PRECISION RADIAL VELOCITY SPECTROMETER

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CHANGE RECORD

Issue	Date	Section affected	Change Description
0.1	4th August 2006	All	Draft for Red team review
0.2	4th September 2006		
0.3	12th September 2006	3.2 5.9.2	Long term stability figure updated Cooldown time recalculated to reflect new temperature requirements
1.0	16th September 2006		Final review before release to Gemini by DWL

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1. INTRODUCTION

1.1 SCOPE

This document will describe the design of the cryostat, main optical bench and optics modules. The design has been developed sufficiently to illustrate that the concept meets with the functional, performance and interface requirements.

2. APPLICABLE AND REFERENCE DOCUMENTS

Reference	Document Title	Document Number	Issue / Date
AD01	Science Requirements	PRVS-SPEC-00005-0001	1.0
AD02	Initial Functional Performance & Requirements Document	PRVS-SPEC-00003-0001	1.0

3. ITEM DEFINITION

This subsystem includes the vacuum vessel, optical bench and optical modules.

3.1 KEY FUNCTIONAL REQUIREMENTS

This subsystem will provide a structure for support of the optics and detector module. It will facilitate alignment of the optics and repeatability on re-assembly.

3.2 KEY PERFORMANCE REQUIREMENTS

The temperature of the components within immediate view of the detector must be lower than 190K.

The dimensional stability of the optical support structure must be consistent with achieving spectral line stability on the detector of better than 0.1 pixel over an integration of 1hour.

Long term temperature stability (months/years) of the optical bench should be better than 0.05K.

3.3 INTERFACE REQUIREMENTS

The instrument must be compatible with the Gemini environment requirements.

It also must interface to the pier lab and its handling equipment.

The layout is designed to be compatible with optical design detailed in document TRE-00003-0001.

Interfaces must be provided to the fibre input coupler.

The closed cycle cooler system must have an appropriate interface to the Gemini facility.

Location of compressor, power type, Helium lines and displacer control cable runs.

4. MECHANICAL DESIGN DESCRIPTION

4.1 DESIGN PHILOSOPHY

Mechanical stability is a key requirement for this subsystem. It is therefore designed as a static bench spectrograph. There are therefore no significant varying gravity vector effects.

Thermal stability is also a key requirement in terms of its affect on the dimensional stability of the optical support structure. Other potentially harmful effects of varying temperature are changes to the refractive index of the transmissive optical components and changing support load deformations of the optics.

The design addresses these concerns by enclosing the entire optical subassembly in a vacuum vessel and supporting it with a structure which has very low conductivity. A radiation shield augmented by multi layer super-insulation is also used to reduce radiative heat loads. The intent is to thermally de-couple the optical bench from rapid ambient variation. This approach guarantees very good short term stability. The bench temperature is also actively controlled to achieve longer term temperature stability.

The vacuum environment also removes optical effects caused by the variability in the refractive index of air due to pressure and temperature fluctuations.

The overall design is very similar to that used successfully in a succession of UKATC instruments such a SCUBA2, WFCAM, UIST, GMOS, CGS4.

Vibration is another potential source of instability. Although no specific vibration related mechanism has been identified for significantly affecting image quality (given the levels expected in the Gemini pier lab and from the cold heads), it seems prudent at this stage in the development of the design to include controlling measures. The spectrograph is therefore supported on anti-vibration supports of the type used on optical benches (‘off the shelf solution’). The closed cycle cooler also uses an anti-vibration mount and flexible wicks on the first and second stages. The closed cycle cooler AV mount is an existing and proven UKATC design used on CGS4 and UIST.

4.2 GENERAL DESCRIPTION

The design consists of a vacuum vessel supported on anti-vibration legs of the type used on optical benches. An optical support structure is mounted within the vacuum vessel on an isolating flexure system. The flexure system supports a radiation shield which envelopes the optical support structure. It also thermally insulates the optical support structure from the radiation shield. The optical components are mounted within substructure modules, and these in turn are mounted to the optical support structure in a semi-kinematic way. The optical bench and radiation shield are maintained at the operating temperature by combining closed cycle refrigerators with servoed resistive heating elements on the optical bench. A liquid Nitrogen pre-cool circuit is provided for the radiation shield and the optical bench. A window/feedthrough provides the interface for the fibre coupling. There are also breakout panels for the instrument vacuum services, electrical services and detector signal cabling.

