



Optics

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A&G REQUIREMENTS

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1.B	14-10-98	5.2.2.7	21	Change request CCIA/0028
1.B	14-10-98	5.2.2.6	21	Modification in source and parent requirement
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2.A		5.1.2.2		Change to refer to DCI
2.A		5.1.5.2		Foot-note added
2.A		5.1.8		Change in wording
2.A		5.1.9		New requirement on Heat Dissipation
2.A.		5.1.10		New performance requirements to replace sensitivity requirements for AG instruments
2.A		5.2		Change title
2.A		5.2.1.2		CANCELLED
2.A		5.2.1.3		CANCELLED
2.A		5.2.2.1		CANCELLED
2.A		5.2.2.2		Change wording
2.A		5.2.2.4		Remove TBC
2.A		5.2.2.5		Change to guideline
2.A		5.2.2.8		Change guideline to requirement
2.A		5.2.2.9		CANCELLED
2.A		5.2.2.10		CANCELLED
2.A		5.2.2.11		CANCELLED
2.A		5.3.1.3		Remove reference to seeing measurement
2.A		5.3.1.4		New guideline
2.A		5.3.2.1		CANCELLED
2.A		5.3.2.2		Change wording
2.A		5.3.2.3		Change wording, remove TBC
2.A		5.3.2.5		CANCELLED
2.A		5.3.2.7		Change guideline to requirement
2.A		5.3.2.8		CANCELLED
2.A		5.3.2.9		New guideline
2.A		5.3.2.10		New guideline
2.A		5.4		Change title
2.A		5.4.1.1		Change title & wording
2.A		5.4.1.4		New requirement (replaces 5.2.1.1)
2.A		5.4.2.1		CANCELLED
2.A		5.4.2.2		CANCELLED
2.A		5.4.2.3		New guideline
2.A		5.4.2.4		New guideline
2.A		5.4.2.5		New guideline
2.A		5.4.2.6		New guideline
2.A		5.7.1.2		Change in wording

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2.A		5.7.1.4		CANCELLED
2.A		5.7.2.1		CANCELLED
2.A		5.7.2.2		Change wording
2.A		5.7.2.4		Change wording
2.A		5.7.2.8		Change to define search area to cover in 10 secs
2.A		5.7.2.10		Reduce range in axial positioning
2.A		5.7.2.13		New requirement
2.A		5.7.2.14		New requirement
3.A	26/06/00	5.1.2.1		OPTI/0088 remove TBD
3.A		5.1.2.2		OPTI/0088 CANCELLED
3.A		5.1.10.2		OPTI/0088 Change wavelength range for throughput
3.A		5.1.10.3		OPTI/0086 Change on-axis optical quality
3.A		5.1.10.7		OPTI/0088 Change wavelength range for dark current
3.A		5.3.1.3		OPTI/0088 Add parent req. Change STS resolution to global modes
3.A		5.3.2.3		OPTI/0086 Change 'at most' to 'approximately'
3.A		5.3.2.10		OPTI/0086 Change 'at most' to 'approximately'
3.A		5.4.1.4		OPTI/0088 Change HRWFS resolution
3.A		5.5		OPTI/0088 CANCELLED
3.A		5.5.1		OPTI/0088 CANCELLED
3.A		5.5.1.1		OPTI/0088 CANCELLED
3.A		5.5.2.2		OPTI/0088 CANCELLED
3.A		5.7.2.6		OPTI/0088 Change lateral position repeatability to 82.5 microns
3.A		5.7.2.7		OPTI/0088 Change lateral stability to 0.02 arcsec for 15° rotation
3.A		5.7.2.10		OPTI/0088 Change axial positioning range to 95mm
3.A		5.7.2.12		OPTI/0088 Change pupil rotation accuracy to 120 microradians
3.A		5.7.2.15		OPTI/0088 New requirement on uncertainty in lateral position
3.A		5.8		OPTI/0088 Change coding of requirements in this section

Applicable documents

N°	Document title	Code	Issue
A.1	GTC System Specification	ESP/STMA/0017-L	1.C

Reference documents

N°	Document title	Code	Issue
R.1	The Acquisition and Guiding System Options	RPT/OPTI/0010-R	1.A
R.2	A&G Services to Telescope and Instrumentation	RPT/OPTI/0061-L	1.A
R.3	A&G System Decomposition	NTE/OPTI/0028-L	1.C
R.4	Support requirements for specifications and SOO/SOW	RPT/STMA/0064-R	1.A
R.5	System Error Budgets	RPT/STMA/0054-R	1.A
R.6	Modes of Observation for the GTC	ESP/CCIA/0025-L	1.A

**List of acronyms and abbreviations**

AG	Acquisition and Guiding
AO	Adaptive Optics
CIR	Central Intensity Ratio
EMC	Electromagnetic Compatibility
FG	Fast Guiding
HRWFS	High Resolution Wavefront Sensor
ICM	Instrument Calibration Module
SCIDAR	Scintillation detection And Ranging
SFS	Segment Figure Sensor
SPS	Segment Piston Sensor
STS	Segment Tilt Sensor
TBC	To Be Confirmed
TBD	To Be Determined
w.r.t.	with respect to



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1. SUMMARY

This document contains the requirements for the Acquisition and Guiding subsystems. These subsystems are listed in Fig.1.

