Southern Africa Large Telescope

Prime Focus Imaging Spectrograph

SAAO Detector Subsystem:

SALT-3190AE0004: Testing Document

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1 Scope

This document describes the testing and commissioning plan for the Detector Subsystem of the Prime Focus Imaging Spectrograph (PFIS) instrument for the Southern African Large Telescope (SALT).

The Detector Subsystem will be developed at the South African Astronomical Observatory (SAAO), will then be shipped to University of Wisconsin (UW), mounted on PFIS for integration and testing, shipped back to South Africa and remounted on PFIS, before being finally mounted on SALT. Different levels of testing will be required at various times in between these stages as will be described in more detail in this document.

1.1 Testing Levels

Three levels of testing is envisaged:

- Basic Functional Test (BFT)
- Extended Functional Test (EFT)
- Full Performance Test (FPT)

These are detailed as follows:

Basic Functional Test (BFT)
- Temperature test
- Dark frame test
- Response to (unfocussed) light test

Extended Functional Test (EFT)
- BFT
- Noise/Gain test
- Image test

Full Performance Test (FPT)
- EFT
- Dark current test
- Well depth test
- Charge Transfer Efficiency (CTE) test
- Quantum Efficiency (QE) test
- Flat Fielding test
- Other miscellaneous tests described below

The required levels of testing to be performed at the various stages of the instrument are shown in Table 1.

Location / Stage	Testing level required
After development at SAAO	FPT
Detector arrives at UW	BFT
Detector mounted on PFIS	EFT
Detector shipped back to South Africa	BFT
Detector mounted on PFIS on SALT	EFT

Table1: Testing at various stages

2 Detectors

CCD chips: Marconi Applied Technologies 44-82

- 2048 x 4096 x 15 micron square pixels
- 30.7 x 61.4 mm imaging area, Frame Transfer mode option
- 2 readout amplifiers per chip
- 3 x 1 mini-mosiac
- CTE: 99.9995 per cent (typical), 99.999 per cent (guaranteed)
- Full well: 200 k e^-/pix (typical), 150 k e-/pix (guaranteed)
- Sensitivity: Thinned, back-illuminated. Deep depletion silicon
- Astro Broad Band anti-reflection coating
- Dark current: 1e^-/pix/hr (typical) at 163 K
- Readout noise: 3.0 e^-/pix at 100 kHz (10.0 µsec/pix)
- 5.0 e^-/pix at 345 kHz (2.9 µsec/pix)
- Quantum Efficiency (QE)

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

Table 2: Quantum Efficiency

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

- Gain: Software selectable from: x1; x2; x4.75; x9.5.
- Prebinning: 1x1 to 9x9, independently in each direction
- Readout speed: Frame transfer architecture: 0.103 sec frame transfer time 100-345 kHz (10-2.9 μsec/pix)

Windowing: Up to10 windows

Quantum efficiency can be partially verified by inspecting the test data sheets that Marconi will supply with each chip. However, this property is so crucial to the performance of the camera that it is desirable to verify the quantum efficiency independently. To achieve this the cryostat will be mounted on an SAAO telescope (e.g. the 1-m) to obtain observations of standard stars through UBVRI filters. These data will then be compared to observations of the same stars with SAAO CCD cameras where the QE of the chip is known, or the stellar flux at the top of the atmosphere can be modelled with a suitable extinction law, reflectivity for the telescope mirrors, absorption by the filters and cryostat window and attenuation by the filter bandpass. The recorded number of photons/sec can then be compared with the number estimated to be arriving at the detector and the QE deduced. QE testing will either be demonstrated, or reported in writing.

Testing of the co-planarity of the 3 x 1 mosaic as well as flatfielding can also be tested with the cryostat on an SAAO telescope. Co-planarity will be tested by carefully focusing a star on the one CCD and then moving it to the other CCD and compare the focus shift, if any. Flatfielding can be tested over small pixel scales since the full array will not be illuminated at the same time.

The manufacture's values for CTE will be verified using the Extended Pixel Edge Response (EPER) method.

All the above tests are **FPT** level tests.

2.1 Cryostat

The PFIS Detector Subsystem requirement is for:

- An evacuated chamber for the detector
- Poisson noise on the dark current pedestal from the longest exposure should be small compared to readout noise of 5 electrons
- There should be a drip tray to catch condensation on the outside of the cryostat arising in the event of loss of vacuum

The first two requirements will be tested by demonstrating that the detector reaches the planned operating temperature and that at this temperature, dark current is less than 1 e^-/pix/hr by obtaining a dark exposure (with the detector sealed from light and in a darkened room). These are **BFT** tests.

The third requirement will be tested by inspection. This is an **EFT** test.