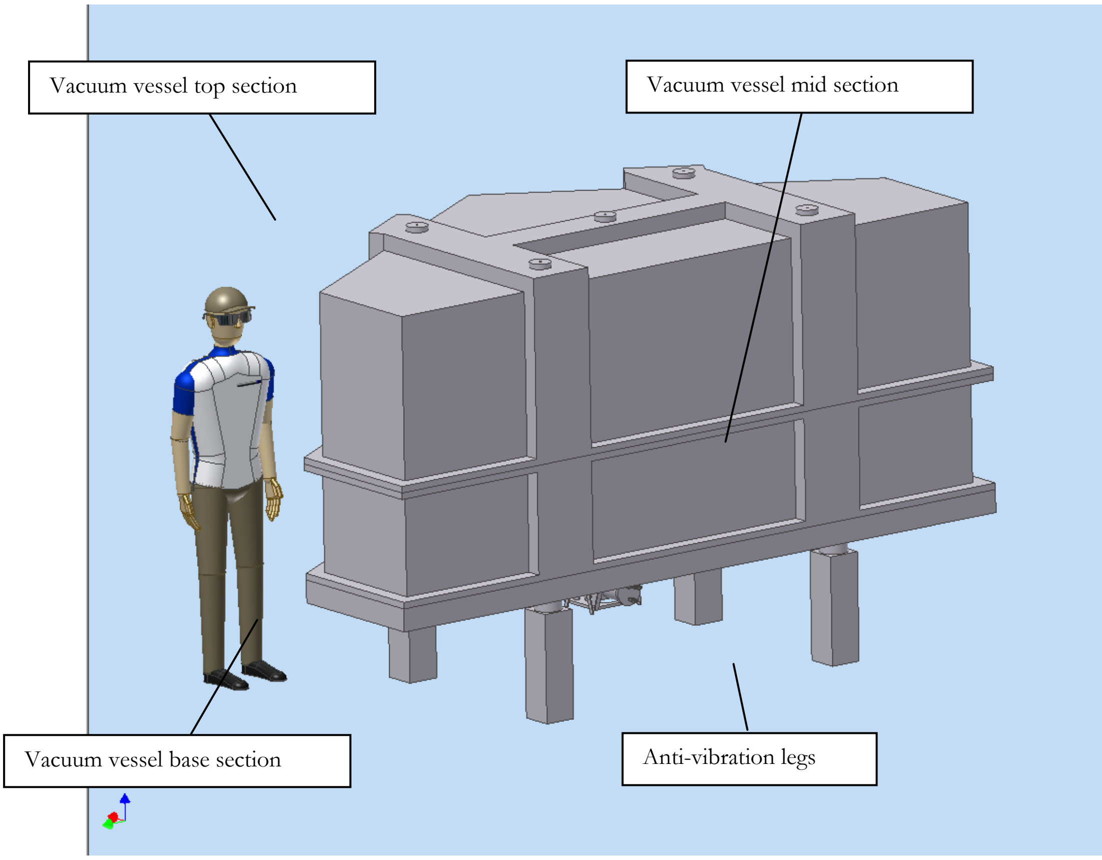


Figure 1. Spectrograph assembly - external

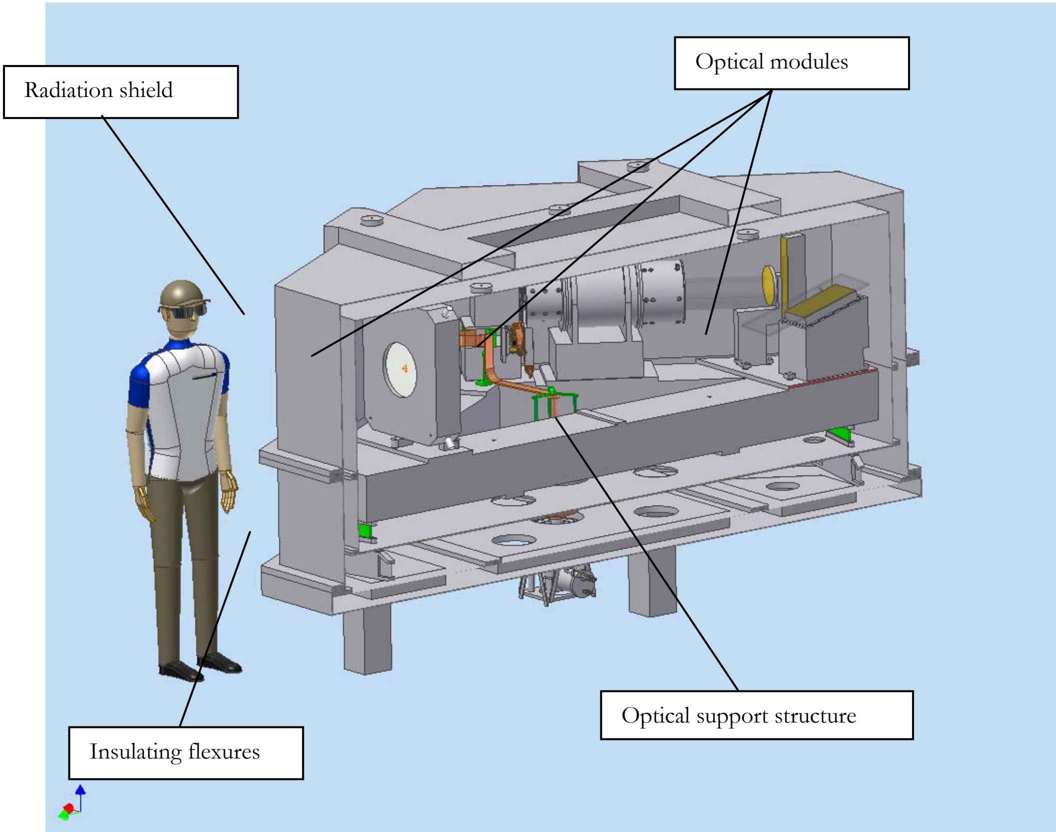


Figure 2. Spectrograph assembly - section

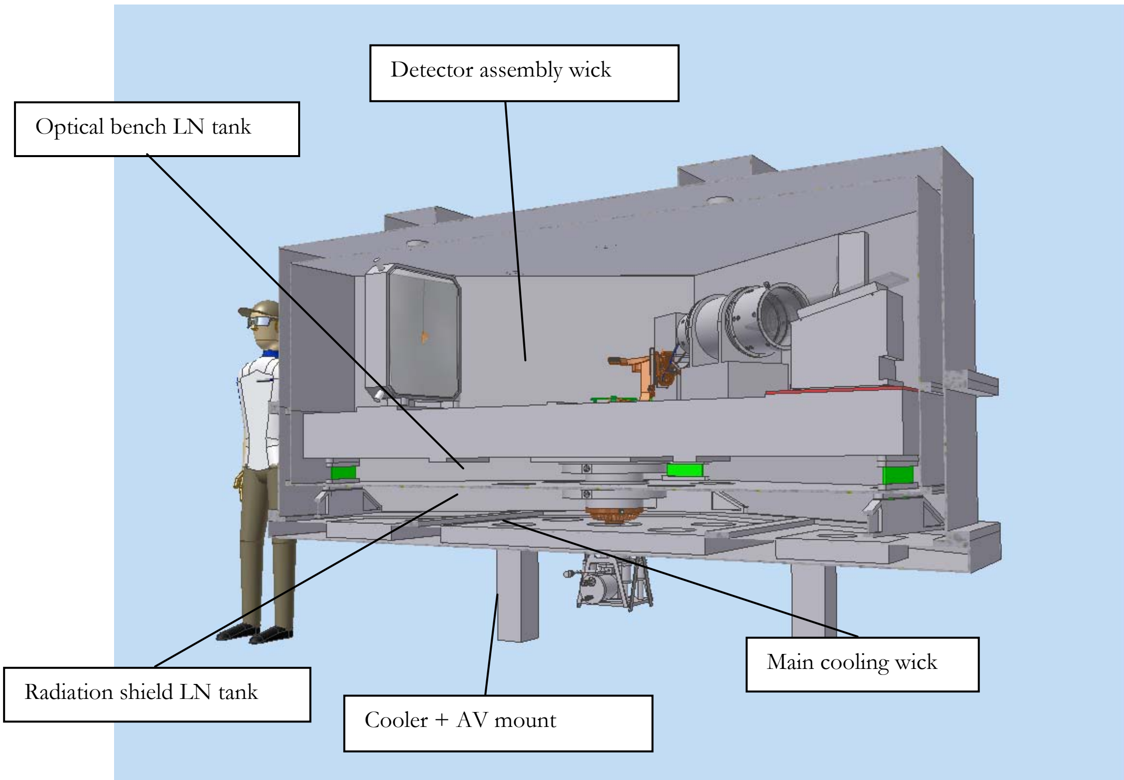


Figure 3. Spectrograph assembly - thermal components

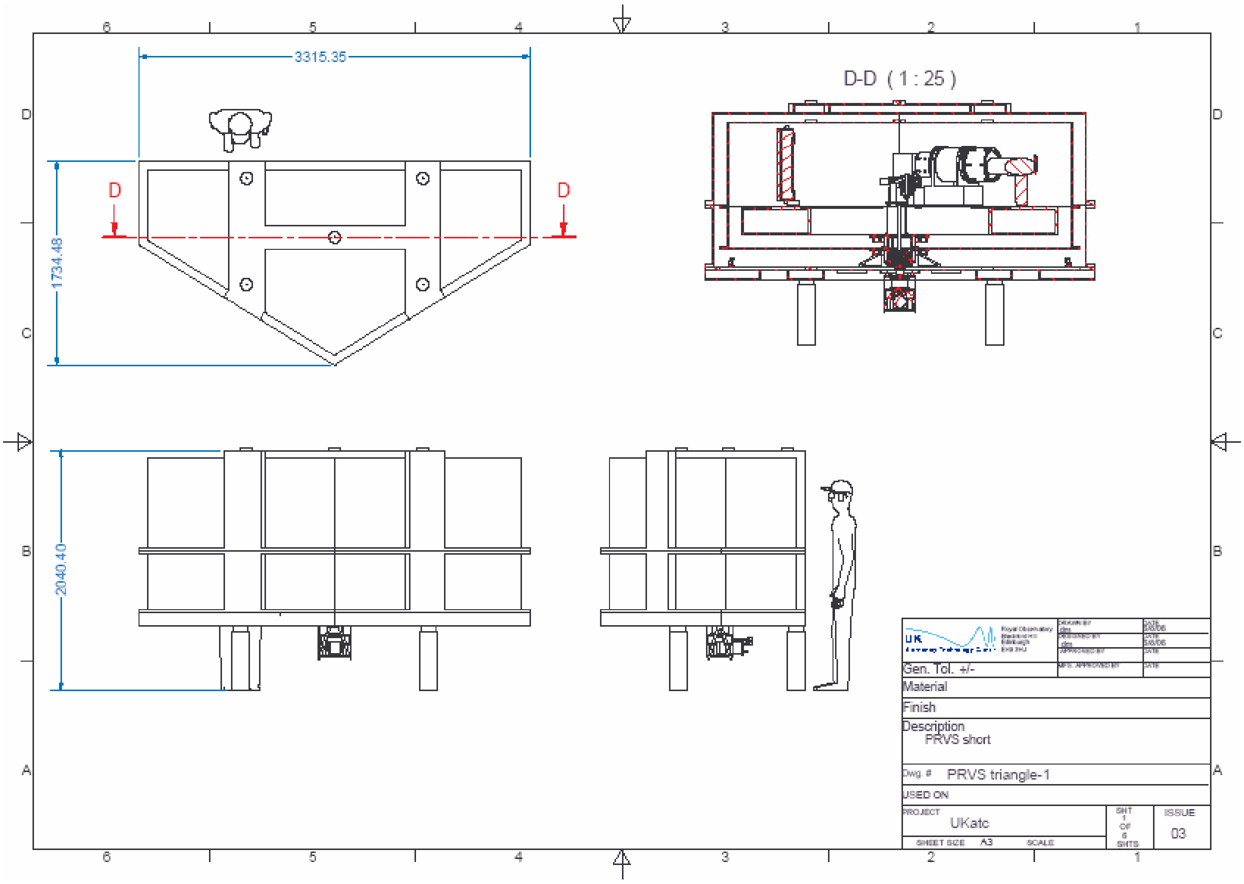


Figure 4. Spectrograph assembly dimensions

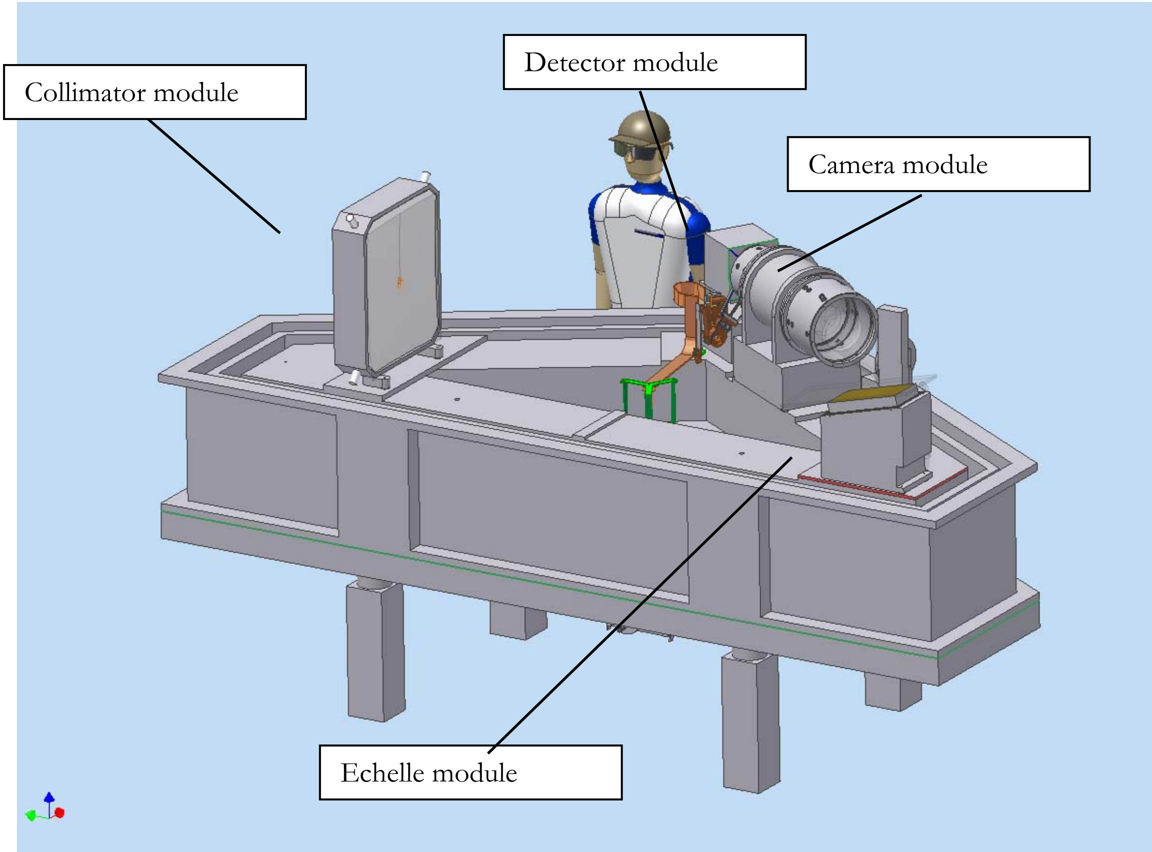


Figure 5. Spectrometer bench

4.3 VACUUM VESSEL

The vacuum vessel is a welded construction from Aluminium alloy 6082 – T5 or equivalent strength, nominal 8mm thickness. Stiffening ribs made from Aluminium Alloy 6061 – T6 structural sections are welded to this. This construction technique will result in an efficient vessel that is relatively simple to manufacture.

The vessel will be designed such that there is a factor of safety of at least 4 of yield strength of the material and deformations are less than 2mm on pump down.

There are three main components, the base section, the mid section and the top section. These will be screwed together along the flange, the screws will be captive.

4.3.1 Vacuum vessel base

The base is the main structural component and provides the interfaces for the external support legs and the internal components. The base also provides breakout panels for the instrument vacuum services, electrical services, detector signal cabling and fibre feed.

The vacuum interface to the top section is a flat machined flange with an o-ring groove. The flange provides tapped holes for the top section.

The vacuum vessel base provides 4 lifting points for handling consisting of M12x2D inserts.

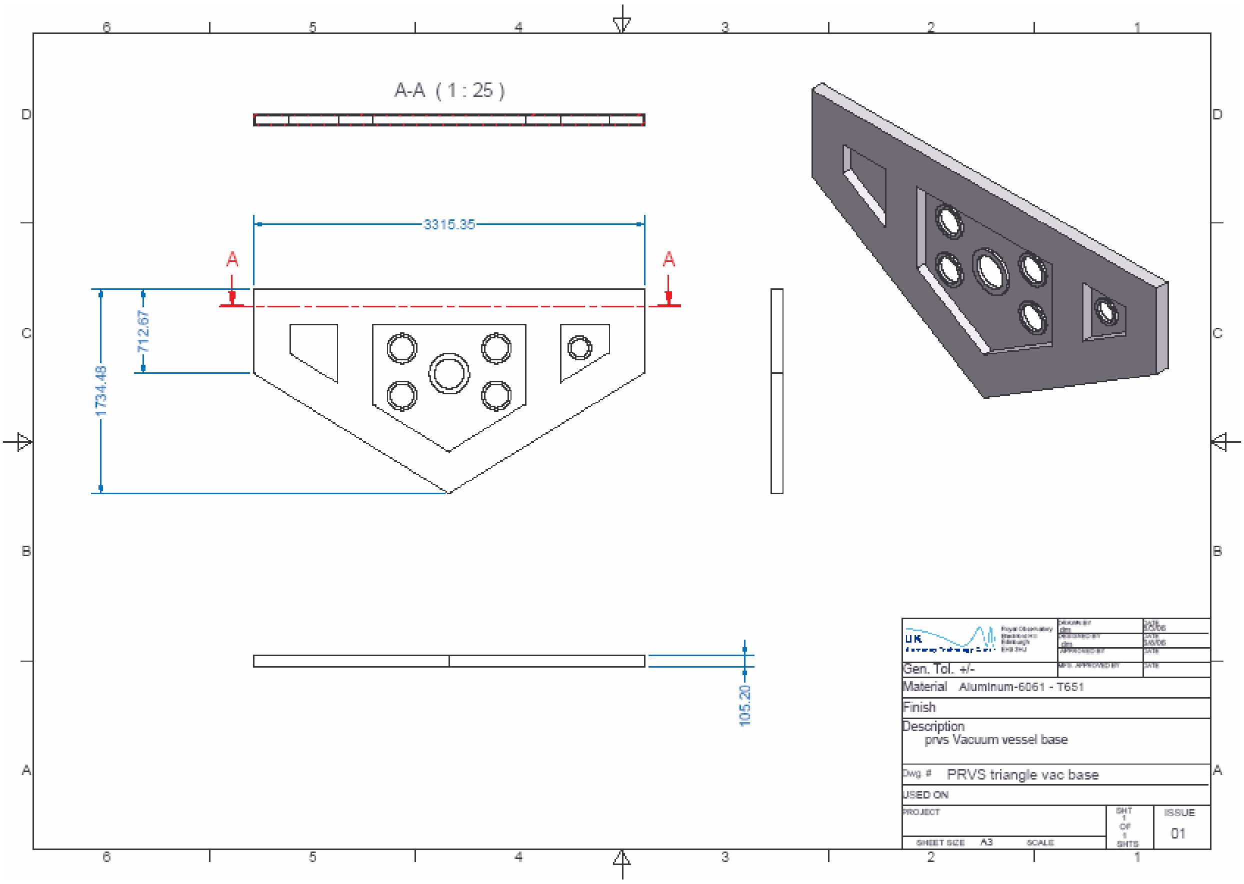


Figure 6. Vacuum vessel base dimensions

4.3.2 The vacuum vessel mid section

The vacuum vessel mid section extends the vacuum vessel to a vacuum flange which is the mount for the vacuum vessel top section.

