Southern African Large Telescope
SALTICAM
Preliminary Design Review

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Functional Performance Requirements Document

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1 Scope

This document is the Functional Performance Requirements Document for SALTICAM, the Verification Instrument, Acquisition Camera and Science Imager of the Southern African Large Telescope (SALT). It specifies the performance requirements that the instrument should meet to fulfill the various roles the instrument will play.

2 Summary

The proposed performance numbers given below are the minimum requirements, mostly due to conservative estimation on the part of the CCD manufacturer. It is anticipated that actual performance, e.g. quantum efficiency, will be substantially better:

Image Quality Goal:	0.3 arcsec (EE50), combined with SALT 0.6 arcsec (EE50), to give 0.67 arcsec image quality, independent of seeing
Science Field of View:	8 arcmin in diameter
Guide Star Field of View:	10 arcmin in diameter
Wavelength range:	320 – 950 nm
Filters:	8 position filter unit: UBVRI filters supplied
CCD chips:	Marconi Applied Technologies 44-82
Format:	2048 x 4096 x 15 micron square pixels
Imaging Area per chip:	30.7 x 61.4 mm^2 imaging area
Readout capabilities:	2 readout amplifiers per chip
Mosaicing:	2 x 1 mini-mosaic
CTE:	99.9995 per cent (typical), 99.999 per cent (guaranteed)

Full well: 200 k e^-/pix (typical), 150 k e^-/pix (guaranteed)

Dark current: 1e^-/pix/hr (typical) at 160 K

Readout noise: 3.3 e^-/pix at 100 kHz (10.0 μsec/pix) (**TBC1**)

5.0 e^-/pix at 333 kHz (3.0 μsec/pix) (**TBC1**)

Sensitivity Thinned, back-illuminated. Deep depletion silicon.

Astro Broad Band anti-reflection coating.

Wavelength	Spectral Response (QE)	
(nm)	Min	Typical
350	40	50
400	70	80
500	75	80
650	70	75
900	45	50

Cosmetics: Grade 0 or 1 cosmetics as shown below:

Defects	Grade 0	Grade 1
Column defects (black or white)	6 or less	12 or less
White spots	500 or less	1000 or less
Total spots (black or white)	1250 or less	2000 or less
Traps	30 or less	50 or less

CCD Controller: SDSU II (Leach) from Astronomical Research Camera Inc.

Gain: Software selectable from: x1; x2; x4.75; x9.5.

Prebinning: 1 x 1 to 9 x 9, independently in each direction

Readout speed: Frame transfer architecture: 0.10 sec frame transfer time

100-333 kHz (10-3.0 μsec/pix) (**TBC2**)

Readout times:

Mode	Prebin	Readout Speed (μsec/pix)	Readout Noise (e^-/pix)	Readout Time (sec)
Full Frame	2x2	10.0	3.3	11.2
Full Frame	2x2	4.0	5	4.6
Frame Transfer	2x2	10.0	3.3	5.7
Frame Transfer	2x2	4.0	5	2.4

Prebinning: 1 x 1 to 9 x 9, independently in each direction

Windowing: Up to 10 windows (**TBC3**)

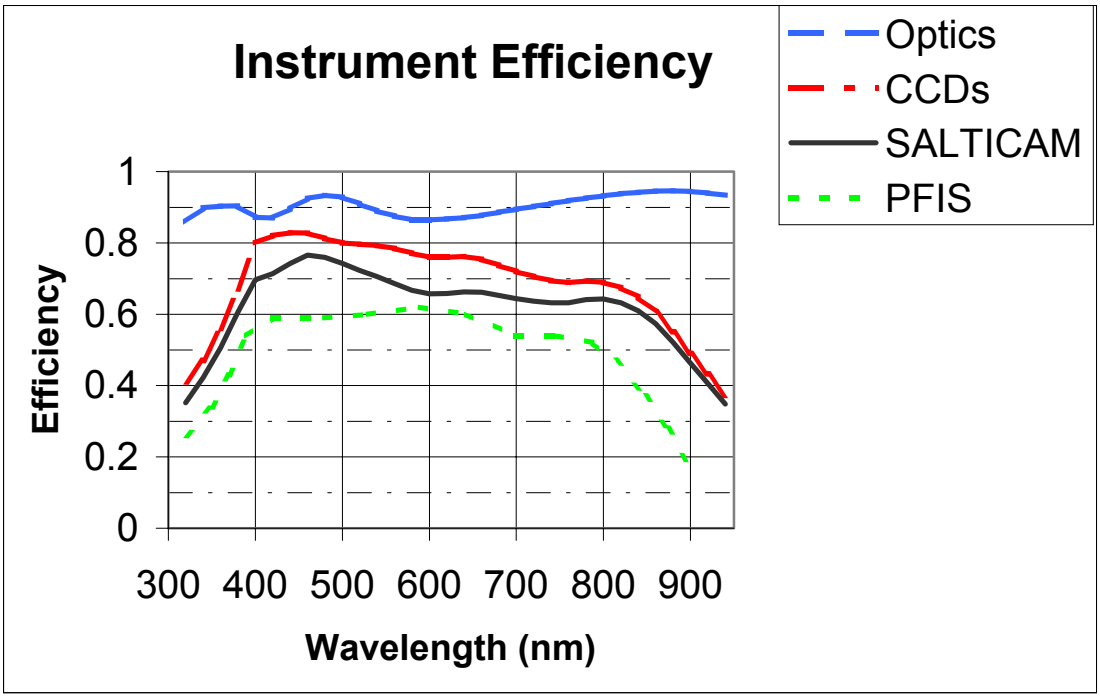
Fastest windowed photometry: 0.1 sec/sample with no dead time (**TBC4**)