2.2 Readout Noise & Gain and Full Well

The PFIS Detector Subsystem requirement is for readout noise of less than 5 electrons at slowest readout speed and have a full well capability of 200k e^-/pix (typical), 150k e^-/pix (guaranteed). This will be tested in the lab by the standard photon transfer curve method using a set of exposures of ever increasing duration. (**FPT**)

When mounted on PFIS the read noise can be obtained by analysing the variance of the bias frame of a zero second exposure readout, applying the noise figure obtained in the lab. (**EFT**)

2.3 Readout Speed

The PFIS Detector Subsystem requirement is for a readout speed which will read out the detector in 5 sec or less. This requirement will be tested in the lab by simply timing readouts (**FPT**). Windowed readout and prebinning will be required to achieve this figure.

2.4 Pre-Binning

The PFIS Detector Subsystem requirement is for software-selected pre-binning from 1x1 to 9x9. Testing will involve demonstrating that the user interface software and SDSU controller software provide this capability. (**EFT**)

2.5 Safety

This is discussed in the Safety Report document SALT -3190AS0001 Detector Safety Issue 1.1.doc. All features of the design will be evaluated in terms of the requirements in the SALT Safety Standards (SALT Safety Analysis: SALT Document 1000AA0030).

2.6 Envelope

The PFIS Detector Subsystem Specification limit of …?? (**TBD**) shall be checked by measuring these dimensions. (**EFT**)

2.7 Mass

The Detector Subsyetem can be weighed and verified to be less massive than the PFIS Detector Subsystem Specification limit. (**EFT**)

2.8 Instrument Temperature Control

The PFIS Detector Subsystem Specification calls for stringent controls on heat dumping on the payload, as well as control of surface temperatures of all electronics and electrical components. The SALT Project are to provide thermal control enclosures into which all electronics will be inserted.

Testing this is a joint SAAO and SALT Project responsibility. By measuring the internal temperature of the thermal control enclosures, it can be established weather the manufacturer's specification is being exceeded. The exterior surfaces of all components, cables, pipes, etc can be measured using a handheld temperature probe and by infrared imaging. (**EFT**)

2.9 Component/Module Replacement

The PFIS Detector Subsystem requirement is for suitable mechanical interfaces to be provided so that handling by the dome crane is possible, and all individual modules to weigh less than 15 kg (so they can be manhandled easily). This will be tested by inspection of the finished framework and weighing of the components prior to assembly. (**FPT**)

2.10 Electromagnetic Radiation

The PFIS Detector Subsystem requirement is for the PFIS Detector Subsystem design to incorporate measures to shield its sensitive electronics from electrical noise. Since electromagnetic interference manifests itself by an increase in the CCD readout noise, often visible as a pattern in CCD frames, good noise performance in the lab will be a measure of the effectiveness of the electromagnetic shielding. Another test for the effectiveness of the electromagnetic shielding is to compare the noise performance in the harsh environment of the telescope to the noise levels obtained in the controlled environment of the lab. The 1-m telescope is notorious for being a noisy environment: the planned observations on the 1-m will allow testing of the shielding of the CCD readout electronics. (**EFT**)

The noise performance on SALT will be compared with the noise levels obtained in the controlled environment of the lab. (**EFT**)

2.11 SDSU II CCD Controller, Subsystem Controller and Power Supply, and CryoTiger Compressor

These modules provide power, control and cooling for the CCDs and control for all mechanisms. Their correct functioning will be implicit in all the (**BFT**) tests..

2.12 Communications with SALT Computers

There is a requirement is for:

- Communications with the PFIS CON computer to receive camera setup information (exposure time, prebinning etc.), to receive instructions for interaction with the images on the PFIS Detector Subsystem display, and to transmit compressed versions of the images to these machines.
- Communications with the Telescope Control System (TCS) server to obtain telescope parameters (e.g. RA/Dec etc.).

- Communications with the Data Processor computer to allow that machine to obtain scientific data from the PFIS Detector Subsystem computer.

These functions will be tested as part of the software testing when the PFIS Detector Subsystem computer is attached to the SALT network and the other machines are present and operating. (**EFT**).

2.13 Communication with the Precision Time Source

The PFIS Detector Subsystem requirement is for the PFIS Detector Subsystem computer to maintain precise time to 1 msec or better and to have scientific images time stamped to 1 msec.

Testing the precision of the computer's timing to 1 sec is by inspection.

Testing the computer's timekeeping to the one second level can be done by writing software to toggle a pin on the computer's printer port, exactly on each second changeover. Measuring this printer port output with the one second edge of the time service using a two channel oscilloscope gives a direct measure of the PC timing.