The lower flange has clearance holes for fasteners to the vacuum vessel base. The top flange has the same pattern of tapped holes for the vacuum vessel top fasteners.

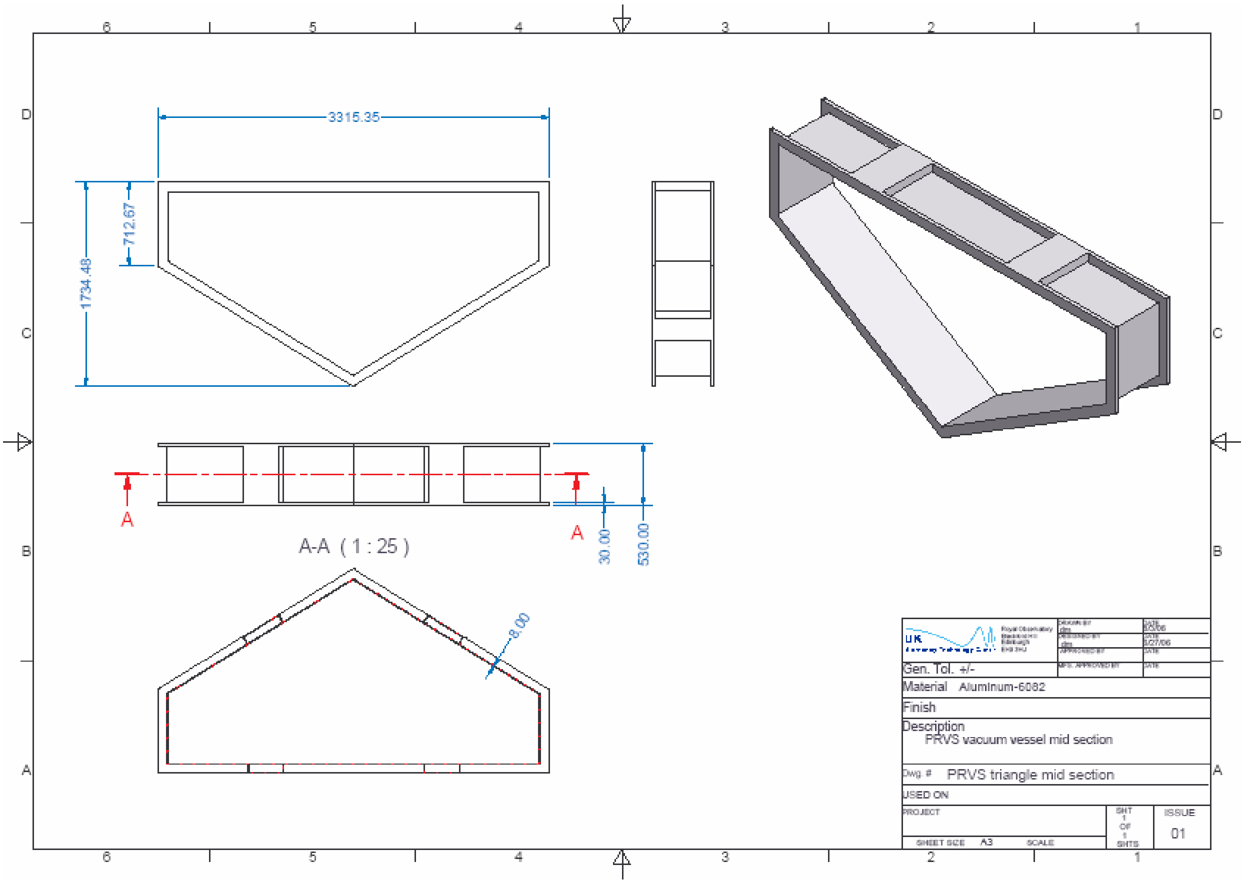


Figure 7. Vacuum vessel mid section dimensions

4.3.3 The vacuum vessel top section

The vacuum vessel top section envelopes the internal radiation shield top section and has no optical interfaces. The vacuum interface is a flat machined flange with good sealing surface finish in the area where the o-ring touches. The flange provides clearance holes for the fasteners which attach it to the base.

The vacuum vessel top section provides 4 lifting points for handling consisting of M12x2D inserts.

Guide pins will be provided on the flange for alignment of the top section to the mid section. These pins also act as feet, on which the top section can be placed during handling to protect the o-ring sealing surface.

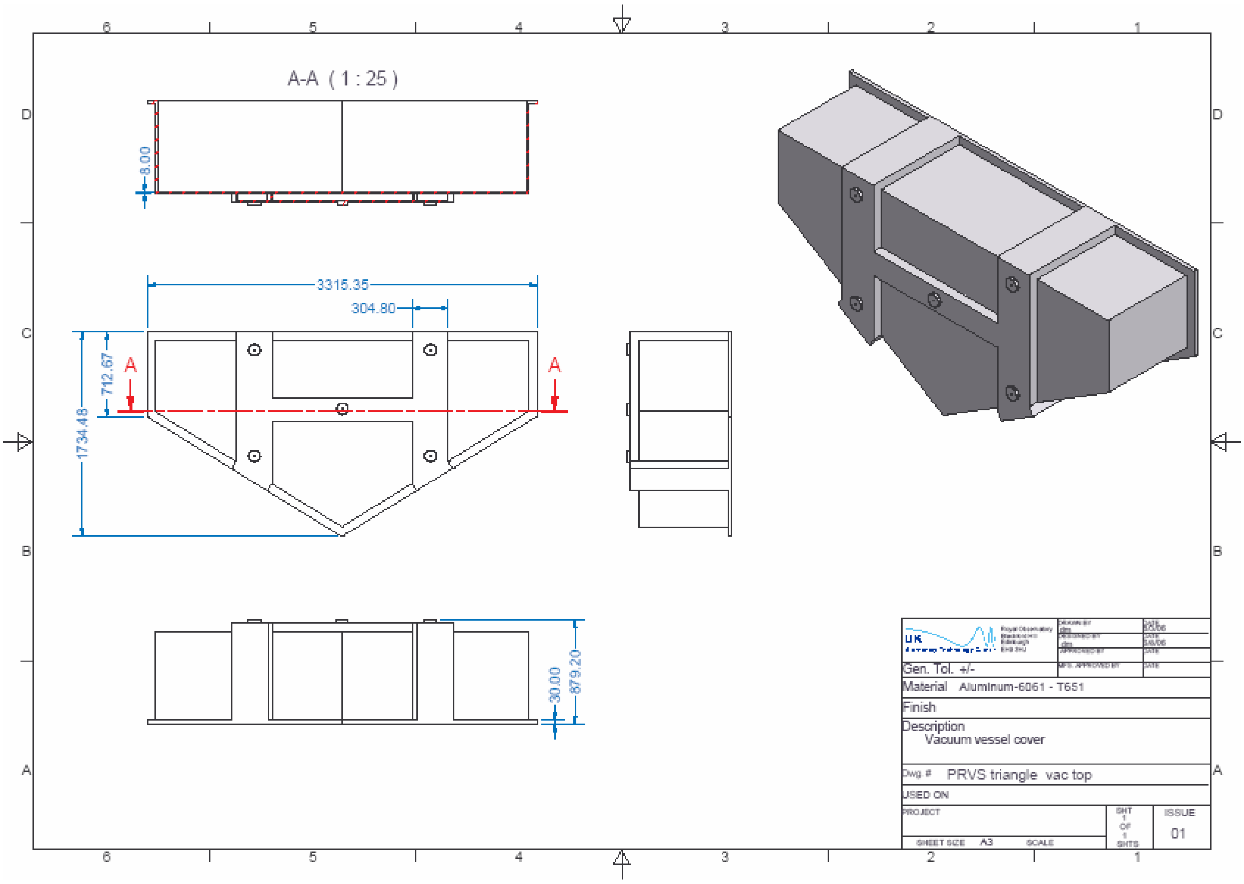


Figure 8. Vacuum vessel top section dimensions

4.3.4 Vacuum components

The required vacuum components are listed in the table below.

Component	function	Comment
Vessel pressure relief valve	Prevent overpressure	Design used from UIST/WFCAM/SCUBA2
Wide range pressure gauge	Monitor pressure 1-1x10^{-8} mbar	
Strain gauge pressure gauge	Monitor pressures 1-1mbar	
Turbo pump gate valve	Close off vessel from turbo pump	
Turbo pump	Pump vessel to 4x10^{-5} mbar	
Roughing pump + accessories	Rough pump vessel to 0.1mbar and act as backing pump for turbo	
LN can pop off valves	Seal and prevent over pressurisation of LN cans.	

4.3.5 Expected vacuum performance

The vacuum performance (based on similar instruments) and relevant properties are summarised in the table below.

Parameter	Value	Comment
Volume	4.4m^3	
Internal area	17.2m^2	

Seals	Viton o-rings length Φ6.6 length 20m	
Pump down time	24 Hours	Assumes 240l/sec turbo pump, ISO 100 port
Vacuum warm	$5x10^{-5}$ mbar*	Assumes 240l/sec turbo pump, ISO 100 port
Vacuum cold	$5x10^{-6}$ mbar*	
Leak rate	$2x10^{-7}$ mbar*	

*Empirical estimate based on WFCAM/SCUBA2

4.4 INTERNAL SUPPORT FLEXURES

There are three internal support flexures arranges to provide a semi-kinematic mount for the internal cold structure. Each flexure is made up of an aluminium alloy foot with a 10G glass fibre blade. The foot attached to the vacuum vessel base. The 10G blade terminates with a second aluminium alloy foot which attaches to the radiation shield base. The blades are bonded and pinned in place.

A second stage of the flexure is comprised of a 10G blade with identical Aluminium alloy feet. This is attached to the first stage of the flexure and the optical support structure.

