Southern African Large Telescope
SALTICAM
Preliminary Design Review

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Cryostat

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Table of Contents

1 Scope 3
2 Overview 3
3 Requirements 3
3.1 Mosaicing 3
3.2 Frame Transfer Mask 4
3.3 Thermal 4
3.4 Vacuum 4
4 Conceptual Design 5
4.1 Structure 5
4.2 Window and Clamp 8
4.3 Thermal Control System 8
4.4 Detector Assembly 11
4.5 Detector Interface 13
4.6 Frame Transfer Mask 14
4.7 Vacuum System 15
4.8 Electrical Connections 15
5 Mass Properties 15
6 Fabrication 16
6.1 Components 16
6.2 COTS items 16
6.3 Cryostat body 16
6.4 Surface finishes 16
7 Risks 17
7.1 Mosaicing 17
7.2 Thermal 17
7.3 Vacuum 17
7.4 Mechanical damage 17
7.5 Risk Management 17

1 Scope

This document describes the mechanical design rationale of the Preliminary Design for the Cryostat as required for the SALTICAM Instrument.

Note: The 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.

2 Overview

In this instrument the Cryostat has multiple functions such as housing the detector module in a suitable environment as well as housing the Frame Transfer Mask mechanism. This document will primarily deal with the functions pertaining to the housing of the detector package and its related requirements. The cryostat forms part of the mechanical sub-system of the two instrument variants and will be mentioned as such in Document 3320AE0001: Structure and Mechanisms.

3 Requirements

3.1 Mosaicing

3.1.1 Requirements

The individual CCD's have the following specifications on the focal plane:

Surface undulation 10μm Peak to valley.

The Optical Alignment requirements are as follows:

Tip/tilt of average focal plane: 20 μm of one edge compared to the other.

Deviation in focal plane orientation between CCD's: 1 arcmin.

Alignment of pixel columns and rows: TBD.

3.1.2 Options

There is one of 2 options available for the execution of the mosaicing, i.e. SAAO in-house (with equipment still under development) or Marconi on sub contract. The decision on mosaicing of CCD's for SALT instrumentation will have to bear in mind that

removal and re-installation will have to be done during the life-cycle of the telescope and its instruments.

a. SAAO in-house:
This method would be preferable provided that suitable equipment can be developed and qualified in time.

b. Marconi:
There is a possibility of having the mosaicing done by the supplier. But there are some reservations about the equipment and level of attainable accuracy.

3.2 Frame Transfer Mask

The specifications for the mechanism are as follows:

Minimal penumbral region.

Three modes of operation:

i. Slot mode.

ii. Obscuration of half the detector.

iii. Full frame exposure (rest position).

Cycle time to place in-beam (slot mode): less than 60 sec.

Slot width: 1 mm.

3.3 Thermal

The temperature requirements of the CCD's are as follows:

Control temperature:	160 K
Peak to valley fluctuation:	better than 0.5 K
Cool down time:	better than 4.5 hours

3.4 Vacuum

The vacuum in the cryostat will have to be maintained to better than 10^{-4} Pa.

4 Conceptual Design

4.1 Structure

The structure of the cryostat consists of 2 main parts, i.e. the front plate and the main body.

4.1.1 Front plate

The front plate (Fig. 1) has the functions of:

a. Carrying and constraining the window in place.

b. Serving as mounting base for the detector assembly.

c. Carrying the Frame Transfer Mask assembly.

