X		
5.1.17.4	Control Algorithms	X		
5.1.17.5	Slew When Tracking Open-Loop	X		X
5.1.17.6	Performance	X	X	X
5.1.17.7	Position measurement	X		X
5.1.17.8	Velocity Measurement	X		
5.1.17.9	Motors	X		X
5.1.17.10	Brakes	X		X
5.1.17.11	Limit switches and end stops	X		X
5.1.17.12	Safety locking	X		
5.1.18.1	Telescope Feedback Requirements *(Guiding, WFS)*	X		
5.1.18.2	Sensor Implementation	X		X
5.1.18.3	Sensor Location	X		X

VISTA TECHNICAL SPECIFICATION		**VERIFICATION METHOD**		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
VISIBLE CAMERA				
5.2.1.1	Visible Camera Optical design characteristics	X		
5.2.2	Lens Barrel Assembly	X		X
5.2.3	Filters.	X		X
5.2.4	Filter Mechanism Assembly	X		X
5.2.5	Shutter Mechanism Assembly	X	X	X
5.2.6	Flexure		X	(X)
5.2.7	Focal Plane Unit Assembly	X	X	X
5.2.7.1	CCD Detectors		X	X
5.2.7.2	Detector Controller	X		
5.2.7.3	Detector Cryostat and Window	X	X	X
5.2.8	Visible Camera Guiding and Wavefront Sensing	X		X
IR CAMERA				
5.3.1.1	Infrared Camera Optical design characteristics	X		
5.3.1.3	Baseline Infrared Camera Optical Design Data	X		
5.3.2	IR Filters	X		X
5.3.3	Filter Mechanism Assembly	X		X
5.3.4.1	Cryostat	X	X	X
5.3.4.2	Lens Mount	X		X
5.3.4.3	Cryogenic Baffle	X	X	X
5.3.5	Flexure		X	X
5.3.6	Focal Plane Unit Assembly	X		
5.3.6.1	IR Detectors	X		X
5.3.6.2	Detector Controller	X		
5.3.6.3	Detector Pre-amps and Circuitry	X		
5.3.6.4	Temperature Sensors, Cabling and Connectors	X		
5.3.7	IR Camera Guiding and Wavefront Sensing	X		X
CONTROL				
5.4.1.1	LCU Hardware	X		
5.4.1.2	Unix Hardware	X		
5.4.1.3	Location of Computing Equipment	X		
5.4.1.4	Local Area Networking	X		
5.4.2.1	Infrastructure	X		
5.4.2.2	Control Hierarchy	X		
5.4.3.1	Functionality *(TCS)*	X		
5.4.3.2	Reuse of ESO Software	X		
5.4.3.3	External Inputs	X		
5.4.4.1	Reuse of ESO Software *(Observation Control)*	X		
5.4.4.2	Hardware Requirements	X		
5.4.5.1	Components *(Instrument Control)*	X		
5.4.5.2	Interfaces	X		
5.4.5.3	Hardware Requirements	X		

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
DATA HANDLING				
5.5.1.1	Reuse of ESO Software	X		
5.5.1.2	Disk Capacities and Data Rates	X		X
5.5.1.3	Visible Camera IWS	X		X
5.5.1.4	Infrared Camera IWS	X		X
5.5.1.5	Data Handling WS	X		X
5.5.1.6	Archive WS	X		X
5.5.1.7	User WS	X		X
5.5.1.8	Pipeline WS	X		X
5.5.2	Near Line Storage	X		
5.5.3	Data Transport	X		
5.5.3.1	Data Format	X		
5.5.4	Quality Assessment			(X)
ENCLOSURE				
5.6.3	Aesthetics	(X)		
5.6.4.1	Environmental Conditions	X		
5.6.4.2	Floor Loading:	X	X	
5.6.4.3	Emergency Lighting	X		
5.6.4.4	Protection against Fire	X		
5.6.5.1	Steel Construction *(Dome)*	X		
5.6.5.2	Cladding	X		X
5.6.5.3	Observing Slit Door	X		X
5.6.5.4	Rotation System	X	X	X
5.6.5.5	Seals	X		X
5.6.5.6	Windscreen	X	X	X
5.6.5.7	Upper Shutter	X	X	X
5.6.5.8	Flat Field	X	X	X
5.6.5.9	Dome Crane	X		X
5.6.5.10	Maintenance Platform	X	X	
5.6.6.1	Construction	X		
5.6.6.2	Access	X		
5.6.6.3	Vibration	X		
5.6.6.4	Drainage	X		
5.6.6.5	Equipment Housing	X		
5.6.6.6	Primary Mirror Washing Requirements	X		X
5.6.6.7	Camera Storage and Support	X		
5.6.7.1	Enclosure Temperature Stabilisation	X	X	X
5.6.7.2	Auxiliary Building	X		X
5.6.7.3	Cooling	X		
5.6.7.4	Ventilation Doors	X		X
5.6.8.1	Command Interface	X		
5.6.8.2	Hardware Interface	X		
5.6.8.3	Manual Control	X		X