The AG-NA subsystems will be installed at a Nasmyth A focus of the GTC. The collection of subsystems defined by AG-NA-AG, AG-NA-FT and AG-NA-SF will be referred to as the ‘AG Instruments’ for convenience.

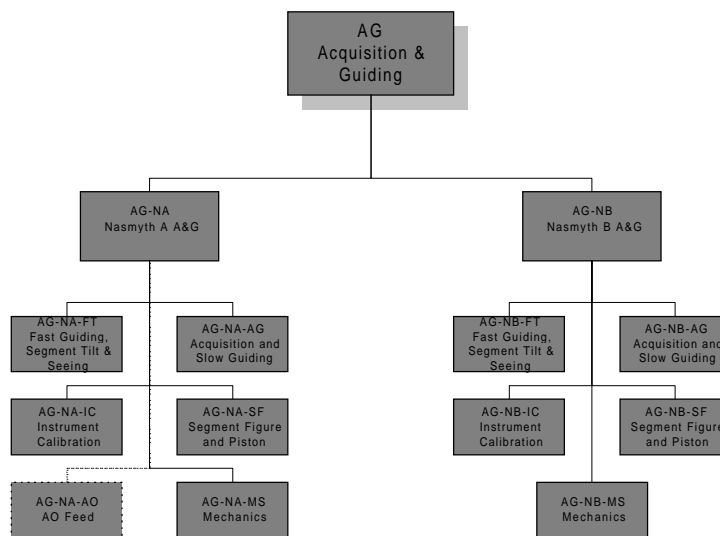


Figure 1

2. INTRODUCTION

2.1 Use of shall/should

“Shall” is used for requirements no matter how stable they are, whereas “should” is reserved for guidelines. Requirements are mandatory and guidelines are not mandatory, although their fulfilment should be strongly pursued.

2.2 Stable and unstable requirements

Unstable or undefined requirements are identified by “TBC” or “TBD” respectively.

2.3 AG-NB subsystem

Since AG-NA and AG-NB are identical subsystems with the exception of the Adaptive Optics Feed, which is only included in AG-NA, requirements in sections 5.2, 5.3,5.4,5.5 and 5.7 apply

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to both AG-NA and AG-NB, although they will be prefixed only with the codes corresponding to AG-NA.

3. DEFINITIONS

3.1 Acquisition

Acquisition refers to placing the required position within the science instrument aperture (see 3.16) at the requested target co-ordinates (projected position in the focal plane) using a celestial reference image.

3.2 Apparatus

This term refers to all electrical and/or electronic elements, as well as equipment, subsystems and installations containing electrical and/or electronic components, that are able to generate electromagnetic disturbances or whose performance can be degraded by electromagnetic disturbance. This term does not refer to:

- individual components such as integrated circuits, electronics boards, resistors and capacitors to be installed in an apparatus, without any intrinsic function to be used by the final user.
- modules produced in series or sets of elemental components to be assembled.
- parts of equipment being commercially available that can not be put in service by themselves.

3.3 Axial position of Instruments

The axial position of an Instrument is its position along its optical axis.

3.4 Central Intensity Ratio

The Central Intensity Ratio (CIR) is defined as the central intensity in a long exposure image provided by the actual telescope divided by the central intensity given by a telescope with the same geometry but no aberrations. It depends on wavelength and seeing, as well as on aberrations.

3.5 Fried Parameter

The Fried parameter is the diameter of a circular area of wavefront over which the mean square error with respect to a perfect wavefront is one square radian.

3.6 Guiding

Guiding refers to maintaining the required position within the science instrument aperture (see 3.16) on the required target co-ordinates (projected position in the focal plane) using a celestial reference image. Guiding does not refer to correction of atmospheric image motion or that induced by external perturbations, such as wind. It is also called slow guiding.

3.7 High Resolution Wavefront Sensing (HRWFS)

A wavefront sensor will be regarded as having high resolution if it is capable of measuring the wavefront phase at points separated by 20 cm or less on the telescope entrance pupil.

3.8 Image motion

Image motion refers to the differential motion between the image of the target and the required position within the science instrument aperture.

3.9 Image motion correction

Image motion correction refers to cancellation of the image motion (see 3.8) induced by atmospheric seeing and external perturbations, such as wind. It is also called fast guiding.

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3.10 Lateral position of Instruments

The lateral position of an instrument is its position in the plane perpendicular to its optical axis.

3.11 Mean Preventive Maintenance Night-Time (MPMNT)

The MPMNT is the night-time per year that the system is not available for operation due to planned (preventive) maintenance tasks.

3.12 Mean Time Between Failures (MTBF)

The MTBF for a system is the mean time between two consecutive failures of the system.

3.13 Mean Time To Repair (MTTR)

The MTTR for a system is the mean time spent in unplanned (corrective) maintenance to repair the system.

3.14 Overall accuracy

The overall accuracy is a statistical measure of the differences between a real value and an ideal one for a number of events (measurements or actuations).

3.15 SCIDAR

SCIDAR refers to a technique which estimates the vertical distribution of atmospheric turbulence based on the spatial correlation of scintillation as measured in a pupil plane.

3.16 Science Instrument aperture

This term refers to the part of the object plane of the science instrument seen by the detector. In the nominal optical configuration that plane matches the focal plane of the telescope.