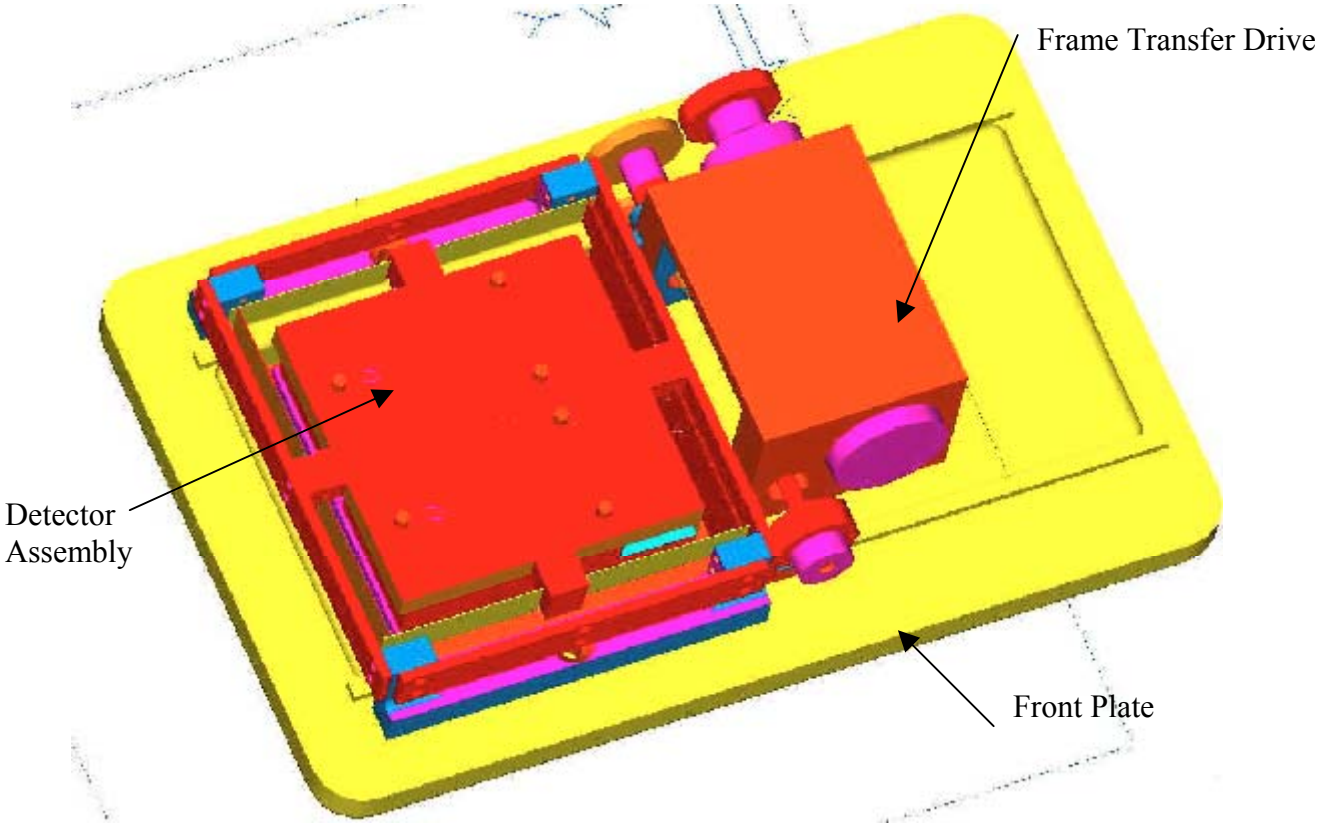


Figure 1: COMPLETE FRONT PLATE ASSEMBLY

The window is recessed into the front plate, rests on a sealing ring that will compress under vacuum and is restrained by a clamp. The detector assembly bolts onto the front plate in such a manner that the rear face of the plate serves as the reference face of the focal plane. The rear face of the plate will mount to the front face of the cryostat body, which said face will in turn reference to the Salticam main structure.

The frame transfer mask and drive assembly is bolted to the front plate as well.

