Southern African Large Telescope
SALTICAM
Preliminary Design Review

Document Number 3320AE0001:
Structure and Mechanisms

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Revision 1.8
3 February 2002

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1 Overview

1.1 Scope

This document describes the mechanical design rationale of the Preliminary Design for the SALTICAM Instrument in its two embodiments, namely the Acquisition/Science Instrument (ACSI) and the Verification Instrument (VI).

Note: The outstanding TBD's in this document will still be worked on between release of this document and the PDR meeting. At PDR a list of outstanding TBD's will be presented.

1.2 Introduction

The generic name Salticam encompasses two embodiments, i.e. the ACSI and the VI. Of the two, the ACSI is the instrument for long-term use and the VI will be used during the initial setup phase (and perhaps at later stages should re-checking of the telescope be required). As the cryostat/detector and shutter will be the only common sub-systems to both modes, this document will deal with the ASCI and VI as two separate instruments. The cryostat and its related details are described in Document 3370AE0001: Cryostat.

2 Acquisition/Science Instrument

2.1 Requirements

From the mechanical perspective the ACSI is required :

a. To Interface with the Prime Focus Imaging Platform that will allow:
   i. Alignment of the instrument with the optical beam (in conjunction with the fold mirror).
   ii. Coarse focusing of the instrument focal plane.

   Both these functions will be achieved via the base frame sub-system.

b. To provide barrels for the lens cells that conform to the following requirements (both for mechanical misalignment as well as flexure):
   i. Maximum decenter of any cell in the barrel: 30-50 μm (see the 3310AE0001 optical.pdf for details).

ii. Maximum tip/tilt of any cell: 0.013-0.025 degrees (see the Optical Document: 3310AE0001 optical.pdf for details).

c. To have a structure that will:
   i. Enable the camera to be easily removed and repeatedly replaced on the base structure.
   ii. Allow fine alignment of the camera to the optical beam.
   iii. Carry the barrels in such a manner that for both mechanical misalignment as well as flexure the following will not be exceeded at the attachment point:
      i. Decenter 100 μm.
      ii. Tip/tilt of the barrel 0.044 degrees.
   iv. Position the barrel reference faces relative to the focal plane to within 100 μm.
   v. Carry the cryostat at a referenced position relative to the optics in such a manner that the cryostat can be removed and replaced with repeatable positional accuracy (radially and axially).
   vi. Carry the filter/shutter module.
   vii. Carry the filter cartridge assembly.

d. To have a shutter mechanism that can:
   i. Complete an opening/closing stroke in less than 100 msec.
   ii. Minimum exposure time: 500 msec.
   iii. Maximum exposure time: 3 hours.

e. To provide for at least 8 filters of 100 mm in diameter, up to 10 mm in thickness and the following individual specifications:
   i. TBD
   ii. TBD
   iii. TBD
   iv. TBD
   v. TBD
   vi. TBD
   vii. TBD
   viii. TBD

f. To be able to focus the camera in order to compensate for:
   i. Thermal effects of the camera itself.
   ii. Relative movement between PFIS and Salticam.
   iii. Inequalities in the optical thickness of the individual filter elements.
g. Provide the volume (as specified by SAAO) for the Autoguider stage. In this case SAAO has developed the overall mechanical principle for SALTICAM Autoguiders and may be contracted by SALT to design the mechanical sub-system for the ACSI.
h. Be enclosed in a light tight container, which will provide access to the sub-system as well as the ability to change filters.
i. Provide the necessary logistics equipment to facilitate removal and installation on the telescope as well as any special tooling needed to maintain the mechanical sub-systems.

2.2 Conceptual Design

2.2.1 General

The ACSI will consist of the following sub-systems:

(A 3D model can be seen in Fig. 1)

a. Base frame.
b. Lens Barrels.
c. Structure.
d. Filter Manipulator/Shutter.
e. Filter Cartridge.
f. Focusing Unit.
g. Autoguider.
h. Cryostat.
i. Covers.

The mechanical structure is required to maintain the front barrel with a tolerance of 100 μm in decentre (from the optical document) and 0.044 degrees in tip/tilt. For the Final Design Review, it is expected that the most sensitive components of the structure for delivering this performance will be:

a. Stiffness of the vertical flanges relative to the central spar.
b. The stiffness of the front barrel/structure interface.
c. The rigidity of the interface between the structure and the base frame.
d. Flexure of the base frame.

FEM analyses will be done for the structure as well as critical areas for heat transfer.

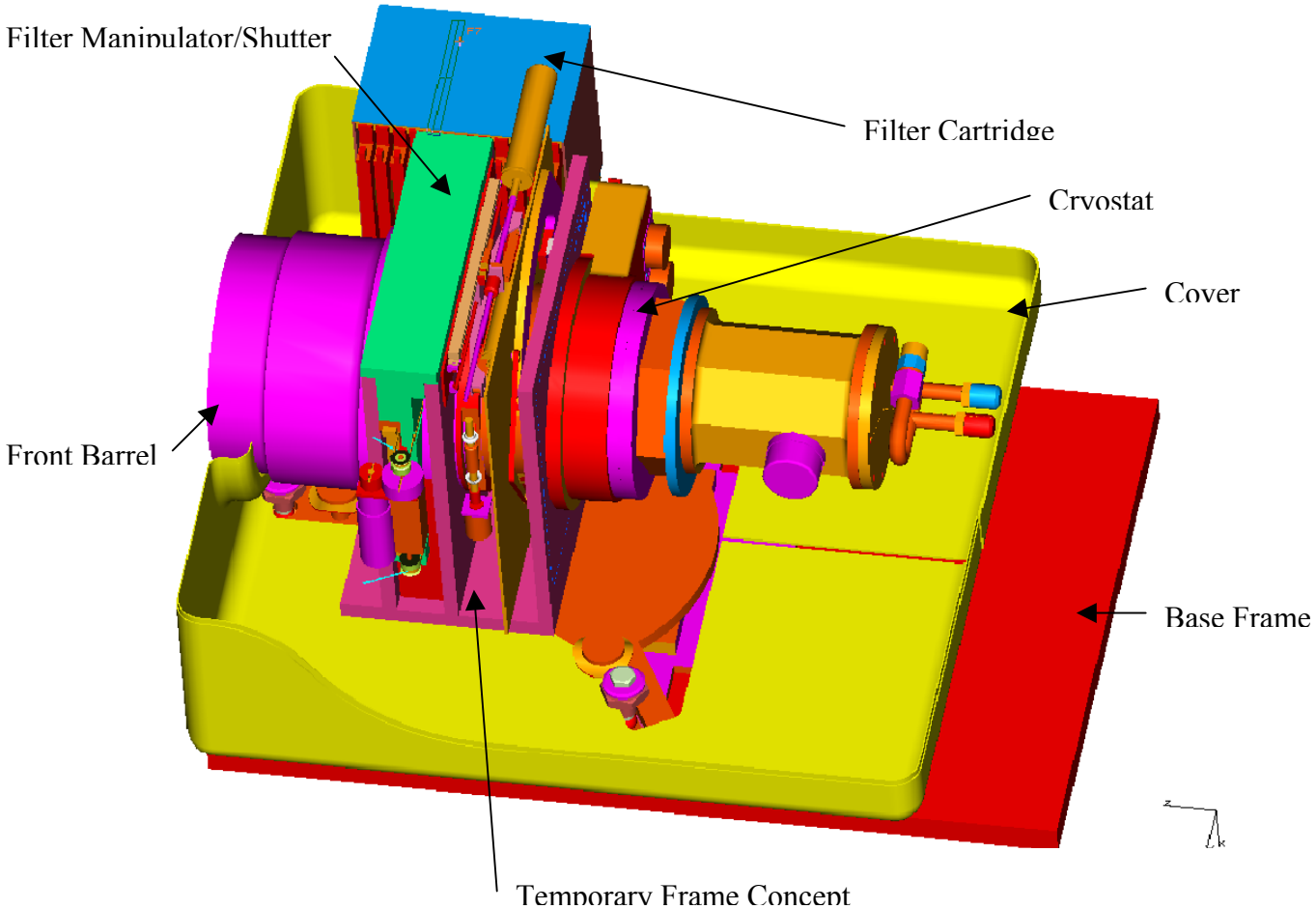


Figure 1: 3D MODEL OF THE ACSI

2.2.2 Base Frame

The base frame will be used to mount Salticam to the surface provided by SALT. In order to make the interface non-critical it is proposed to align the frame in-situ and then permanently bond the interfaces of the provided surface. Primary alignment will be achieved by adjusting both the base frame and the fold mirror. This alignment will only be necessary in a plane parallel to the mounting surface provided (Fig. 2) to a tolerance of TBD arcsec. The mounting surface provided will be such that the adjustment in the plane perpendicular to the mounting surface will be within the range of the kinematic mounts on the structure. The fold mirror however will need to be adjusted such that the optical centerline is parallel to the mounting surface (Fig. 3) and within the adjustment range of the camera structure. The primary focus will be achieved by means of a sliding interface on the base frame that can be set and permanently locked (Fig. 4). The physical design is still very much TBD.