3.17 Seeing

Seeing refers to the effect of atmospheric and local turbulence on wavefronts collected by the telescope. A numerical value for seeing is given by the full-width at half-maximum of an image obtained with a large perfect telescope with an exposure time which is long compared to the coherence time of the atmosphere.

3.18 Segment Figure Sensor (SFS)

A segment figure sensor is a device capable of measuring figure errors including at least tip-tilt, defocus and both modes of astigmatism of the primary mirror segments.

3.19 Segment Tilt Sensor (STS)

A segment tilt sensor is a device capable of measuring tip-tilt of the primary mirror segments.

3.20 Segment Piston Sensor (SPS)

A segment piston sensor is a device capable of determining the piston of the primary mirror segments.

3.21 Target

The term 'Target' refers to the astronomical object of interest.

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4. SCOPE

This document applies to the systems which will be provided by the GTC to allow Acquisition and Guiding at a Nasmyth focus as well as those systems required for calibration of the Telescope Behaviour Model and Closed Loop Active Optics, calibration of Instruments and insertion of AO. The collection of all these subsystems is presented in Fig.1 and will be referred to as the 'AG subsystems'.

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5. REQUIREMENTS

5.1 General Requirements

All the requirements in the following section shall have the following code: RQ/AG/NNN, where NNN is the index that appears immediately before the requirement title.

5.1.1 Functional Requirements

5.1.1.1 Acquisition

Parent Requirements: SP/GTC/5.2.14.2

A subsystem shall be provided which shall allow targets to be positioned accurately inside the science aperture.

5.1.1.2 Off-axis slow guiding

Parent Requirements: SP/GTC/5.2.14.2

A subsystem shall be provided to allow guiding using off-axis reference sources.

5.1.1.3 Off-axis fast guiding

Parent Requirements: SP/GTC/5.2.14.2, SP/GTC/5.2.4.2

A subsystem shall be provided to allow image motion correction using off-axis reference sources.

5.1.1.4 Calibration of the Telescope Behaviour Model (TBM)

Parent Requirements: SP/GTC/6.6.3.1, SP/GTC/6.6.3.3

A subsystem shall be provided to measure the behaviour of the optical system in order to identify and update the value of the parameters of the telescope behaviour model.

5.1.1.5 Wavefront sensing for Closed Loop Active Optics (CLAcO)

Parent Requirements: SP/GTC/6.6.5.2

A subsystem shall be provided to allow the operation of closed-loop active optics simultaneously with the scientific observations.

5.1.1.6 Measurement of Seeing parameters

Parent Requirements: SP/GTC/5.3.4.1

A subsystem shall be provided to allow measurement of the value of the Fried parameter simultaneously with the scientific observations.

5.1.1.7 Instrument Calibration Facilities guideline

Source: Instrumentation group

A subsystem should be provided to allow calibration of the scientific instruments.

5.1.1.8 Beam extraction/return for Adaptive Optics guideline

Source: Optics Group, NTE/OPTI/0019-R

A subsystem should be provided to allow extraction of the telescope beam to an adaptive optics correction unit and re-insertion of the corrected beam.

5.1.2 Physical Characteristics Requirements

5.1.2.1 Nasmyth envelope

Parent Requirements: SP/GTC/7.1.12.2.1

The AG-NA subsystems shall occupy the volume shown in DR/AG-NA/000.

5.1.2.2 CANCELLED (8/06/00)

Parent Requirements: SP/GTC/5.2.5.6.1

The AG-CI subsystems shall occupy the volume shown in drawing **TBD** of the interface control document **TBD**.

5.1.3 General conditions

The following requirements shall apply to all the AG subsystems.

5.1.3.1 Environmental conditions

Parent Requirements: SP/GTC/5.3.6, SP/GTC/8.2.6.5.2

Source: RPT/STMA/0064-R(1.A, 4.2.1)

The AG subsystems shall be designed to operate and survive the conditions internal to the GTC telescope dome as stated in Table 5.1.

	Nominal conditions¹	Limit of operation	Survival limit
Temperature	-2°C to +19°C	N/A	-15°C to +35°C
Thermal variation (at night) in 15 minutes	0°C to 0.9°C	N/A	N/A
Thermal variation (at night) in 1 hour	0°C to 1.8°C	N/A	N/A
Thermal variation (at night) in 2 hours	0°C to 2.4°C	N/A	N/A
Relative humidity	2% to 87%	90% (or condensation)	0% to 100% with condensation
Atmospheric pressure	770 to 790 mbar	N/A	N/A
Wind	TBD	TBD	TBD

Table 5.1

5.1.3.2 Earthquake survival

Parent Requirements: SP/GTC/5.3.6.5

The AG subsystems shall be able to support earthquakes as defined by the applicable regulations without suffering any damage.

5.1.3.3 Dust guideline

Parent Requirements: SP/GTC/5.3.6.9

Source: RPT/STMA/0064-R(1.A, 4.2.1.1)

The design of the AG subsystems should ensure that they will operate without degradation of the required performance during and after episodes of Saharan dust.

¹ Nominal conditions are those in which the specified performances are matched without any degradation.