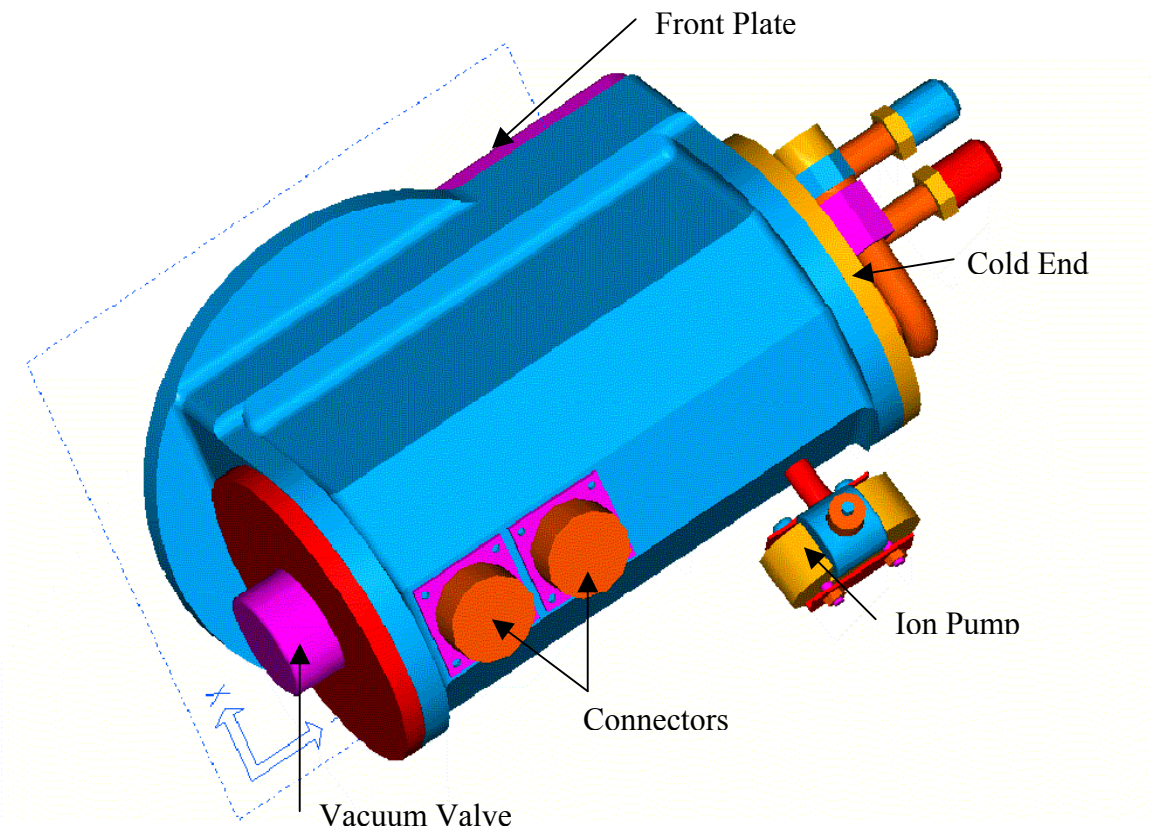


Figure 2: CRYOSTAT WITH TRANSVERSE COLD END

4.1.2 Main body

There are 2 possible concepts for the main body:

a. One with the cold end installed transversely to the optical centerline (Fig. 2). This will be the preferred concept provided that the complete Autoguider unit can be made to fit between the rear end barrel and the cryostat window and not attach to the cryostat. This is preferred, as it will allow the cryostat to be

removed for maintenance without disturbing the autoguider and also has better volumetric efficiency.

b. A concept where the cold end is installed with its centerline parallel to the optical centerline (Fig. 3). This will provide the ability to carry the rotating stage of the Autoguider on the cryostat body. This method will only be investigated if it proves impossible to mount the complete Autoguider up front.

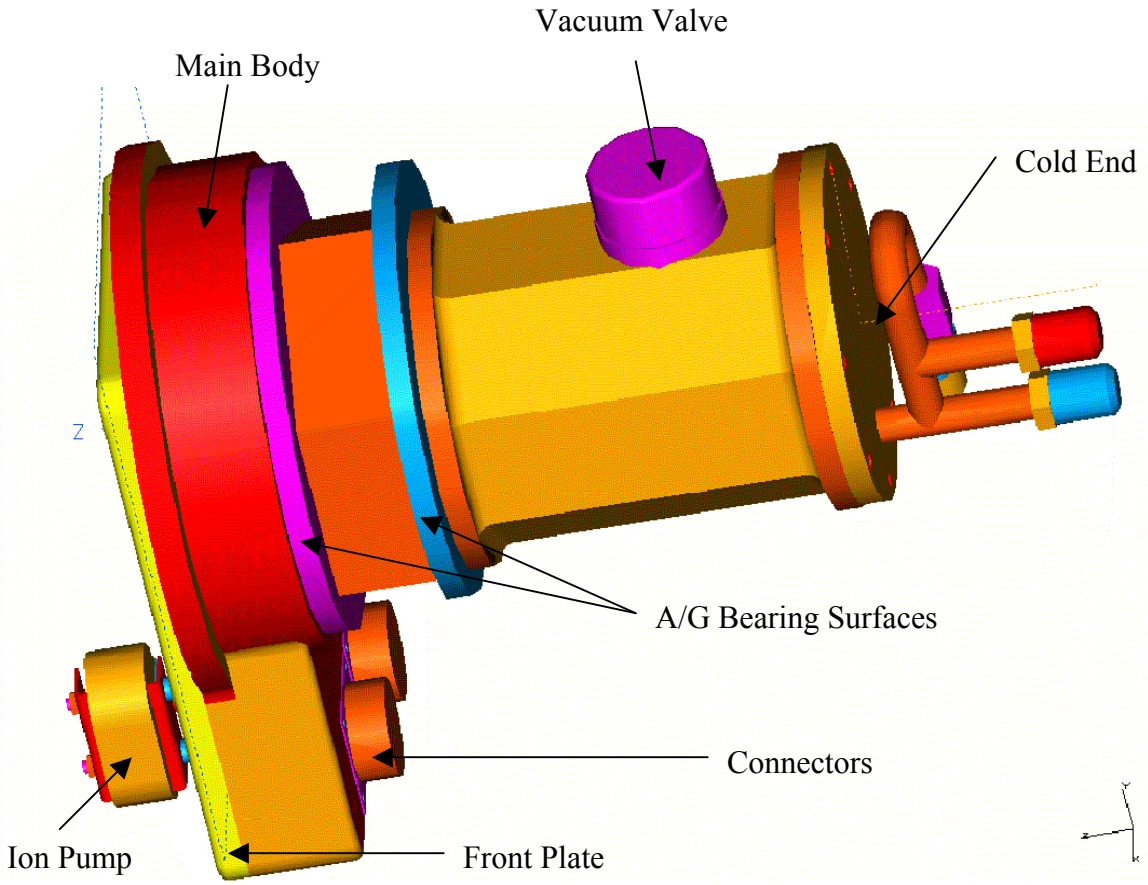


Figure 3: CRYOSTAT WITH INLINE COLD END

The main body has the functions of:

a. Referencing the front pate (and hence the focal plane) to the structure.