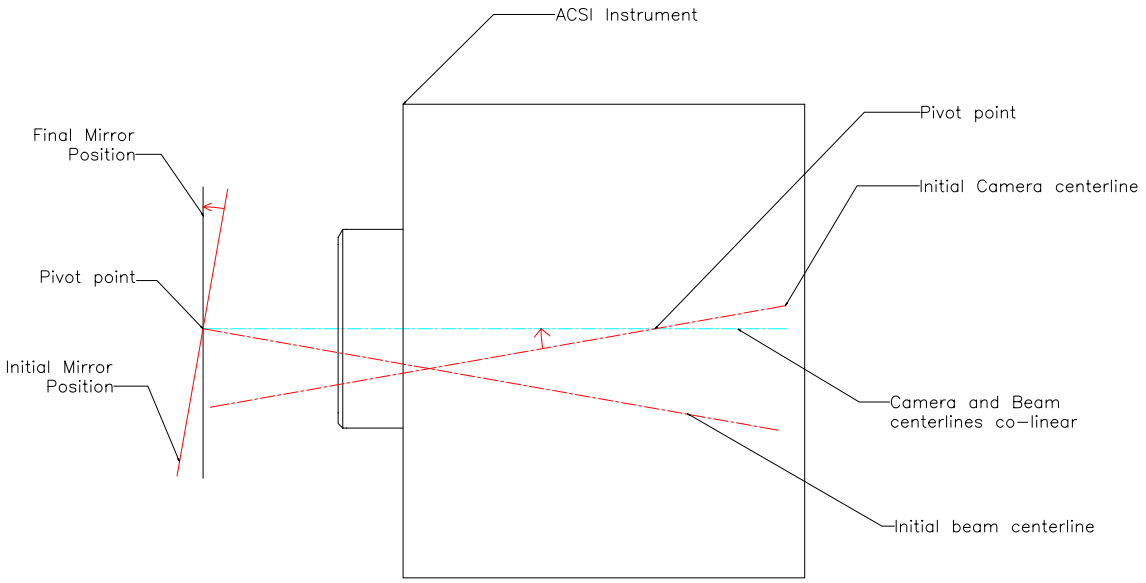


Figure 2: SCHEMATIC TOP VIEW OF ALIGNMENT // TO SURFACE

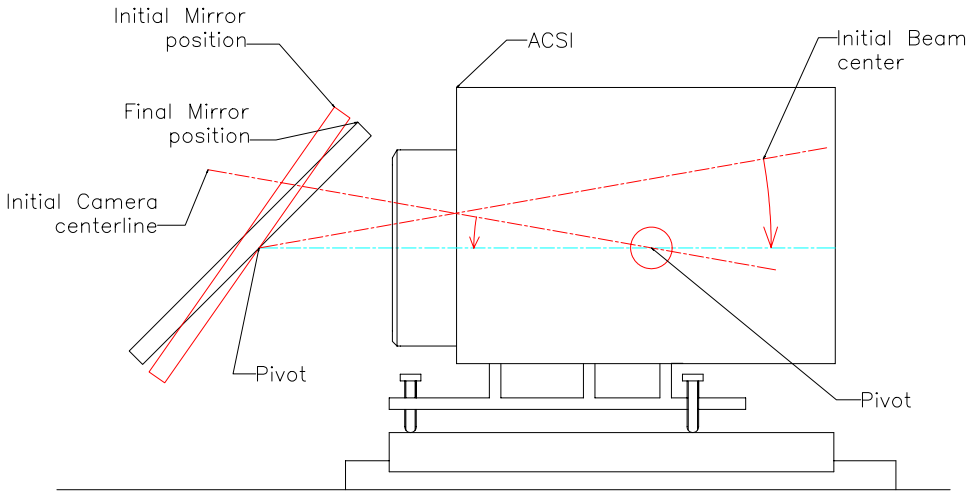


Figure 3: SCHEMATIC SIDE VIEW OF OPTICAL BEAM // TO SURFACE

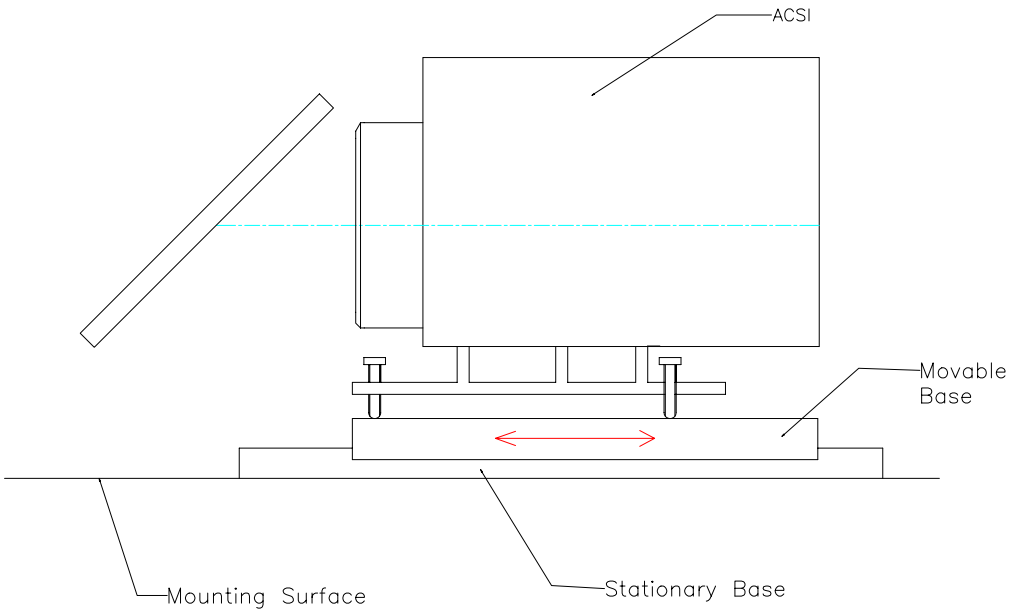


Figure 4: SCHEMATIC SIDE VIEW OF INSTRUMENT PRIMARY FOCUS SETTING

2.2.3 Lens Barrels

The design of the lens cells and the mounting of the lenses in the cells has been sub-contracted. Agreement with the contractor on the internal geometries of the barrels has been reached.

The front barrel (Fig. 5) will be mounted in a precision sliding fit with a precision spacer to ensure the position of the reference point to the focal plane within 50 μm. The exact outside geometry of the barrel will only be determined after FEM analysis of the barrel flexure, as the intrinsic design is a cantilevered tube. Machining tolerances will be within 20 μm on critical positioning interfaces.