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5.1.4 Reliability Requirements

5.1.4.1 MTBF

Parent Requirements: SP/GTC/5.4.2

Source: System Engineering group

The AG system shall have an MTBF of at least 1000 hours (**TBC**)

5.1.4.2 MTTR

Parent Requirements: SP/GTC/5.4.2

Source: System Engineering group

The AG system shall have an MTTR of less than or equal to 4 hours (**TBC**)

5.1.5 Support Requirements

5.1.5.1 Accesibility

Parent Requirements:SP/GTC/5.4.8

It shall be possible to dismount the AG subsystems and access their components in a straightforward manner in order to facilitate maintenance.

5.1.5.2 MPMNT

Parent Requirements:SP/GTC/5.4.8

Source: System Engineering group

The AG subsystems shall have an MPMNT² of 30 hours (**TBC**).

5.1.6 EMI requirements

5.1.6.1 General Rerquirement

Parent Requirements: SP/GTC/5.7.1

Each apparatus (see 3.2) of the AG system shall meet the electromagnetic immunity generic standard UNE-EN 50082-2 and the electromagnetic emission generic standard UNE-EN 50081-2.

5.1.6.2 Emission standard guideline

Parent Requirements:SP/GTC/5.7.2

Each apparatus (see 3.2) of the AG system should meet the electromagnetic emission levels stated in the electromagnetic emission generic standard UNE-EN 50081-1.

5.1.6.3 Product or family standards

Parent Requirements:SP/GTC/5.7.3

Those apparatus (see 3.2) of the AG system for which any product standard or product family standard is applicable, therefore taking precedence over the generic standards stated in requirements 5.1.6.1 and 5.1.6.2, the same criteria shall be applied, i.e., electromagnetic immunity shall be maximized and electromagnetic emission shall be minimized.

² In the case of the AG subsystems, MPMNT shall include such tasks as flat-fielding and calibration of detectors.

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5.1.7 Standardization Guideline

Parent Requirements: SP/GTC/5.4.8

The components of the AG subsystems should be standard, commercial and well proven and should be selected in such a way as to facilitate their maintenance.

5.1.8 Scattered Light Guideline

Parent Requirement: SP/GTC/5.2.7.1

The design of the AG subsystems should aim to minimise the amount of light scattered from the AG subsystems to the detector of the scientific instrument.

5.1.9 Heat Dissipation Guideline

Parent Requirement: SP/GTC/12.4.1.1

The design of the AG subsystems should aim to minimise the amount of heat dissipation.

5.1.10 AG Instruments Performance Requirements.

5.1.10.1 Operating wavelength Range

Parent Requirement: 5.1.1.1, 5.1.1.2, 5.1.1.3, 5.1.1.4, 5.1.1.5, 5.1.1.6

The transmission and image quality of the Instruments shall be optimized over the wavelength range $0.38 \mu\text{m} < \lambda < 1.0 \mu\text{m}$.

5.1.10.2 Total Throughput

Parent Requirement: 5.1.1.1, 5.1.1.2, 5.1.1.3, 5.1.1.4, 5.1.1.5, 5.1.1.6

Source: NTE/OPTI/0043-L(1.A,3.1.1.1)

The product of the optical transmission of the instruments (excluding any beamsplitters) and the detector quantum efficiency shall be at least 24% in the the V-band.wavelength range 0.6-0.9 μm with the exception of the ASG Camera for which the product shall be at least 64% in the range 0.5-0.6 μm .

5.1.10.3 On-axis optical quality

Parent Requirement: 5.1.1.1, 5.1.1.2, 5.1.1.3, 5.1.1.4, 5.1.1.5, 5.1.1.6

Source: NTE/OPTI/0043-L(1.A,3.1.1.5)

The image diameter encircling 80% of the energy calculated using geometric ray tracing (including the nominal telescope configuration) shall be less than 0.20 arcsecs when the guide probe is on-axis.

5.1.10.4 Stray Light Rejection

Parent Requirement: 5.1.1.1, 5.1.1.2, 5.1.1.3, 5.1.1.4, 5.1.1.5, 5.1.1.6

Stray light entering the AG aperture beam at angles larger than 0.25 (TBC) degrees from the nominal telescope beam shall be rejected.

5.1.10.5 Detector cosmetic quality

Parent Requirement: 5.1.1.1, 5.1.1.2, 5.1.1.3, 5.1.1.4, 5.1.1.5, 5.1.1.6

Source: Instrumentation group

The detectors employed shall be at least of scientific grade 1.

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5.1.10.6 Detector read noise

Parent Requirement: 5.1.1.1, 5.1.1.2, 5.1.1.3, 5.1.1.4, 5.1.1.5, 5.1.1.6
Source: NTE/OPTI/0043-L(1.A,3.1.1.2)

The detector readout noise shall be no more than 7 electrons per pixel at the nominal readout speed.

5.1.10.7 Detector dark current

Parent Requirement: 5.1.1.1, 5.1.1.2, 5.1.1.3, 5.1.1.4, 5.1.1.5, 5.1.1.6

The detector dark current shall be less than the sky background³ expected in the wavelength range 0.6-0.9 μm with the exception of the ASG Camera for which the corresponding wavelength range shall be 0.5-0.6 μm .

5.2 Acquisition & Slow Guide Camera

All the requirements in the following section shall have the following code: RQ/AG-NA-AG/NNN and RQ/AG-NB-AG/NNN, where NNN is the index that appears immediately before the requirement title.