Software: LabVIEW user interface, Real Time Linux C module to control array controller

3 Instrument Efficiency, Count Rates And Signal-To-Noise

"Typical" instrument and system efficiencies are shown in Fig. 1 and were calculated for the on-axis field position using:

- **Optics:** (i) No absorption in any of the lens material or cryostat window; Absorption by Sylgard 184 at two doublet interfaces; (ii) Reflection at 10 air-glass interfaces using the Spectrum Thin Films BBAR coating; (iii) Reflection at 2 air-glass interfaces using a single layer of MgF2 coating (see the 3310AE0001 optical.pdf for details). The reflection or absorption in any filter is **not** included.



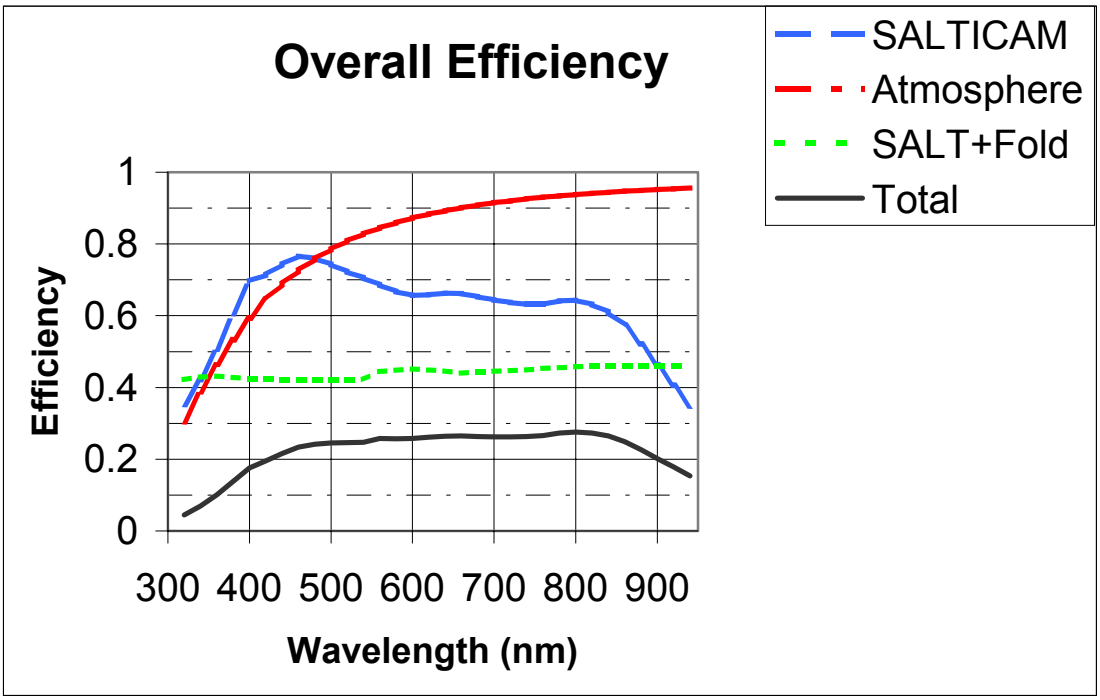


Figure 1. Instrument Efficiencies

- **CCDs:** Quantum efficiency as shown in the "typical" plot in Section 3.2 of the 3360AE0001 detector.pdf.
- **SALTICAM:** in the top panel of Fig. 1 is the product of the Optics and the CCDs curves.
- **PFIS:** Performance taken from Fig. 5 of the PFIS PDR Instrument Description Document.
- **Atmosphere:** the standard atmospheric extinction curve for Sutherland at a zenith distance of 37 degrees.
- **SALT + Fold:** this is the **minimum** throughput taken from the System specification and includes reflectivity of the SALT Primary Mirror and the spherical aberration corrector (SAC), the SAC central obscuration, four per cent light losses at the four surfaces of the ADC, and the reflectivity of the fold mirror using the Livermore coating performance as supplied by David Buckley.
- **Total:** in the bottom panel of Fig. 1 is the product of the SALTICAM, Atmosphere and SALT+Fold curves.