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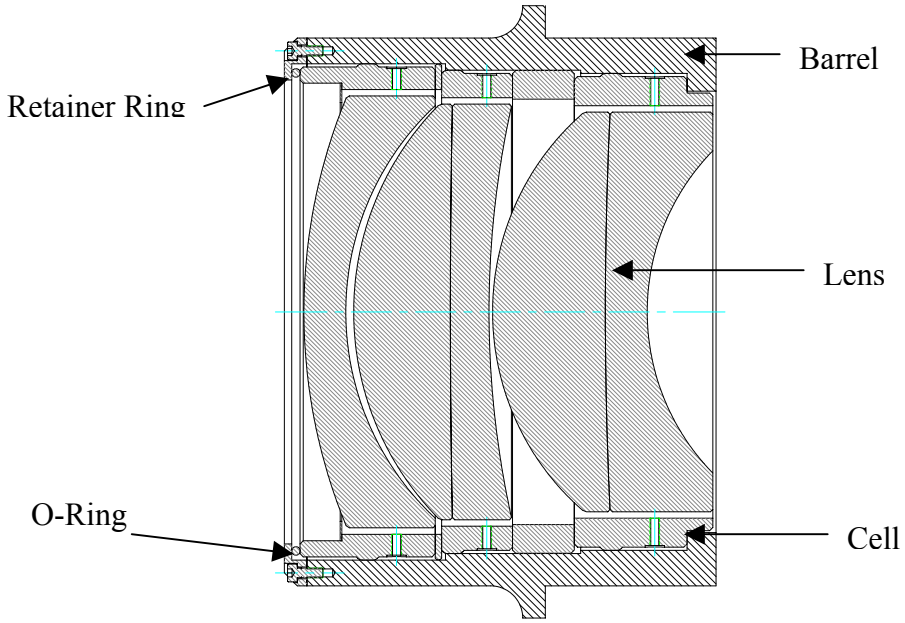


Figure 5: FRONT BARREL ASSEMBLY

The rear barrel is less sensitive to flexure as it will be supported over most of its length inside the focusing mechanism (Fig. 6). The axial positioning tolerance on the reference point of the cells is also less critical because this barrel is the focusing element of the camera.

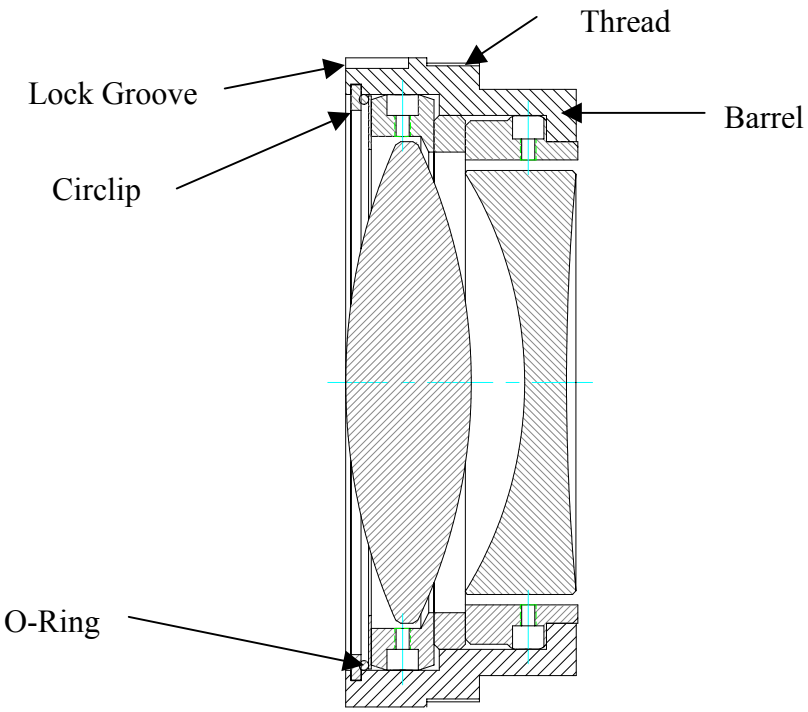


Figure 6: REAR BARREL ASSEMBLY

2.2.4 Structure

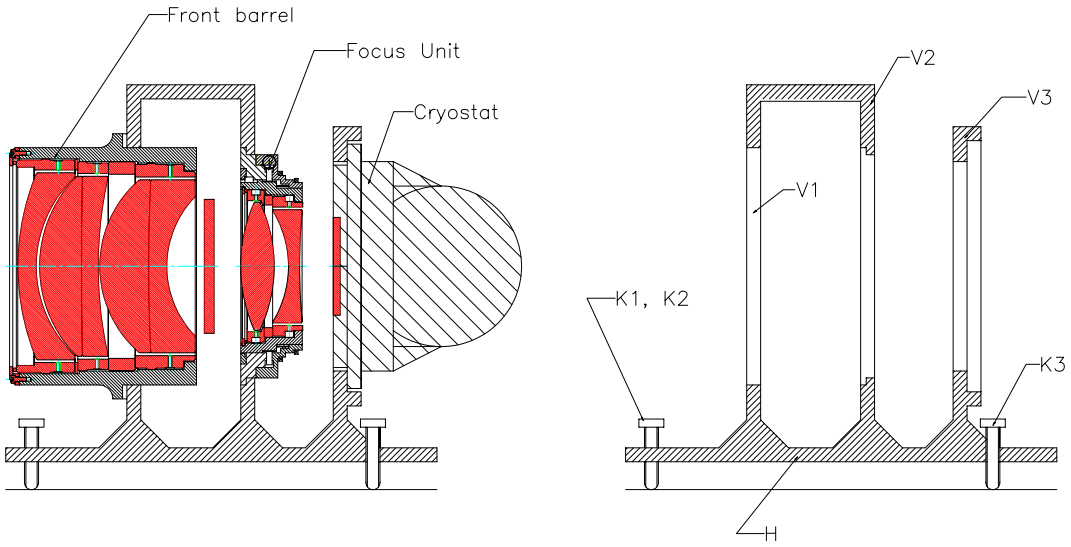


Figure 7: STRUCTURAL CONCEPT

The concept of the structure is as in Fig. 7. All the functions are shown conceptually as the final design is still very much TBD. The exact layout and geometry will only be determined once the sub-systems have been designed and sufficient FEM analyses performed.

Kinematic mountings (K1, K2, K3) will be used to align as well as tilt the camera to the optical beam in the plane perpendicular to the provided mountings surface. There is no provision on the structure for rotational alignment of the camera in the plane parallel to the mounting surface, as this will have to be achieved by the fold mirror and the base frame.

The central spar H will be designed such that it provides maximum stiffness to the structure for torsional deflection as well as bending. It will also integrate with the flanges in such a manner that the flanges do not deflect significantly.

Vertical flange V1 will be used to mount the front barrel. The mounting method will be a precision sliding fit for radial location and a precision ground spacer to achieve the correct distance to the focal plane. Fixing will be with bolts spaced radially around the pull down flange.

Vertical flange V2 will carry the focus unit. The focus unit will have the rear barrel on axis inside and the auto guider on axis to the rear and in front of V3.

The cryostat will be carried on flange V3 in such a manner that the flange will make provision for:

a. The fibers of the autoguider to rotate through 220 degrees.

b. The cryostat to be centered radially.

c. The cryostat focal plane to be referenced to the rear face of V3.

The filter/shutter module will fit in between V1 and V2.

An extension to the central spar H will serve as mounting point for the filter cartridge unit.

The enclosure assembly will be attached to the structure in such a manner that the complete camera can be removed as an integral unit.