5.2.1 Functional Requirements

5.2.1.1 Acquisition & Slow Guiding concept

Parent Requirements: 5.1.1.1, 5.1.1.2
Source: RPT/OPTI/0061-L (1.A., 4.0)

The AG camera shall allow targets to be positioned accurately inside the science aperture. This shall be carried out by integrating an image on a detector (which shall be referred to as the 'acquisition detector') and identifying either the target or a reference source with a known offset from the target to be observed.

5.2.1.2 CANCELLED(16/04/99)

Parent Requirements: 5.1.1.4
Source: NTE/OPTI/0028-L

It should be possible to adapt the optics in front of the acquisition detector in order to insert a lenslet array allowing high-resolution wavefront sensing.

5.2.1.3 CANCELLED(16/04/99)

Parent Requirements: SP/GTC/6.7.12
Source: NTE/OPTI/0028-L(1.B, 4.1.3)

The design should consider the possibility of imaging the telescope pupil onto the detector and providing a fast shutter in order to allow determination of the vertical distribution of turbulence.

5.2.1.4 Filters

Parent Requirements: SP/GTC/5.2.14.3.4

It shall be possible to insert neutral (5 (TBC) values) and standard B,V,R,I filters before the acquisition detector. It shall also be possible to observe without filters.

³ This shall correspond to the mean zenith brightness when there is no moonlight, which is approximately 0.036 photons/cm²/sec/ μm /arcsec² at 0.5 μm and 0.1 photons/cm²/sec/ μm /arcsec² at 0.8 μm .

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5.2.2 Performance Requirements

5.2.2.1 CANCELLED(16/04/99)

Source: RPT/OPTI/0061-L(1.A,4.6)

It shall be possible to measure the centroid of the image of a reference star of magnitude⁴ $V=23$ with an rms error of less than 0.01 arcsecs (two-dimensional) using an exposure time of 60 seconds, when the seeing is 0.4 arcsecs and the sky background in the V band is 19.35 magnitudes per square arcsec⁵.

5.2.2.2 FOV

Parent Requirements:SP/GTC/5.2.14.3.3

The field of view of the acquisition detector shall be at least one arcminute by one arcminute when used for acquisition.

5.2.2.3 Windows for Slow Guiding when chopping

Source:RPT/OPTI/0061-L(1.A,5.2.1.9),Science group

In order to provide slow guiding while chopping, it shall be possible to define at least two windows for centroiding of size 3×3 arcseconds, with a separation up to at least 15 arcseconds.

5.2.2.4 Pixel scale guideline

Parent Requirements:5.2.2.1

Source: RPT/OPTI/0061-L(1.A.,5.2.1.6)

The pixel scale of the acquisition detector should be at most 0.1 arcsecs per pixel.

5.2.2.5 Detector Readout Speed guideline

Source: RPT/OPTI/0061-L(1.A,4.5)

It should be possible to read out the whole AG detector at a rate of at least 1Hz.

5.2.2.6 Window Readout speed

Parent Requirements:5.2.2.3,SP/GTC/5.2.9.3.3, SP/GTC/9.1.1

Source: RPT/OPTI/0061-L(1.A,5.2.1.7), RPT/STMA/0054-R 1.A

It shall be possible to read out the slow guiding windows simultaneously at a speed of at least 10 Hz.

5.2.2.7 Readout synchronisation with chopping

Parent Requirements:5.2.2.3,SP/GTC/5.2.9.3.3

Source: RPT/OPTI/0061-L(1.A,5.2.1.9)

For chopping at less than 5 Hz, it shall be possible to read out the guiding windows synchronously with the chopping.

⁴ It is assumed that a $V=0$ magnitude star provides $3.9 \times 10^{-11} \text{ W m}^{-2} \text{ nm}^{-1}$ at the top of the Earth's atmosphere, in a filter of width 90 nm centered at 550 nm.

⁵ This value corresponds to an estimate of the mean zenith sky brightness when the moon is full.

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5.2.2.8 Optimization

Source: RPT/OPTI/0061-L(1.A,5.2.1.8), Optics group

It shall be possible to optimise the slow guiding sampling rate as a function of guide star magnitude, sky magnitude, seeing and windshake.

5.2.2.9 CANCELLED(16/04/99)

Source: RPT/OPTI/0061-L(1.A,6.4), Optics group

The HRWFS sensor shall allow sampling of the telescope pupil at points separated by 20cm.

5.2.2.10 CANCELLED(16/04/99)

Source: NTE/OPTI/0028-L(1.B,4.1.2)

The HRWFS should have a pixel scale of no more than 0.1 arcsecs per pixel (TBC).

5.2.2.11 CANCELLED(16/04/99)

Source: NTE/OPTI/0028-L(1.B,4.1.2)

The HRWFS should have a field of view of at least 2 arcsecs at each subaperture (TBC).

5.3 Fast Guider/Segment Tilt Sensor (STS)

All the requirements in the following section shall have the following code: RQ/AG-NA-FT/NNN and RQ/AG-NB-FT/NNN, where NNN is the index that appears immediately before the requirement title.

5.3.1 Functional Requirements

5.3.1.1 Concept

Parent Requirements: 5.1.1.3

The fast guider/Segment tilt sensor shall use a detector with fast readout, providing the data necessary for the telescope control system to correct windshake and atmospheric image motion with the telescope secondary mirror.

