Southern African Large Telescope
SALTICAM

Document Number 3390AS0001:
Software Specification

Darragh O’Donoghue
Luis Balona
Dave Carter
Etienne Bauermeister
Geoff Evans
Willie Koorts
James O’Connor
Faranah Osman
Stan van der Merwe

Issue 1.4
22 October 2002
### Issue History

<table>
<thead>
<tr>
<th>Number And File Name</th>
<th>Person</th>
<th>Issue</th>
<th>Date</th>
<th>Change History</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>DOD</td>
<td>1.0</td>
<td>10 Aug 2002</td>
<td>VI FDR version</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1</td>
<td>16 Sep 2002</td>
<td>Post-VI FDR development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2</td>
<td>27 Sep 2002</td>
<td>Completed</td>
</tr>
<tr>
<td>3390AS0001 SALTICAM</td>
<td></td>
<td>1.3</td>
<td>21 Oct 2002</td>
<td>Post-completion update!</td>
</tr>
<tr>
<td>Software Specification Issue 1.4.doc</td>
<td></td>
<td>1.4</td>
<td>22 Oct 2002</td>
<td>Further updates before software PDR.</td>
</tr>
</tbody>
</table>

### TABLE OF CONTENTS

1. **Scope** .................................................................................................................. 5
2. **Referenced Documents** .......................................................................................... 5
3. **Customer Furnished Equipment and Responsibilities** ........................................... 6
4. **Functional Requirements: SALTICAM CON** .............................................................. 8
   4.1 Program/Exposure Initiation/Termination ................................................................. 8
   4.2 Image Display and Interaction .................................................................................. 9
   4.3 Data Storage ........................................................................................................... 9
   4.4 Offsetting and Closed Loop Guiding ....................................................................... 9
   4.5 Communication With Precision Time Source ............................................................ 9
   4.6 Communication With SALTICAM KER ...................................................................... 10
   4.7 Communication With SALTICAM PCI ...................................................................... 10
   4.8 Communication With SALTICAM SDSU .................................................................... 10
5. **Functional Requirements: SALTICAM KER** ............................................................... 11
   5.1 Communication With SALTICAM SOMMI ................................................................. 11
   5.2 Communication With SALTICAM SAMMI ................................................................. 11
   5.3 Communication With SALTICAM MMI .................................................................... 12
   5.4 Communication With The TCS ................................................................................ 13
   5.5 Communication With The Science Database ............................................................. 13
   5.6 Communication With SALTICAM CON ................................................................... 14
6. **Functional Requirements: SALTICAM MMI** ............................................................... 15
7. **Functional Requirements: SALTICAM SDSU (including PCI and Subsystem Controller)** ........................................................................................................... 16
   7.1 Sub-Systems Controller ........................................................................................... 16
8. **Technical Requirements** ........................................................................................... 17
   8.1 Software Architecture ............................................................................................. 17
   8.2 Software Interfaces .................................................................................................. 17
   8.3 Modes, States and Events ....................................................................................... 18
   8.4 Software Capabilities .............................................................................................. 21
      8.4.1 Communication .................................................................................................. 21
      8.4.2 Initialisation ...................................................................................................... 21
      8.4.3 Command Interpretation and Generation ......................................................... 21
      8.4.4 Status Reporting .............................................................................................. 21
   8.5 Operating System ..................................................................................................... 21
   8.6 Resource Allocation ................................................................................................ 21
9. **Generic Software Requirements** ............................................................................. 22
10. **Software Testing** .................................................................................................... 23
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>Verification cross-reference matrix</td>
<td>23</td>
</tr>
<tr>
<td>10.2</td>
<td>Detailed Test Requirements</td>
<td>23</td>
</tr>
<tr>
<td>10.2.1</td>
<td>Interface Test</td>
<td>24</td>
</tr>
<tr>
<td>10.2.2</td>
<td>Initialization</td>
<td>24</td>
</tr>
<tr>
<td>10.2.3</td>
<td>Command Interpretation and Generation</td>
<td>24</td>
</tr>
<tr>
<td>10.2.4</td>
<td>Status Reporting</td>
<td>24</td>
</tr>
</tbody>
</table>
### ACRONYMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>AC</th>
<th>Acquisition Camera (SALTICAM mode)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACSI</td>
<td>Acquisition Camera and Science Imager (SALTICAM configuration)</td>
</tr>
<tr>
<td>ATP</td>
<td>Acceptance Test Procedure</td>
</tr>
<tr>
<td>ATR</td>
<td>Acceptance Test Report</td>
</tr>
<tr>
<td>BITE</td>
<td>Built-in Test Equipment</td>
</tr>
<tr>
<td>CDR</td>
<td>Critical Design Review</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial off the shelf</td>
</tr>
<tr>
<td>ELS</td>
<td>Event Logger Software</td>
</tr>
<tr>
<td>HET</td>
<td>Hobby-Eberly Telescope</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output (Device)</td>
</tr>
<tr>
<td>ICD</td>
<td>Interface Control Dossier</td>
</tr>
<tr>
<td>MMI</td>
<td>Man-Machine Interface</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failures</td>
</tr>
<tr>
<td>MTTR</td>
<td>Mean Time to Repair</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>OPT</td>
<td>Operational Planning Tool</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>PDR</td>
<td>Preliminary Design Review</td>
</tr>
<tr>
<td>PFIS</td>
<td>Prime Focus Imaging Spectrograph</td>
</tr>
<tr>
<td>PI</td>
<td>Principal Investigator (Astronomer)</td>
</tr>
<tr>
<td>PIPT</td>
<td>PI Planning Tool</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable-Logic Controller</td>
</tr>
<tr>
<td>SA</td>
<td>SALT Astronomer</td>
</tr>
<tr>
<td>SALT</td>
<td>Southern African Large Telescope</td>
</tr>
<tr>
<td>SAMMI</td>
<td>SA Machine Interface</td>
</tr>
<tr>
<td>SC</td>
<td>Software Component (e.g. part fo the TCSS)</td>
</tr>
<tr>
<td>SDB</td>
<td>Science Database</td>
</tr>
<tr>
<td>SDD</td>
<td>Software Design Document</td>
</tr>
<tr>
<td>SDP</td>
<td>Software Development Plan</td>
</tr>
<tr>
<td>SI</td>
<td>Software Item (the TCSS is a Software Item) OR Scientific Imager (SALTICAM mode) (context will define which is meant)</td>
</tr>
<tr>
<td>SO</td>
<td>SALT Operator</td>
</tr>
<tr>
<td>SOMMI</td>
<td>SO Machine Interface</td>
</tr>
<tr>
<td>SRS</td>
<td>Software Requirement Specification</td>
</tr>
<tr>
<td>STARCAT</td>
<td>Object Catalogue</td>
</tr>
<tr>
<td>SW</td>
<td>Software</td>
</tr>
<tr>
<td>TBC</td>
<td>To Be Confirmed</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Determined</td>
</tr>
<tr>
<td>TCS</td>
<td>Telescope Control System</td>
</tr>
<tr>
<td>TCSS</td>
<td>TCS Server</td>
</tr>
<tr>
<td>VI</td>
<td>Virtual Instrument (Labview function) OR Verification Instrument (SALTICAM mode) (context will define which is meant)</td>
</tr>
</tbody>
</table>
1 Scope

