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VLT TEST CAMERA

Technical Specification

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CHANGE RECORD

Issue/Rev.	Date	Section/Paragraph Affected	Reasons/Remarks
1	23.8.95	all	first issue
2	29.8.96	1	clarification added
		3	specification for Part B added, operational modes clarified
		Figures 1 - 3	updated/added
		3.1.1.5, 3.2.1.4 - 6	control hardware and software updated/added
		3.1.2	interfaces clarified, filter list updated
		3.1.3 - 5	added
		3.2.1	enlarged and updated
		3.3	updated

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LIST OF ACRONYMS

ADC .... Atmospheric Dispersion Compensator
AGS .... Acquisition and Guiding Sensor (of adapter)
AR .... Anti-Reflection
CCD .... Charged Coupled Devices
DRS .... Data Reduction Software
EMC .... Electromagnetic Compatibility
ESO .... European Southern Observatory
FORS .... FOcal Reducer Spectrograph
FOV .... Field of view
ICCD .... Imaging CCD
ICS .... Instrument Control Software
LAN .... Local Area Network
LCU .... Local Control Unit
LRU .... Line Replaceable Unit
MIDAS .... Munich Image Data Analysis System
PGS .... Peripheral Guide Sensor
PIS .... Pupil Imaging Sensor
TBC .... To Be Confirmed
TBD .... To Be Defined
TCCD .... Technical CCD
TCS .... Telescope Control Software
UIP .... User Interface Panel
UT .... Unit Telescope
VLT .... Very Large Telescope
VLTTC .... VLT Test Camera
VLTO .... VLT Observatory
WFS .... Wavefront Sensor

1. SCOPE

This document establishes the performance, design, development and test requirements of the two VLT Test Cameras (VLTTC) which are identified with the code 11960 in the VLT product tree.

The two Test Cameras do not have identical functionality. Except where this specification refers specifically to VLTTC #1 or VLTTC #2, these requirements apply for both versions of the Test Camera.

2. APPLICABLE DOCUMENTS

The following documents of the exact issue shown form part of this technical specification.

Number	Document Title	Document Number
AD1	VLT Observatory Requirements for Nasmyth Instruments	VLT-SPE-ESO-10000-0006 Issue 2, 20 Sep 1995
AD2	VLT Optics: Design of telescope optics	VLT-TRE-ESO-10000-0526 Issue 1, 18 Feb 1994
AD3	VLT Environmental Specification	VLT-SPE-ESO-10000-0004 Issue 5, 27 May 1993
AD4	VLT Electronic Design Specification	VLT-SPE-ESO-10000-0015 Issue 3, 30 Mar 1993
AD5	Electromagnetic Compatibility and Power Quality Specification, Part II	VLT-SPE-ESO-10000-0003 Issue 1, 05 Feb 1992
AD6	VLT Software Management Plan	VLT-PLA-ESO-00000-0006 Issue 2, 21 May 1995
AD7	VLT Software Requirements Specification	VLT-SPE-ESO-10000-00011 Issue 2, 30 Sep 1992
AD8	VLT Software. VLT Instrumentation Software Specification	VLT-SPE-ESO-17212-0001 Issue 2, 12 Apr 1995
AD9	LCU Software Specification	VLT-SPE-ESO-17210-0002 Issue 2.2, 26 Oct 93
AD10	General Safety Requirements for Scientific Instruments	VLT-SPE-ESO-10000-0017 Issue 2, 16 Sep1992
AD11	Requirements for safety analyses	VLT-TRE-ESO-00000-0467 Issue 1, 23 Jul 1993
AD12	Service Connection Point. Technical Specification	VLT-SPE-ESO-10000-0013 Issue 3.1, 5 Mar 1995
AD13	CCD Detector Control Software Specs	VLT-SPE-ESO-17240-0227 Issue 1, 08 Apr 93
AD14	ESO-MIDAS. MIDAS Environment	MID-SPE-ESO-11000-0001 Issue 1.2, 1 May 1994
AD15	VLT Software. Programming Standards	VLT-PRO-ESO-10000-0228 Issue 1, 10 Mar. 1993
AD16	VLT Software. INS Common Software Specification	VLT-SPE-ESO-17240-0385 Issue 2, 4 May 1995
AD17	Real-Time-Display Software Specifications	VLT-SPE-ESO-17240-0250 Issue 1.0, 24 June 1995
AD18	Nasmyth Instrument Rotator flange	VLT-DWG-ESO-11420-0-021000-0001, Issue 1.3, 24 Dec 1994
AD19	Cassegrain Instrument Rotator flange	VLT-DWG-ESO-11410-0-021000-0001, Issue 1.4, 31 May 1994

AD20	Cassegrain handling device interface	VLT-DWG-VIC-13111-121101 VLT-DWG-VIC-13111-300021
AD21	Small TCCD interface drawing	VLT-IDW-DJO-11710-0000, Issue f, 05.01.96
AD22	Large TCCD interface drawing	VLT-IDW-DJO-11720-0000, Issue c, 05.01.96
AD23	ACE box interface	VLT-IDW-DJO-11700-0000, Issue b, 28.06.95
AD24	Scientific CCD dewar interface	TBD
AD25	Active Optics Requirements	VLT-SPE-ESO-17210-0878, to be released

3. REQUIREMENTS

3.1. ITEM DEFINITION

3.1.1. Item Description and Diagrams

3.1.1.1. General description

The VLT Test Camera (VLTTC) contains image detectors and analysis devices that will be used during the technical commissioning and scientific verification phases of the VLT. It consists of two main assemblies, referred to here as Part A and Part B, together with some common components and support equipment. The VLTTC can be mounted on either the Cassegrain or Nasmyth foci of the VLT Unit telescopes.