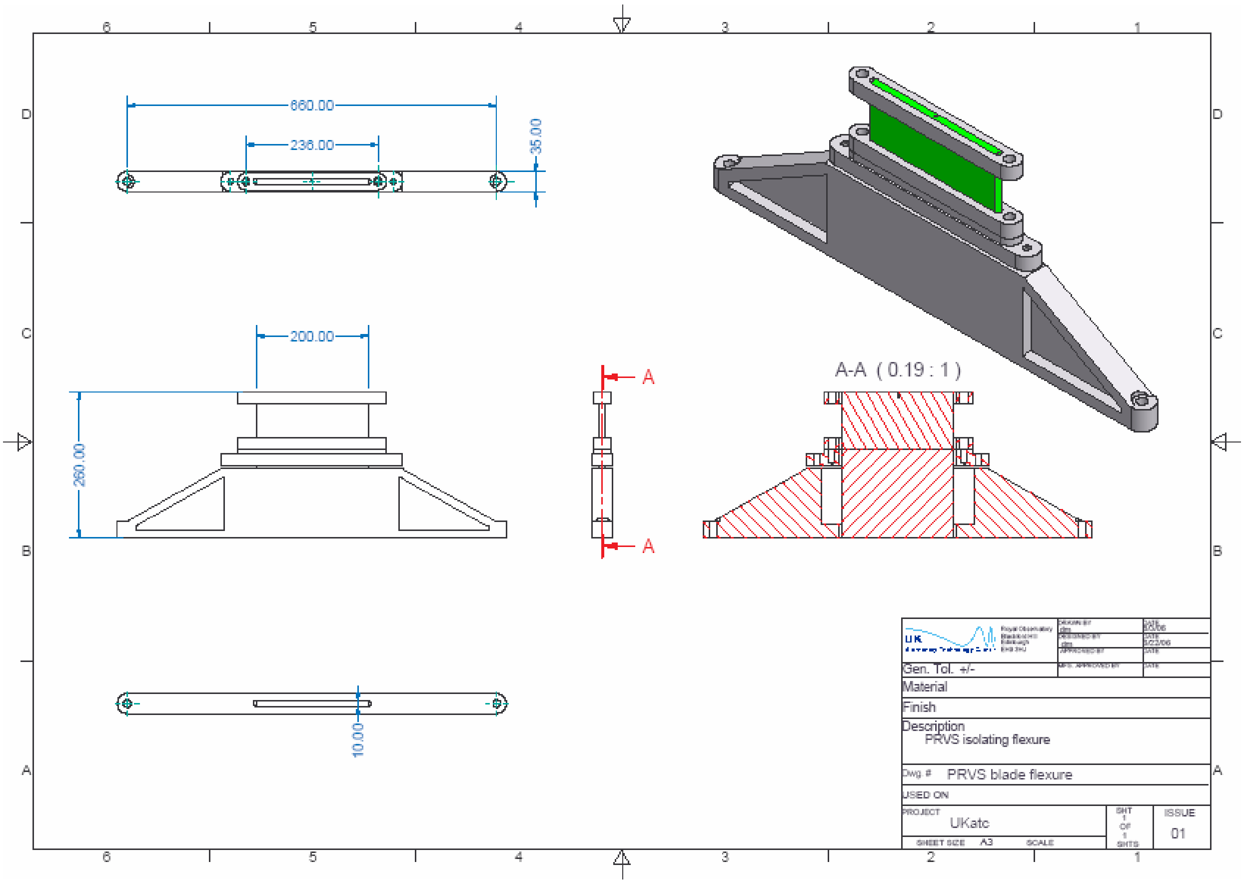


Figure 9. Internal support flexure dimensions

4.5 RADIATION SHIELD

The radiation shield completely envelopes the cold structure. It is a welded construction in Aluminium alloy 6082-T5 10mm and 6mm sheet. It has three major parts, the radiation shield base, radiation shield mid section and the radiation shield top section. These will be screwed together along the flange, the screws will be captive.

4.5.1 Radiation shield base

The radiation shield base is a flat pate, possibly with stiffening ribs. It is supported at the apex of the three internal trusses by three interface components which also provide thermal isolation. The shield base has penetrations for the optical input, array cabling and thermal control cabling. The cables are heat sunk to the radiation shield base by clamping to a flat surface.

An interface is also provided for the annular pre-cool tank.

The base provides a line of tapped holes around its edge for the radiation shield cover fasteners.

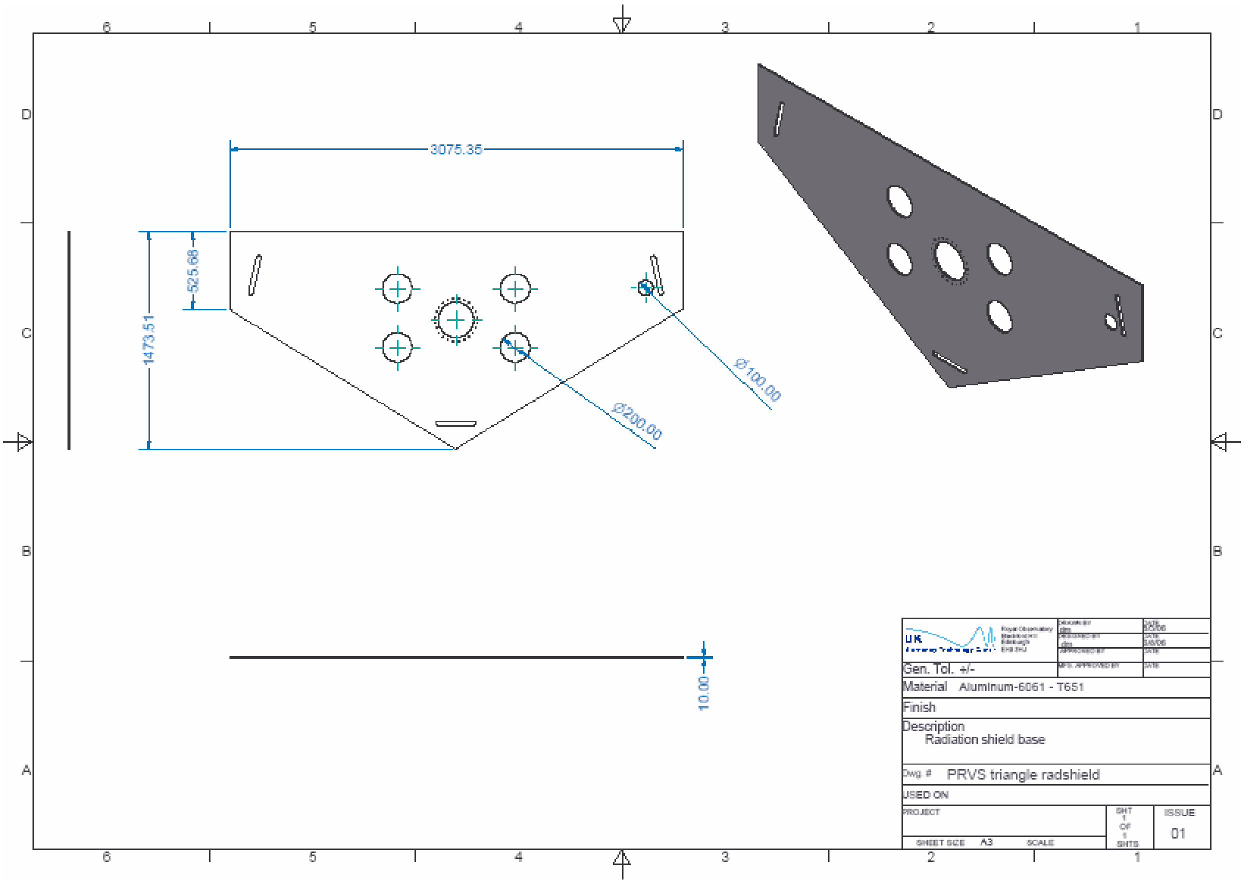


Figure 10. Radiation shield base dimensions

4.5.2 Radiation shield mid section

The radiation shield mid section extends the radiation shield to a flange which is the mount for the radiation shield top section.

The lower flange has clearance holes for fasteners to the radiation shield base. The top flange has the same pattern of tapped holes for the radiation shield top fasteners.

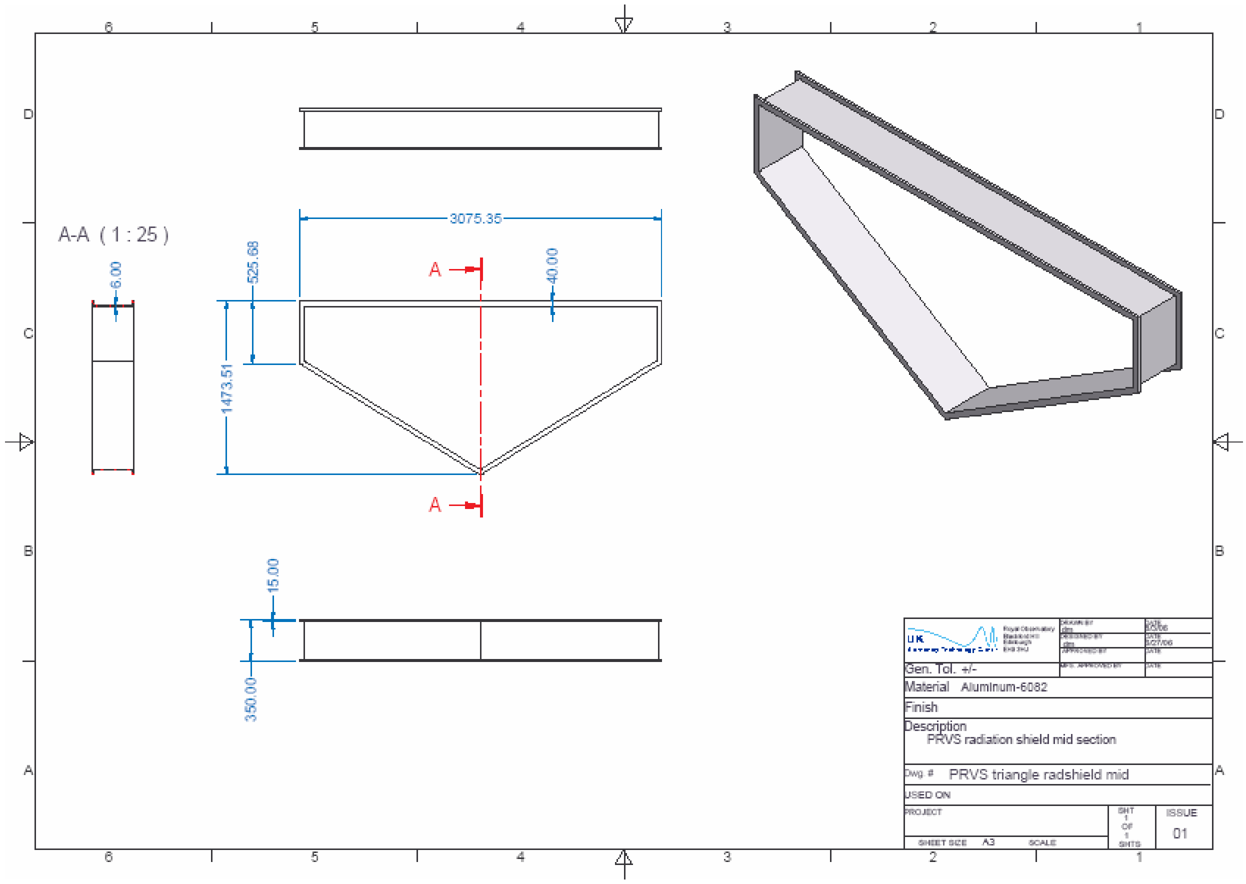


Figure 11. Radiation shield mid section dimensions

4.5.3 Radiation shield top section

The radiation shield top section completely envelopes the optical support structure and is a plain cover with no electrical or optical interfaces.

The radiation shield top section provides 4 lifting points for handling consisting of M12x2D inserts.