2.2.5 Filter manipulator/Shutter module

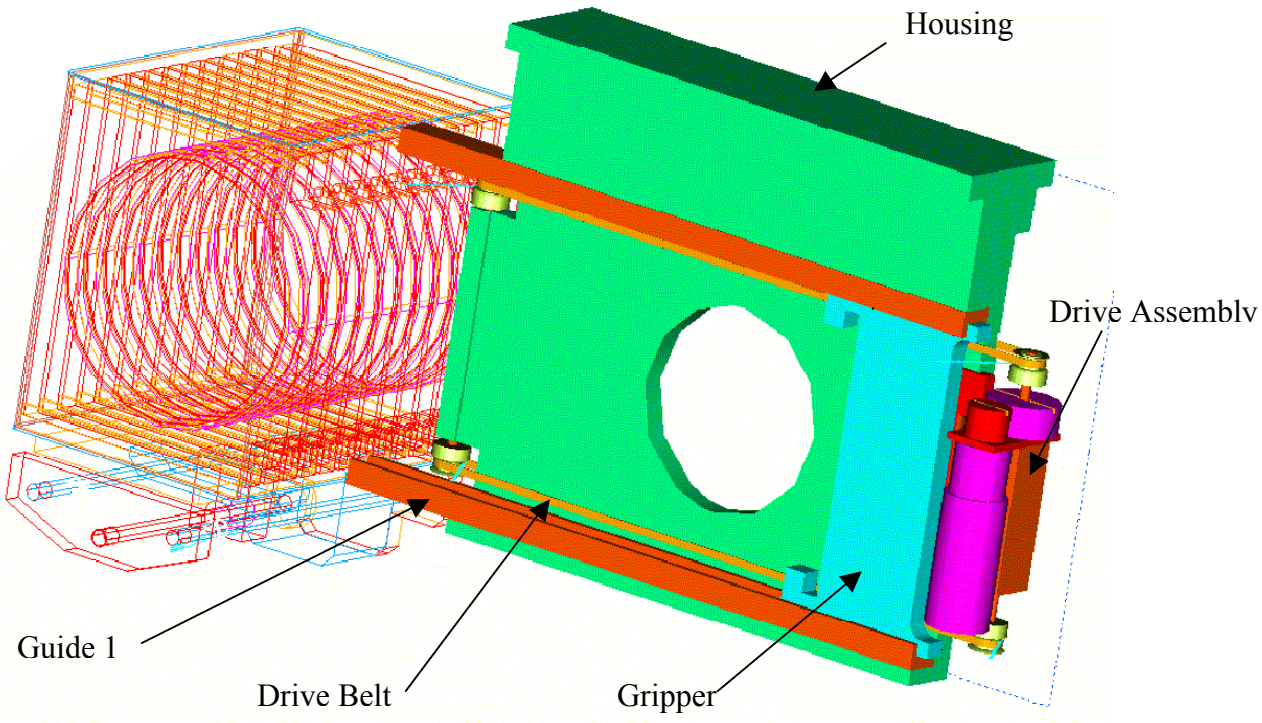


Figure 8: FILTER MANIPULATOR / SHUTTER MODULE

The shutter and the filter manipulator will be integrated into one module that will be placed between the first and second vertical flanges (V_1, V_2). This is in order to facilitate easy removal and repositioning for service or repairs (Fig. 8).

The filter manipulator will take a filter frame from the filter cartridge and pull it to the in-beam rest position. The filter will be returned after use and the cartridge assembly will then index to the next required filter after which the process will be repeated. The estimated cycle time for a filter from in-beam to in-cartridge is approximately TBD sec. The indexing should take approximately TBD sec per filter station, which gives a worst-case duration on filter change of TBD sec from command to expel the first filter of the cartridge from in-beam to in-beam location of the last filter in the cartridge.

The shutter will be a modified PRONTOR 100E (Schematic in Fig. 9). The perimeter of the housing will be modified for more space if needed. The drive mechanism has also been redesigned to reduce the heat load on the system and maintain the dimensional constraints. Two options exist at present, an over-center spring mechanism and dual latching solenoids that are linked.

The over-center mechanism consists of a lever actuated by two low profile single acting solenoids. The stroke of the solenoid will be equivalent to half the required travel of the lever. The spring will supply the force to allow the lever to complete the remainder of the travel.

For the option with linked solenoids, a direct drive mechanism is adopted as shown in the sketch. Latching solenoids employ a long-life permanent magnet that securely retains the plunger once the power is removed. Thereby allowing the actuator to travel to the maximum position by energizing the solenoid. The plunger will remain secure in this position until the opposing solenoid is energized reversing the process.

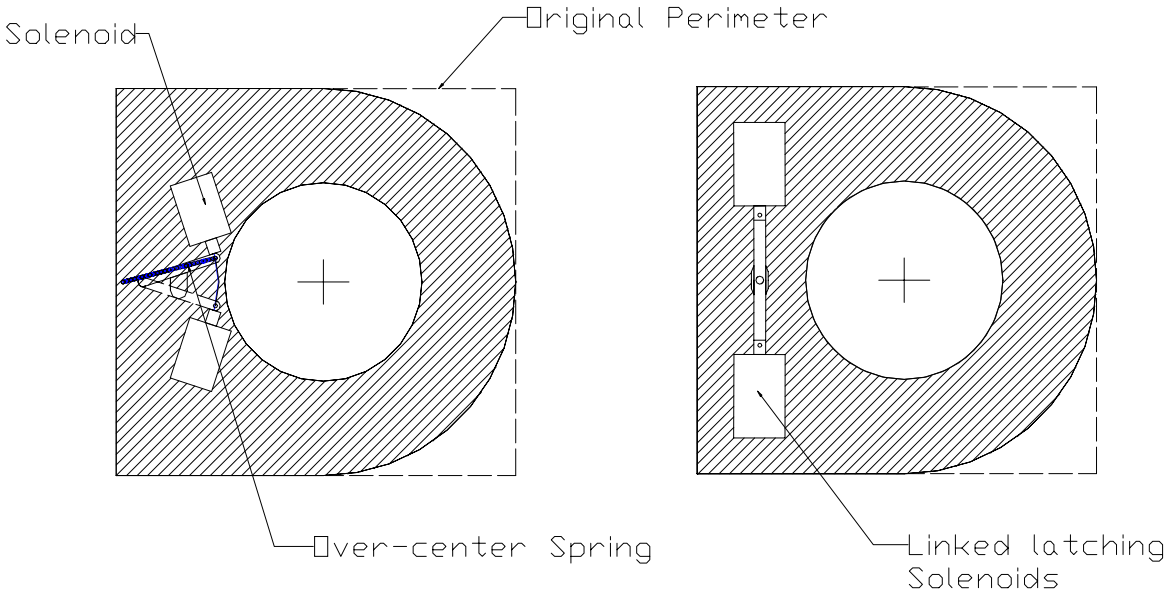


Figure 9: SCHEMATIC LAYOUT OF THE SHUTTER MODIFICATION OPTIONS

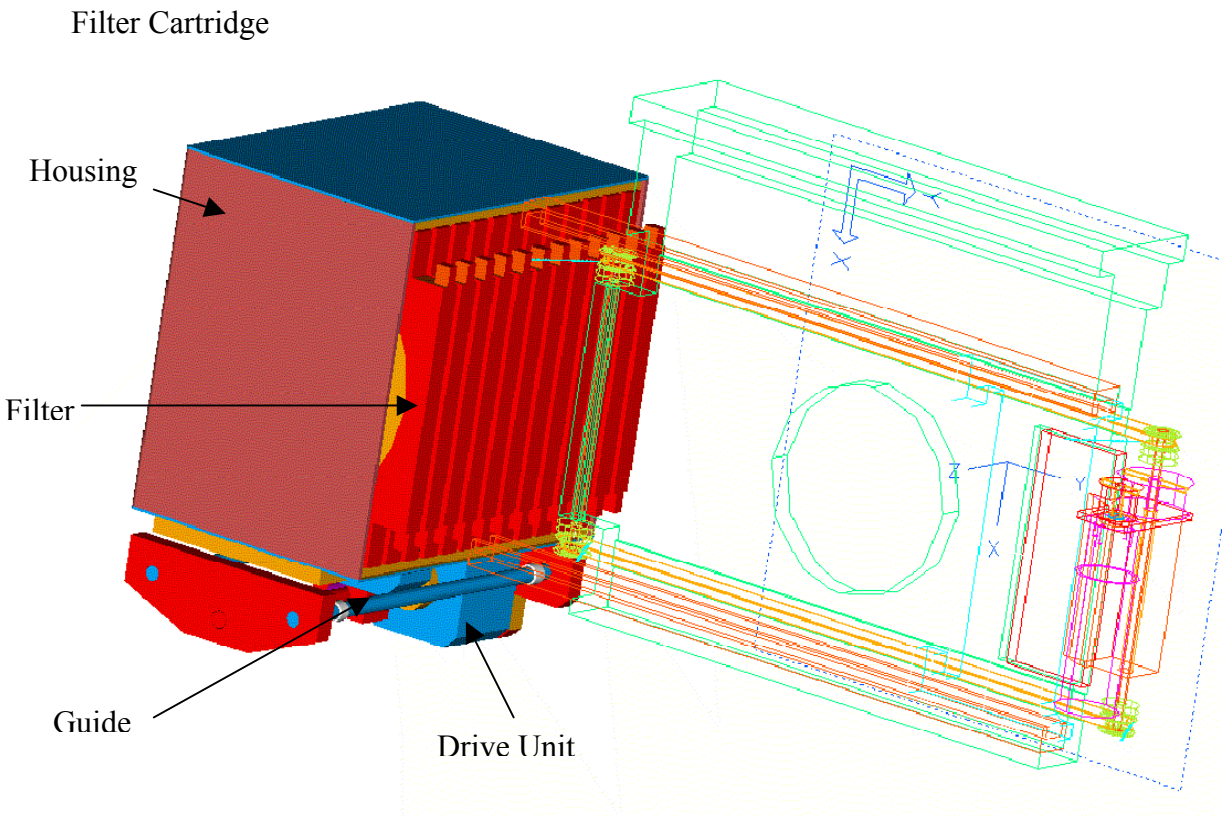


Figure 10: FILTER CARTRIDGE

The filter cartridge is designed to accommodate up to 12 filters (Fig. 10). The cartridge is moved with a linear stepper drive to indexed positions. The gripper will take the filter from the cartridge and slide it to the in-beam position. Polymer material will be used for the filter frames and the filters will most probably be bonded to the frame.