3.1.1.2. Part A

Part A contains a large format detector for recording direct images with the VLT. It shall have the following main components:

1. A mechanical structure for the various opto-mechanical functions. The structure shall be internally baffled to prevent stray light reaching the detector.
2. A large format imaging CCD (ICCD) detector system, plus a peripheral guide sensor[1] (PGS) detector in a single dewar.
3. An optical system to re-image the telescope image plane onto the ICCD.
4. A mechanical shutter for the ICCD.
5. A filter wheel for the ICCD.
6. A manually inserted image plane mask in the telescope focal plane.
7. A manually inserted pupil plane mask. In VLTTC #1 this mask shall be mounted in a fixed orientation. In VLTTC #2 the mask shall be remotely controlled to follow the telescope pupil rotation.
8. Part A shall also dispose mounting locations for four TCCD heads to allow peripheral images in the Cassegrain and Nasmyth fields to be recorded for image scale stability measurements.

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[1] If the baseline CCD chip with the PGS is not available, then it will not be possible to carry out differential image movement measurements specified in section 3.1.1.6.

Figure 1 shows the overall external view of the VLTTC, and Figure 2 shows the optical arrangement of Part A.

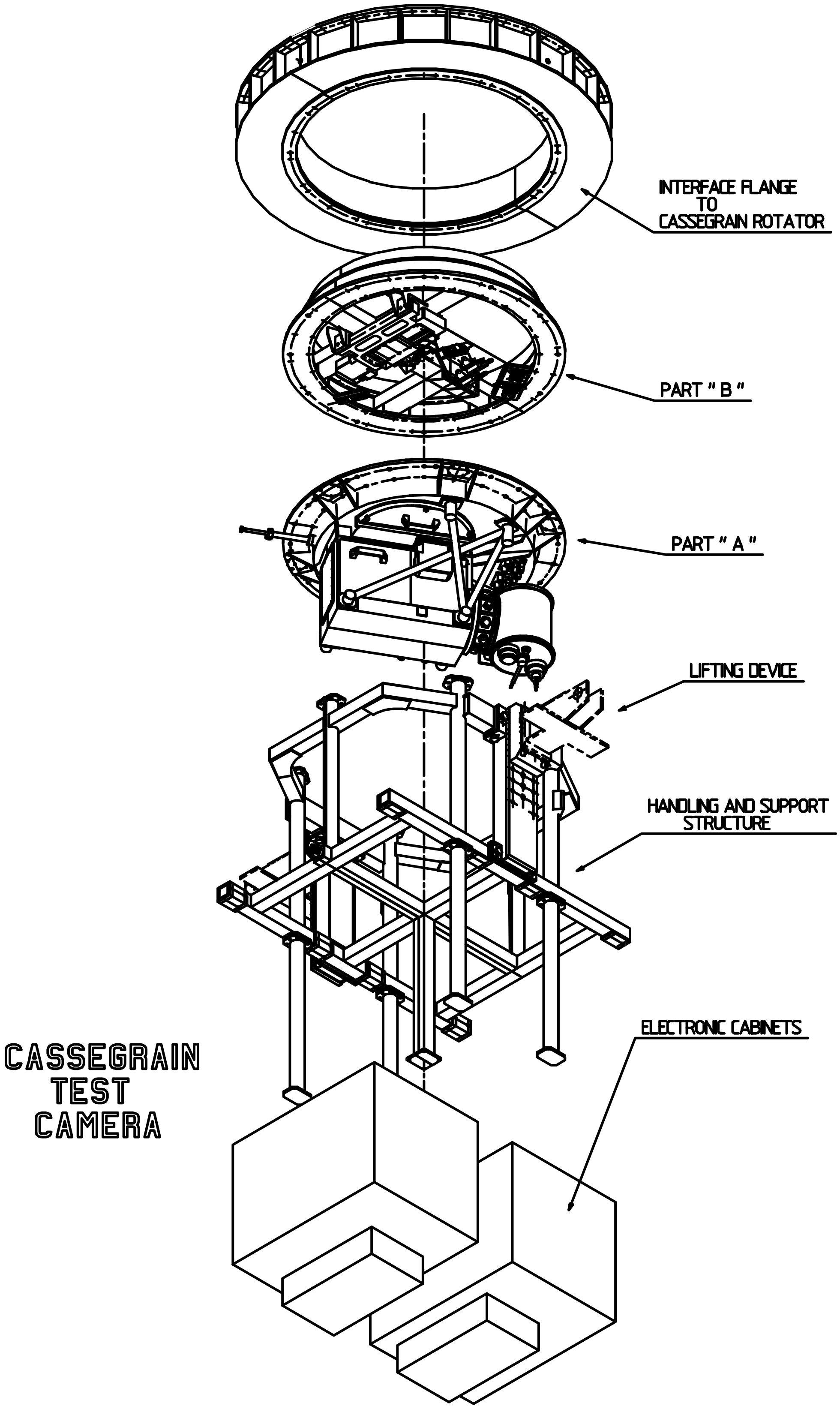

Figure 1: Exploded view of the Cassegrain VLTTC.