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	**HEADING**	**DESIGN**	**ANALYSIS**	**TEST**
5.6.9.2	Stiffness	X	X	
5.6.9.3	Vibration	X		
5.6.9.4	Access	X		
AUXILIARY EQUIPMENT				
5.7.2	Equipment Location	X		
5.7.3.1	Washing Facility	X		X
5.7.3.2	Water Supply for mirror washing	X		
5.7.3.3	Mirror Washing	X		X
5.7.3.4	Lighting	X		
5.7.3.5	Hazardous Material	X		
5.7.3.6	Emergency Shower	X		
5.7.4	Transformer Room *(Power Substation)*	X		
5.7.5	Electrical Power Distribution Room	X		
5.7.6	Plant Room	X		
5.7.7	Office/rest area	X		
5.7.8	Sanitary Provision	X		
5.7.9	Heat Exchange	X		
5.7.10	Storage	X		
5.7.11	Computing Facilities	X		
COATING PLANT				
5.8.2	Coating the Primary Mirror	X		X
5.8.3	Lower Vessel	X		
5.8.4	Upper Vessel	X		
5.8.5	Magnetron	X		X
5.8.6	Vacuum Pumping Equipment	X	X	X
5.8.7	Power Requirements	X		
5.8.8	Cooling	X		
5.8.9	Plasma Gas	X		
5.8.10	Lighting	X		
5.8.11	Coating Plant Control	X		X
SERVICE AND HANDLING EQUIPMENT				
5.9.1	General	X		
5.9.2	Lifting Equipment	X		X
5.9.3	Basic Handling Equipment	X		
5.9.4	Special Handling Equipment	X		X
TEST EQUIPMENT				
5.10.1	Test Camera	X	X	X
5.10.2	Reflectometer	X		
5.10.3	Filter Transmission Monitor	X		
OPERATIONAL REQUIREMENTS				
6.1.1	Control of Equipment	X		

VISTA TECHNICAL SPECIFICATION		VERIFICATION METHOD		
SECTION	HEADING	DESIGN	ANALYSIS	TEST
6.1.2	Independent Operation of Cameras	X		
6.1.3	Calibration Procedures	X		
6.1.4	Observing Modes	X		
6.1.5	Observing and Engineering Logs	X		
6.1.6	Handling Faults	X		
6.1.7	Weather Monitoring	X		
6.1.8	Readout Noise Pickup	X		X
RELIABILITY MAINTAINABILITY & SAFETY REQUIREMENTS				
7.2.1	Overall Availability		X	
7.2.2	Specific Reliability requirements		X	
7.3.1	Guidelines for Diagnostic and Maintenance by SW	X		
7.3.2.1	Predictive Maintenance	X		
7.3.2.2	Preventive Maintenance		X	
7.3.2.3	Overhaul	X		
7.3.2.4	On-site repair/ Corrective Maintenance	X		X
7.3.3	Monitoring and Test Routines	X		
7.3.4	Spares	X		
7.3.5.1	In Situ Cleaning	X		
7.3.5.2	Primary Mirror coating	X		X
7.3.5.3	Camera Change	X		X
7.3.5.4	Camera Intervention	X		X
7.4	Safety	X	X	X
GENERAL REQUIREMENTS FOR DESIGN AND CONSTRUCTION				
8.2	Material Part and Processes	X		
8.3	Painting / Surface treatment	X		
8.3.1	Paints	X		
8.3.2	Surface treatments	X		
8.4	Electromagnetic compatibility	X	X	
8.5	Nameplates and product marking	X		
8.6	Workmanship	X		

ANNEX A Mapping Table SRD to VISTA Technical Specification

The following table maps the requirements listed in AD 01 to the appropriate section of the VISTA Technical Specification. A column for comments is used to clarify points (e.g. where an SRD requirement is a SOW function or where the VTS requirement that can be achieved differs from that in AD 01).

Specific goals within the SRD have been retained on a best efforts basis, the VPO will endeavor to approach these goals unless cost or schedule are compromised.

