

SALT Commissioning and Acquisition Instrument Requirements

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10 September 2001

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1 INTRODUCTION

It is required of the SALT Project Team that an instrument, or instruments, capable of general target acquisition and verification of the SALT telescope performance, be available at the time of SALT commissioning (i.e. at 'first-light'). Furthermore it is required that the Commissioning Instrument be capable of conducting immediate first light observations with a public relations and educational value. Any additional scientific functionality, over and above the basic requirements set out below, should be funded out of the SALT Instrumentation budget.

The requirements for a target Acquisition Camera and a Commissioning Instrument are written separately. However, it may be possible (and desirable) to combine the required functionality into a single instrument, which would inevitably save on resources, for the instrument itself and also for the Prime Focus Platform and its payload.

In addition, certain requirements of the Acquisition system relate directly to the planned SALT instrumentation. Multi-object spectroscopy (with slits and fibres) will require acquisition imagery over the whole 8 arcmin diameter field of view.

2 SUMMARY OF REQUIREMENTS FOR SALT ACQUISITION SYSTEM

2.1 FIELD OF VIEW

The SALT Acquisition Camera should be able to access the entire science Field of View, namely a circle of nominal diameter 8 arcmins, or a rectangular region of equivalent area.

For the current SAC designs under consideration (i.e. entrance pupils of 10.5-m or 11.0-m in diameter) with an f/4.2 beam, this implies that the science FoV will be a circle of 102.6 mm or 107.5 mm in diameter for the two respective pupils, at plate scales of 214 or 224 μm/arcsec, respectively. A single (or mosaiced) CCD of this size, while desirable, would be well outside of the

budget for an acquisition system, since CCD price scales as the area of silicon. For this reason alone, it is inevitable that the acquisition system will need to incorporate some focal reduction optics, to decrease the detector size while still covering the science FoV. Such optics must be of sufficient quality so as not to compromise the detection of the faintest objects expected to be observed with SALT (i.e. to R ~ 25). Although off-set positioning of brighter targets may be possible, for fainter targets the astrometric precision may be lacking, requiring the object to be placed on a slit, fibres or apertures by the SALT Operator.

2.2 PIXEL SCALE

The pixel scale shall have a sampling of < 0.30 arcsec/pixel, so that the PSF is adequately sampled in an un-binned CCD frame. For an 8 arcmin diameter FoV, this requirement implies the detector should be at least 1920 pixels on a side. Assuming 15 μm pixels results in a plate scale of < 60 μm/arcsec. A standard size CCD of 2048 x 2048 x 15 μm pixels would cover a 30.7 mm diameter FoV. If this were the 8 arcmin diameter science FoV, then a focal reduction of ~3.5 will be required. If two CCD chips were butted, this could reduce the required focal reduction by a factor of 2×, easing the optical design requirements.

2.3 SENSITIVITY

The Acquisition Camera should have sufficient sensitivity (unbinned) to record the image of a point source of magnitude R = 21 in a 10-sec exposure, with a 5σ significance in median seeing conditions (FWHM = 0.9 arcsec). The camera shall have sufficient sensitivity in the B-band such that it is no worse than 5x less sensitive that at R. i.e. it should have a 5σ detection at B= 19 in a 10-sec exposure in median seeing conditions.

Because the Acquisition Camera needs to record images of science objects, which are potentially very faint, the system needs to have good performance characteristics so as to register a suitable image in as short a time as possible. For this reason, the CCD needs to be of good overall sensitivity, and be cosmetically good quality.

The detector should therefore be a scientific grade CCD (grade 1 or better), with DQE values as set out in the first column of the following table. In addition, the overall throughput of the Acquisition Camera, inclusive of all optical elements, but exclusive of telescope optics, will be as follows (column 2):

Waveband	CCD DQE	Total instrument efficiency (exclusive of telescope)
B band:	>50%	>40%
V band:	>75%	>60%
R band:	>75%	>60%
I band:	>50%	>40%

Some blue sensitivity (i.e. at B) will be required in order that very faint blue objects (e.g. quasars) are detectable.