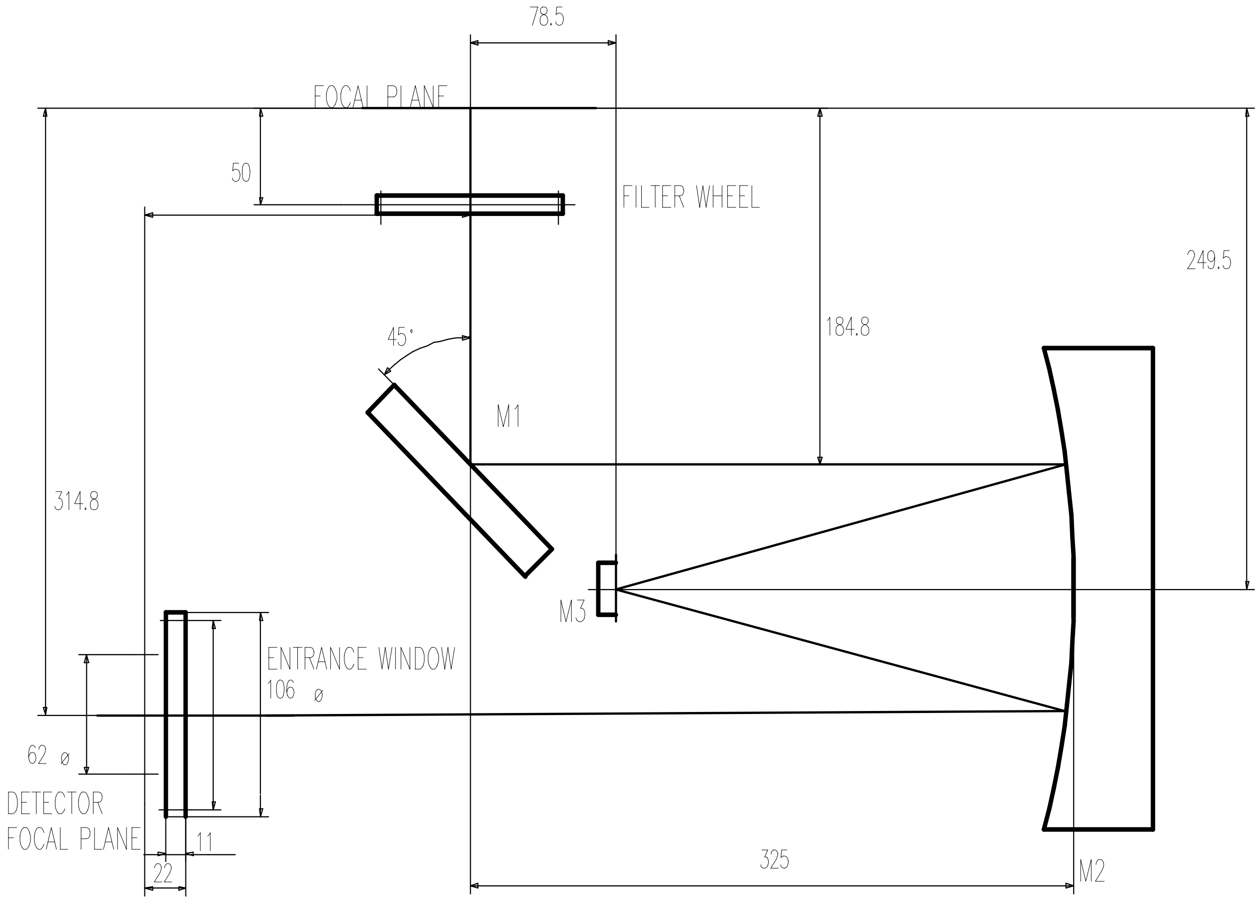

Figure 2: Optical design of the main imaging camera of Part A

3.1.1.3. Part B

Part B contains two optical detector systems to record the telescope wavefront deformations and pupil image respectively. These functions are located before the telescope focal plane as indicated in Figure 3. It shall have the following main components:

1. A mechanical structure that supports the pre-focus opto-mechanical functions.
2. Two large format TCCD systems to record the wavefront and pupil images
3. An optical system comprising a collimator lens, beam-splitter, folding mirror, Shack-Hartmann lenslet array and imaging objective.
4. A remotely controlled pickup mirror assembly which provides an exchangeable pickup mirror to reflect the light into Part B, as well as an optional knife-edge in the reflected focal plane, and a calibration source for the WFS.

Note that these functions in Part B shall only be provided for VLTTC #1.