This document specifies the requirements for SALTICAM Software.

According to the Software Development Plan (3390BP0001 SALTICAM Software Development Plan Issue 1.0), the software will comprise:

- **SALTICAM Kernel Software (designated SALTICAM KER).**
- **SALTICAM MMI Software (designated SALTICAM MMI).** This is the interface to SALTICAM for development and maintenance via the SALTICAM PC keyboard. It will be similar to SALTICAM SOMMI and SALTICAM SAMMI. It may also function as SALTICAM SAMMI.
- **SALTICAM Control Software (designated SALTICAM CON).** This is the software that will:
  - Control all the hardware.
  - Contain the master copy of all the instrument parameters.
- **SALTICAM PCI Card Software (designated SALTICAM PCI).** This is software that is supplied by Astronomical Research Cameras (ARC) with their SDSU II CCD controllers. It runs in the DSP processor on the PCI interface card supplied with ARC CCD controllers. If Real Time Linux is used, the functionality of the PCI driver within the Real Time Linux operating system environment will be emulated by SAAO developed software.
- **SALTICAM SDSU II Control Software (designated SALTICAM SDSU),** including the software in the subsystem controller. This is software that is initially supplied by ARC with their SDSU II CCD controllers. The supplied software will be used as a prototype for an SAAO developed equivalent, tailored for the SALTICAM application.

In addition, there are two further items of software which are the responsibility of the SALT Project:

- **SALT Operator SALTICAM MMI Software (designated SALTICAM SOMMI).** This is the main operator interface to SALTICAM in Verification Instrument (VI) or Acquisition Camera (AC) modes.
- **SALT Astronomer SALTICAM MMI Software (designated SALTICAM SAMMI).** This is the main astronomer interface to SALTICAM in Science Imager (SI) mode. It is possible that SALTICAM MMI will function in the same machine as SALTICAM SAMMI, or be identical to or a subset of SALTICAM SAMMI.

The relationships of these software items to each other are shown in Fig. 1.

The main purpose of the software suite is to:

- Interact with the MMIs (SALTICAM SOMMI/SAMMI/MMI) to enable them to control the SALTICAM hardware to obtain images of the focal plane of SALT.
- Display the images on the SALTICAMPC monitor near the SO or SA. The SOMMI/SAMMI/MMI should be able to control this display, as well as interact with it (placement of markers etc.).
- Store the images on the SALTICAM PC disc in FITS format.
- Enable the SOMMI/SAMMI/MMI to use simple algorithms to make quantitative measurements on the displayed image.
- Interact with the TCSS to obtain telescope status information and adjust the pointing of the telescope either to place targets in the entrance apertures of the scientific instruments or perform closed loop guiding.
- Monitor the safety of the instrument and preventing unsafe or inappropriate operation.

2 Referenced Documents

The following documents are referenced in this specification and are applicable to the extent specified herein.
3 Customer Furnished Equipment and Responsibilities

SALTICAM will have its own fully functioning MMI, which may be used not only to enable the human operator to control the instrument, but also for development and maintenance purposes. In normal operation, the MMI shall be via SALTICAM SOMMI or SAMMI. It is possible that the SALTICAM MMI will be used by the SAMMI for controlling the instrument in SI mode. SALTICAM SOMMI and SAMMI are the responsibility of the Customer.
Figure 1. SALTICAM Modules From The Software Perspective

Language Legend:
- LabVIEW
- C
- DSP Asm

SO Workstation
- SALTICAM SOMMI
  - SOMMI Data
  - Socket/Other I/O
  - Channel

SALTICAM PC Monitor
- Full image, markers

SA Workstation
- SALTICAM SAMMI
  - SAMMI Data
  - Socket/Other I/O
  - Channel

SALTICAM PC
- SALTICAM MMI
- SALTICAM KERNEL
- SALTICAM CONTROL
- SDSU II
- SDSU II Controller
- Subsystem Controller

TCS Server
- TCS
- TCS Data Socket

Data Processor
- Science Database
4 Functional Requirements: SALTICAM CON

SALTICAM CON will be the “central control room” of the instrument. For this reason, we consider its functional requirements first.