b. Providing space for the detector package.

c. Providing space for the frame transfer mask.

d. Carrying the cold end.

e. Mounting of the connectors, cryopump and vacuum detector.

f. If required carrying the rotating stage of the Autoguider.

4.2 Window and Clamp

The window is of fused silica and nominally 5 mm thick. The edges are profiled such that one side will constrain the sealing o-ring and the other end provides a recess for the lens clamp to partially pull the window down. This clamp will ensure no leakage into the cryostat under no or low vacuum conditions. The window clamp is nominally 2.5 mm thick and recessed into the front plate (Fig. 4). It is also envisaged that the inside surface of the window, except for the clear aperture, will be coated with material that will minimize radiation. In order to prevent the front surface from frosting up a dry air flow or a heater pad is under investigation. A further option under investigation is the bonding of a smaller window into the front plate with thermally conductive adhesive.

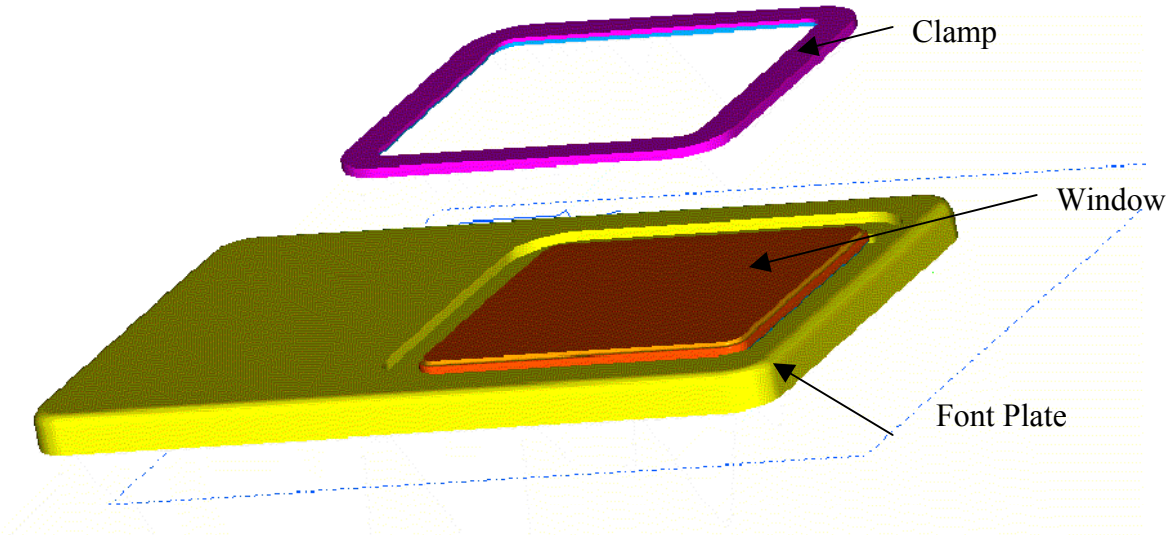


Figure 4: WINDOW CLAMP

4.3 Thermal Control System

In the past with liquid nitrogen dewars the thermal management was done on a basis of enough cooling capacity, trimming of the cold path to match the required characteristics and a good dollop of sound experience. To be able to calculate the required cooling capacity it will be necessary to characterize the following heat sources:

- Generated by the chip.

- Radiated from the front face and window onto the chip surface.
- Radiated onto the rest of the cold assembly.
- Conducted in via the electrical connectors.
- Conducted in via the mechanical mountings.

4.3.1 Worst Case

Presently the heat load onto the detector assembly is estimated as follows:

Radiation from walls: TBD

Radiation from window: TBD

Conductance through mechanical connectors: TBD

Conductance through connector wires:

Copper wires: TBD

Manganin wires: TBD

NOTE:

1. The radiation calculations will be made with no shielding and average emissivities (no biasing for radiation at specific spectral range).
2. The contact resistance of the wire connectors taken as non-existent (worst case).