2.2.6 Focusing Unit

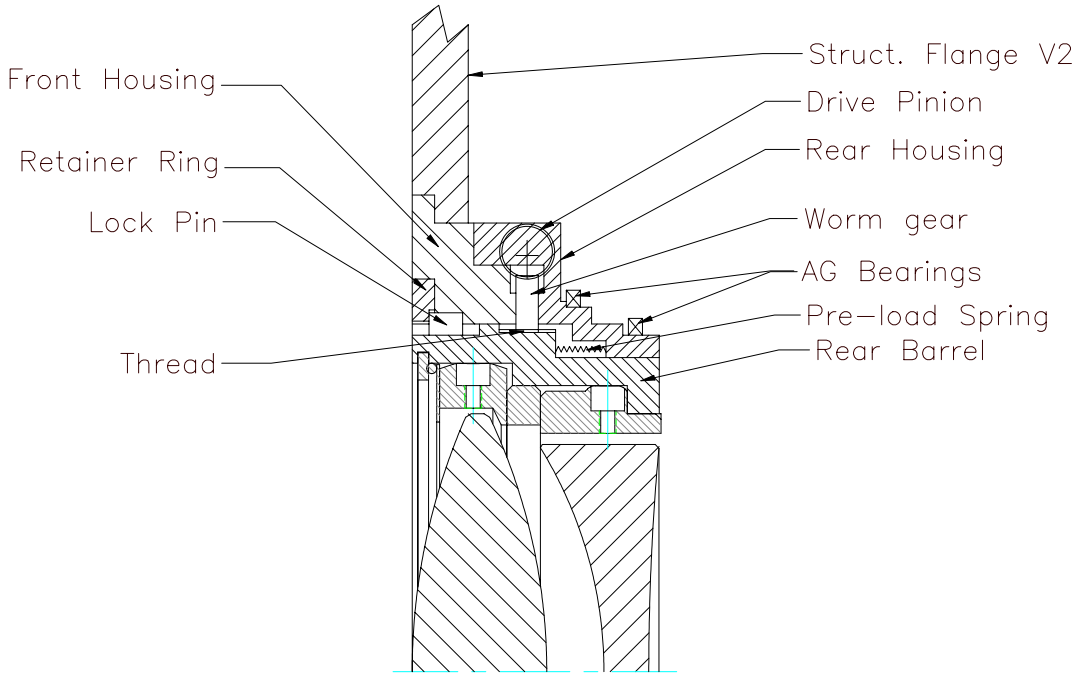
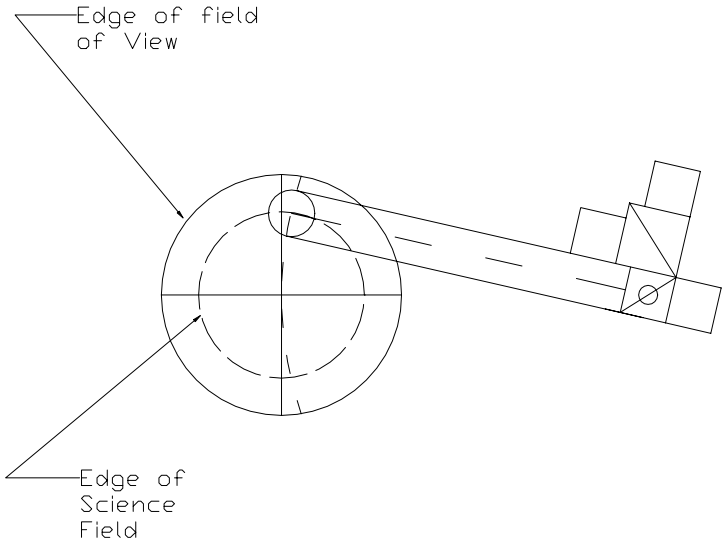


Figure 11: SCHEMATIC OF FOCUSING UNIT

A schematic cross section of the unit can be seen in Fig. 11. The rear barrel will have a thread as indicated around which a threaded worm wheel will fit. A stepper motor will drive a pinion gear to rotate the wheel. This pinion will be set for minimum (zero?) lash. The barrel is restrained from turning by 3 pins placed on the interface between the barrel and the housing. A compression spring will pre-load the thread and worm wheel to the front of the housing. The focus range will be 6 mm and the drive unit should be able to traverse this distance in approximately 20 sec with a incremental focus change of TBDμm per step



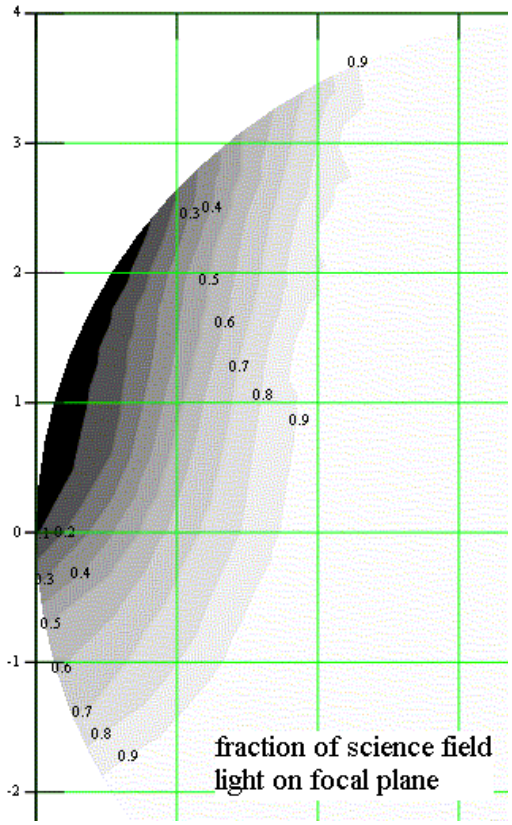
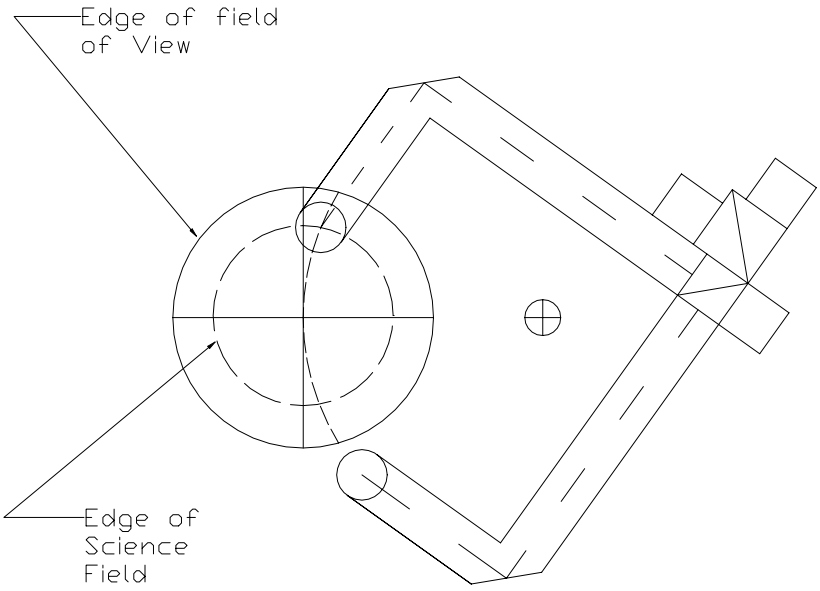