SALTICAM CON will control the master copy of all camera parameters. These parameters are listed here:

1. The “program”, if any, defining the sequence of operations and hardware parameters for the next observation.
2. If no “program” is required, the filter required for the next image.
3. If no “program” is required, whether or not frame transfer mode is required for the next image. If it is, in what position the frame transfer mask position is required for the next image.
4. If no “program” is required, what exposure time is required for the next image.
5. If no “program” is required, what prebinning is required for the next image.
6. If no “program” is required, what windowing, if any, is required for the next image.
7. If no “program” is required, what gain is required for the next image.
8. If no “program” is required, what readout speed is required for the next image.
9. If no “program” is required, whether or not the next image is to be stored on disk.
10. If no “program” is required, values of other parameters (TBD).
11. An important additional parameter is whether or not repeat mode is enabled. Repeat mode is applicable regardless of whether or not program mode is enabled.

The concept of a “program” is an important one for SALTICAM instrument control. If the next image is to be obtained in “program” mode, the values of all camera parameters are predefined in a specific “program”. For example, a sequence of images through 3 different filters with different exposure times etc. can be defined. As another example, a “faint star acquisition” can be defined in which a single image through a clear filter is required, with other camera parameters set so as to optimise the detectability of objects at the limit of the telescope. Such a program would be used to relieve the SALT Operator from fiddling with the numerous parameters available when trying to acquire faint targets. Other “programs” could be defined for obtaining bias images, dark images, repeated short exposures (“video camera” mode) etc.

On the other hand, users can set all individual camera parameters (2-10 in the above list). In addition, single exposures or programs can be placed in repeat mode (item 11 in the above list).

In this manner, flexibility of operation as well as ease of routine use are assured. This catering for “opposite ends of the operational spectrum” is sufficiently important that it assumes the position of a requirement of the software, as opposed to a design feature.

4.1 Program/Exposure Initiation/Termination

If SALTICAM is in “program mode”, SALTICAM CON can initiate the start of the next program. SALTICAM CON can also abort a currently executing program.

Likewise, if SALTICAM is not in program mode, SALTICAM CON can start the next exposure or abort the current exposure.

4.2 Image Display and Interaction

SALTICAM CON will display images obtained by the instrument with adequate resolution on a large monitor in the SALT Control Room. This monitor will be the SALTICAM PC Monitor (as indicated in Fig. 1). Control of brightness and contrast shall be part of the display algorithms. Displaying the image in any orientation of RA and Dec is required (TBD1).
SALTICAM CON will also manage interaction with the displayed image to place marks/boxes/windows on the display, select objects on the display, overlay catalogues on the display etc.

4.3 Data Storage

SALTICAM CON will also control and manage data storage (in FITS format) on the SALTICAM PC’s disk. (It is necessary that SALTICAM CON carry out this task as opposed to SALTICAM KER or SALTICAM MMI as in very high speed mode, minimum latency is required).

4.4 Offsetting and Closed Loop Guiding

SALTICAM CON will also perform any calculations required for (i) positioning a target in the entrance aperture of any instrument; (ii) closed loop guiding. These calculations will return the telescope pointing offsets to SALTICAM KER for onward transmission to the TCSS.

4.5 Communication With Precision Time Source

SALTICAM KER shall obtain data from the Precision Time Source in order to ensure that the SALTICAM computer keeps Universal Time to 1 millisec accuracy or better at all times by providing suitably coded GPS-referenced time to the SALTICAM computer.

4.6 Communication With SALTICAM KER

SALTICAM CON shall exchange data with SALTICAM KER in order to:

• Receive commands from SALTICAM KER and provide update confirmation of changes to SALTICAM hardware parameters (items 1-10 at the start of Section 4). Definitions of any valid programs are included here.
• Receive commands from SALTICAM KER to initiate/terminate the next program/exposure or terminate the current program/exposure. Reporting of the outcome of the command is also required.
• Receive commands from SALTICAM KER to enable interaction with the SALTICAM PC Monitor: place marks/boxes/windows on the display, select objects on the display, overlay catalogues on the display etc. (Status return is via the appearance of the display).
• Receive commands from SALTICAM KER about the storage of data in FITS format. Reporting the outcome of the command is also required.
• Receive commands from SALTICAM KER to (i) perform calculations for offsetting a target into the entrance aperture of any scientific instrument; or (ii) initiate/stop closed loop guiding. Once initiated, centroids of one or more guide objects will be calculated and pointing corrections deduced for return to SALTICAM KER for onward transmission to the TCSS. In high time resolution mode, guide star centroiding may be achieved from the scientific images. The outcome of the command must be reported back to SALTICAM KER.

SALTICAM CON will send any additional status required back to SALTICAM KER.
SALTICAM CON will also transmit, on request, compressed images (no larger than 500 x 500 pixels) to SALTICAM KER.

4.7 Communication With SALTICAM PCI

SALTICAM CON shall communicate with SALTICAM PCI in order to verify that the interface is functioning properly.

4.8 Communication With SALTICAM SDSU

SALTICAM CON shall communicate with SALTICAM SDSU in order to effect all hardware control via bi-directional communication. Control & status, and CCD Read out data - data rate (on internal optical fibre) up to 250 Mbits/sec (equates to 3.9 Mpixels/second, theoretical maximum speed). Image size up to 17.6 Mpixels, but usually 4.2 Mpixels.