Testing the accuracy of image timestamping to a precision of 1 msec can be done by using the CCD system (fitted with a simple camera lens) to capture an image of the display of a frequency counter. The frequency counter counts milliseconds, re-started from zero each second from the time service. The number captured thus acts as an exact millisecond timestamp of a frame for testing purposes to be compared to the computer time stamp of the same frame. (**FPT**)

2.14 Communication with CCD and Subsystem Controller

The PFIS Detector Subsystem requirement is for control and status to be exchanged, as well as reading out CCD data at speeds of up to 64 Mbits/sec. This will be tested by demonstrating that the PFIS Detector Subsystem computer is controlling the camera and subsystems and reading out data at the required speeds. (**FPT**)

2.15 PFIS Detector Subsystem Man-Machine Interface (MMI)

The PFIS Detector Subsystem requirement is for the PFIS CON or PFIS Detector Subsystem MMI to setup the camera, initiate the acquisition and readout of images, control the display and storage of the data and manage display interaction. The MMI must be exportable to the SA MMI computers. Testing will involve showing that all this functionality is present in the software and working. (**EFT**)

2.16 PFIS Detector Subsystem Algorithms

The PFIS Detector Subsystem requirement is for algorithms for display interaction (extracting spectra, controlling image display, placing markers on the display, fitting Gaussians etc.). Testing will involve showing that all this functionality is present in the software and working. Test images will be used for **FPT**; real images at the telescope for **EFT**.

2.17 CCD Controller and Subsystem Controller Functions

The requirement is for the CCD Controller and Subsystem Controller to control all aspects of the CCD (e.g. download control code, set/unset frame transfer mode, set prebin factor, set windows, readout the CCD) and Subsystems (control of the Ion Pump). Testing will involve demonstrating that all this functionality is present in the software and working. (**FPT**)

2.18 Thermal Control Functions

The requirement is for the CCD detector temperature to be sensed and controlled and for the CCD controller internal temperature to be sensed. This will be tested by showing that the PFIS Detector Subsystem computer and CCD controller provide this functionality and that it is working (**BFT**).

2.19 Cryotiger Functions

The requirement is for the Cryotiger to cool the detectors. Testing will be as per the previous subsection.

3 Commissioning Plan

The required levels of testing to be performed at the various stages of the instrument are shown in Table 1 above.

Table 3 below indicates which tests are to be performed at what stage. A "✔" indicates that the test is valid and a "✕", that it is not valid for a specific instance. Refer to Section 2 for the detailed description of each test.

TEST	BFT	EFT	FPT
Detectors			
Frame transfer mode functioning		✔	✔
QE demonstration/report			✔
CTE test (99.9995% or better)			✔
Co-planarity test results			✔
Flatfielding test results			✔
Cryostat			
Detector reaches temperature	✔	✔	✔
Dark current < 1 e^-/pix/hr			✔
Drip tray installed and functional		✔	
Readout Noise & Gain and Full Well depth			
Photo transfer curve noise/gain test (<5 e^- @ slowest)		✔	✔
Full well depth test (150k e^-/pix or better)			✔
Noise from bias of zero second exposure		✔	✔
Readout Speed (@ 2 x 2 binning)			
Timed to be 5 sec or less			✔
Pre-binning			
1x1 to 9x9 pre-binning is possible		✔	✔

TEST	BFT	EFT	FPT
Envelope			
Measured dimensions within allowed values		✔	✔
Mass			
Measured mass within allowed values		✔	✔
Instrument Temperature Control			
Thermal enclosures internal temperature not exceeded		✔	
External surfaces measurements within range		✔	
Component/Module Replacement			
Suitable mechanical handling interfaces provided			✔
Individual modules not exceeding 15kg			✔
Electromagnetic Radiation			
Good noise performance in lab			✔
Absence of extra noise on 40-in			✔
Good noise and absence of pattern on SALT		✔	
Communication with PFIS/SALT Computers			
PFIS/SA computers – received camera setup info		✔	
PFIS/SA computers – image interaction instructions		✔	
PFIS/SA computers – transmit compressed images		✔	
TCS server – obtained telescope parameters		✔	
Data reduction PC – obtained data from PFIS Detector Subsystem		✔	

TEST	BFT	EFT	FPT
Communication with Precision Time Source			
PFIS Detector Subsystem PC within 1 sec from time service			✓
PFIS Detector Subsystem PC within 1 msec from time service			✓
Communication with CCD & Subsystems Controller			
CCD Control and Status communication in order			✓
PFIS Detector Subsystem PC is controlling camera and subsystems			✓
PFIS Detector Subsystem MMI/PCON computer			
MMI can set up camera		✓	
MMI can initiate acquisition and readout of images		✓	
MMI can control data storage and display		✓	
MMI can manage display interaction		✓	
MMI is exportable to SA MMI computers		✓	
PFIS Detector Subsystem Algorithms			
All algorithms can operate on test images			✓
All algorithms can operate on telescope images		✓	
CCD – and Subsystems Controller functions			
All CCD Controller functionality present and working			✓
All Subsystems controller " " " "			✓
Thermal Control Functions			
CCD detector temperature sensed and controlled	✓	✓	✓
CCD controller internal temp sensed and controlled	✓	✓	✓
Thermal enclosures internal temp sensed & controlled		✓	
Cryotiger Functions			
Cryotiger cold end reaches required temperature	✓	✓	✓

Table 3. Commissioning plan