Based upon these calculations it can be assumed that the maximum cooling load will be TBD watt and would point to the TBD gas blend of the Cryotiger. Areas still to be investigated are the possible modulation of the cooler pump and the possibility of running two cold ends off one pump.

4.3.2 Optimised version

The optimized version will employ the following measures to reduce heat loads:

- Heat shield around detector assembly.
- Surface coatings to reduce radiation.
- Possibly a cold saddle to remove heat influx via the electrical wiring.

For the optimized version the heat influx was calculated as follows:

Radiation from window: TBD

Radiation from walls: TBD

Conductance through mechanical elements: TBD

Conductance through electrical wiring: TBD

The cold saddle on the electrical wiring will not reduce the required cooling capacity, but will decrease the heatflow into the CCD's.

The cold path will consist of the following elements:

a. Heater elements.

b. Temperature sensors.

c. Thermal manifold.

d. Cold braid.

e. Junction.

f. Cold end.

g. Trap.

h. Compressor/heat exchanger.

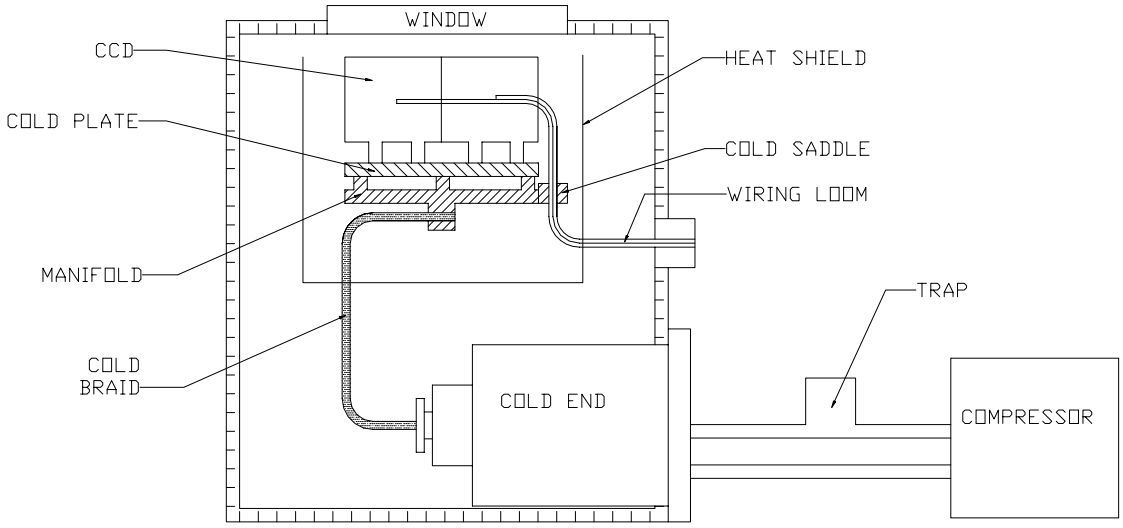


Figure 5: SCHEMATIC OF THERMAL SYSTEM

The thermal manifold will be designed such that an even temperature distribution through the CCD Invar package can be ensured. This will be achieved through either contacting on the cold plate or directly onto the underside of the package in appropriate places. Heater elements and temperature sensors will be attached to the manifold such that a temperature fluctuation of less than 0.5 K can be achieved. A cold braid will lead from the manifold to the junction that is attached to the cold end. The arrangement will be such that it will facilitate trimming the heat flow to an acceptable level as well as easy connection/ disconnection upon assembly/disassembly of the cryostat. The dividing of the flow between PFIS and Salticam needs investigating as well as the possible modulation of the cooling capacity via an inverter drive on the compressor (System Schematic in Fig. 5).

4.4 Detector Assembly

The assembly consists of the following:

2 x CCD's

1 x cold plate

4 x G10 flexures

2 x invar pedestals

1 x heat shield set

Fasteners and clamp plates

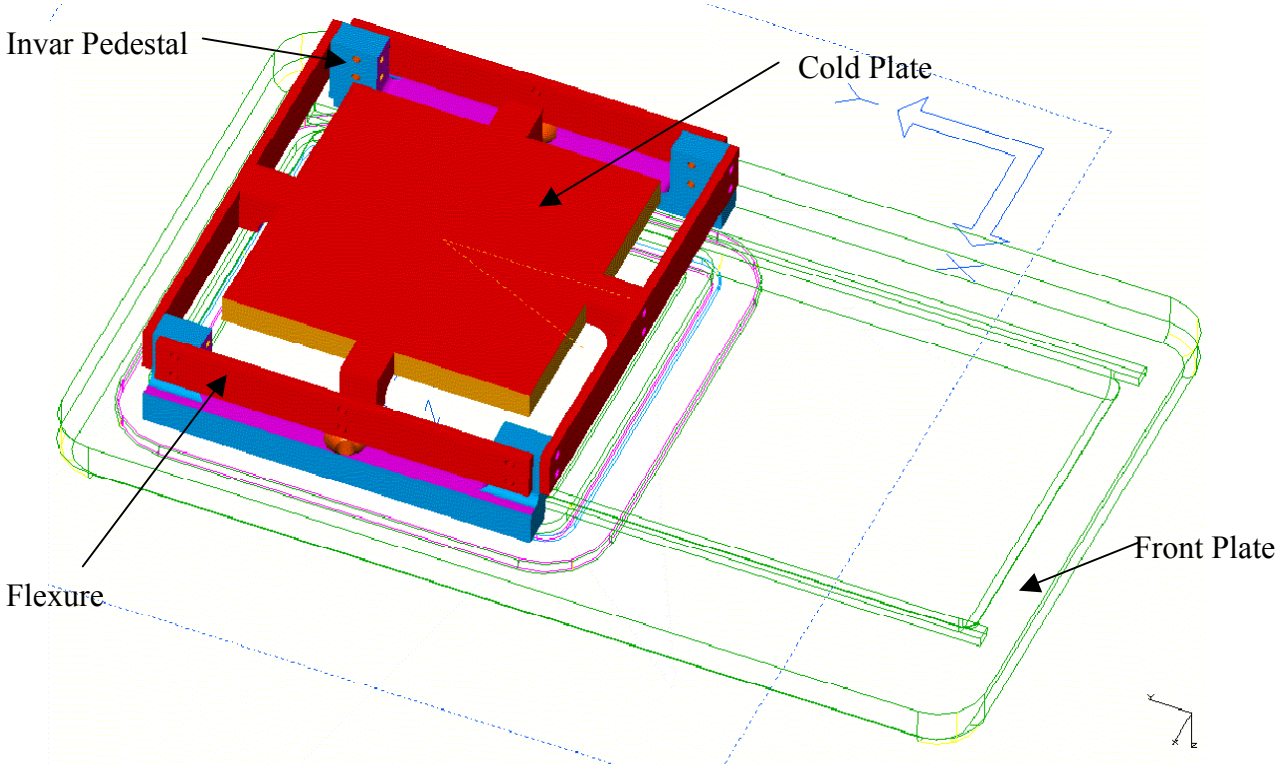


Figure 6: FLEXURE MOUNTING OF COLD PLATE TO PEDESTALS

Four G10 flexures will carry the CCD/cold plate assembly (Fig. 6). This material has good flex as well as thermal properties. The invar pedestals will ensure negligible movement of the focal plane relative to the reference plane. A set of thermal shields suitably coated for minimum radiation will encapsulate the assembly except for the focal plane and where the cold plate attachment points protrude through.

4.4.1 Mounting Method

a. The CCD's will be mounted on an Invar cold plate 6 mm thick. It is envisaged that the standard Marconi method of attachment and alignment be used.

b. The focal planes of the CCD's will be aligned to a dedicated bolt on bracket to give the zero reference for the planes. This bracket will then be utilized to mount the detector assembly to the front plate of the cryostat. This said face of the front plate will then also serve as the zero reference of the focal planes to the cryostat (Fig. 7). This method removes any dimensional criticality from the cold plate (except for flatness).