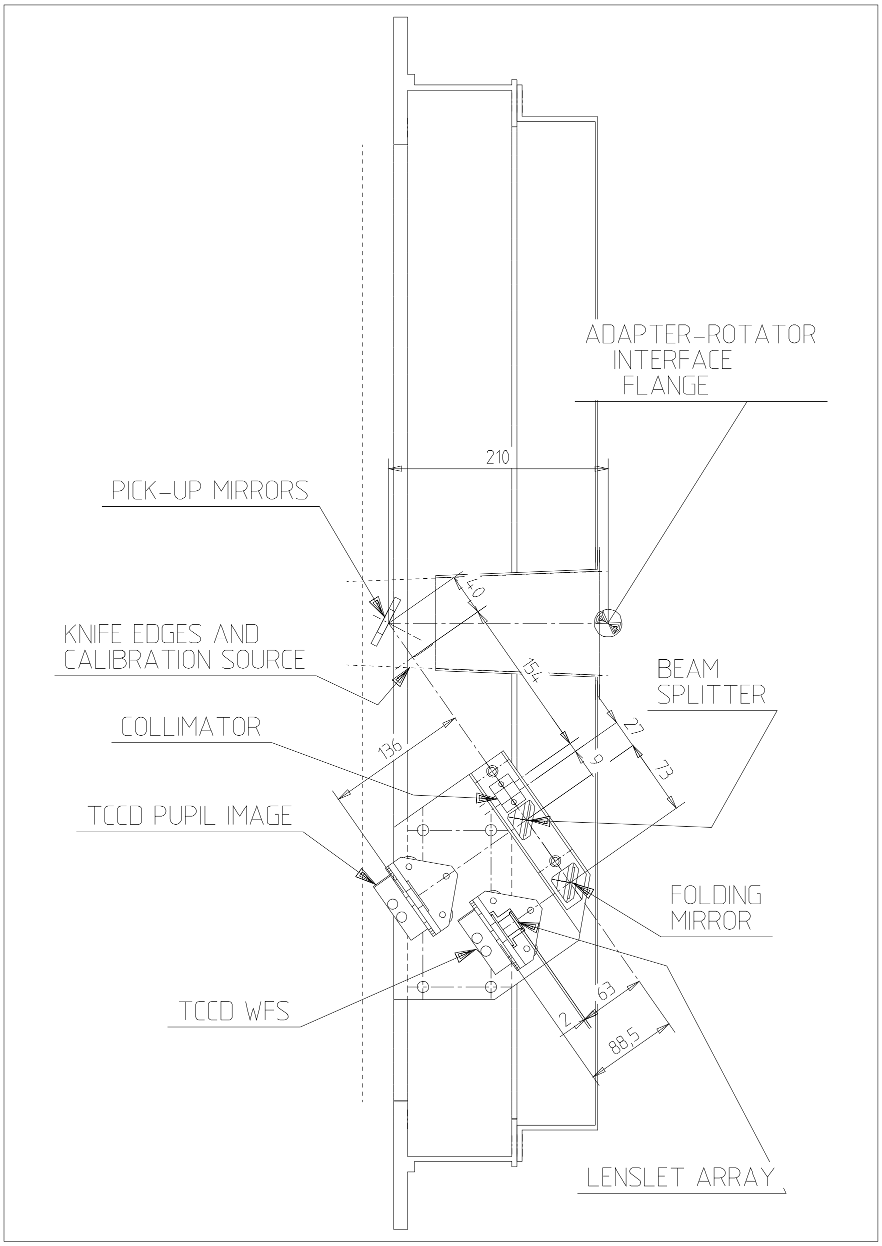

Figure 3: Layout of optical components of Part B

3.1.1.4. Common components

The common components comprise:

1. Interface flanges to allow the VLTTC to be mounted on either the Cassegrain or Nasmyth Rotators and common supporting structure for Parts A and B
2. An integrated support stand to allow the VLTTC to stand on the ground when not attached to the telescope. This stand shall also accommodate the control electronics on the VLTTC.

   The VLTTC shall include all special handling and maintenance equipment necessary for installation, operation, removal and maintenance of the VLTTC.

3.1.1.5. Control electronics and software

The control electronics and software shall control the motorised functions and CCDs, allow basic data display, reduction and archiving, and provide maintenance test procedures.

3.1.1.6. Modes of operation

The following modes of operation are foreseen:

		approximate light division (%)				
No.	Mode	ICCD	WFS	PIS	Adapter	Comments
1	Direct imaging	100	0	0	Independent	Full field available for ICCD
2a	Simultaneous direct imaging, pupil imaging and WFS	20	40	40	Independent	≥ 45 arcmin unvignetted FOV for ICCD
2b	Simultaneous direct imaging and pupil imaging with knife edge	20	40	40	Independent	≥ 45 arcmin unvignetted FOV for ICCD
3a	On-axis wavefront sensing	0	50	50	Independent	Simultaneous pupil imaging also possible
3b	Differential wavefront sensing	0	50	50	Adapter WFS controlled by VLTTC	Synchronous operation of wavefront sensors in VLTTC and adapter. Simultaneous pupil imaging also possible
3c	On-axis wavefront sensor calibration	0	50	50	Independent	Fibre light source inserted
4a	Image motion	100	0	0	Independent	Using PGS. Simultaneous use of ICCD possible.
4b	Differential image motion	100	0	0	Adapter AGS controlled by VLTTC	Synchronous operation of PGS and AGS in adapter. Simultaneous use of ICCD possible
5	Focusing mode	0	50	50	independent	Knife edge inserted
6a	Coronographic mode (simplified)	100	0	0	independent	Using fixed image plane and pupil plane masks only
6b	Coronographic mode (full)	100	0	0	independent	Using fixed image plane and rotating pupil plane masks.
7a	Absolute image scale measurements	100	0	0	independent	Using ICCD only
7b	Relative image scale measurements	100	0	0	independent	Using peripheral field TCCDs and ICCD with windowed

						readout.

3.1.2. Interface Definitions

The VLTTC has interfaces to the following external VLT subsystems:

3.1.2.1. Nasmyth and Cassegrain Rotators

The mechanical interfaces to the Rotators are defined in AD18 and AD19 respectively.

3.1.2.2. Cassegrain carriage

The interface to the Cassegrain carriage is defined in AD20.

3.1.2.3. Technical CCD systems

The optical and mechanical interfaces for the small and large format TCCD systems are defined in AD21 and AD20 respectively. The mechanical interface to the ACE box is specified in AD23.

3.1.2.4. Imaging CCD system

The optical and mechanical interfaces for the imaging CCD system (ICCD) are defined in AD24.

3.1.2.5. Telescope services

The VLTTC shall be connected to the telescope service supplies (electricity, cooling fluid, compressed air, interlocks, LAN and Time Reference system) at the SCP foreseen for the Cassegrain instrument when mounted on the Cassegrain Rotator (SCP 1-N[2]), or one of the SCPs foreseen for Nasmyth instruments when mounted on the Nasmyth Rotator (SCP 15-N to SCP 18-N).

The SCP boxes are described in AD12, and the interface requirements for these are specified in AD1. (Note that the SCP interface requirements for the Cassegrain focus are the same as for the Nasmyth focus.)

3.1.3. Major Component List

The major components of the VLTTC are as follows:

1. Part A opto-mechanical assembly
2. Part B opto-mechanical assembly
3. Common mechanical parts, adaptation flanges and handling/maintenance equipment
4. Control electronics
5. Control and data handling Software

3.1.4. Furnished Property List

1. LCU Common Software

[2] Where 'N' is the Unit Telescope number.

2. CCD Control Software
3. VLT Common Workstation Software and tools
4. Cassegrain carriage.

3.1.5. Loaned Property List

The following equipment will be loaned to the VLTTC from other VLT subsystems (applicable for VLTTC #1 only):

1 Two Large format TCCD systems

2 Two Small format TCCD Heads

3 One Shack-Hartmann lenslet array

4 One collimator lens and imaging objective

3.2. CHARACTERISTICS

3.2.1. Performance Characteristics

3.2.1.1. Part A

3.2.1.1.1. Mechanical structure

The mechanical structure shall be completely light-tight except for the beam entry openings.