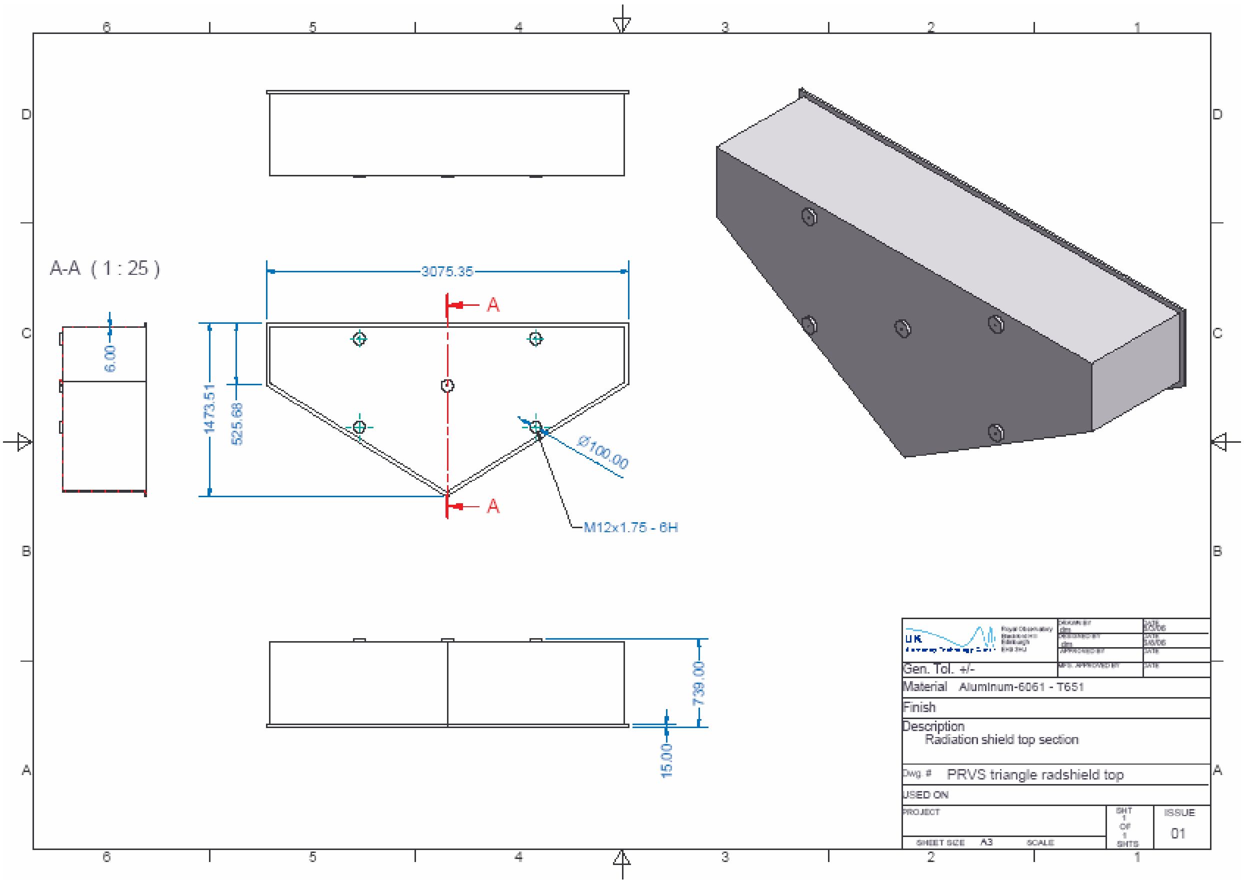


Figure 12. Radiation shield top section

4.5.4 MLI

Multi-layer super-insulation will be used around the radiation shield. This will consist of two blankets, each with 15 layers. Each blanket will have a tear resistant outer layer with the edges sewn in place. Velcro edges will be used on the seams which need to be split for assembly.

4.6 OPTICAL SUPPORT STRUCTURE

The optical bench is a triangular structure from box beams. It is supported by the three internal support flexures and provides the mechanical interfaces for the optics modules. The interfaces to the modules are provided by raised pads which are machined to be co-planar. The modules are located in a semi-kinematic way on these pads by means of three thick shim pads and three locating cylinders arranged to form a 'V'. The locating cylinders are held in place by shoulder screws.

An interface is also provided for the annular liquid Nitrogen pre-cool tank, consisting of a flat machined area with tapped holes for the fasteners.

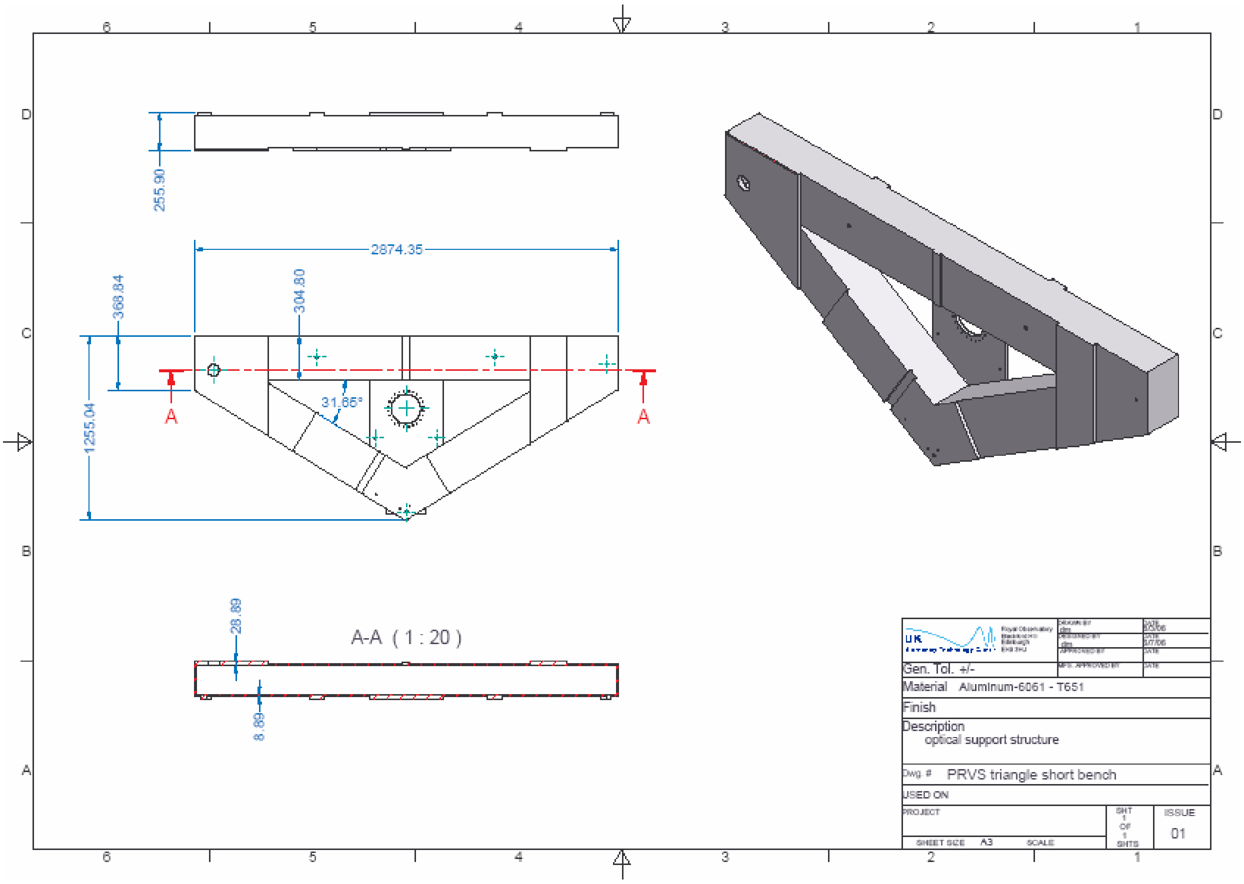


Figure 13. Optical support structure dimensions

4.7 OPTICS MODULES

Each of the optics modules is a removable sub assembly fastened to the optical support structure semi-kinematically and positioned by controlled tolerances. Thick shims are used to allow adjustment of each module in all degrees of freedom.

4.7.1 Fibre input

The vacuum vessel base provides a circular port for mounting of the fibre input assembly. The radiation shield and optical support structure have apertures for the assembly and routing of the fibre/slit assembly. The slit assembly will be mounted off the optical support structure.

4.7.2 Collimator assembly

The collimator is held in the collimator mount which provides interface features for mounting to the optical bench and handling equipment. The collimator mount is a rectangular structure that enclosed the collimator with a generous clearance. It is assumed that the collimator will be manufactured from Zerodur and the bezel from Aluminium alloy. The mirror is held axially by three spring tabs pushing directly through it onto Teflon pads located on the inside of the collimator mount. The radial support is provided by Teflon defining rods pre-loaded against the mirror with a spring. The Teflon components are sized to compensate for the thermal contraction difference between the collimator and the bezel when cooled from room temperature to operating temperature.

A hole is provided through the back to facilitate removal and insertion of the optic.

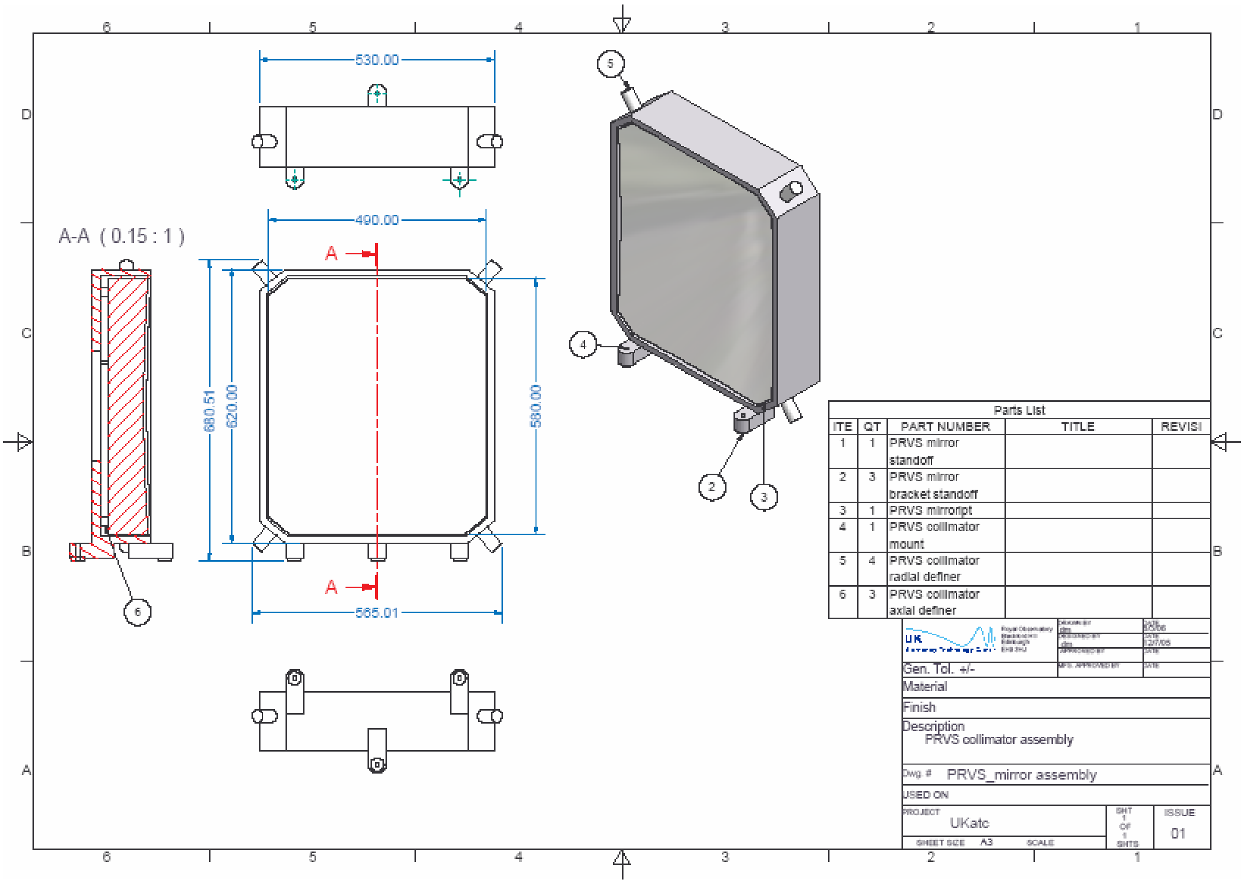


Figure 14. Collimator assembly

4.7.3 Echelle assembly

The echelle is held in the echelle mount which provides interface features for mounting to the optical bench, handling equipment and a protective cover. The mount is a rectangular structure that enclosed the echelle with a generous clearance. It is assumed that the echelle substrate will be manufactured from Zerodur and the mount from Aluminium alloy. The echelle is held axially by three spring tabs pushing directly through it onto machined pads located on the mount. The radial support is provided by springs which push the echelle into a V formed by three pads machined into the mount.