SALTICAM CON shall issue commands to SALTICAM SDSU in order to:

- Request controller status
- Download CCD-specific control/executable code
- Filter selection and positioning
- Set full frame, frame transfer or slot mode
- Frame Transfer mask in/out
- Set pre-bin factor
- Set window/s if any
- Set gain factor & readout speed
- Start/stop exposure
- Open/close shutter
- Shift image to store area
- Read out CCD data
- Focus control
- Various test functions such as charge pumping, noise testing etc.
5 Functional Requirements: SALTICAM KER

SALTICAM KER will primarily be used to relay information between the software items running in the SALTICAM PC, and those running in other computers, as mentioned at the start of Section 4 and illustrated in Fig. 1. This information comprises commands and associated parameters to mediate MMI control, update the camera parameters (items 1-10 at the start of Section 4), initiate closed-loop guiding if necessary, initiate the acquisition, readout and storage of images etc.

5.1 Communication With SALTICAM SOMMI

SALTICAM KER may exchange data (commands and associated parameters) with SALTICAM SOMMI residing in the SOMMI machine. Data exchange shall be via the Data Socket Server in the SOMMI machine (or via an alternative, mutually agreed communication protocol).

If SALTICAM SOMMI is not in MMI control, it may receive a command from SALTICAM KER to assume MMI control.

If SALTICAM SOMMI is in MMI control, SALTICAM KER may receive commands from SALTICAM SOMMI in order to:

- Return MMI control to another MMI (SALTICAM MMI or SALTICAM SAMMI)
- Update SALTICAM hardware parameters (items 1-10 at the start of Section 4). This request will be forwarded to SALTICAM CON. The outcome of the request will be returned to SALTICAM SOMMI. “Program” definition is included here.
- Initiate/Abort the next/current program or exposure. This request will be forwarded to SALTICAM CON. The outcome of the request will be returned to SALTICAM SOMMI.
- Enable interaction with the SALTICAM PC Monitor: place marks/boxes/windows on the display, select objects on the display, overlay catalogues on the display etc. The outcome of the request will be via the SALTICAM PC display.
- Control the storage of data in FITS format. Reporting the outcome of the command is also required.
- Carry out simple image processing algorithms:
  i. A readout of pixel position, RA and Dec of a mouse-type pointer.
  ii. Fitting of Gaussian functions to point sources.
  iii. 2-d line plots of image brightness in any direction across the image.
  iv. Simple aperture photometry to estimate magnitudes of objects.
  v. Simple image processing function such as background subtraction, smoothing or median filtering.

Results of these operations will be reported either directly to SALTICAM SOMMI or via the SALTICAM PC display.

- (i) Offset a target into the entrance aperture of any scientific instrument or (ii) initiate/stop closed loop guiding. Once initiated, centroids of one or more guide objects will be calculated and pointing corrections deduced for transmission to the guiding system in the TCS. In high time resolution mode, guide star centroiding may be achieved from the scientific images. The outcome of the command must be reported back to SALTICAM SOMMI.

SALTICAM KER will transmit any additional status required back to SALTICAM SOMMI.

SALTICAM KER will also transmit, on request, compressed images (no larger than 500 x 500 pixels) to SALTICAM SOMMI.

5.2 Communication With SALTICAM SAMMI

SALTICAM KER may exchange data (commands and associated parameters) with SALTICAM SAMMI residing
in the SAMMI machine. Data exchange shall be via the Data Socket Server in the SAMMI machine (or via an alternative, mutually agreed communication protocol).

If SALTICAM SAMMI is not in MMI control, it may receive a command from SALTICAM KER to assume MMI control.

If SALTICAM SAMMI is in MMI control, SALTICAM KER may receive commands from SALTICAM SAMMI in order to:

- Return MMI control to another MMI (SALTICAM MMI or SALTICAM SOMMI)
- Update SALTICAM hardware parameters (items 1-10 at the start of Section 4). This request will be forwarded to SALTICAM CON. The outcome of the request will be returned to SALTICAM SAMMI. “Program” definition is included here.
- Initiate/Abort the next/current program or exposure. This request will be forwarded to SALTICAM CON. The outcome of the request will be returned to SALTICAM SAMMI.
- Enable interaction with the SALTICAM PC Monitor: place marks/boxes/windows on the display, select objects on the display, overlay catalogues on the display etc. The outcome of the request will be via the SALTICAM PC display.
- Control the storage of data in FITS format. Reporting the outcome of the command is also required.
- Carry out simple image processing algorithms:
  - A read out of pixel position, RA and Dec of a mouse-type pointer.
  - Fitting of Gaussian functions to point sources.
  - 2-d line plots of image brightness in any direction across the image.
  - Simple aperture photometry to estimate magnitudes of objects.
  - Simple image processing function such as background subtraction, smoothing or median filtering.
  Results of these operations will be reported either directly to SALTICAM SAMMI or via the SALTICAM PC display.
- (i) Offset a target into the entrance aperture of any scientific instrument or (ii) initiate/stop closed loop guiding. Once initiated, centroids of one or more guide objects will be calculated and pointing corrections deduced for transmission to the guiding system in the TCS. In high time resolution mode, guide star centroiding may be achieved from the scientific images. The outcome of the command must be reported back to SALTICAM SAMMI.

SALTICAM KER will transmit any additional status required back to SALTICAM SAMMI.

SALTICAM KER will also transmit, on request, compressed images (no larger than 500 x 500 pixels) to SALTICAM SAMMI.

5.3 Communication With SALTICAM MMI

If SALTICAM MMI is in MMI control (as is assumed at initiation of all software items), SALTICAM KER may receive a command from SALTICAM MMI to transfer MMI control to one of the other MMIs (SALTICAM SOMMI or SALTICAM SAMMI).