The design shall ensure that the internal sub-assemblies can be easily accessed for maintenance.

The overall stability of the structure, together with all the contained sub-assemblies, shall be such that:

- Within a rotation of the VLTTC through 180° about a horizontal axis the image on the ICCD shall not move by more than 10 μm.
- A rotation of the main axis by 60° in any direction from vertical axis (as at the Cassegrain focus) shall not cause a shift of the image on the ICCD of more than 10 μm.

3.2.1.1.2. ICCD Camera system

The ICCD shall have a field of approximately 1.5 x 1.5 arcminutes on the sky with a pixel scale not more than 0.05 arcsec/pixel.

The CCD shall have a minimum RQE values not less than those shown below at the wavelengths indicated:

Wavelength	300nm	500nm	700nm	900nm
VLTTC #1	0.4	.7	.7	.4
VLTTC #2	0.5	.85	.85	.5

The flatness and mounting of the CCD shall be such the CCD surface shall not be more than ±150 μ from a plane parallel to the dewar mounting flange.

The readout time for a 2048×2048 field shall be ≤ 60 s, and preferably ≤ 30 s. With a 2×2 binned image, it shall be possible to readout the same field in ≤ 20 s, and preferably in ≤ 10s.

The RMS readout noise of the ICCD shall be ≤ $10e^-$ at the slowest readout rate.

The dark current shall be ≤ $10e^-.pixel^{-1}.hr^{-1}$.

Autonomy of cryostat ≥ 48 hrs.

The ICCD control system shall allow normal, binned and windowed readout modes. Windows may be defined up to the total field size of the CCD.

3.2.1.1.3. PGS

The PGS shall be a frame transfer CCD and allow exposure times down to 10 ms. The chip storage area shall not be light sensitive.

The frame transfer time shall be ≤1.5 ms.

It shall be possible to read out a window of 80×80 pixels at repetition rates of ≥ 10 Hz, and preferably ≥ 20 Hz.

3.2.1.1.4. Optical system

The optical image quality of the ICCD, including the quality of all the optical components, the stability of the mechanical structure and component misalignments, shall be such that a telescope image with 80% of the light energy concentrated in a diameter of 0.3 arcsecond shall not be degraded by more than 10% under the worst case operational conditions.

The unvignetted optical field shall be $61 \times 61 mm^2$ diameter.

All reflective surfaces of optical elements shall be aluminium with high reflectivity coatings. The overall transmission of the optical train of Part A shall be ≥ 0.75 over the range 310 - 1100 nm, and ≥ 0.85 over the range 400-900 nm. The specification of the of coatings shall correspond to the state-of-the-art of commercially available coatings.

3.2.1.1.5. Shutter

The opening and closing time of the shutter shall not exceed 50 ms. The minimum exposure time shall be 0.2 s. The accuracy and reproducibility of the integration time shall be ≤ 5 ms.

The shutter shall not dissipate more than 50 mW of electrical power when in the open or closed state.

3.2.1.1.6. Filter wheel and filters

The following basic filters shall be provided for the test cameras:

U, B, V, R, I, Z, ND1, ND2, ND3 and clear filter (UBK7 or silica)

The optical filters shall be AR coated and have a surface flatness compatible with the overall image quality requirements. The surfaces shall be parallel to ≤ 10 arcminutes.

The optical thickness (n×physical thickness) of all filters shall be 15 ± 0.05mm.

The neutral density filters shall be of an absorption type (no metallic coatings) and AR coated. They shall have a density tolerance of ±10% in the range 400-700nm.

The filter-wheel shall have at least 6 positions and shall not vignette field of the ICCD or the PGS.

It shall be possible to exchange filters during day-time without removing the VLTTC from the telescope.

The control system shall be able to position the filters with a precision of 0.25 mm measured at the centre of the filter.

3.2.1.1.7. Image plane mask

It shall be possible to insert a mask in the centre of the telescope focal plane to occult the light from a stellar object. The full ICCD field shall be unobscured when the mask is removed. With the mask inserted, the detected field shall be ≥ 45 arcsecs.

The masks shall consist of an etched metal foil in a rigid frame, or similar construction. The mask shall be optically black and have a flat upper surface with sharp edges (the use of blackened wires, for example, is not acceptable). Two masks shall be provided initially in the form of a simple cross with bar widths 4 and 8 arcseconds respectively.

The mask shall be inserted manually, but the position status of the mask shall be detected by the control electronics.

3.2.1.1.8. Pupil plane mask

The pupil plane mask shall obscure light diffracted by the secondary mirror support of the telescope.

In the case of VLTTC #2, the pupil mask shall be able to follow a pupil rotation of up to $0.5°.sec^{-1}$ with an accuracy of ± 0.5°. The setting speed shall not be less than 10°/sec.

The mask shall be easily removable during the day-time when not required.

In the case of VLTTC #1, it shall be possible to insert a fixed (non-rotating) pupil mask when required.

The control electronics shall be able to detect whether a mask is installed.

3.2.1.1.9. TCCD Mounting locations

The structure of Part A shall provide four mounting positions for TCCD camera heads so that the CCD image planes lie in the (curved) focal plane of the telescope. The location of these mountings shall be at the edge of the Nasmyth and Cassegrain fields and diametrically opposed.

The same ACE boxes shall be used as for the TCCD systems in Part B - i.e. these latter TCCD systems will not be used when those mounted in Part A are in operation. The switching of the

ACE boxes between the TCCDs in Part B to those in Part A will be done manually during day time.