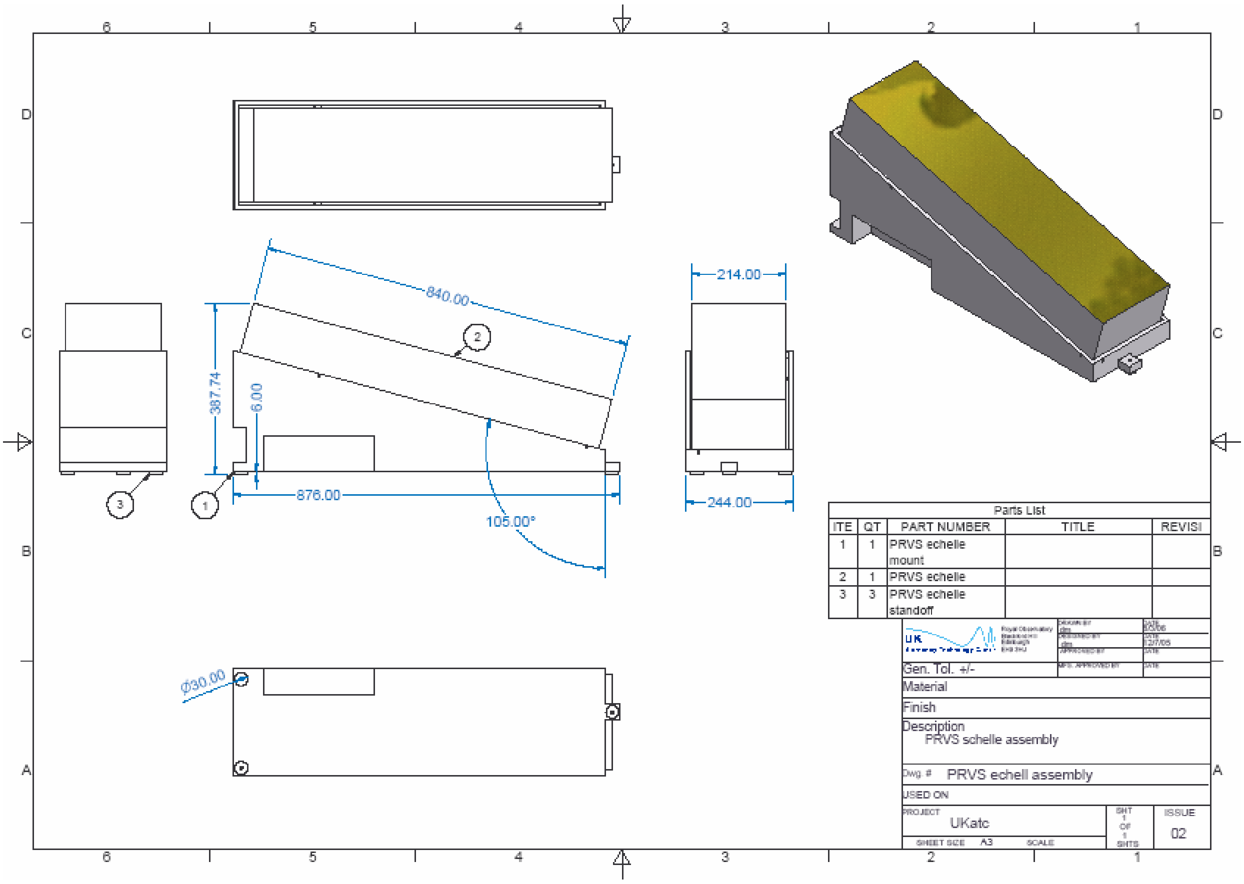


Figure 15. Echelle assembly dimensions

4.7.4 Spectrum mirror module

This mirror will mount off the optical support structure by means of a support bracket or possibly an integral mount. It will use the same semi-kinematic interface to the bench as the other modules.

4.7.5 Cross disperser module

This grating will mount off the optical support structure by means of a support. It will use the same semi-kinematic interface to the bench as the other modules.

4.7.6 Camera assembly

The main structural components of the camera assembly are the lens tube and the camera mount. The camera mount provides the interface to the optical support structure and handling equipment. It supports the cylindrical camera assembly in a split clamp type arrangement.

The camera structure is comprised of a tubular component with a flange at each end. The flanges provide an accurate locating spigot diameter to two lens barrels, one at each end.

The lens barrels each contain three lenses, axially positioned by cylindrical spacers and retained by a sprung loaded retaining ring. The radial position of the lenses is defined by Teflon radial defining rods, preloaded against the lenses by springs. The defining rods a sized to compensate the thermal contraction difference between the lenses and the lens barrels when cooled from room temperature to operating temperature.

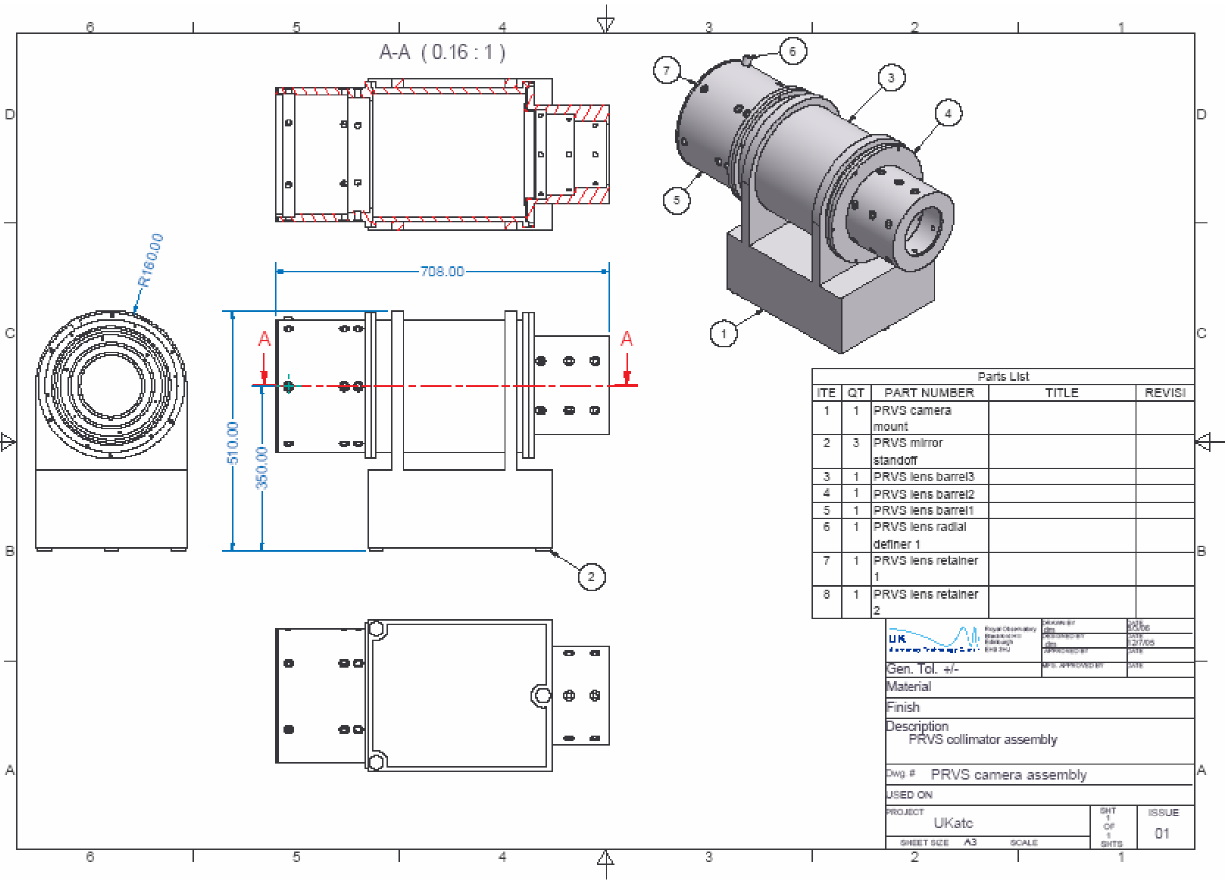


Figure 16. Collimator assembly dimensions

4.7.7 Shutter mechanism

The shutter mechanism is intended to close off the detector view for flat fielding. The mechanism will be a copy of the shutter mechanism developed for the SCUBA2 instrument. This is in the advanced AIV stage.

The shutter mechanism is a modular design comprising of a chassis, motor mount sub assembly and balanced shutter blade.

The chassis provides the mechanical interface detail to the detector module including four captive shims for alignment adjustment. The chassis also supports four CFRP A-frame trusses that in turn support and insulate the motor mount sub assembly.

The motor mount sub assembly provides the mechanical interface for the motor and geared paddle shaft. It also has features for mounting the position control micro-switches. There are four micro switches, two at each end of travel. Each pair provides a datum and an end of travel signal. An interface is provided on the motor mount sub assembly for a copper wick to the main 1st stage cooling wick. Another interface is provided for the brackets that hold the motor and status connectors. Provision is made for mounting a temperature sensor.

The motor is a PHYTRON stepper motor capable of operation in vacuum down to 40K. The stepper motor drives the paddle shaft through a 5:1 reduction spur gear set. The micro switch actuator assembly is mounted onto the paddle shaft. The actuation point of each micro switch can be adjusted individually.

The paddle assembly is mounted onto the output shaft above the actuator assembly. This includes a thermally insulating hub consisting of three CFRP shear flexures. The paddle consists of two main components, the copper hub and the aluminium paddle. The copper hub has provision for adjusting the balance of the paddle by movable counter weights. It also provides an interface for the copper wick attached to the 1st stage cooling wick. A temperature sensor is mounted on the centre of the aluminium paddle.

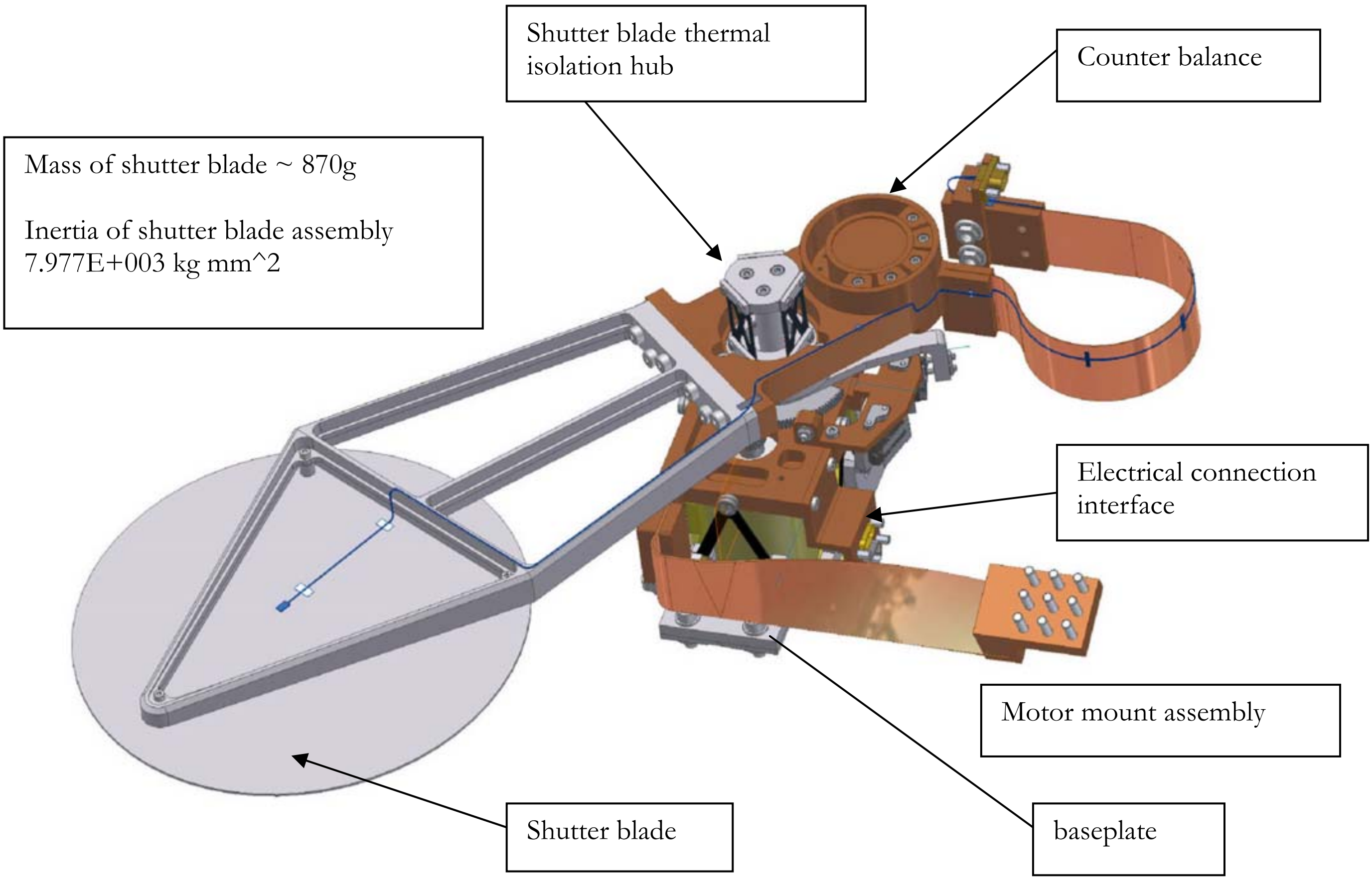


Figure 17. Cold shutter assembly

4.7.8 Detector assembly

The detector assembly is comprised of the detector assembly mount, thermal isolation, detector box mount and detector box.

