Southern African Large Telescope
High-Resolution Spectrograph

SALT HRS

3200AE0015 Functional Performance Requirements Document

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Issue History

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		…		Various edits
	PLC	1.5	9 September 2004	Revised following PDR
	PLC	1.6	15 October 2004	SALT HRS team input
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	PLC	1.8	13 November 2004	Revised Detector section
	SIB	2.0	15 Mar 2005	CDR version
	MDA	2.1	16 March 2005	Final edit

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1 Scope

This document is the Functional Performance Requirements Document for the Southern African Large Telescope High-Resolution Spectrograph (SALT HRS). It specifies the performance requirements that SALT HRS should meet to satisfy the overall science goals of the instrument.

2 SALT HRS science requirements

SALT HRS is designed to be a single object high-resolution spectrograph with the following characteristics:

2.1 Resolving power

SALT HRS is designed to operate in three different resolving power configurations: an internally mounted fibre giving R=16,000 plus two image slicers giving R=37,000 and R=65,000 respectively. SALT HRS will deliver spectra that exceed 90% of each of these as-designed resolving powers at the blaze wavelength for each order.

2.2 Wavelength coverage

The spectrograph will be capable of wavelength coverage from 370 to 890nm, but with a blind spot of ~10nm at the dichroic crossover wavelengths.

2.3 Observing modes

2.3.1 Fixed object and sky

In this mode a single object and adjacent background field will be observed simultaneously.

2.3.2 Nod and shuffle

In this mode the fibre will be moved (nodded) simultaneous with the charge being moved (shuffled) on the CCD, providing on-chip summing of source and two sky samples. Nod and shuffle will only be available for the lowest resolving power configuration.

3 Optical specifications

3.1 Fibre feed and collimator

3.1.1 Fibre input

At the fibre input, the FIF will provide the user with the option of selecting separate object and sky fibres with variable separation at the centre of the focal plane (that is, close to on-axis). It is assumed that a 500 μm fibre placed in the telescope focal plane will capture at least 80% of the energy from a point source given a telescope image quality of EE(80) = 2.1".

3.1.2 Fibre output

The fibres will introduce no more than 20% focal ratio degradation for telecentric input at the telescope focal plane.

3.1.3 Image slicers

Provide two dual-fibre image slicers delivering resolving powers of at least 90% of their targets, R=37,000 and R=65,000.

3.1.4 Collimator

The collimator will accept and collimate 95% of the light exiting the fibres and/or image slicers assuming 10% focal ratio degradation.

3.2 Dispersive elements

Provide sufficient two-dimensional dispersion to achieve the resolving power, wavelength coverage, operational modes and background and sky subtraction. There will be at least 5 rows on the CCD between each order for the removal of background light from the two-dimensional images.

3.3 Cameras

The cameras are required to ensure at least 2 pixel Nyquist sampling of the smallest slit-limited resolution element given in 2.1 and be capable of the wavelength coverage given in 2.2.

4 Detectors

Specifications for the CCD Camera vendor for the SALT HRS PI is given in SALT-3290AE0001.

4.1 CCD system for blue camera

E2V Technologies 44-82, Grade 0
Thinned, back illuminated CCD
Astro BB antireflection coating
2k x 4k x 15micron square pixels
2 readout amplifiers per chip

For charge shuffling in the direction of cross-dispersion, the CCD must be aligned with the columns in this direction.

The CCD will have the following parameters:
CTE: The charge transfer efficiency shall be better than 99.999 per cent.
Full well: The peak charge storage shall be greater than 150,000 e^-/pix.
Sensitivities, quantum efficiency: The CCD QE, as a function of wavelength, shall equal or better the values shown in the table below:

Wavelength (nm)	Minimum QE (%)
350	>40
400	>70
500	>75

Dark current: The dark current shall be less than 1 e^-/pix/hour at a temperature of 160 K.
Readout noise: At a readout speed of 20 kpix/sec, the readout noise must be less than 3 electrons per pixel RMS.
Cosmetics: The CCD cosmetics shall equal or better the values shown in the table below:

Defects	Grade 0
Column defects (black or white)	6 or less
White spots	500 or less
Total spots (black or white)	1250 or less
Traps	30 or less

where the definition of the defects is as in the E2V Technologies data sheet, except that the definition of a black spot is a pixel which has 50 per cent or less responsivity.

CCD controllers: The CCD controller shall be appropriate for the CCD camera supplier's hardware.
Gain: At least two gain settings, under software control, shall be supplied.
Pre-binning: Pre-binning of 1 x 1 to 9 x 9, independently adjustable in each direction, shall be available.
Readout speed: The device will be capable of operating at readout speeds of up to 1 million pixels/sec.
Readout times: The time to read out the CCD array shall be less than or equal to the values shown in the table below:

Prebin/ Readout Speed	Readout Time (sec)	Readout Noise (e^-/pix)
1 x 1 Slow (100kHz)	50	4
2 x 2 Slow (100kHz)	15	5
1 x 1 Fast (400kHz)	18	9
2 x 2 Fast (400kHz)	6	10

Windowing: The CCD controller and software shall enable up to 5 windows to be selectable.
Software: The CCD controller software shall be in LabVIEW and/or C.