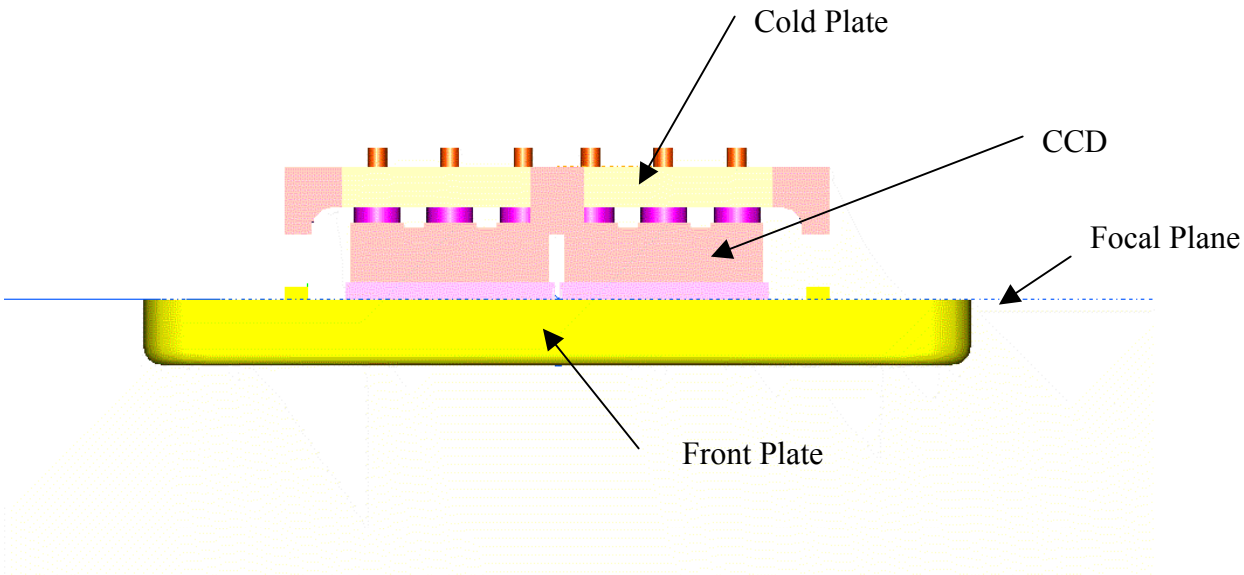


Figure 7: CO-PLANARITY OF FOCAL PLANE AND REAR OF FRONT PLATE

4.5 Detector Interface

The interior face of the front plate will be used as the mounting and reference plane of the detector package. The cold plate/CCD assembly will be attached to the inner mounting pedestals with G10 flexures. The method of assembly will be as follows:

a. The two invar pedestals will be bolted to the front plate.

b. The cold plate assembly (with the gauging bracket in place) will be clamped in position with the guide rods.

c. Once it is established that the detector assembly is in the correct location, the G10 flexures will be attached and tightened.

d. After checking the installation the gauge bracket and guide rods will be removed.

e. Following this the electrical connections will be made and the front plate screwed down in position.

f. Once the front plate is in position the cold path will be connected through an aperture in the body of the cryostat.