Figure 12: VIGNETTING ON SCIENCE FIELD WITH ONE PROBE



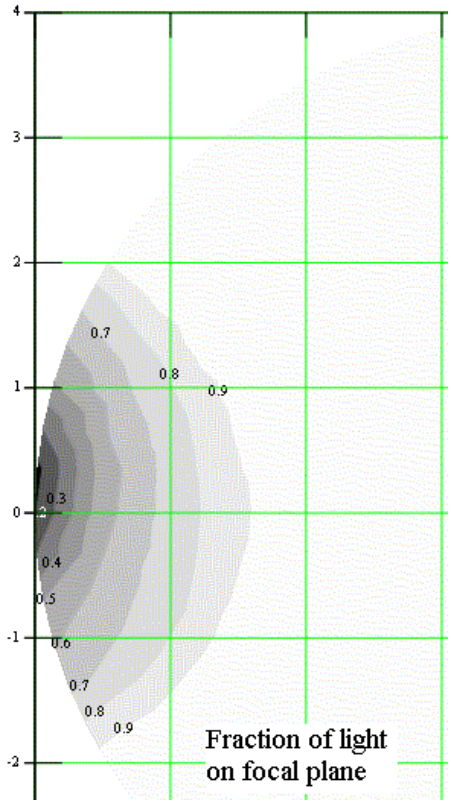


Figure 13: VIGNETTING WITH 2 PROBES

2.2.7 Autoguider

The initial concept was developed with one pick-off probe to cover the complete field of view, but the vignetting on the science field (when the pick-off is on the perimeter between the guide field and science field) was considered excessive. An analysis was done and two pick-off mirrors will be used, as the vignetting of the science field by one probe will be unacceptable (Figs. 12, 13). The beams will enter the beam-splitter at 90° to each other and then be split into three fibers, one for guidance and two for focus.

The intention is to mount the autoguider between flanges V2 and V3. The principle of operation is depicted in Fig. 14.

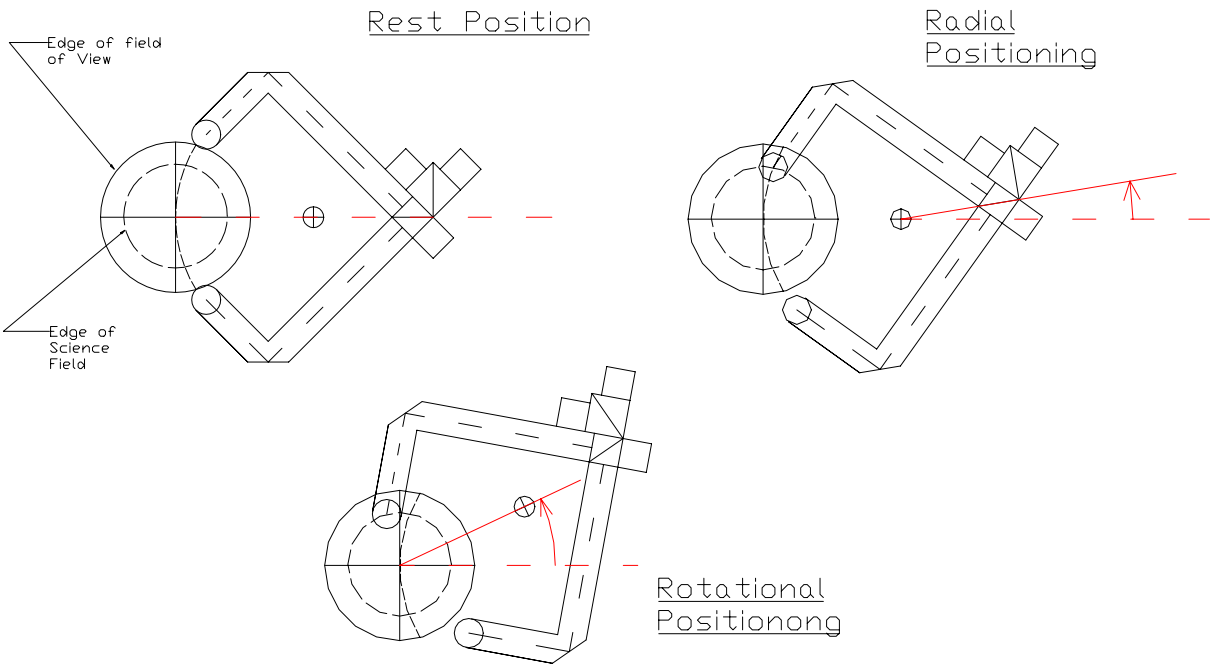


Figure 14: SCHEMATIC PRINCIPLE OF AUTOGUIDER OPERATION

As per Fig. 14 for rotational positioning the autoguider mechanics will comprise a rotary stage with rotation from –110° to +110°, which will be driven with a capstan drive and

actuated by a linear stage. This unit will control the rotational position of the pick-off mirrors.

A second rotational stage will be fitted to this unit, which will control the radial position of the pick-off mirror. This unit will rotate from – 31.5° to + 31.5° and in so doing enable both mirrors to be moved from totally outside the guide field to onto the optical centerline. This movement will be achieved by a capstan type drive along an angle sector and actuated by a linear stage.

The mode of operation would be firstly to set the radius at which the pick-off would have to rotate. Secondly the angle through which it will have to move will be determined and the assembly rotated accordingly. The Guidance Software will do the decision of which pick-off to use and the related control calculations.

It is intended to control both drives with linear encoders having a positional accuracy to 2 μm and a resolution of 0.5 μm. This will relate to the theoretical accuracy of placement on the perimeter of the guide field of 0.051 arcsec in rotational accuracy (due to tolerances in manufacturing this value will definitely increase) and TBD arcsec in radial accuracy. The incremental resolutions of adjustment will be 12.5% of the accuracy value.

An aperture will be placed just above the upper surfaces of the pick-off prisms to minimize light entering the probe not in use.

2.2.8 Cryostat

The cryostat was dealt with in 3370AE0001 cryostat.pdf. It will be located in flange V3. The locating interface will be such that it can be positioned radially and the reference to the focal plane will be the machined rear face of flange V3.

2.2.9 Covers

The covers will be designed such that the instrument will be enclosed in a light tight box. It will be attempted to put the filter cartridge unit external to the enclosure to facilitate easy removal and replacement of filters.

2.2.10 Connections

Connections of services to the instrument will have to be such that the minimum of vibrations or thermal load will be imparted.

2.2.11 Logistic Equipment

The following logistic equipment will be provided:

a. Manuals conforming to the SALT requirement.

b. Any special mechanical tooling that will be required to adjust or maintain the instrument.

c. Dedicated containers for shipping/storage of the instrument.

d. It is also foreseen that a special handling fixture will be provided for the installation/removal of the instrument.

2.3 Mass Properties

The instrument will consist of the following with the relevant masses (TBC):

Base frame	2.5 kg
Structure	4.0 kg
Front barrel (incl. optics)	7.5 kg
Rear barrel assembly	3.5 kg
Autoguider	5.0 kg
Cryostat	5.5 kg
Filter/shutter unit	3.5 kg
Filter cartridge unit	5.5 kg
Enclosure	3.0 kg
	40.0 kg

2.4 Fabrication

The fabrication will utilize as many COTS components and systems as possible. Metal components that are not COTS will be either machined from solid stock materials or from investment castings (obtained via the Rapid Prototyping route).

It is envisaged that a substantial number of components will be manufactured from polymer stock materials such as Acetal, Vesconite and PTFE. These materials will be sourced from reputable suppliers.

The enclosure will be manufactured from heat formed polymer composite, metal or a combination of said materials.

All measuring equipment will be calibrated; the necessary process equipment will be characterized and set. Sub-contractors will have to demonstrate their conformance to specifications.

2.5 Risks

The following areas of risk have been identified:

2.5.1 General

The following are perceived as general risks:

a. Changing of requirements during the development process.
b. Interfacing hardware not conforming/performing to specification.

2.5.2 Design

During the design process the following risks will have to be accounted for:

a. Inadequate specification of tolerances.
b. Specifying unrealistic tolerances.
c. Incorrect/incomplete information used as design/simulation inputs.

2.5.3 Manufacturing

For manufacturing the following risks will have to catered for:

a. Lack of proper metrology (equipment and operator performance).
b. Process capability of the equipment.
c. Time scales.

2.5.4 Assembly and Testing

During assembly and testing the following are perceived risks:

a. Damage to sensitive components.
b. Marring of critical locating interfaces.
c. Inadequate testing facilities.