4.2 CCD system for red camera

Fairchild Imaging CCD486 (data sheet, Rev 061804), Grade 1
Thinned, back illuminated CCD
Broadband antireflection coating
4k x 4k x 15micron square pixels
4 readout amplifiers per chip

For charge shuffling in the direction of cross-dispersion, the CCD must be aligned with the columns in this direction.

The CCD will have the following parameters:
CTE: The charge transfer efficiency shall be better than 99.999 per cent.
Full well: The peak charge storage shall be greater than 100,000 e^-/pix.
Sensitivities, quantum efficiency: The CCD QE, as a function of wavelength, shall equal or better the values shown in the table below:

Wavelength (nm)	Minimum QE (%)
550	>80
650	>80
800	>80
900	>50

Dark current: The dark current shall be less than 1 e^-/pix/hour at a temperature of 160 K.

Readout noise: At a readout speed of 50 kpix/sec, the system (CCD plus controller) readout noise must be less than 4 electrons per pixel RMS.
Cosmetics: The CCD cosmetics shall equal or better the values shown in the table below:

Defects	Grade 1
Column defects (total)	6 or less
Point defects (dark or hot)	200 or less
Cluster defects	25 or less

where the definition of the defects is as in the Fairchild Imaging CCD486 data sheet, Rev 061804.
CCD controllers: The CCD controller shall be appropriate for the CCD camera supplier's hardware.
Gain: At least two gain settings, under software control, shall be supplied.
Pre-binning: Pre-binning of 1 x 1 to 9 x 9, independently adjustable in each direction, shall be available.
Readout speed: The device will be capable of operating at readout speeds of up to 1 million pixels/sec.
Readout times: The time to read out the CCD array shall be less than or equal to the values shown in the table below:

Prebin/ Readout Speed	Readout Time (sec)	Readout Noise (e^-/pix)
1 x 1 Slow (100kHz)	50	4
2 x 2 Slow (100kHz)	15	5
1 x 1 Fast (400kHz)	18	9
2 x 2 Fast (400kHz)	6	10

Windowing: The CCD controller and software shall enable up to 5 windows to be selectable.
Software: The CCD controller software shall be in LabVIEW and/or C.

5 Instrument performance

5.1 Image quality

A minimum image quality of 80% encircled energy within 25μm diameter must be obtained at 90% of all blaze wavelengths.

5.2 Stability

The optical and mechanical design of the spectrograph will allow both the radial velocity precision and the line profile to be intrinsically stable.

5.2.1 Radial velocity precision

The minimum requirement is for 30 m s^{-1} radial velocity precision for observations of sharp-lined G, F or K dwarfs and taken with a signal to noise $S/N > 100$ in the medium resolving power mode.

5.2.2 Line profile stability

Minimum requirement of less than 1% change in the wavelength calibration lamp line profile over a 12 hour period for a fully illuminated pupil. The calibration lamp line intensity must remain stable to within 10% over 12 hours.

5.3 Scattered light

The level of stray light is to be less than 5% of the local continuum averaged over the orders centred on the blaze wavelength.

5.4 Ghosts

Ghost images are to be less than 1% of the local continuum averaged over the orders centred on the blaze wavelength.

6 Spectrograph throughput

The SALT HRS (from the entrance to the fibre instrument feed to the CCD detector inclusive) will deliver throughput as a function of wavelength, resolving power and observing mode of at least 75% of the target throughputs in the following table, assuming the telescope delivers EE80 of 2.1" at the focal plane and with focal ratio degradation of 10% and that the CCD QEs are as given in 4.1 and 4.2.

Resolving power (nominal)	Mode	Throughput (%) excl telescope	
		480 nm	650 nm
16,000	Fixed/N&S	21.5	29.2
37,000	Fixed	15.1	20.3
65,000	Fixed	9.6	12.9

7 Mechanical specifications

7.1 Mechanical stability

The spectrograph will be mechanically stable and isolated from the telescope facility such that any external sources of vibration will not resonate with natural frequencies of the spectrograph.

7.2 Thermal and pressure stability

7.2.1 Thermal isolation

The operating temperature will be in the range 15 to 20° C over a 12 month period, and the temperature will be stable to within 1° C over a 1 day period.

7.2.2 Vacuum enclosure

The spectrograph will be in an enclosure and maintained at pressures between 1 and 4 hPa.

8 Instrument control and reduction software

8.1 Instrument control

There will be software provided for:

- Control of fibre feed selector;
- Control of target and calibration exposures, exposure meter, shutter and CCD;
- Control of the camera focus and monitoring of the temperature and pressure environment.

8.2 Reduction software

There will be software provided for:

- Quick-look extraction for monitoring by SALT Astronomer;
- Science-quality extraction and calibration of spectra.