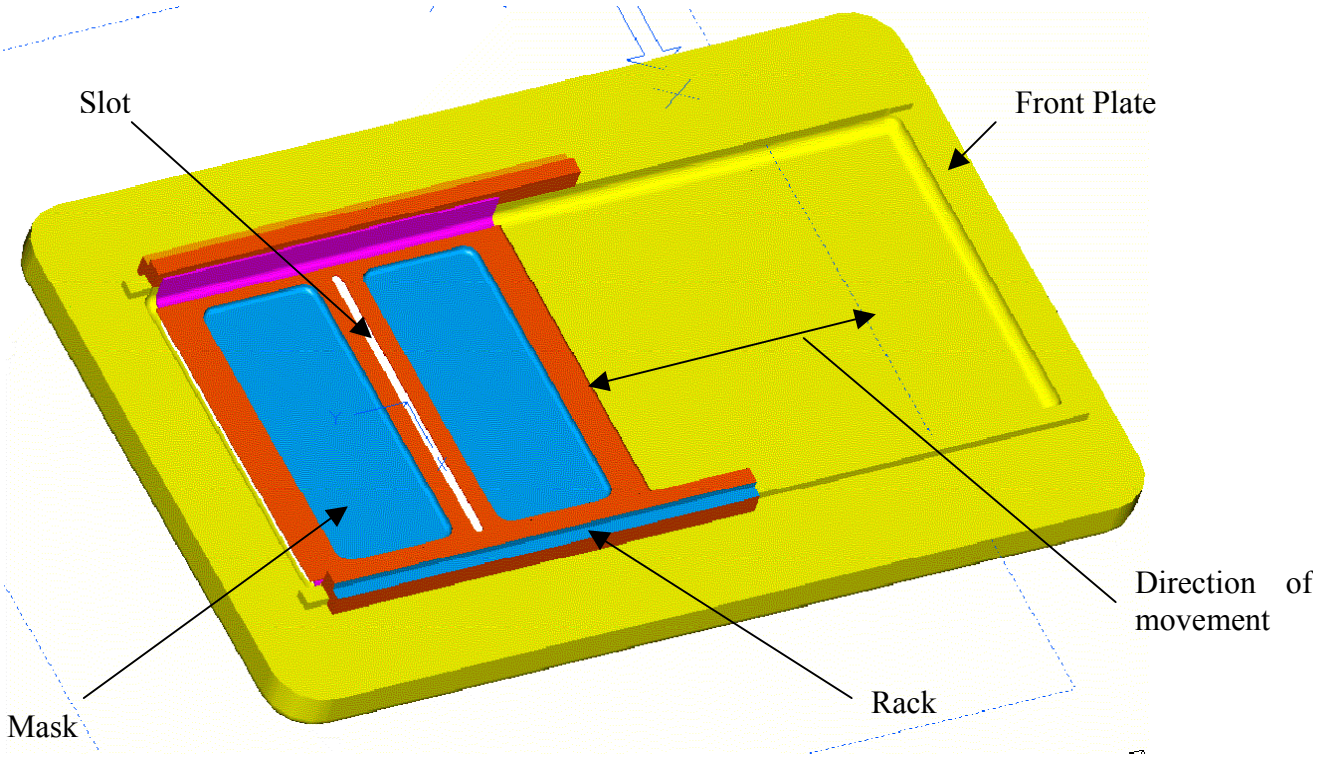


Figure 8: FRAME TRANSFER MASK IN SLOT MODE

4.6 Frame Transfer Mask

The cryostat will carry the Frame Transfer Mask internally. The reason for internal mounting is to limit the width of the penumbral region: the region on the detector which is partially vignetted by the frame transfer mask. The mask will be made from profile stiffened Beryllium Copper sheeting. It will function in one of two modes, i.e. half obscuration (normal mode) and slot mode with the rest position being full frame exposure. The slot mode is required for highest time resolution imaging. Fig. 8 shows the mask in slot mode. A cryogenic vacuum specification motor will be used to drive the mask mechanism. Two Acetal racks (one on either side of the mask) will be used to move the mask and also serves as the guiding mechanism. Motion control will be open loop with a reference point and stepper motor. The mask will be pre-loaded in its operating positions with a spring-loaded detent to ensure lash free positioning.

4.7 Vacuum System

A Varian 0.2 l/s micro ion pump will be use to maintain vacuum over an extended period. It is not envisaged that a zeolite getter will be used unless the pump is unable to pump the required molecules at an acceptable rate.

A Granville Philips micro ion gauge will be used to monitor the integrity of the vacuum if the ion pump is incapable of providing a direct output based on the level of molecules present. If there is not enough physical space the gauge will have to be omitted and the vacuum monitored indirectly by the level of heat input required.

Depending on the outcome of the Autoguider design, one of two cryostat concepts is possible. It is expected that the following sealing surfaces will have to be catered for:

- Casing split line.
- Cold end attachment face.
- Aperture for connecting cold braid.
- Window/lid interface.
- Three electrical connectors.
- Vacuum pump interface.

The intention is to use Viton o-rings on all sealing surfaces, except the possible bonding of the window into the lid. It is not foreseen that metallic sealing rings will be required on any of the sealing surfaces.

In order to minimize molecule attachment to interior surfaces, it is planned to electro-polish most of the internal surfaces, including the surfaces that will have protective coatings applied to them.

All internal holes and jointing surfaces will be designed such that the potential for molecules traps will be minimized.

4.8 Electrical Connections

It is expected that there will be at least three electrical connectors going through the vacuum wall. Two will be for the CCD's and one for the Frame Transfer Mask. These connectors will be of the CANON type and well suited to HVAC environment.

5 Mass Properties

The following mass properties are estimated (TBC) for the cryostat:

Front plate and window:	0.5 kg

Cryostat body:	2.0 kg
Detector assembly:	0.5 kg
Cold end	1.5 kg
Vacuum system	0.5 kg
Connectors, wiring and cold path	0.5 kg
Total Mass	5.5 kg

The above does not make provision for the wiring looms going to the cryostat, nor the cooler hoses.

6 Fabrication

6.1 Components

The majority of components that are not COTS will be machined from solid.

6.2 COTS items

These items will be compatible with a high vacuum cryogenic environment.

6.3 Cryostat body

There are 3 options available:

a. Machine from solid.

b. Use Rapid Prototyping for vacuum cast components (provided that the casting spec can meet the porosity requirements for HVAC).

c. Our preferred approach is a combination of a and b.

6.4 Surface finishes

All surfaces will have to be finished to a very low R_A value and in some instances electro-polishing of the surface will be needed. Special coatings may have to be deposited on some surfaces in order to minimize thermal radiation.

7 Risks

7.1 Mosaicing

There are two major risks as presently perceived:

a. SAAO will not have its facility developed and characterized in time for the Salticam detector.

b. The Marconi procedure will not be accurate enough.

7.2 Thermal

The major perceived risks are as follows:

a. Insufficient/inaccurate information for calculation of heat loads.

b. Below par performance of the materials/processes used for producing the required reduction in heat influx.

7.3 Vacuum

Most risks pertain to virtual leaks and physical leaks:

a. Unclean surfaces or surfaces with bad surface treatment that are inside the container

b. Sealing elements and sealing surfaces that are not up to standard

7.4 Mechanical damage

As most components inside the cryostat are small and fragile, the utmost care will need to be taken to ensure that no patent or latent failure will occur due to undetected damage during the manufacturing and assembly.

7.5 Risk Management

Pro-active steps have been taken to address these risks. In some instances SAAO has sound experience and the correct procedures and checks will minimize these risks.