2.4 READOUT TIME AND TIME RESOLUTION

The readout time of the Acquisition Camera should be < 5 sec in full-frame (unbinned) mode, and < 0.5 sec in binned mode, and/or a suitably windowed sub-array (read out noise and read out time may be traded to improve one over the other). Read-out noise shall be <5 electrons/pixel at the slowest readout rate, inclusive of all electronics external to the CCD. Full well depth shall be >100,000 electrons/pixel.

Frame transfer CCDs will be the preferred detector devices, but if mechanical shutters are employed, the meantime between failures has to be better than 1 failure per 5 x 10^5 shutter openings [N.B. With continuous operation using 1 sec exposures and assuming ~250 useable nights per year of 8 h average duration, with an average time spent acquiring targets of ~10% of the total observing time, there will be ~7 x 10^5 shutter openings in a typical year]. Replacement shutters must be able to be installed *in situ* in < 2 hours (TBC).

2.5 GRAPHICAL INTERFACE

The Acquisition Camera display shall allow for the CCD image to be overlaid with fiducial marks indicating slit and fibre positions, guide stars, etc. In addition, the display software should be versatile enough to allow for several LUTs (look-up tables) as well as image enhancement features (e.g. noise filtering, smoothing, etc).

Since the Acquisition Camera is an integral part of the Prime Focus Platform's Optical Payload, the acquisition GUI must form part of the Telescope Control System (TCS). It may be developed separately, and possibly run on its own computer, but the interfacing and display must be part of the TCS.

2.6 FILTERS

A set of broad-band filters (TBD, but probably Sloan Digital Sky Survey and/or UBVRI filters) should be able to be inserted in the Acquisition Camera. There should be provision for at least 8 separate filters, and sufficient accessibility to allow for filter changes during daytime maintenance.

3 SUMMARY OF REQUIREMENTS FOR COMMISSIONING INSTRUMENT

The aims of the Commissioning are two-fold, namely:

- Verification of the SALT performance in terms of the specifications on image quality, throughput, pointing and tracking accuracy.
- Provide first-light images accessible to the public and which also have a PR value in advertising SALT's performance and success. In addition, if such an instrument is able to provide some scientifically useful data, this will be an added benefit, but not a requirement.

3.1 FIELD OF VIEW

The Commissioning Instrument shall be capable of accessing the entire science field of view, namely a circle on the sky of 8 arcmin diameter. This requirement comes from the need to adequately sample the PSF over the entire science FoV. No additional optics (other than possibly a flat fold mirror) should be employed after the SAC (i.e. no focal reducer) so as to ensure that errors in such optics are decoupled from the telescope optics, thus enabling an unequivocal verification of SALT's Image Quality. For an affordable CCD detector, this means that the entire science FoV will *not be covered* by the detector, *in a single exposure*. This will therefore require the detector to be mounted on a moving X,Y stage in order to adequately cover the entire science FoV.

The size of such a CCD should be chosen such that just two positions of the stage are needed to cover the entire field. This implies a CCD of at least 60 mm square. A centred position will cover the inner 4 arcmin of the FoV, while a position offset by 2 arcmin will cover the FoV from the centre to the edge. Two such positions will avoid requiring many smaller regions to be "stitched" together to form the whole FoV, which is what would be required if smaller CCDs were used. In addition, with only two positions it will be easier to ensure that both the CCDs and X-Y stage are mounted flat (i.e. coplanar with the focal plane). Lastly, a CCD covering at least 4 arcmin will deliver images that will satisfy the PR/publicity requirements, which would not be the case for smaller devices with consequently smaller fields.

3.2 RESOLUTION AND CCD SIZE

The resolution of the Commissioning Instrument shall be < 0.25 arcsec/pixel in an un-binned mode. At least this resolution is required to adequately sample the PSF. To cover a 4 arcmin diameter FoV, this implies a detector with an active area of size 60 mm on a side (to allow some overlap). The size of the CCD, in pixels, is then determined by the pixel size. The following table indicates the required parameters for a CCD chip.