2.5.5 Commissioning

The following are risks during this phase:

a. Unqualified persons trying to operate or tampering with the equipment.
b. Transport damage.

c. Handling damage.

2.5.6 Risk Management

The following types of strategies will be/are employed to mitigate the risks:

a. Potential equipment for manufacturing has been identified and process capability studies are being performed to ensure meeting of the required specifications.

b. Deficiencies in measuring capabilities have been identified and a program has been started to rectify this.

c. It is foreseen that proper storage and handling facilities will be provided to ensure the safety of the equipment.

d. Potential sub-contractors have been identified for manufacturing and metrology assistance.

3 Verification Instrument

3.1 Requirements

From a mechanical perspective the Verification Instrument (V1) is required to:

a. Interface with a mounting surface (which interface will be provided by SALT to SAAO requirements) in such a manner that the focal plane of the instrument can be adjusted and locked to be co-planar with the prime focus of the Telescope.

b. Provide a mechanism for manually changing the alignment so that the whole field of view can be observed. This mechanism will lock in discrete positions such that overlapping regions with adjacent positions exist in order for exposures to be "tiled". This method will ensure the capturing of a calibrated image of the complete field of view. A suitable space is to be provided to accommodate potential future mechanizing of the alignment system in one axis.

c. Provide a shutter mechanism of performance equal to that of the ACSI.

d. Provide a filter mechanism with at least 8 filter elements and a longest duration for putting a filter in-beam of not more than TBD seconds.

e. Provide a detector system equal to that of the ACSI.

f. Be designed such that the optical path shall be light tight once the shutter has been closed.

3.2 Conceptual Design

3.2.1 General

The VI will consist of the following sub-systems:

(A 3D model can be seen in Fig.15)

a. Detector system.

b. Alignment system.

c. Shutter,

d. Filter.

e. Structure.

For the Final Design Review it is expected that the most sensitive components for delivering this performance will be:

a. The structure onto which the VI is mounted (responsibility of SALT).

b. The stiffness of the XY-slide arrangement.

It is not foreseen that a FEM analysis will be done or the XY-slides.

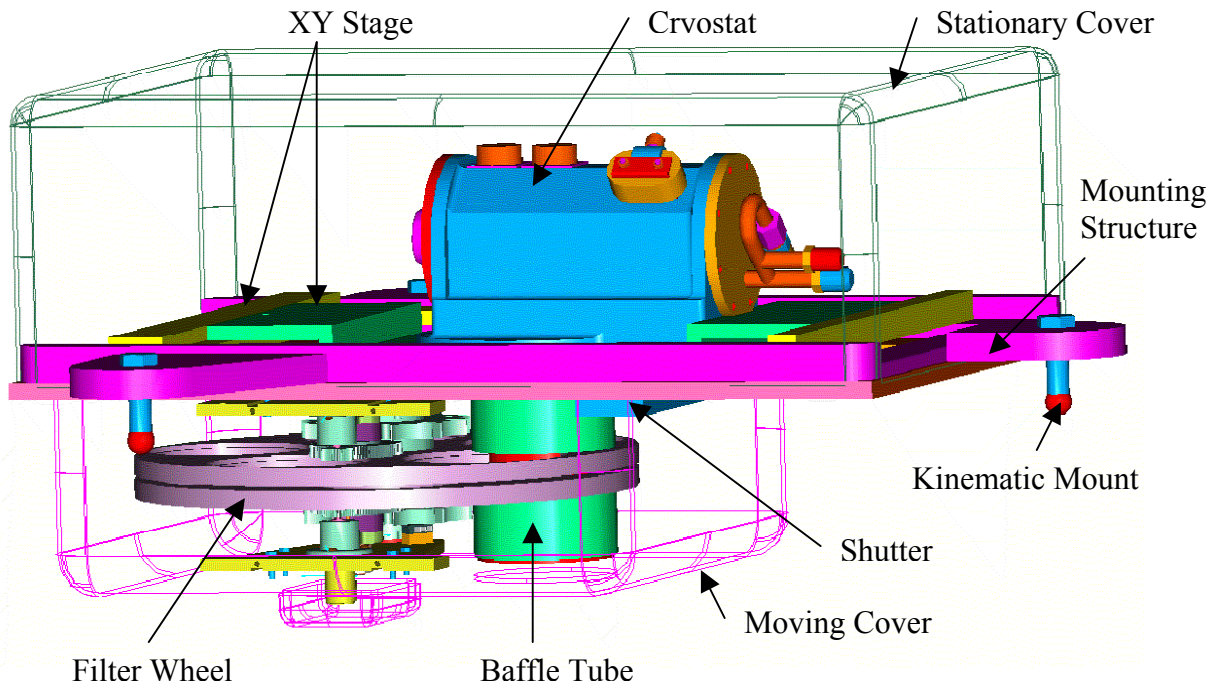


Figure 15: 3D MODEL OF VERIFICATION INSTRUMENT

3.2.2 Detector System

The complete cryostat as used in the ACSI will be used for the VI. The description of the of it can be found in Document: 3370AE0001 cryostat.pdf

3.2.3 Alignment System

It is envisaged that a sliding XY stage with dowel pin or V-groove locks will be used for a matrix of 3x3 locking positions. These 9 positions will ensure that the total field of view can be covered. Adjustment will be manual by removing the securing stop(s) and shifting to the required position. This system will be manually adjusted (and locked in position) for tip, tilt and axial displacement initial setting of the instrument parallel to the

mounting interface and at the correct stand off. The intended mechanism can be seen in Fig. 16.

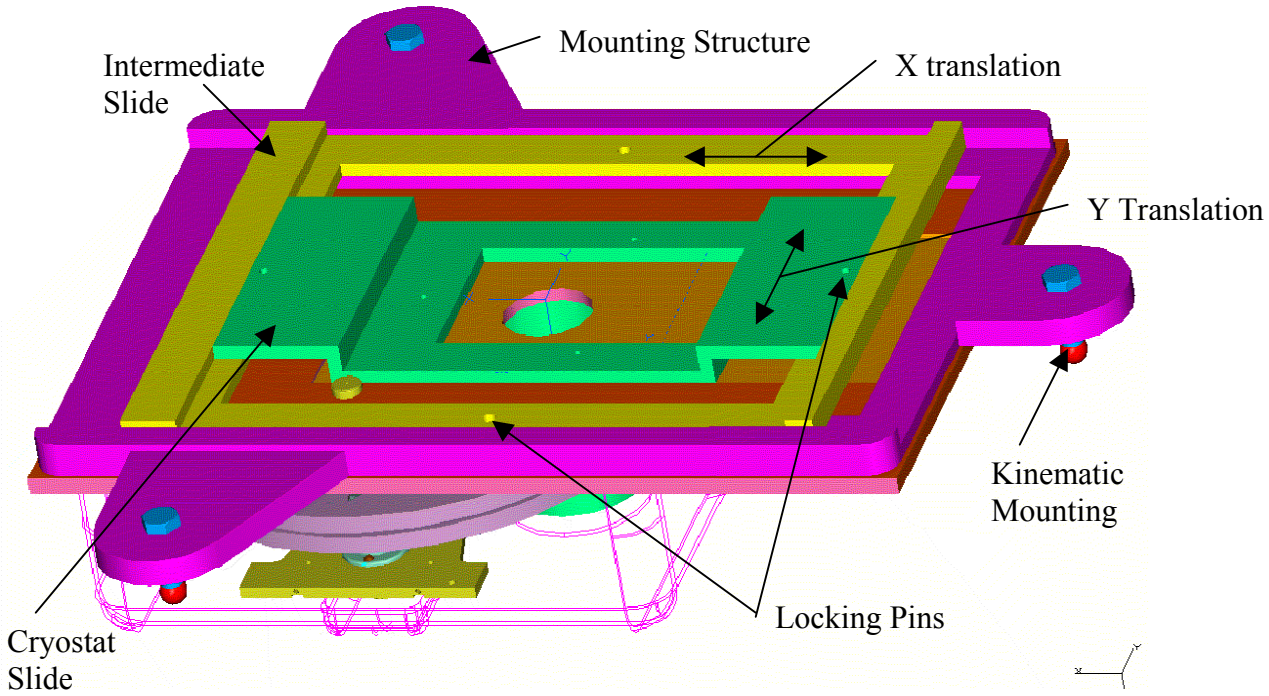


Figure 16: XY ALIGNMENT SYSTEM

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3.2.4 Shutter Unit

It is intended to use the shutter of the ACSI as is and attaching it to the front end of the light tight portion of the instrument. Fig. 17 illustrates the shutter in position.