5.3.1.2 Fast Guiding mode

Parent Requirements: 5.1.1.3

The fast guiding mode shall allow measurement of the centroid of the image of a reference source at a rate fast enough to allow compensation of seeing-induced tip-tilt as well as windshake. In this mode, the instrument shall be referred to as the 'fast guider'.

5.3.1.3 Segment Tilt Sensor mode

Parent Requirements: 5.1.1.5, SP/GTC/6.6.5.3

Source: NTE/OPTI/0028-L(1.B,4.1.2)

It shall be possible to adapt the optics of the fast guider to allow insertion of a subaperture array the resolution of which will permit the measurement of low-order global modes of the primary mirror, with the images formed by the subapertures focused on the fast guiding detector.

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5.3.1.4 Seeing measurement guideline

Parent Requirements: 5.1.1.6

The segment tilt sensor mode should allow the measurement of seeing.

5.3.2 Performance Requirements

5.3.2.1 CANCELLED (16/04/99)

Parent Requirements: SP/GTC/9.1.2 (Item 2)

Source: RPT/OPTI/0061-L(1.A, Appendix I)

It shall be possible to measure the centroid of the image of a reference star of magnitude $V=16$ with an rms error of not more than 0.0058 arcsecs (two-dimensional) using an exposure time of 5 milli-seconds, when the seeing is 0.4 arcsecs⁶ and the sky background in the V band is 19.35 magnitudes per square arcsec.

5.3.2.2 Fast guider FOV

Source: RPT/OPTI/0061-L(1.A, 5.2.2.5)

The field of view of the fast guider shall be at least three arcseconds by three arcseconds.

5.3.2.3 Fast guider pixel scale guideline

Parent Requirements: 5.3.2.1

Source: RPT/OPTI/0061-L(1.A, 5.2.2.6)

The pixel scale of the fast guider detector should be approximately 0.1 arcsecs per pixel.

5.3.2.4 Detector Readout Speed

Parent Requirements: SP/GTC/9.1.2 (Item 2), 5.4.1.4

Source: RPT/OPTI/0061-L(1.A, 5.2.2.7)

It shall be possible to read out the whole fast guider detector at a rate of at least 200 Hz with a goal of 500 Hz.

5.3.2.5 CANCELLED(16/04/99)

Parent Requirements: SP/GTC/9.1.2 (Item 2), 5.4.1.4

Source: RPT/OPTI/0061-L(1.A, 5.2.2.7)

It should be possible to read out the whole fast guider detector at a rate of 500 Hz.

5.3.2.6 Fast guiding while chopping

Source: RPT/OPTI/0061-L(1.A, 5.2.2.9)


It shall be possible to provide fast guiding while chopping at up to 1 Hz (TBC).

5.3.2.7 Optimization

Source: RPT/OPTI/0061-L(1.A, 5.2.2.8)

It shall be possible to optimise the fast guiding sampling rate as a function of guide star magnitude, sky magnitude, seeing and windshake

⁶ With this seeing, the short-exposure image full-width at half-maximum is assumed to be 0.25 arcsecs.

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5.3.2.8 CANCELLED (16/04/99)

Parent Requirements: SP/GTC/9.1.1 (Item 1)
Source: RPT/STMA/0054-R(1.A,3.6.4)

It shall be possible to measure the primary mirror segment tip-tilt with a one-dimensional rms error of less than 0.01 arcsecs using a reference star of magnitude V=18 with an exposure time of 60 seconds, when the seeing is 0.4 arcsecs and the sky background in the V band is 19.35 magnitudes per square arcsec.

5.3.2.9 STS FOV guideline

Source: NTE/OPTI/0043-L(1.A,4.2), RPT/OPTI/0061-L(1.A,5.2.2.5)

The field of view of the segment tilt sensor subapertures should be at least two arcseconds by two arcseconds.

5.3.2.10 STS pixel scale guideline

Source: NTE/OPTI/0043-L(1.A,4.2), RPT/OPTI/0061-L(1.A,5.2.2.6)

The pixel scale when operating in STS mode should be approximately 0.2 arcsecs per pixel.

5.4 High Resolution wavefront sensor & Segment Figure Sensor

All the requirements in the following section shall have the following code: RQ/AG-NA-SF/NNN and RQ/AG-NB-SF/NNN, where NNN is the index that appears immediately before the requirement title.

5.4.1 Functional Requirements

5.4.1.1 Segment Figure Sensor Concept

Parent Requirements: 5.1.1.5

The Segment Figure Sensor shall allow determination of the tilt, focus and astigmatic errors of each segment in parallel with scientific observations.

5.4.1.2 Spatial Resolution

Parent Requirements: SP/GTC/6.6.5.3
Source: NTE/OPTI/0028-L(1.B,4.1.2)

The SFS shall provide at least seven subapertures per primary mirror segment.

5.4.1.3 Availability

Parent Requirements: SP/GTC/9.1.1 (Item 1)

It shall always be possible to measure at least the tip-tilt of all primary mirror segments simultaneously.

5.4.1.4 High Resolution Wavefront Sensor Concept

Parent Requirements: 5.1.1.4

The High Resolution Wavefront Sensor shall allow measurement of wavefront phase at points separated by 35cm or less on the telescope entrance pupil.