Pixel size	Minimum CCD dimensions (pixels)
15μm	4000 x 4000
22μm	2730 x 2730
30μm	2000 x 2000

For the smaller pixel size (e.g. 15 μm), a butted CCD would probably be required. The butting will need to minimize the gap between the chips as far a possible.

3.3 SENSITIVITY

The Commissioning Instrument shall be of sufficient sensitivity to record images to allow the verification of the imaging performance, tracking and pointing accuracy of SALT. It should also be sufficiently sensitivity to record images that will show SALT's performance favourably in terms of publically accessible images. Although the requirement for scientific quality data has been dropped, the sensitivity should be sufficient to take full advantage of SALT's large light collecting area.

The CCD detector should have at least some sensitivity (>5% DQE) at 320 nm, the lower limit of SALT's wavelength capability. This is so that the PSF can be determined at this wavelength, or a narrow interval near it.

The CCD detector shall be a cosmetically good, science grade device (Grade 1 or better), capable of rapid readout, and operable in a high-speed mode (e.g. frame transfer) allowing no more than 5 sec dead-time between full-frame (unbinned) exposures. Read-out noise shall be <5 electrons per pixel at the slowest readout, inclusive of all electronics external to the CCD. Full well depth shall be >100,000 electrons/pixel. The detector shall be capable of both on-chip binning by factors 2 x 2, 3 x 3 and 4 x 4, as well as the ability to window up to 16 subarrays of uniform size and 8 subarrays of varying form factor and binning ratio. The deadtime shall be <1 sec in this windowed mode, allowing for trailed tracking tests to be undertaken. Exposure times in the windowed mode shall be short enough as to sample the 'averaged short exposure' (ASE) PSF, decoupled from the variable image motion component of intrinsic seeing. This requires exposures of <0.05 sec duration (TBC) in maximum windowed mode.

3.4 OTHER INSTRUMENT REQUIREMENTS

The Commissioning Instrument will include a set of at least 8 filters, remotely controllable and of highest possible throughput. These filters would ideally comprise a set of broadband SDSS ("Sloan") and UBVRI filters, plus a set of special purpose interference filters (e.g. H-alpha, H-beta, OII). The latter will be of great value for producing excellent quality images with good PR value. In addition, some narrower band filters may be required to sample the PSF over various narrower wavelength intervals (e.g. 320-340 nm). The Commissioning Instrument must either employ an ADC before light enters it, or have ADC functionality included.

The detector will either be cooled using a Peltier device or closed cycle cooler, and will not use LN_2 cryogen cooling.

4 CONCLUSIONS

From a telescope commissioning perspective, the sensitivity requirements at short wavelengths (down to ~320 nm) demands the use of thinned, back-illuminated CCDs. This is so that image quality (IQ) can be verified over the wavelength capability range of SALT. In addition, IQ also needs to be verified over the entire science FoV, i.e. in a circle of 8 arcmin diameter. While, in principle, this could be done with a small CCD mounted on an X-Y translation stage, this would require the accurate mounting of such a small chip to ensure its orthogonality to the optical axis. In addition, the mapping of the entire focal surface would then be a more complex procedure, for which time dependent seeing effects would need to be properly deconvolved. As the acquisition requirement calls for a large CCD (2048 × 2048), or mosaic of CCDs (to cover the entire science FoV in a single exposure), it is obvious that the same commissioning instrument CCD (or mosaic) could serve both purposes. The two roles could therefore be satisfied in the one instrument as follows:

1. A mosaic of two 2048 × 4096 CCDs would cover the central 4 arcmin diameter FoV, with no optics. Mounting this on a translation stage would allow the entire science FoV to be covered with 4 offset exposures. This arrangement would serve as the commissioning instrument, at the straight-through (PFIS) focus. It would be capable of conducting all IQ test as well as tracking and pointing tests. [For comparison, a 1024 × 1024 pixel CCD, of the same pixel scale, would require 64 separate exposures to map the entire science FoV.]

2. With suitable focal reduction fore-optics, the same commissioning instrument could serve as the acquisition camera at the folded acquisition focus.

With the option of using UV-transmitting optics, the above system could become a UV-sensitive imager, capable of conducting unique science observations (e.g. high speed U-band photometry).