The typical performance is satisfactory and competitive. Comparison with PFIS is, of course, unfair on PFIS, as SALTICAM is an imager and not a dispersive instrument: PFIS has the disperser efficiency and reflectivity losses from a substantially larger number than the twelve air-glass surfaces of SALTICAM. The similarity of the efficiencies at 600 nm suggests that the PFIS optics will be coated more efficiently than SALTICAM (see the 3310AE0001 optical.pdf for discussion of the coating efficiency).

Minimum and expected (i.e. typical efficiencies) are shown in the following table and are obtained by multiplying the quantum efficiencies shown for the CCDs in the table above by 0.85 (allowing up to 15 per cent for losses in the optics: reflection at twelve air-glass interfaces and absorption in the doublet bonding agent).

Wavelength	Instrument Efficiency (%)	
(nm)	Min	Typical
350	34	43
400	60	68
500	64	68
650	60	64
900	34	43

3.1 Count Rates And Signal-To-Noise For A Star With U=B=V=R=I=20

Using the overall efficiency shown in the bottom panel of Fig. 1, the area of each SALT mirror (8660 cm^2), count rates for point sources were calculated and are shown in the third column of the table below. Dark sky count rates are shown in the rightmost column from measurements made recently at Sutherland by Dr. J. Menzies. Note that these are "monochromatic" magnitudes. Users can calculate signal-to-noise ratios by:

- integrating across the appropriate filter (multiplying by the full width, half maximum of the filters and its peak transmission is a good start)
- calculating the number of square arcsec to include in the point source measurement and its associated sky subtraction
- calculating the sky contribution by multiplying this number by the rightmost column of the table below, and then calculating the sky noise
- calculating the readout noise contribution

Natural seeing at Sutherland has median EE80 of 1.7 arcsec. When combined with the SALT image quality requirement of EE80 of 0.9 arcsec and allowing for modest degradation (0.55 arcsec EE80) by SALTICAM, median image quality on the detector will have EE80 of about 2.0 arcsec, corresponding to pi square arcsec. Assuming one second exposures and 2 x 2 prebinning (30 micron or 0.28 arcsec pix: ~40 pix will be used in the measurement), count rates and signal-to-noise in 2 x 2 prebinned images through UBVRI filters for 3.14 square arcsec can then be calculated. The results are shown in the Table.

Wavelength (nm)	Photon Rates Per Sec		
	Point Source	Sutherland Sky (No Moon) /Square Arcsec	
	(photon/sec/Ang)	(Magnitudes)	(photons/sec/Ang)
360	0.6	22.5	0.06
440	2.5	22.5	0.25
550	2.0	21.5	0.50
640	1.5	20.8	0.72
790	1.1	19.9	1.21

Filter	FWHM (Ang)	Photon Rates In One SecFrom A Point Source (photons)	Photon Rates In One Sec From Sky (No Moon) (photons)	Effective Noise (photons)	Signal-To-Noise
U	700	420	132	39	10
B	1000	2500	785	65	38
V	900	1800	1410	65	27
R	1500	2250	3393	82	27
I	1500	1650	5702	91	18

4 List of TBC Issues

These "To Be Confirmed" items will be resolved when the limitations of the Leach CCD controller as well as the CCD chips are defined. The numbers given above are therefore current best estimates, must be considered as provisional and may improve or get worse. As an example, those familiar with ULTRACAM's likely high time resolution capability will be curious as to why the SALTICAM detectors will take 0.1 sec to perform a frame transfer. This results simply from the larger size of the CCDs to be used in SALTICAM, compared to the Marconi 47-20s in ULTRACAM. Indications from Marconi are that the CCDs can probably be clocked at a faster rate, but this remains to be verified. In this regard, an ultrafast imaging capability is planned in which a long thin strip near the frame transfer boundary is imaged. This will contain the program target and a comparison star and 10 Hz sampling rate will be achieved with no dead time. The exact performance cannot be guaranteed at present until the characteristics of the controller are fully explored.

TBC1 - Readout noise of 3.3 and 5 e^-/pix at readout rates of 100 and 333 kHz

TBC2 - Readout rates in the range 100-333 kHz

TBC3 - Number of windows allowed

TBC4 - Very high speed photometric performance