If SALTICAM MMI is not in MMI control, it may receive a command from SALTICAM KER to assume MMI control.

If SALTICAM MMI is in MMI control, SALTICAM KER may receive commands from SALTICAM MMI in order to:

- Update SALTICAM hardware parameters (items 1-10 at the start of Section 4). This request will be forwarded to SALTICAM CON. The outcome of the request will be returned to SALTICAM MMI.
“Program” definition is included here.

- Initiate/Abort the next/current program or exposure. This request will be forwarded to SALTICAM CON. The outcome of the request will be returned to SALTICAM MMI.
- Enable interaction with the SALTICAM PC Monitor: place marks/boxes/windows on the display, select objects on the display, overlay catalogues on the display etc. The outcome of the request will be via the SALTICAM PC display.
- Control the storage of data in FITS format. Reporting the outcome of the command is also required.
- Carry out simple image processing algorithms:
  1. A read out of pixel position, RA and Dec of a mouse-type pointer.
  2. Fitting of Gaussian functions to point sources.
  3. 2-d line plots of image brightness in any direction across the image.
  4. Simple aperture photometry to estimate magnitudes of objects.
  5. Simple image processing function such as background subtraction, smoothing or median filtering.

Results of these operations will be reported either directly to SALTICAM MMI or via the SALTICAM PC display.

- (i) Offset a target into the entrance aperture of any scientific instrument or (ii) initiate/stop closed loop guiding. Once initiated, centroids of one or more guide objects will be calculated and pointing corrections deduced for transmission to the guiding system in the TCS. In high time resolution mode, guide star centroiding may be achieved from the scientific images. The outcome of the command must be reported back to SALTICAM MMI.

SALTICAM KER will transmit any additional status required back to SALTICAM MMI.

### 5.4 Communication With The TCS

SALTICAM KER may exchange data with the TCS residing in the TCSS machine. Data exchange shall be via the Data Socket Server in the TCSS machine (or via an alternative, mutually agreed communication protocol).

SALTICAM KER may request information from the TCS:

- Telescope pointing data including telescope azimuth, tracker position, hour angle, zenith distance, RA, Dec, Epoch etc.
- Target pointing data such as target name, RA, Dec, Epoch etc.
- Additional data .... (SALT to specify)

SALTICAM KER will supply the TCS with such information as it requires (SALT to specify):

- Yak-blah, yak-blah (SALT to specify)
- Yadda yadda yadda (SALT to specify)
- Additional yadda yadda (SALT to specify)

SALTICAM KER may send pointing commands to the TCS in order to:

- Place objects in the entrance apertures of the scientific instruments
- Function as guiding corrections during closed loop guiding

### 5.5 Communication With The Science Database

At low priority, so as to avoid interference with SALTICAM’s normal operations, SALTICAM KER will transmit one or more images to the Data Processor computer. SALTICAM images may be as large as 17.6 M pixels (of 2 bytes/pixel) but will usually be no larger than 4.2 M pixels. Data rates to be determined by the data reduction requirements.
5.6 Communication With SALTICAM CON

SALTICAM KER shall exchange data with SALTICAM CON in order to:

- Issue commands to SALTICAM CON and provide update confirmation of changes to SALTICAM hardware parameters (items 1-10 above). “Program” definition is included here.
- Issue commands to SALTICAM CON to initiate/terminate the next program/exposure or terminate the current program/exposure. Reporting of the outcome of each command is also required.
- Issue commands to SALTICAM CON to enable interaction with the SALTICAM PC Monitor: place marks/boxes/windows on the display, select objects on the display, overlay catalogues on the display etc. (Status return is via the appearance of the display).
- Issue commands to SALTICAM CON about the storage of data in FITS format. Reporting the outcome of the command is also required.
- Issue commands to SALTICAM CON in order to carry out simple image processing algorithms:
  i. A read out of pixel position, RA and Dec of a mouse-type pointer.
  ii. Fitting of Gaussian functions to point sources.
  iii. 2-d line plots of image brightness in any direction across the image.
  iv. Simple aperture photometry to estimate magnitudes of objects.
  v. Simple image processing function such as background subtraction, smoothing or median filtering.
Results of these operations will be reported either directly to SALTICAM KER or via the SALTICAM PC display.
- Issue commands to SALTICAM CON to (i) perform calculations for offsetting a target into the entrance aperture of any scientific instrument; or (ii) initiate/stop closed loop guiding. Once initiated, centroids of one or more guide objects will be calculated and pointing corrections deduced for return to SALTICAM KER for onward transmission to the TCSS. In high time resolution mode, guide star centroiding may be achieved from the scientific images. The outcome of the command must be reported back to SALTICAM KER.

SALTICAM CON will send any additional status required back to SALTICAM KER.

SALTICAM CON will also transmit, on request, compressed images (no larger than 500 x 500 pixels) to SALTICAM KER.
6 Functional Requirements: SALTICAM MMI

The SALTICAM MMI will be used to provide a user interface to control the instrument. It is expected that very similar functionality shall reside with SALTICAM SOMMI and SALTICAM SAMMI. SALTICAM MMI will be used in the development and maintenance of SALTICAM software.

In normal operational mode, and upon initiation of all software units, it is assumed that MMI control will reside with SALTICAM MMI.

If SALTICAM MMI is/is not in MMI control, SALTICAM MMI may issue/receive a command to/from SALTICAM KER to transfer/receive MMI control to/from one of the other MMIs (SALTICAM SAMMI or SALTICAM SOMMI).