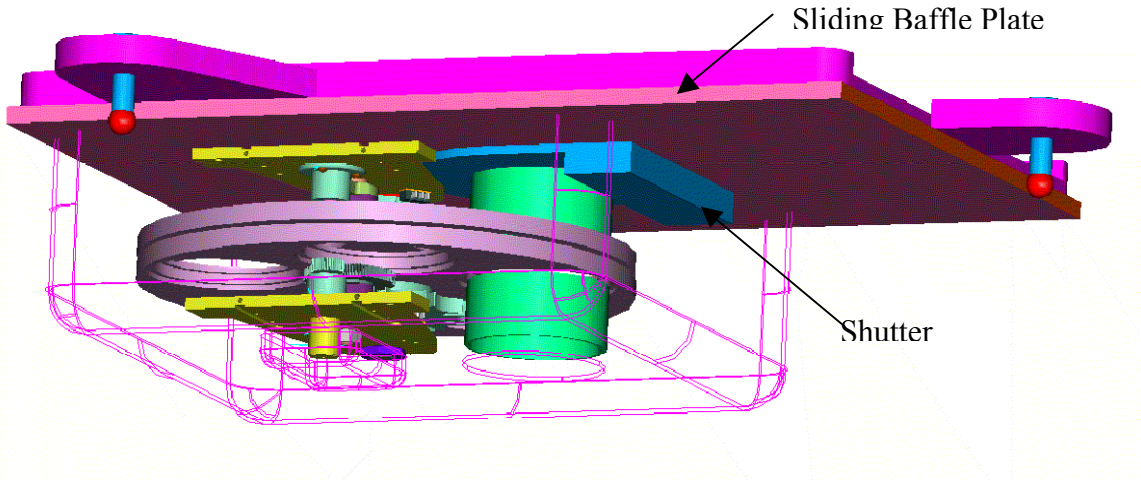


Figure 17: SHUTTER POSITION

3.2.5 Filter Unit

Two filter wheels will be used, each with 4 filters and a clear aperture. Suitable baffle tubes will be placed inside the instrument to minimize stray light.

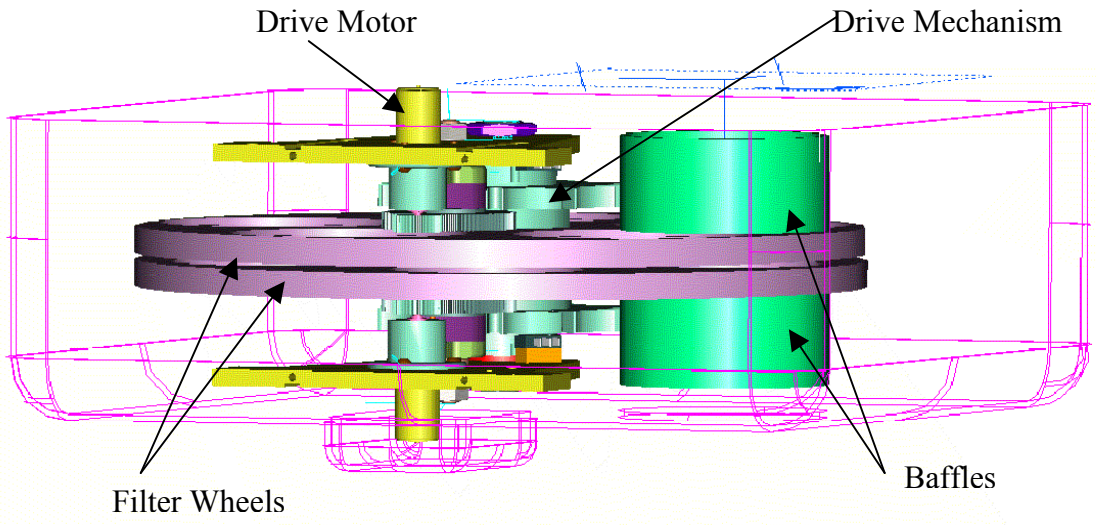
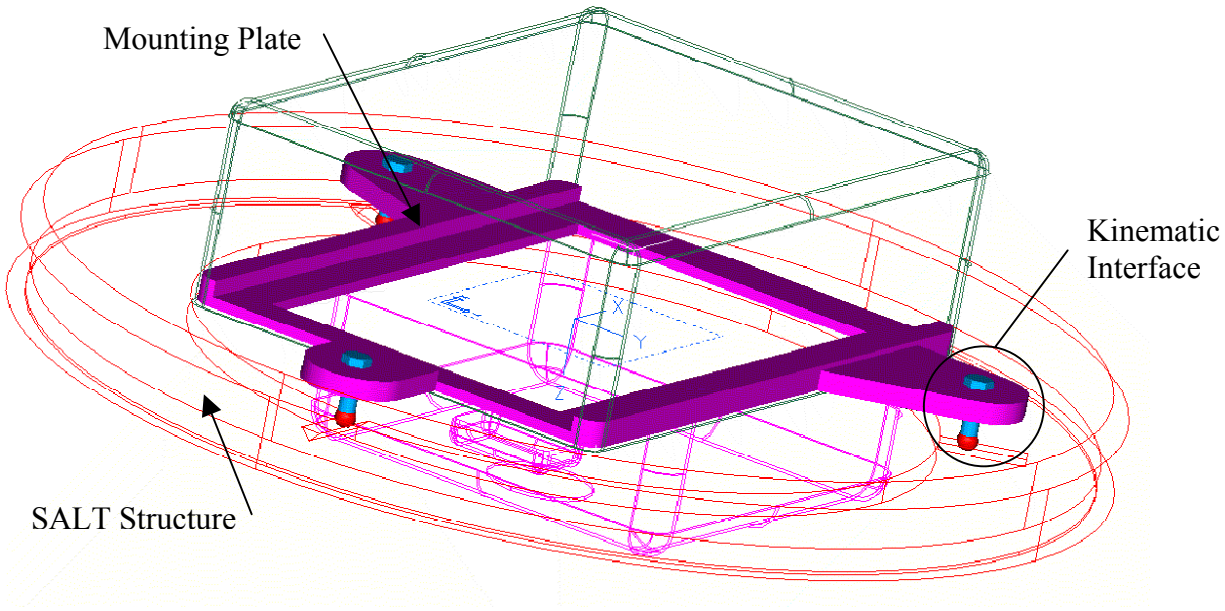


Figure 18: FILTER UNIT

3.2.6 Structure

The mounting plate of the VI will interface with the points provided on the structure and be restrained by spring loaded couplings. The plate will be adjusted for tip/tilt and Z-axis position relative to the mounting plane after which it will be locked. A top cover will be provided to mount onto the mounting plate and a bottom cover that will mount onto the sliding baffle.



3.2.7 Logistic support

Any special tooling will be provided if necessary. A dedicated transport/storage container is not foreseen, but a transport/handling frame will be provided.

3.3 Mass Properties

Detector system:	5.5 kg
Alignment system:	16.5 kg
Shutter unit	0.6 kg
Filter unit	6.8 kg
Structure	25 kg
Total	51 kg

3.4 Fabrication

The design will attempt to utilize as many systems, sub-systems and components from the ACSI as logically feasible. COTS elements will be used where possible. In the light of this instrument being for temporary use the structural components will most probably be manufactured from stock material.

All materials will be sourced from reputable suppliers.

All measuring equipment will be calibrated; the necessary process equipment will be characterized and set. Sub-contractors will have to demonstrate their conformance to specification.

3.5 Risks

The risks identified for this instrument are the same as for the ACSI with the following additions:

a. The extended use of the VI (beyond the scheduled completion) will jeopardize the scheduled delivery date of the ACSI.

b. Damage to the items common to both instruments will delay the delivery date of the ACSI.

c. It should be noted that this instrument is on the critical path of the SALT commissioning schedule and all efforts will be made to stay on schedule. Amongst these will be the maximizing of the scheduling of final design and manufacture to occur in parallel.