A-1 Requirements from SRD Section 4

SRD	VTS Section	Comment
4.1.1	1.1	
4.2.1	4.6	
4.3/1	4.7	
4.3/2 (Goal)	4.7	
4.3.1/1	5.2.3, 5.3.2	
4.3.1/2	5.10.3	
4.3.1/3	4.7	
4.3.1/4	4.12.6	
4.3.1/5 (Goal)		Not VPO Reqt
4.3.1/6 (Goal)		Not VPO Reqt
4.3.2/1	5.2.4, 5.3.3	
4.3.2/2	5.2.4	
4.3.2/3 (Goal)		Max of 12 filter slots for Visible camera (exceeds Req)
4.3.2/4	7.3.5.4	
4.3.2/5	5.3.3	
4.3.2/6	5.3.3	
4.3.2/7	7.3.5.4	
4.3.2/8	5.2.3	
4.3.2/9	5.2.4, 5.3.3	
4.3.2/10 (Goal)		Goal (a) IR blocker Goal (b) Not possible
4.3.2/11	5.2.4	
4.3.3/1	7.3.5.3	
4.3.3/2	7.3.5.4	
4.3.3/3	7.3.5.3	
4.3.3/4	7.3.5.3	

SRD	VTS Section	Comment
4.4.1/5		SOW
4.4.2/1	4.9.1.2	
4.4.2/2 (Goal)		
4.4.2/3 (Goal)	4.8.3	This will be met
4.4.2/4		SOW
4.5.1/1	4.10	
4.5.1/2	4.10	
4.5.1/3	4.10	
4.5.1/4 (Goal)		
4.5.2/1	4.13.1.2	
4.5.2/2 (Goal)		
4.5.2/3	5.1.17.5+ 5.1.17.6	
4.5.2/4	4.13.1.3	
4.5.2/5	4.13.1.3	
4.5.2/6 (Goal)		
4.5.2/7	4.13.1.4	
4.5.2/8	4.8.1	
4.5.2/9 (Goal)	5.1.10.8.2	Software limit defined to enable this goal
4.5.2/10	4.8.1	
4.5.3/1	4.14.1	
4.5.3/2 (Goal)		
4.5.3/3	4.9	
4.5.3/4	4.14.3	Partly compliant: Non-sidereal tracking - SIQ loss above 2 arcsec per min
4.5.3/5 (Goal)		
4.6.1/1	4.11	

SRD	VTS Section	Comment
4.3.3/5 (Goal)		Cannot be met
4.4.1/1	4.9.1.1	see note on 4.9.1.1/1 page 28
4.4.1/2	4.9.1.1	
4.4.1/3.a	4.9.1.1	
4.4.1/3.b	4.9.1.1	
4.4.1/3.c		SOW
4.4.1/3.d		SOW
4.4.1/3e (Goal)		
4.4.1/4 (Goal)	4.8.2	

SRD	VTS Section	Comment
4.6.2/1	4.11	
4.6.3/1	4.11	
4.6.4/1	4.8.2 5.2.7.1, 5.3.6.1	
4.6.5/1	5.2.7, 5.3.6	
4.6.6/1	4.15.1 4.15.2	
4.6.6/2	4.12.5 5.2.7.1 5.2.7.2 5.3.6.1	Ghosts (4.12.5) Chg bleeding (5.2.7.1, 5.2.7.2) Remnants (5.3.6.1)
4.6.6/3 (Goal)	4.15.1	
4.6.6/4 (Goal)		Will not be met
4.6.6/5	4.15.3	

A-2 Requirements from SRD Section 5-7

SRD	VTS Section	Comment
5.2/1	4.12.2	System Throughput [1] *(see footnote)*
5.2/2	4.12.3	
5.2/3	4.12.4	
5.2/4	4.12.7	10% variation
5.2/5 (Goal)		Narrow Band Filters are not VPO responsibility
5.2/6	4.15.1	
5.2/7	4.12.3	
5.2/8	4.12.3	
6.3/1	4.13.2 4.15.4.1, 4.15.4.4, 5.2.4, 5.2.5, 5.3.3	
6.3/2	4.8.3	
6.3/3	4.8.2	SRD Req is ≥2.24 VTS meets ≥2.05
6.3/4 (Goal)	4.8.3	Now Requirement
6.3/5 (Goal)		
7.1/1		SOW
7.1/2	7.2.1	
7.1/3 (Goal)		
7.1/4	5.5.3.1, 6.1.7	VTS does not fully match SRD, relies on input from ESO Weather site

SRD	VTS Section	Comment
7.1/5	4.16.8	External to firewall
7.3/1		SOW
7.3/2	6.1.3	
7.3/3	6.1.4	
7.4/1		ESO PPARC MOU
7.5/1	5.5.1	
7.5/2	5.5.4	
7.5/3	5.5.4	
7.5/4	5.5.4	
7.5/5	4.16.7	
7.5/6		ESO PPARC MOU
7.6/1	4.16.6	
7.6/2 (Goal)		
7.7/1	4.16.8	
7.8/1		ESO PPARC MOU
7.9/1	SOW	
7.9/2	SOW	

______oOo______

[1] **NOTE** - the requirements in the SRD are not met for U_L and B, but are exceeded at some other passbands, particularly H and K_S.