If SALTICAM MMI is in MMI control, then it will communicate with SALTICAM KER in order to:

- Update SALTICAM hardware parameters (items 1-10 above). This request will be forwarded to SALTICAM CON. The outcome of the request will be returned to SALTICAM MMI. “Program” definition is included here.
- Initiate/Abort the next/current program or exposure. This request will be forwarded to SALTICAM CON. The outcome of the request will be returned to SALTICAM MMI.
- Enable interaction with the SALTICAM PC Monitor: place marks/boxes/windows on the display, select objects on the display, overlay catalogues on the display etc. The outcome of the request will be via the SALTICAM PC display.
- Control the storage of data in FITS format. Reporting the outcome of the command is also required.
- Carry out simple image processing algorithms:
  i. A read out of pixel position, RA and Dec of a mouse-type pointer.
  ii. Fitting of Gaussian functions to point sources.
  iii. 2-d line plots of image brightness in any direction across the image.
  iv. Simple aperture photometry to estimate magnitudes of objects.
  v. Simple image processing function such as background subtraction, smoothing or median filtering.

Results of these operations will be reported either directly to SALTICAM MMI or via the SALTICAM PC display.

- (i) Offset a target into the entrance aperture of any scientific instrument or (ii) initiate/stop closed loop guiding. Once initiated, centroids of one or more guide objects will be calculated and pointing corrections deduced for transmission to the guiding system in the TCS. In high time resolution mode, guide star centroiding may be achieved from the scientific images. The outcome of the command must be reported back to SALTICAM MMI.

SALTICAM MMI will solicit any additional status required from SALTICAM KER.
7 Functional Requirements: SALTICAM SDSU (including PCI and Subsystem Controller)

The SDSU controller software shall:

- Respond to commands from CON and reply with status and data as appropriate.
- Control the CCD detector clock and bias voltages correctly and safely at all times.
- Maintain the CCD detectors at a constant temperature (within 0.5°C P-V).
- Control the SALTICAM shutter unit.
- Start/stop exposures, controlling the exposure times to <10 msec accuracy in shuttered mode, and 1 msec accuracy in frame transfer or slot mode.
- Read out the CCD detectors and transmit the digital data to CON. Readout to be accomplished at a range of specified speeds (pix/sec), gain factors, prebin/window formats and modes as shown in the table below. Readout speed jitter must be kept to a minimum during image readout.
- Provide functionality for testing such as charge pumping, etc.
- Transmit messages between CON and the sub-systems controller.

<table>
<thead>
<tr>
<th>Readout Mode</th>
<th>Readout Speed</th>
<th>Prebin</th>
<th>Window</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full frame</td>
<td>Fast or slow</td>
<td>X by Y</td>
<td>Yes</td>
<td>Exposure defined by shutter</td>
</tr>
<tr>
<td>Frame transfer</td>
<td>Fast</td>
<td>X by Y</td>
<td>Yes</td>
<td>Exposure defined by frame transfer. Frame transfer mask in FT position</td>
</tr>
<tr>
<td>Slot mode</td>
<td>Fast</td>
<td>X by Y</td>
<td>Yes</td>
<td>Exposure defined by frame transfer. Frame transfer mask in slot position</td>
</tr>
<tr>
<td>Driftscan</td>
<td>Fast or slow</td>
<td>X</td>
<td>No</td>
<td>Exposure defined by drift rate &amp; length of CCD (61.5 mm). CCD must be aligned with edge (4102 pix) in E-W direction.</td>
</tr>
</tbody>
</table>

7.1 Sub-Systems Controller

Auxiliary subsystems excluding the shutter will be controlled by an SAAO designed PIC microcontroller-based unit. The shutter assembly will be controlled directly by the SDSU controller via the sub-systems controller to maintain better control of exposure timing.

The Sub-Systems controller shall:

- Respond to commands received from CON and return status
- Perform all instrument control functions required:
  - Filter change
  - Frame transfer mask positioning
  - Focus mechanism control
  - Ion pump on/off control
- Monitor and control temperatures as required
8 Technical Requirements

8.1 Software Architecture

Fig. 1 shows the major software blocks of SALTICAM along with the external and internal interfaces. Fig. 1 also shows the languages to be used in the different software blocks.

8.2 Software Interfaces

Table 1 provides details of each of the interface shown in Fig. 1. This data indicated here is for information only. The most current data will be identified in the SALT Data ICD, referenced in Section 2.

Table 1: SALTICAM Software Interfaces

<table>
<thead>
<tr>
<th>Number</th>
<th>Interfacing applications</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2</td>
<td>CON ¬ SDSU</td>
<td>See Section 4.8 (and 4.7).</td>
</tr>
<tr>
<td>3</td>
<td>CON ¬ Display</td>
<td>See Section 4.2.</td>
</tr>
<tr>
<td>4,5</td>
<td>CON ¬ KER</td>
<td>See Section 4.6.</td>
</tr>
<tr>
<td>6,7</td>
<td>KER ¬ MMI</td>
<td>See Section 5.3</td>
</tr>
<tr>
<td>8</td>
<td>KER ¬ D-Base</td>
<td>Transmission of stored image data to the science data base. See Section 5.5</td>
</tr>
<tr>
<td>9,10</td>
<td>KER ¬ TCS</td>
<td>SALTICAM communication with the TCS. See Section 5.4</td>
</tr>
<tr>
<td>11</td>
<td>SAMMI ¬ KER</td>
<td>Commands and data from SAMMI to KER. See Section 5.2.</td>
</tr>
<tr>
<td>12</td>
<td>SOMMI ¬ KER</td>
<td>Commands and data from SOMMI to KER. See Section 5.1.</td>
</tr>
<tr>
<td>13</td>
<td>KER ¬ SAMMI</td>
<td>Image data and status from KER to SAMMI. See Section 5.2.</td>
</tr>
<tr>
<td>14</td>
<td>KER ¬ SOMMI</td>
<td>Image data and status from KER to SOMMI. See Section 5.1.</td>
</tr>
<tr>
<td>15</td>
<td>KER ¬ PCI, SDSU</td>
<td>Commands and data from CON to/from SDSU via PCI.</td>
</tr>
</tbody>
</table>
8.3 Modes, States and Events