3.2.1.2. Part B

3.2.1.2.1. Mechanical structure

The mechanical structure of Part B shall be completely light-tight except for the beam entry opening.

A dust cover shall be provided to prevent dust entering the VLTTC when not installed on the telescope. It shall not be possible to install the VLTTC on the telescope with the dust cover in place.

The design of the structure shall ensure that the sub-assemblies contained within it can be easily accessed for maintenance.

The overall stability of the structure, together with all the contained sub-assemblies, shall be such that:

- Within a rotation of the VLTTC of 180° about a horizontal axis (as at the Nasmyth focus) the image of the WFS reference source images on the WFS shall not move by more than 10 μm
- A rotation of the main axis by 60° in any direction from vertical axis (as at the Cassegrain focus) shall not cause a shift of the WFS reference source images on the WFS of more than 10 μm. The telescope pupil image shall not move on the PIS by more than this same amount.

3.2.1.2.2. TCCD systems

The axis of the optical system of Part B shall be coincident with the physical centre of the imaging area of the CCDs to within ±0.5mm. The front surface of the threaded flange of the CCD heads shall be perpendicular to the optical axis to within ±0.5°.

It shall be possible to disconnect the cables and hoses to the CCD heads without removing the VLTTC from the telescope.

3.2.1.2.3. Optical system

The Shack-Hartmann lenslet array shall be identical to those used in the VLT Adapters.

The 45° beam-splitter shall be dielectric multi-layer filter and optically neutral in the range 400 - 700 nm at the working angle of incidence. The beam-splitter shall divide the light intensity equally between the WFS and PIS detectors with a tolerance of ±10% over this wavelength range. The internal absorption shall be ≤ 1%.

The collimator lens shall provide a pupil image on the lenslet array and, via the beam-splitter, on the PIS. The pupil image shall be of a similar size as that in the Cassegrain and Nasmyth adapter WFSs. The transmission of the collimator shall be better than 95% in the range 400 - 900 nm.

3.2.1.2.4. Pick-up mirror assembly

The pickup mirror assembly shall allow one of six different optical configurations to be set as follows:

1. Clear: In this configuration all the light from the telescope is directed into Part A. There shall be no vignetting of the full field of the ICCD or the PGS. An opaque screen shall prevent direct or scattered light from the telescope beam entering optical train of Part B

2. Beamsplitter: In this configuration a dielectric or metallic film beam-splitter shall allow 10 - 20% of the incoming light to be transmitted into Part A, and the remainder to be reflected into Part B. The light intensity division shall be optically neutral (±10%) in the range 400 - 700 nm at working angle of incidence. Internal absorption shall be ≤ 1% in the case of a dielectric BS. The rear surface shall be coated with a high efficiency AR coating. The surface flatness shall be ≤ $\lambda/10$ (633nm) over the central 20mm Ø. The unvignetted field on the ICCD shall be ≥ 45 arcseconds diameter.

   An alternative dichroic prismatic beam-splitter shall also be provided which shall transmit short wavelengths and reflect long wavelengths. The cross-over wavelength shall be in the range 550 - 600 nm. Other specifications are as for the neutral beam-splitter above.

3. Beamsplitter + knife-edge: This configuration shall provide the same characteristics as configuration 2, but with the addition of a knife edge inserted at the centre of the image plane of Part B. In this configuration the knife edge shall be conjugate with the ICCD focus. The front surface of the knife edge shall be flat and the edge of the rear edge bevelled.

4. Mirror: In this configuration a plane aluminised mirror reflects all the light into Part B. The size of the reflective surface shall be at least 20mm Ø, and it shall have a surface quality ≤ $\lambda/20$ over this area.

5. Mirror + knife-edge: This configuration shall provide the same characteristics as for configuration 4, but with the addition of a knife edge inserted at the centre of the image plane of Part B. The knife edge shall located in the same plane as for position 3.

6. Calibration source: In this configuration an optical reference fibre shall be placed in the focal plane of Part B on the optical axis to provide a calibration source for the WFS. The fibre position shall be adjusted to lie within 0.5 mm of the axis of rotation of the VLTTC when mounted on the rotator. The precision of the positioning of the fibre shall be ≤ 0.1 mm. An opaque screen shall prevent direct or scattered light from the telescope beam entering the optical train of Part B.

   The fibre shall be illuminated by a LED located in the LCU in an identical way to the adapter calibration source. The intensity shall be remotely adjustable and be such that the peak sub-aperture signals recorded by the WFS in 10s are approximately 10^5 e^-.pixel^{-1}. The minimum signal shall be approximately 0.1% of the peak intensity.

General requirements for the beam-splitter assembly:

The front surface of the mirror and beam-splitter shall be in the same plane so that changing from one position to the other, and vice-versa, shall not cause a movement of the focus of Part B of more than 0.05mm, or a movement of the pupil image on the PIS ≥ 0.1 mm.

When the beam-splitter or pick-up mirror are removed, the TCS shall be requested by the VLTTC control system to automatically compensated for the offset caused by the optical thickness of the beam-splitter.

The linear positioning accuracy of the beam-slitter mechanism shall be $\leq \pm 0.1$ mm.

The maximum time taken to move from one configuration to any other shall not exceed 20 seconds. The movement of the pick-up mirror slide shall be perpendicular to both the telescope axis and the main optical axis of part B.

It shall be possible to exchange individual mirror units from the pick-up mirror assembly during the day time without removing the VLTTC from the telescope. After exchange there shall be no need to optically realign the mirror units in order to meet the requirements given above.

The following table gives a summary of the observational modes used by each beam-splitter configuration:

Position	Configuration	Observational Modes
1	Clear	1, 4a, 4b, 6a, 6b, 7a, 7b
2	Beamsplitter	2a,
3	Beamsplitter + knife-edge	2b
4	Mirror	3a, 3b
5	Mirror + knife-edge	5
6	Calibration source	3c

3.2.1.3. Common components

3.2.1.3.1. Mounting flanges

The Cassegrain and Nasmyth mounting flanges shall be exchangeable without removing of any other parts of the VLTTC or electronic boxes. The exchange of mounting flange shall be carried out with the VLTTC standing on its support with the optical axis vertical.