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5.4.2 Performance Requirements

5.4.2.1 CANCELLED(16/04/99)

Parent Requirements:SP/GTC/9.1.1 (Item 1)

Source:RPT/STMA/0054-R

Using an integration of 300 seconds in seeing of 0.9 arcsecs⁷ it shall be possible to measure segment defocus and each mode of segment astigmatism with an rms error of less than 12 (TBC) nm each at the wavefront.

5.4.2.2 CANCELLED(16/04/99)

Parent Requirements:SP/GTC/9.1.1 (Item 1)

Source:RPT/STMA/0054-R

It shall be possible to measure the primary mirror segment tip-tilt with a one-dimensional rms error of less than 0.01 arcsecs using a reference star of magnitude V=18 with an exposure time of 60 seconds, when the seeing is 0.4 arcsecs and the sky background in the V band is 19.35 magnitudes per square arcsec.

5.4.2.3 HRWFS pixel scale guideline

Source: NTE/OPTI/0043-L(1.A,3.2)

The HRWFS should have a pixel scale of no more than 0.2 arcsecs per pixel .

5.4.2.4 HRWFS FOV guideline

Source:NTE/OPTI/0043-L(1.A,3.2)

The HRWFS should have a field of view of at least 3 arcsecs by 3 arcsecs at each subaperture .

5.4.2.5 SFS pixel scale guideline

Source: NTE/OPTI/0043-L(1.A,3.2)

The HRWFS should have a pixel scale of no more than 0.2 arcsecs per pixel .

5.4.2.6 SFS FOV guideline

Source:NTE/OPTI/0043-L(1.A,3.2)

The HRWFS should have a field of view of at least 3 arcsecs by three arcsecs at each subaperture .

5.5 CANCELLED (21/06/00)

All the requirements in the following section shall have the following code: RQ/AG-NA-IC/NNN, where NNN is the index that appears immediately before the requirement title.

5.5.1 CANCELLED (21/06/00)

5.5.1.1 CANCELLED (21/06/00)

Parent Requirements:5.1.1.7

Source: RPT/OPTI/0061-L(1.A,8.1)

⁷ This corresponds approximately to the 75% percentile value of seeing at the GTC site.

⁹ By 'median conditions' it is understood that the field rotation is less than 15° and the temperature change is less than 1.8°. The corresponding rms two-dimensional stability for a field rotation of 90° is 0.1 arcseconds.

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A wavelength calibration system should be provided.

5.5.1.2 CANCELLED (21/06/00)

Parent Requirements: 5.1.1.7

Source: RPT/OPTI/0061-L(1.A, 8.2)

A flat-fielding system should be provided

5.6 Adaptive Optics Insertion module

All the requirements in the following section shall have the following code: RQ/AG-NA-AO/NNN, where NNN is the index that appears immediately before the requirement title.

5.6.1 AO General guideline

Parent Requirements: 5.1.1.8

Source: NTE/OPTI/0019-R, RPT/OPTI/0061-L

The design of the AG system should consider the provision of an Adaptive Optics service which will correct the beam before arriving at the telescope focus.

5.7 Mechanisms

All the requirements in the following section shall have the following code: RQ/AG-NA-MS/NNN and RQ/AG-NB-MS/NNN, where NNN is the index that appears immediately before the requirement title.

5.7.1 Functional Requirements

5.7.1.1 Overall Concept

Source: NTE/OPTI/0028-L(1.B, 5.0)

Two guide arms shall be provided, which shall be referred to as Guide arm 1 and Guide arm 2. They shall be supported by a chassis.

5.7.1.2 Guide arm 1 Concept

Source: NTE/OPTI/0028-L(1.B, 5.0)

Using Guide Arm 1 it shall be possible to position a mirror (which shall be referred to as 'the probe') to extract the light from any reference source and direct it towards the AG, HRWFS and SFS instruments.

5.7.1.3 Guide arm 2 Concept


Source: NTE/OPTI/0028-L(1.B, 5.0)

Using Guide Arm 2 it shall be possible to position a mirror (which shall be referred to as 'the probe') to extract the light from any reference source and direct it towards the fast guider and STS instruments.

5.7.1.4 CANCELLED(16/04/99)

Source: NTE/OPTI/0028-L(1.B, 5.0)

The chassis shall provide mechanical support for all the AG subsystems (with the exception of the segment piston sensor).

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5.7.1.5 Actuations

Source: SP/GTC/9.1.1 (Item 1)

It shall be possible to focus the AG subsystems. It shall also be possible to maintain the pupil position and orientation.

5.7.2 Performance Requirements

5.7.2.1 CANCELLED(16/04/99)

Parent Requirements: SP/GTC/5.2.14.3.1

Source: RPT/OPTI/0061-L(5.2.1.1)

It shall be possible to position both guide arm probes anywhere within an area of not less than 0.08 (TBC) m² within the focal plane. The inner boundary of this area shall be 445 mm (TBC) from the center of the field of view.

5.7.2.2 Position

Parent Requirements: SP/GTC/5.2.14.3.1

It shall be possible to position both guide arm probes anywhere within a field of view of diameter 992mm centered on the center of the field of view available at the Nasmyth foci. It shall also be possible to completely withdraw all components to avoid shadowing of the same area.