Fig. 2 illustrates the different modes of SALTICAM. See Table 2 for a description of these modes. Table 3 describes the mode transition events.
### Table 2: SALTICAM Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
<th>States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead</td>
<td>Power to Salticam Computer, CCD and Subsystem Controller, and Cryotiger compressor is switched off.</td>
<td>CCD Controller, Subsystem Controller and Cryotiger Compressor switched on.</td>
</tr>
<tr>
<td>Off</td>
<td>Power to Salticam Computer is switched off; power to CCD and Subsystem Controller, and Cryotiger compressor is switched on.</td>
<td>SALTICAM computer switched on. Boot-up scripts have been executed. Ready to initialise.</td>
</tr>
<tr>
<td>Standby</td>
<td>Power to Salticam Computer, CCD and Subsystem Controller, and Cryotiger Compressor is switched on. In this state the Salticam Computer is running.</td>
<td>Controller code down-loaded. MMI selected. All software modules now running. System health has been checked.</td>
</tr>
<tr>
<td>Ready in VI, AC or SI modes</td>
<td>All subsystems powered up and initialised: • Detector controller active with default (VI, AC, SI mode) setup • Detectors at set point temperature • Shutter closed. • Filter unit to default position. • Frame Transfer Mask out of beam.</td>
<td></td>
</tr>
<tr>
<td>Maintenance Mode</td>
<td>Full instrument parameters available for MMI.</td>
<td>Under SO control.</td>
</tr>
<tr>
<td>Snapshot Mode</td>
<td>Exposing and reading out a single image.</td>
<td>Can be aborted.</td>
</tr>
<tr>
<td>Program Mode</td>
<td>Executing a pre-defined sequence of exposures.</td>
<td>Can be aborted.</td>
</tr>
<tr>
<td>Image Processing Mode</td>
<td>Post-processing a previously obtained image: e.g. adjusting its display or overlaying markers on it; centroid calculations etc.</td>
<td>Under SO control.</td>
</tr>
<tr>
<td>Input Mode</td>
<td>Instrument parameters being updated by operator interaction with MMI.</td>
<td>See those listed in Section 4: “Functional Requirements for SALTICAM CON.”</td>
</tr>
<tr>
<td>Error</td>
<td>Any errors, which affect the capability of the instrument to perform as designed, will place Salticam in this mode. Sensor readings and status reporting will continue as far as possible. Error reporting must be sufficient to guide the telescope operator to the source of the problem.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 3: SALTICAM Mode Transitions

<table>
<thead>
<tr>
<th>EVENT T</th>
<th>From Mode</th>
<th>To Mode</th>
<th>SENSOR/INPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>DEAD</td>
<td>OFF</td>
<td>Button – Cryotiger Compressor Button – CCD Controller Button – Subsystem Controller</td>
</tr>
<tr>
<td>1</td>
<td>OFF</td>
<td>DEAD</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>OFF</td>
<td>STANDBY</td>
<td>Button – Salticam Computer Button – Salticam Computer</td>
</tr>
<tr>
<td>3</td>
<td>STANDBY</td>
<td>OFF</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>STANDBY</td>
<td>READY</td>
<td>On successful power up and auto/operator initialisation sequence Software/operator initiated shutdown sequence</td>
</tr>
<tr>
<td>5</td>
<td>READY</td>
<td>STANDBY</td>
<td></td>
</tr>
<tr>
<td>6, 13</td>
<td>READY</td>
<td>ERROR</td>
<td>Error conditions. For example: • Problem with subsystems: e.g. Filters, Shutter, Frame Transfer Mask. • Problem with detector temperature • Problem with controller over-temperature • Problem with fibre data comms. Operator initiated – on detecting problems</td>
</tr>
<tr>
<td>7</td>
<td>ERROR</td>
<td>READY</td>
<td>Error Recovery – Operator initiated</td>
</tr>
<tr>
<td>8</td>
<td>READY</td>
<td>MAINTENANCE</td>
<td>In Maintenance mode: detailed control enabled. Operator initiated.</td>
</tr>
<tr>
<td>9</td>
<td>READY</td>
<td>SNAPSHOT</td>
<td>Taking a single image with current parameters. Operator initiated.</td>
</tr>
<tr>
<td>10</td>
<td>READY</td>
<td>PROGRAM</td>
<td>Performing a pre-defined sequence of images. Operator initiated.</td>
</tr>
<tr>
<td>11</td>
<td>READY</td>
<td>IMAGE PROCESSING</td>
<td>Post-processing of a pre-obtained image from Maintenance, Snapshot or Program modes</td>
</tr>
<tr>
<td>12</td>
<td>MAINTENANCE SNAPSHOT PROGRAM IMAGE PROC.</td>
<td>READY</td>
<td>Operator initiated: mode over. Exposure &amp; readout finished/aborted Program finished/aborted Operator initiated: mode over.</td>
</tr>
<tr>
<td>13</td>
<td>READY</td>
<td>READY</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>ERROR</td>
<td>STANDBY</td>
<td>Error conditions not resolved.</td>
</tr>
<tr>
<td>15</td>
<td>READY</td>
<td>INPUT</td>
<td>Operator initiated: parameter update. System returns to READY mode.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>READY</td>
<td></td>
</tr>
</tbody>
</table>
8.4 Software Capabilities

8.4.1 Communication
a. SALTICAM SW shall communicate with the other SALT subsystems, using the methods described in Fig. 1 and the Functional Requirements sections, as amended by the SALT Data ICD.
b. The variables communicated shall be defined using the cluster data types identified in the SALT Data ICD.
c. The standard “SALT Communication Module” shall be used to perform Labview Data Socket communication, at a rate commensurate with the requirements of the applicable data.
d. Exceptions to the above shall only be allowed with approval of the SALT Systems Engineer.