The detector assembly mount provides the interface to the optical support structure and handling equipment.

The thermal isolation is made up from four 10G composite shear flexures. This results in a stiff structure that is an efficient thermal insulator. The detector mount will provide a repeatable mechanical interface for the detector box and the cooling strap interface.
The detector box will provide a mechanical interface for the detectors, detector PCB, temperature sensors and cabling connectors. The cabling from the detector to the radiation shield will be flexi-cable heat sunk on the radiation shield.

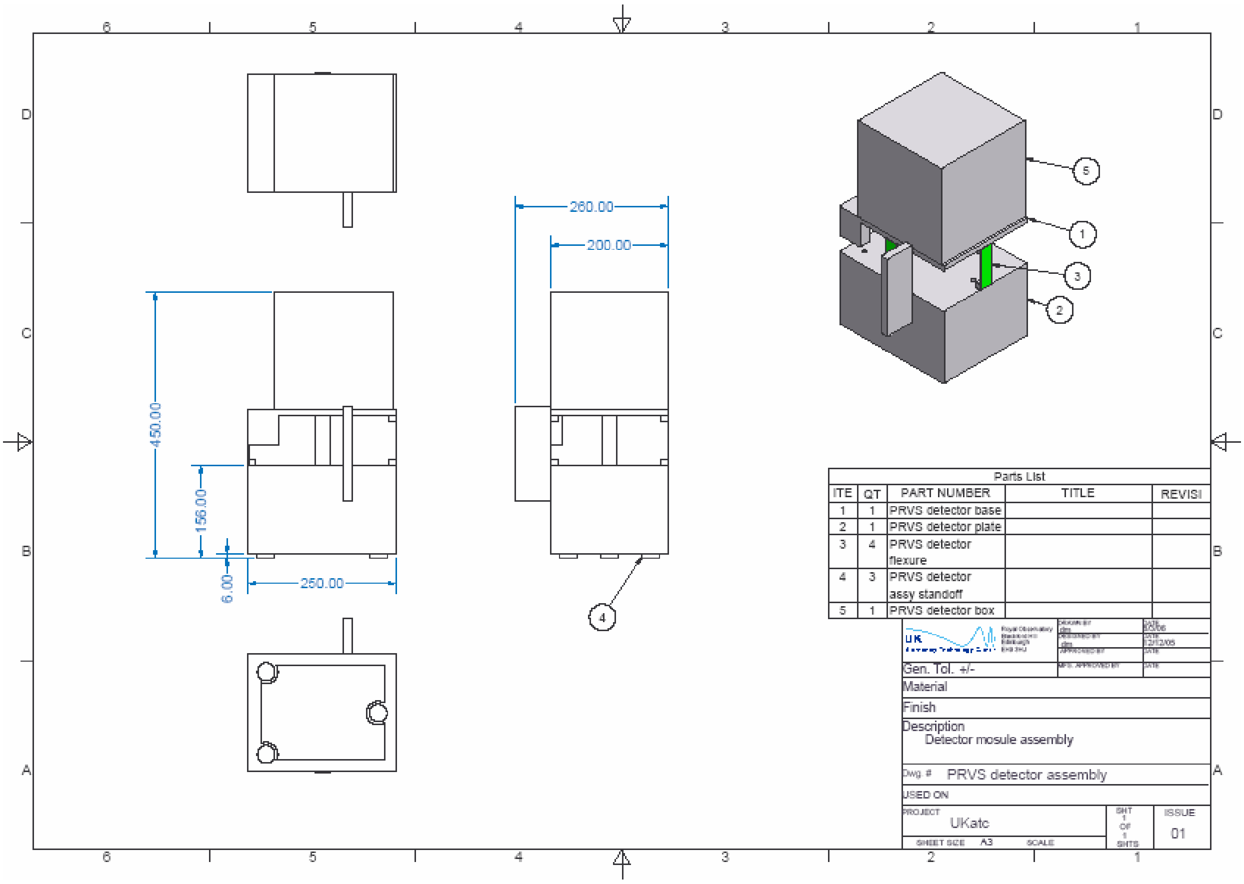


Figure 18. Detector module assembly

5. THERMAL ANALYSIS

5.1 DESCRIPTION OF THE THERMAL DESIGN

The thermal design can be described as having a temperature controlled cryogenic optical support structure suspended in a vacuum vessel by means of three thermally insulating support flexures. The flexures also support a radiation shield which surrounds the optical bench. MLI will be used on the radiation shield. The optical bench and support structure are tied together thermally near the closed cycle cooler by means of copper wicks.

The steady state cooling will be performed by a two stage closed cycle refrigerator on an AV mount. This will be attached to the central plate on the optical bench and radiation shield in the same vicinity. Resistive heaters and a temperature sensor will be used on this plate to control the temperature in conjunction with an external controller.

A pre-cool system is provided which consists of two annular LN cans, one on the radiation shield and one on the optical bench. LN is circulated through these cans to rapidly cool the structures. The heaters can also be used to accelerate the warm up.

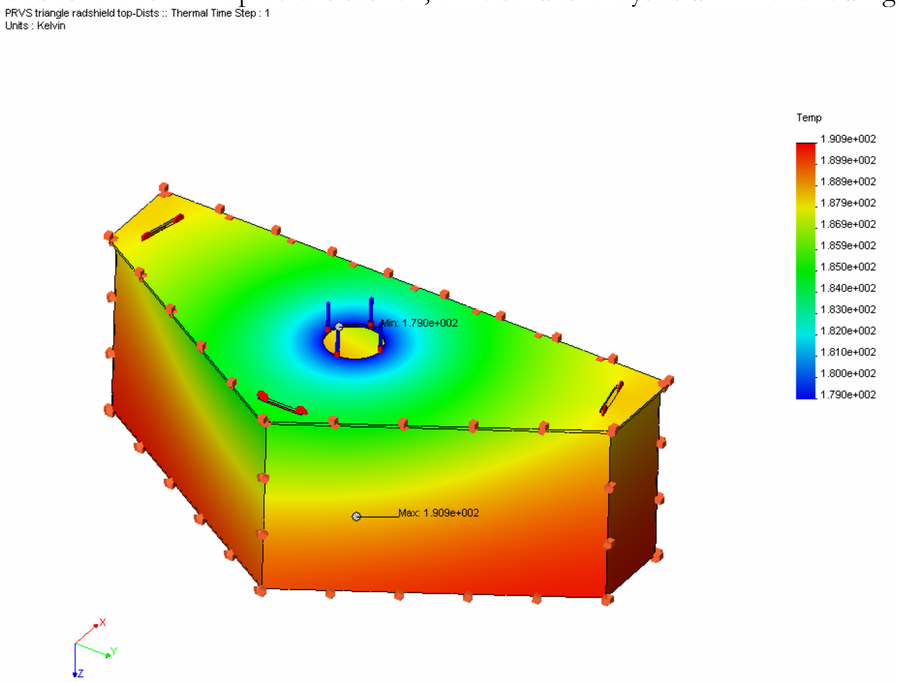
5.2 RADIATION SHIELD HEAT LOADS

The radiation shield heat loads include radiation from the vacuum vessel, conduction from the support trusses, cabling, fibre and LN can feedthroughs.

Parameter	Value	Comment	Estimated heat load (W)
Area of radiation shield	13.6m^2		
Effective emmissivity	0.013	(Gives 5w/m^2 empirically w/MLI, 150K radshields, 293K amb.) Conservative.	
			58.0
Shear web area	2000mm^2		
Shear web length	105mm		
Shear web conductivity	45W/m	G10 integrated 293-200	
			3.0
Cable area	5mm^2	Estimate	
Cable length	500mm		
Cable conductivity	40000W/m		0.4
LN tube area	50mm^2	4 tubes, 20mm dia. wall thickness 0.2	
LN tube length	500mm		
LN tube conductivity	1400W/m		0.14
Fibre area	6mm^2	2x2mm dia.	
Fibre length	500mm		
Fibre conductivity	96W/m	Glass equivalent	0.001
Ambient temperature	293		
Radshield control temp	200		
Total heat load			**62.0**

5.3 RADIATION SHIELD TEMPERATURE DISTRIBUTION

Using the heat load estimates in the previous section, a model was analysed with the following results.



As can be seen from the plot, there is a temperature distribution of 12K across the radiation shield.

5.4 OPTICAL BENCH HEAT LOADS

The optical bench heat loads include radiation from the vacuum vessel, conduction from the support trusses, cabling, fibre and LN can feedthroughs.

Parameter	Value	Comment	Estimated heat load (W)
Area of optical bench	13.6m²	This has been approximated to radiation shield	
Effective emmissivity	0.026		
			3
Shear web area	2000mm²		
Shear web length	60mm		
Shear web conductivity	5W/mK	G10 integrated 211-200	
			0.16
Cable area	5mm²	Estimate	
Cable length	500mm		
Cable conductivity	4400W/m		0.044
LN tube area	50mm²	4 tubes, 20mm dia. wall thickness 0.2	
LN tube length	500mm		
LN tube conductivity	150W/m		0.015
Fibre area	6mm²	2x2mm dia.	

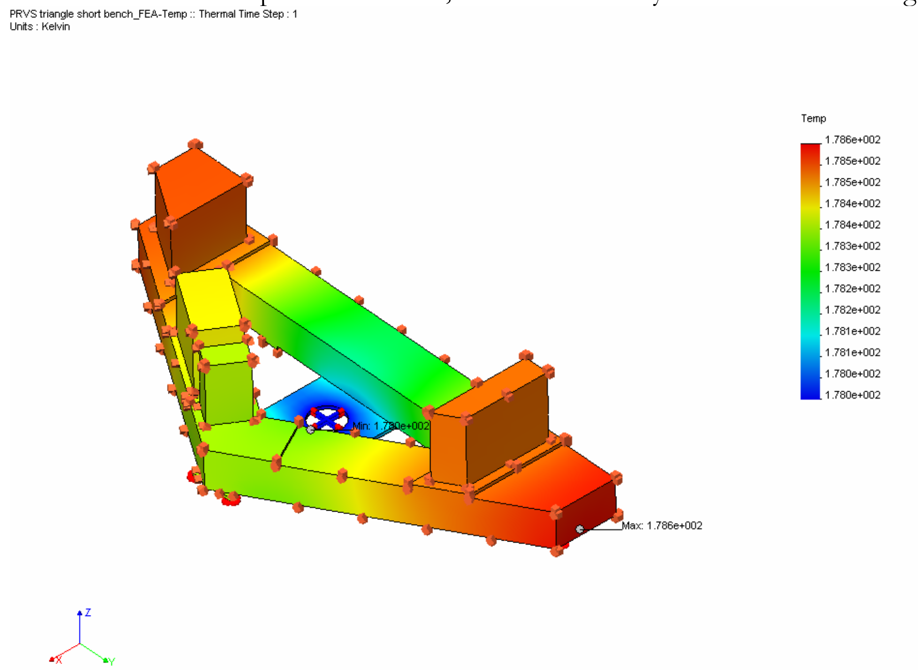
Fibre length	500mm		
Fibre conductivity	10W/m	Glass equivalent	0.00012
Radshield temperature	211		
Bench control temp	200		
Total heat load			3.2