3.2.1.3.2. Handling/maintenance equipment

The VLTTC shall be installed on the Cassegrain rotator using the VLT Cassegrain Carriage. Any necessary adaptation pieces required for this carriage shall be provided as part of the VLTTC.

Suitable handling devices shall also be provided to install the VLTTC on the Nasmyth Adapter/Rotator. The handling procedures shall use, as far as possible, existing handling equipment at the VLTO.

Liquid nitrogen (LN_2) storage tanks shall be furnished to provide a local supply of LN_2 in the enclosure for the ICCD during periods of operation. The type and final number of tanks shall be co-ordinated with other VLT systems requiring LN_2.

3.2.1.4. Control electronics

The control electronics shall be constructed to conform to VLT standards for instrumentation. These are specified Sections 4.18 and 4.19 of AD1, and are also applicable to the Cassegrain instruments.

The following table give a summary of the mechanical functions of the VLTTC to be controlled.

Function name	Type	VLTTC No.	Min. resolution (bits)
Filter Wheel	rotary	1 & 2	12
Shutter Part A	on-off	1 & 2	1
Pupil plane Mask (VLTTC #2)	rotary	2	10
Pickup mirror assembly	linear	1	12
Calibration lamp control	on-off + intensity control	1	1+ 12
Calibration lamp status	binary	1	3
Image plane mask position	$3 \times$ on-off	1 & 2	3
Pupil plane mask status	on-off	1	1

The control electronics, insofar as this is consistent with the other requirements of this specification, shall be attached directly to the VLTTC structure so that the removal from Cassegrain to the Nasmyth focus, and vice versa, is as simple as possible. If it is not possible for all the electronic equipment to be attached directly to the VLTTC structure, then the space allocated for Cassegrain and Nasmyth instrument electronics in the M1 Cell and on the Nasmyth platform respectively shall be used.

Cables to and from the VLTTC shall be grouped in a single umbilical, and shall be supported in a way to allow free movement of the VLTTC throughout the permitted angle of rotation specified in Section 3.2.2.4.

The control of the VLTTC will be from the Workstation foreseen for VLT instruments. All control and data exchange between the Instrument Workstation to the VLTTC shall be handled in the same way as for normal VLT instruments.

3.2.1.4.1. LCUs and LANs

Separate LCUs shall be provided for the VLTTC control electronics, and for each CCD camera.

Each CCD LCU shall be equipped with an 8 Mb CPU and TIM module. All LCUs shall use the same Control LAN. A separate LAN for data transfer shall be used which, if need be, may be shared by the two TCCD systems. The ICCD system shall use a separate LAN for data transfer.

3.2.1.5. Software

3.2.1.5.1. General requirements

The VLTTC software shall conform to the general requirements for VLT software as specified in AD6 and AD7. The programming standards shall conform to AD16

The general scope of the software for the VLTTC shall be subset of the software required for normal VLT instruments as specified in AD8. In particular, the VLTTC software shall include the software specified for Stage 1 in Section 2.4 of AD8, as well as a sub-set of that specified in Stage 2. This latter shall include software for the creation of set-up files, data display, basic data reduction tools and data archiving, as well as basic maintenance software. Communication with the user shall be through optimised User Interface Panels (UIP).

The VLTTC software shall use currently available SW packages, such as the LCU common software (AD9), instrument common software (AD17), and CCD common software (AD13), as well as software developed for other VLT subsystems, such as the TCCD software and the active optics WFS analysis software (AD25).

3.2.1.5.2. Control software requirements

The control software shall allow all mechanical functions of the VLTTC to be controlled and monitored from a UIP. This UIP shall be integrated with the standard panels for the TCCD and ICCD to allow a coherent overview of all operation functions of the instrument and their status. All the modes of operation listed in Section 3.1.1.6 shall be supported.

The control software shall transfer information on the focus and telescope pointing axis offsets corresponding to the actual mode of operation of the VLTTC.

It shall be possible, at the demand of the user, to store any image received from the VLTTC in the VLT data archive. The stored data shall include the minimum information necessary to identify the conditions and instrumental configuration applicable.

It shall be possible to take synchronous exposures with the AGS in the adapter and the PGS, using windowed readout. Similarly, it shall be possible to record synchronous exposures made with the WFSs in the VLTTC and the adapter/rotator. Synchronisation shall be effected using the Time Interface Module.

Maintenance software shall include hardware test software for the VLTTC functions. It shall be integrated with existing maintenance and test software from other VLT software packages relevant to the VLTTC, including the TCCD, ICCD and active optics systems.

3.2.1.5.3. Display and analysis software requirements

It shall be possible to display all CCD images obtained from the VLTTC immediately after readout, as well as reduced the data, cross sections, contour plots, etc.

It shall also possible to display the real-time data from windowed readout frames from the PGS at speeds of $\geq$ 10Hz.

Standard data reduction procedures using standard on-line MIDAS procedures shall be available to analyse VLTTC images, compute statistics, etc. (See AD14).

In addition, it shall be possible to analyse the WFS images using the software foreseen for the VLT active optics system.

It shall be possible to record the centroid positions of sequences of synchronous, windowed readout images, as well as the statistics of the centroids (rms motion and direction compared to mean, rms differential motions and directions)

3.2.2. Physical Characteristics

3.2.2.1. Construction materials

The material used of the main mechanical structure of Parts A and B, as well as the telescope adaptation flanges, shall be made of steel.

The optical mirrors of Part A shall be made of optical crown glass (B270), or other suitable optical glass having a coefficient of linear expansion of $\geq 8 \times 10^{-6}.C^{-1}$.