8.4.2 Initialisation
a. The SALTICAM PC and SW shall initialise to a safe, known state. Communication with the SDSU controller and subsystem controller shall be established and all hardware shall be placed in a safe, “ready” mode.
b. The SW shall monitor the status of each subsystem’s initialisation and shall only complete initialisation when all the subsystems are known to be ready, unless this process is aborted via an operator command.
c. No hardware movement or CCD operations shall be allowed without operator intervention.

8.4.3 Command Interpretation and Generation
a. All commands to/from the TCSS, SOMMI, SAMMI or the Data Processor shall be text-based. These commands will define the required action and appropriate parameters associated with the action.
b. SALTICAM SW shall interpret the commands and change modes and/or initiate the appropriate action, only if appropriate (see c.).
c. SALTICAM SW shall only initiate actions or change modes, if it is appropriate in terms of safety or allowable instrumental operation. A set of “operating rules” shall define this operation, incorporating the actual states of the instrument.
d. Changing modes shall be implemented using a state machine, following a matrix of present states, required states, conditions to be met and actions to be performed.
e. When SALTICAM is placed in maintenance mode, the above requirements can be overridden.
f. It shall be possible to operate the instrument in a limited fashion, with some of the subsystems in Maintenance mode.

8.4.4 Status Reporting
a. SALTICAM SW shall report to the SOMMI, SAMMI and its local MMI, all status information.

8.5 Operating System

SALTICAM SW shall run the Linux or Real Time Linux operating system.

8.6 Resource Allocation

The TCS software shall be capable of performing its function on a PC with the following specifications:
- 2GHz Pentium
- 256MB memory
- 800 x 600 resolution (local MMI)
9 Generic Software Requirements

SALTICAM Software shall comply with the requirements specified in the SALTICAM Software Development Plan and the Labview Coding Standard, as referenced in section 2.
10 Software Testing

10.1 Verification cross-reference matrix

The software specified herein must be verified for compliance with this specification, as indicated in the table below. Where appropriate, detailed test methods have been defined in the next section.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scope</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Referenced Documents</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Customer Furnished Equipment and Responsibilities</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Functional Requirements: CON</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1</td>
<td>Program/Exposure Initiation/Termination</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2</td>
<td>Image Display and Interaction</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>Data Storage</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>Offsetting and Closed Loop Guiding</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5-4.8</td>
<td>Communications with Precision Time Source, KER, PCI and SDSU</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Functional Requirements: KER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1</td>
<td>Communication with SOMMI</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>Communication with SAMMI</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.3</td>
<td>Communication with MMI</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.4</td>
<td>Communication with the TCS</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>Communication with the Database</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.6</td>
<td>Communication with CON</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Functional Requirements: MMI</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Functional Requirements: SDSU</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Technical Requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.1</td>
<td>Software Architecture</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.2</td>
<td>Software Interfaces</td>
<td>SI/TCS/S T</td>
<td>10.2.1</td>
<td></td>
</tr>
<tr>
<td>8.4</td>
<td>Software Capabilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.4.1</td>
<td>Communication</td>
<td>SI/S T</td>
<td>10.2.1</td>
<td></td>
</tr>
<tr>
<td>8.4.2</td>
<td>Initialisation</td>
<td>SI/S T</td>
<td>10.2.2</td>
<td></td>
</tr>
<tr>
<td>8.4.3</td>
<td>Command Interpretation and Generation</td>
<td>SI/TCS/S T</td>
<td>10.2.3</td>
<td></td>
</tr>
<tr>
<td>8.4.4</td>
<td>Status Reporting</td>
<td>SI/TCS T</td>
<td>10.2.4</td>
<td></td>
</tr>
<tr>
<td>8.5</td>
<td>Operating System</td>
<td>SI D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.6</td>
<td>Resource Allocation</td>
<td>SI D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Generic Software Requirements</td>
<td>SI R</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Test Level defines the level of integration at which this particular requirement will be verified. This could be SC - Software Component (parts of this software on their own), SI - Software Item (this spec’s software on its own), TCS (this software integrated with other parts of the TCS), S - System (this software working with the whole telescope).

Note 2: Test method could be R- Review, D – demonstrate (not quantitative or precise), T – Test (most comprehensive).

10.2 Detailed Test Requirements
10.2.1 Interface Test

The interface and communication capability will be tested by the following process:
- Check that the correct communication modules are implemented (according to the ICD).
- Using the TCSS, check that communication is established with the TCS.
- Using the actual subsystems, check that data is correctly passed and interpreted.

10.2.2 Initialization

This will be verified by starting up the system and verifying that:
- All software units are communicating with each other and functioning correctly.
- All hardware is safe and in the initialisation position.
- All health checks are working.

10.2.3 Command Interpretation and Generation

All commands will be executed and shown to be working.

10.2.4 Status Reporting

All status requests will be generated and the responses checked. Timeouts will also be checked.