5.7.2.3 Motion while guiding

Parent Requirements: SP/GTC/5.2.10.3.3

Source: ESP/CCIA/0025-L

It shall be possible to move the probes while guiding in order to facilitate the observation of targets which move at non-sidereal rates as well as observations without field rotation.

5.7.2.4 Shadowing

Source: Instrumentation group

The shadowing of the focal plane caused by the guide arms or any other AG subsystem shall be minimised.

5.7.2.5 Clashes

Source: Optics group

Provision shall be made to ensure that the guide arms shall not collide with each other or with any other devices in the focal plane.

5.7.2.6 Repeatability of Lateral Position

Parent Requirements: SP/GTC/5.2.14.3.2

The rms one-dimensional repeatability of the lateral position of the AG Instruments with respect to the science camera shall be better than 12.482.5 microns (0.015(0.1 arcseconds).

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5.7.2.7 Stability of Lateral Position

Parent Requirements: SP/GTC/9.1.1 (Item 1)

The rms two-dimensional stability of the AG Instruments with respect to the science aperture shall be better than 16.5 microns (0.02 arcsecs) over one hour in median conditions⁹.

5.7.2.8 Time to Position

Source: RPT/OPTI/0061-L(1.A,5.2.1.3), NTE/OPTI/0043-L(1.A,3.1.4.1)

It shall be possible to position either probe inside an area of outer radius 992mm, inner radius 496mm and area 0.2 m² in less than 10 seconds

5.7.2.9 Pupil position guideline

Source: NTE/OPTI/0028-L(1.B,5.0)

The motion of the guide arm should passively maintain the optical axis of the AG Instruments aligned with the center of the telescope pupil in order to maintain the pupil image position.

5.7.2.10 Range of Axial positioning

Source: Optics group

The range of axial positioning shall be 95 mm with a goal of 120 mm¹⁰.

5.7.2.11 Repeatability of axial positioning

Parent Requirements: SP/GTC/9.1.1 (Item 1)

Source: RPT/STMA/0054-R(3.5.1.1.8.4)

The repeatability of the axial position of the AG Instruments with respect to the science camera shall be better than 25 (TBC) microns.

5.7.2.12 Pupil rotation accuracy

Parent Requirements: SP/GTC/9.1.1 (Item 1)

Source: RPT/STMA/0054-R

The orientation of the exit pupil of the telescope w.r.t. the entrance pupil of the AG instruments shall be known with an accuracy better than 120 microradians.

5.7.2.13 Pupil de-rotation range

Parent Requirement: SP/GTC/9.1.1 (Item 1)

It shall be possible maintain the orientation of the pupil for a rotation of the telescope exit pupil of at least 60 degrees.

5.7.2.14 Shadowing while guiding

Source: Optics group, Instrumentation group

It shall be possible to define areas of the focal plane which shall not be shadowed by the guide arms while guiding.

¹⁰ Both Guide Arms shall provide mechanisms to focus the AG subsystems they support in order to compensate for field curvature over the entire focal plane and allow for movement of the telescope focal plane by ± 15 mm.

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5.7.2.15 Uncertainty in lateral position

Source: Optics Group

The rms two-dimensional uncertainty in the lateral position of the AG Instruments with respect to the science camera shall be better than 17.2 μm (0.021 arcseconds).

5.8 Segment Piston Sensor (SPS)

All the requirements in the following section shall have the following code: RQ/AG-NA-SF/NNN and RQ/AG-NB-SF/NNN, where NNN is the index that appears immediately before the requirement title.

5.8.1 Functional Requirements

5.8.1.1 Concept

Parent Requirements: SP/GTC/9.1.1, SP/GTC/6.6.3.3.

The SPS shall allow nocturnal/twilight phasing of the primary mirror segments.

5.8.2 General Requirements

5.8.2.1 Accuracy

Parent Requirements: SP/GTC/9.1.1 (Item 1)

Source: RPT/STMA/0054-R

It shall be possible to measure segment piston errors with an accuracy such that the corresponding Central Intensity Ratio is not less than 0.991 at an observing wavelength of 0.5 microns when the seeing is 0.4 arcsecs.

5.8.2.2 Measurement time

Parent Requirements: SP/GTC/6.6.3.2

Source: Optics group

It shall be possible to measure segment piston errors with the accuracy stated in 5.8.2.1 in less than 2 hours when the seeing is 0.9 arcsec.

5.8.2.3 Range guideline

Source: RPT/OPTI/0061-L, Optics group

It should be possible to achieve the accuracy stated in 5.8.2.1. when the initial rms piston error is at least 10 microns (**TBC**), measured at the mirror.

5.8.2.4 Operation guideline

Parent Requirements: SP/GTC/6.6.3.3

It should be possible to carry out the measurement of segment piston errors in parallel with scientific observations.

5.8.2.5 Field Rotation

Source: Optics group

If the SPS needs compensation of field rotation, then the rotation mechanism shall be provided by the AG-CI-SP subsystem.

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6. VERIFICATION OF REQUIREMENTS

6.1 Verification of reliability/maintainability requirements

A model shall be developed for the reliability/maintainability of all AG subsystems. All components of the AG subsystems shall have MTBF, MTTR and MPMNT allocations.

6.2 Verification of other requirements

All other requirements specified in this document shall be verified by revision of the relevant documentation, visual inspection or simple measurements.