The substrate for the 100% reflecting pick-up mirror shall be made of Zerodur. The substrate for the partially reflecting pick-up mirrors shall be made of UBK7 or fused silica.

3.2.2.2. Mass and centre of gravity

The mass of the VLTTC, together with all electronic systems and cables, shall not exceed 2000 kg. The moment applied to the rotator flange by the VLTTC shall not exceed 20000 kNm under the worst case conditions.

3.2.2.3. Volume

The VLTTC shall not exceed the maximum design volume foreseen for either Cassegrain of Nasmyth instruments.

3.2.2.4. Angle of rotation

The design of the VLTTC cable wrap shall assure an uninterrupted rotation of the VLTTC of ± 180° from the mid-point.

3.2.2.5. Thermal requirements

No heat producing components shall be located inside the VLTTC, except for those that are only used intermittently and where there is no risk that the heat produced will influence the optical image quality.

The shutters shall be of a type that only require electrical power during the opening and closing operations.

The surface temperature of the VLTTC electronic racks shall not exceed the range ambient ±2C, and shall be cooled where necessary using the telescope cooling system. The interface to this system is described in Section 4.18.1.2 of AD1.

3.2.3. Reliability

The VLTTC shall be designed for a working lifetime of not less than 5 years with an average use of all functions of 10 times per day. No special reliability requirements are imposed.

3.2.4. Maintainability

The VLTTC shall be design to allow easy manual exchange of filters and focal plane masks when mounted on either the Nasmyth of Cassegrain foci.

The instrument shall be designed to allow the easy day-time exchange of all line replaceable units.

3.2.5. Environmental Conditions

The instrument shall be designed to withstand the environmental conditions described in AD3. In addition, it shall be possible to set-up and align the optical system at 20°C and then use the

VLTTC in the operational temperature range specified in AD3 (0-15°C) without further adjustment.

3.2.6. Transportability

No special requirements.

3.3. DESIGN AND CONSTRUCTION

3.3.1. Materials, Parts and Processes

3.3.1.1. Surface treatments

Internal surfaces of the VLTTC shall be painted matt-black or black anodised to reduce reflections.

All parts shall be protected against corrosion according to DIN 55928-TO5. External steel surfaces shall be painted with an epoxy paint.

3.3.2. Electromagnetic Compatibility

The VLTTC shall be in conformity with the EMC requirements specified in AD5 and AD4.

3.3.3. Name Plates and Product Marking

All main parts and exchangeable units (Line Replaceable Units) shall be equipped with name-plates that shall be visible after installation giving the following information:

1. Unit, assembly and sub-assembly numbers as appropriate
2. A serial number which shall include the product code number (11960)
3. Name of manufacturer.

3.3.4. Workmanship

No special requirements.

3.3.5. Interchangeability

It shall be possible to replace the complete VLTTC Part A with the IR array test cryostat for observations in the 1-5μm region .

3.3.6. Safety

The VLTTC shall comply with the general safety standards specified in AD10. The required safety analyses shall be compliant with AD11.

A safety limit switch shall be provided to detect if the instrument rotator exceeds the pre-set angular limits if there is a danger that the VLTTC or other telescope equipment could be damaged by such a circumstance. This safety switch shall be connected through the local interlock of the SCP used. (see Section 4.18.1.1.2 of AD1).

All VLTTC sub-assemblies shall be designed to operate in a fail-safe mode. In cases where one sub-assembly may interfere, or cause danger to another, interlocks shall be provided to prevent damage. No single hardware or software failure shall cause damage to either the VLTTC itself, VLTO personnel or to other telescope equipment. No user error shall be allowed to cause to damage. Any maintenance level software command that could lead to a potentially dangerous situation shall be protected by password and warnings shall be displayed.

3.3.7. Human Engineering

No special requirements.

3.4. DOCUMENTATION

The following documentation shall be made available for the VLTTC:

3.4.1. Assembly/Installation manual

This manual shall contain the assembly procedures for the VLTTC after shipment. It shall describe the handling and installation procedures and include warnings of any risks involved in these operations.

3.4.2. Operation/User manual

This manual shall describe the operation at the telescope, as well as the software operation manual. It shall provide cross-references to other user manuals for more detailed information on delivered sub-systems.

3.4.3. Maintenance manual

This manual shall include a full description of the VLTTC, and include full as-built mechanical and electrical drawings for the instrument. It shall provide cross-references to other maintenance manuals for more detailed information on delivered sub-systems.

The maintenance manual shall also give the results of the acceptance tests results for the VLTTC and the CCD detectors, and provide documentation on the electronics components where these are not given elsewhere.

A list of the test procedures and expected results shall be given, both for the complete system and for individual sub-assemblies.

3.5. MAINTENANCE

Except where specifically mentioned to the contrary in this document, the general maintenance concept and requirements shall be as specified in Section 7 of AD1.

3.6. PERSONNEL AND TRAINING

Not applicable

3.7. MAJOR COMPONENT CHARACTERISTICS

Not applicable

3.8. PRECEDENCE

In the event of conflict between this specification and the documents reference in Section 2, the contents of this specification shall be considered a superseding requirement.

4. PRODUCT ASSURANCE PROVISIONS

4.1. GENERAL

The compliance of the final design with this requirement document shall be verified by the WP manager and any discrepancies reported to the project office.

Quality control on the single components and on the assembled VLTTC shall be carried out by allocated ESO staff.

4.2. QUALITY CONFORMANCE VERIFICATIONS

The following tests are foreseen to take place in the ESO laboratories and will be documented:

1. Test and characterisation of the CCD chips
2. Transmission of the filters
3. Reflectivity of the mirrors
4. Flexure test of the integrated VLTTC

5. PREPARATION FOR DELIVERY

No special requirements.

6. NOTES

Not applicable