5.4.1 Shutter mechanism heat loads

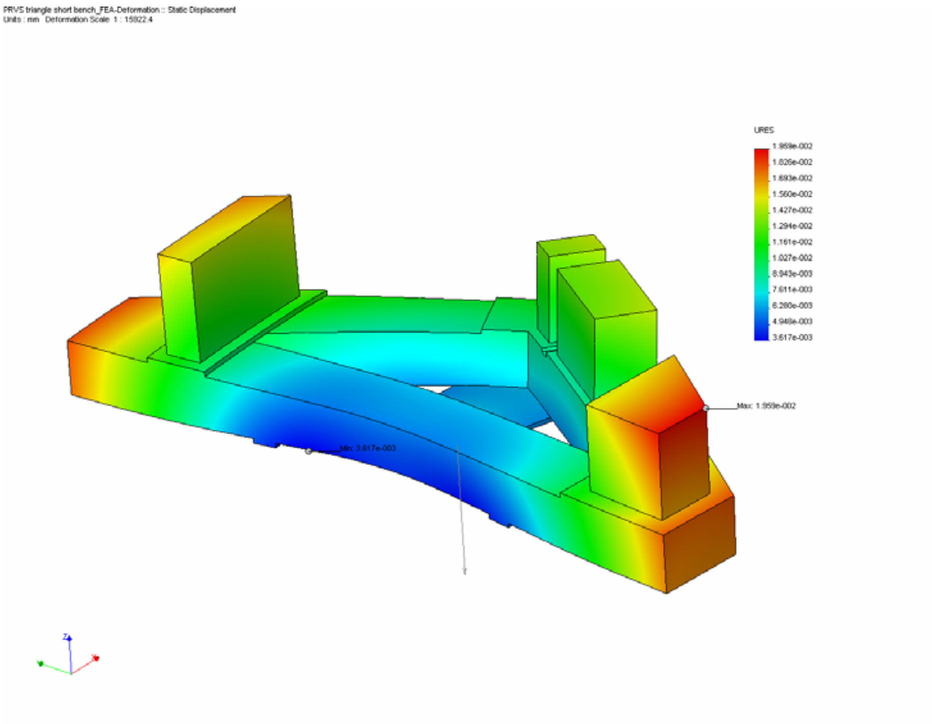
The shutter mechanism is thermally insulated from the optical bench and is linked directly to the main firsts stage cooling wick. The heat from the mechanism does not pass through the optical support structure. The deployment and retraction time is 20 seconds with a power consumption of 5w. The duty cycle expected to be very low resulting in negligible average heat loads when compared to the other first stage heat loads.

5.5 OPTICAL BENCH TEMPERATURE DISTRIBUTION

Using the heat load estimates in the previous section, a model was analysed with the following results.



As can be seen from the plot, there is a temperature distribution of 0.6K across the optical bench. This temperature distribution will distort the bench as shown below.



The primary effect is for the bench to expand about the cold wick attachment area. The bench also bows slightly and the included angles change. Maximum angles are of the order of 8 microradians, expansion 0.012mm from the centre. The results are tabulated for the optical subassemblies in the table below.

Sub assembly	Displacement X (microns)	Displacement Y (microns)	Displacement Z (microns)	Rotation X (µrad)	Rotation Z (µrad)
Input group	-0.387	-11.537	7.287	1.489	-4.026
Collimator	0.595	10.193	7.898	-2.926	3.680
Camera	5.824	-7.856	7.327	2.446	-8.359
Detector	9.918	-1.886	6.567	2.771	-6.668

5.6 HEAT LOADS ON THE VACUUM VESSEL

The vacuum vessel temperature will reach equilibrium temperature when the radiated and conducted loads into the cold structure equal the convected heat from the ambient air.

Parameter	Area (m^2)	Convective heat transfer co-eff, h (W/m^2K)	Comment
Area top surface	4.0	1.3*	Estimated at sea level
Area vertical sides	5.0	1.44*	
Area bottom surface	4.0	0.69*	
Estimated temperature	16 C		$DT=Q/\sum h_iA_i$, 20C ambient

*These values are applicable to sea level.

5.7 CLOSED CYCLE REFRIGERATOR

The refrigerator will be a two stage GM such as the CTI1050. A power temperature curve is shown below. The star indicated the position where such a cooler would be working for PRVS with the heaters switched off.

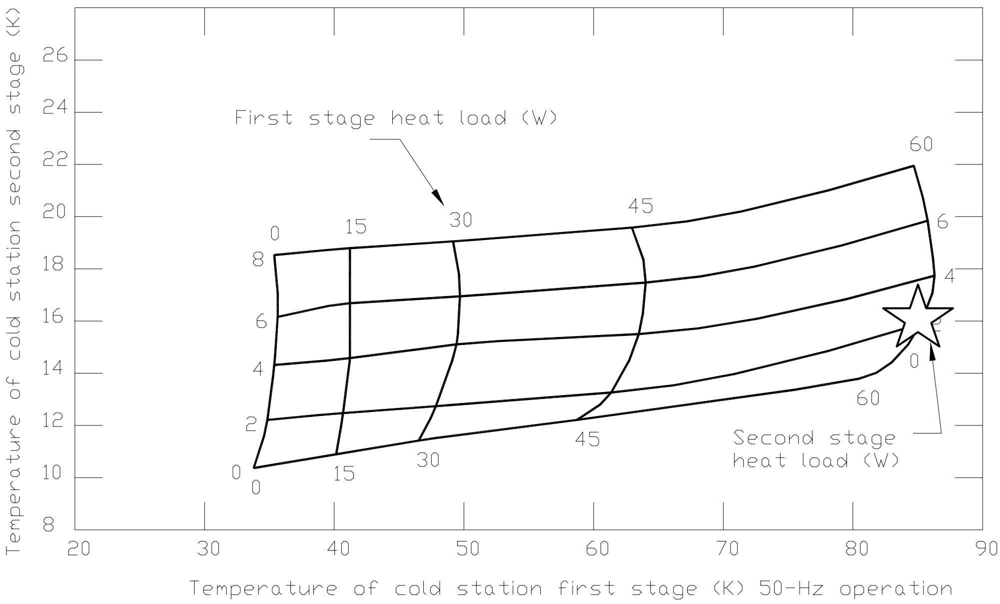


Figure 19: Power temperature curve for Closed Cycle Refrigerator

This cold head will be mounted on a (UKATC) standard anti-vibration mount.

5.8 STEADY STATE TEMPERATURES

The following table represents an estimate of the temperatures from the cooler to various components based on the heat loads calculated in the preceding sections.

Stage	Temperature (K)	Stage temp (K)	Comment
First stage		90	
DT first stage wick	31	121	Open loop
DT radiation shield	12	133	Open loop
DT optical bench	0.6	121.6	Open loop
First stage	35	124	47W heating
DT first stage wick	54*	178	47W heating
DT radiation shield	12	190	47W heating
DT optical bench			
Second stage		16**	Open loop
DT second stage wick	4*	20	Open loop
DT Second stage	7	27	47W heating OSS
DT Second stage	14	41	14W detector heating
DT second stage wick	28	69	14W heating

*The figures for conductance of the copper wicks are extrapolated from measured results for the WFCAM instrument.

** Assumes a 2W heat load into the detector box from cabling.

5.9 RESPONSE TO STEP CHANGE IN AMBIENT TEMPERATURE

In considering a step change in temperature, the steady state effects can be estimated and also the system response or time constant. These results can then be scaled to represent a likely change in ambient conditions. In this section, the instrument response to an arbitrary 1K change in ambient is analysed.

5.9.1 Steady state response

Assume that the ambient temperature changes by 1K, the following table shows the estimated effects on the system temperatures.

Effect	Increased heat load on next stage in (W)	Increase in temperature (K)	Comment
Vacuum vessel	1.6%	1	
Radiation shield	1.6%	0.18	
Optical support structure		0.011	

5.9.2 Effect on optical bench alignment of 10K ambient variation steady state

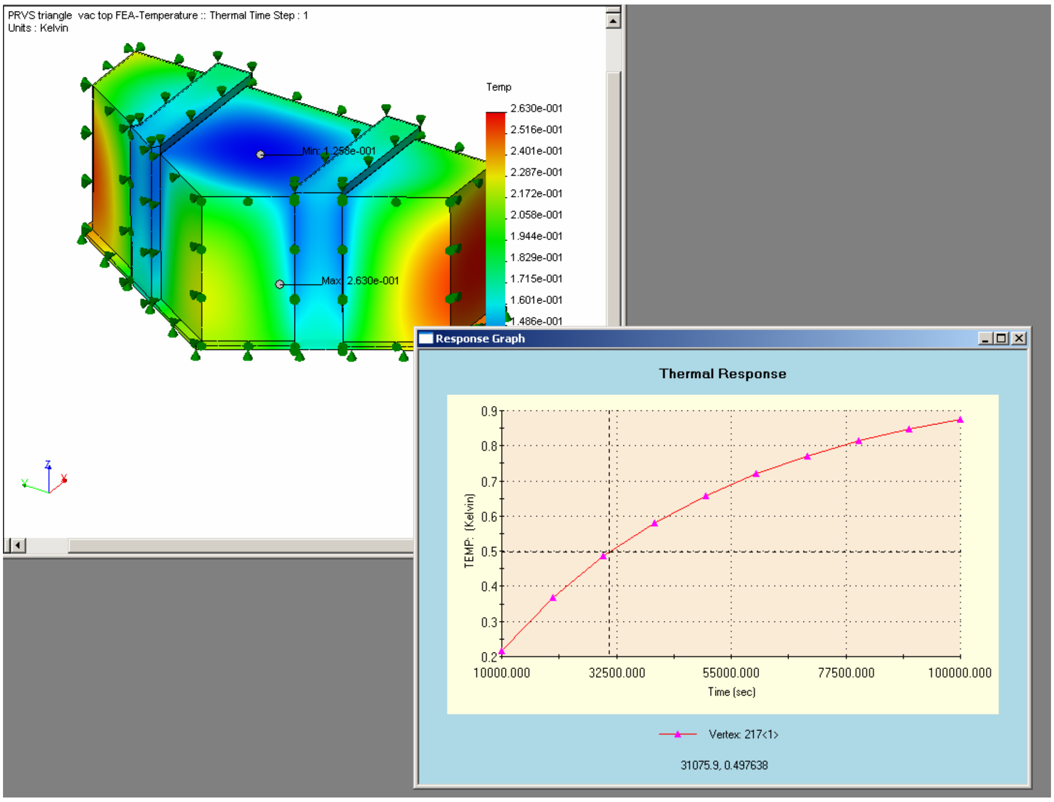
From the above table, a 10K change in ambient will result in heat loads changing by approximately 16%. This in turn will cause the steady state temperature gradients of the optical bench to vary by the same amount and also the deformation. This is estimated from the previous section to be a 0.1K temperature variation resulting in the following changes.

Sub assembly	Displacement X (microns)	Displacement Y (microns)	Displacement Z (microns)	Rotation X (μrad)	Rotation Z (μrad)
Input group	-0.0619	-1.846	1.166	0.238	-0.644
Collimator	0.0952	1.631	1.264	-0.468	0.589
Camera	0.932	-1.257	1.172	0.391	-1.337
Detector	1.587	-0.302	1.051	0.443	-1.067

These deformations result in a displacement of the lines on the detector of 0.08 pixels but this would take many hours to reach steady state. From the dynamic response calculated in the following section, a 10K step change would cause the radiation shield temperature to change by 0.012K/hour. As all heat loads to the optical bench come from the radiation shield, this is the maximum rate of change of the optical bench (in reality it will be a small fraction of this). So for these conditions the maximum image motion is estimated to be 0.001pixels compared to the requirement of 0.1pixels.

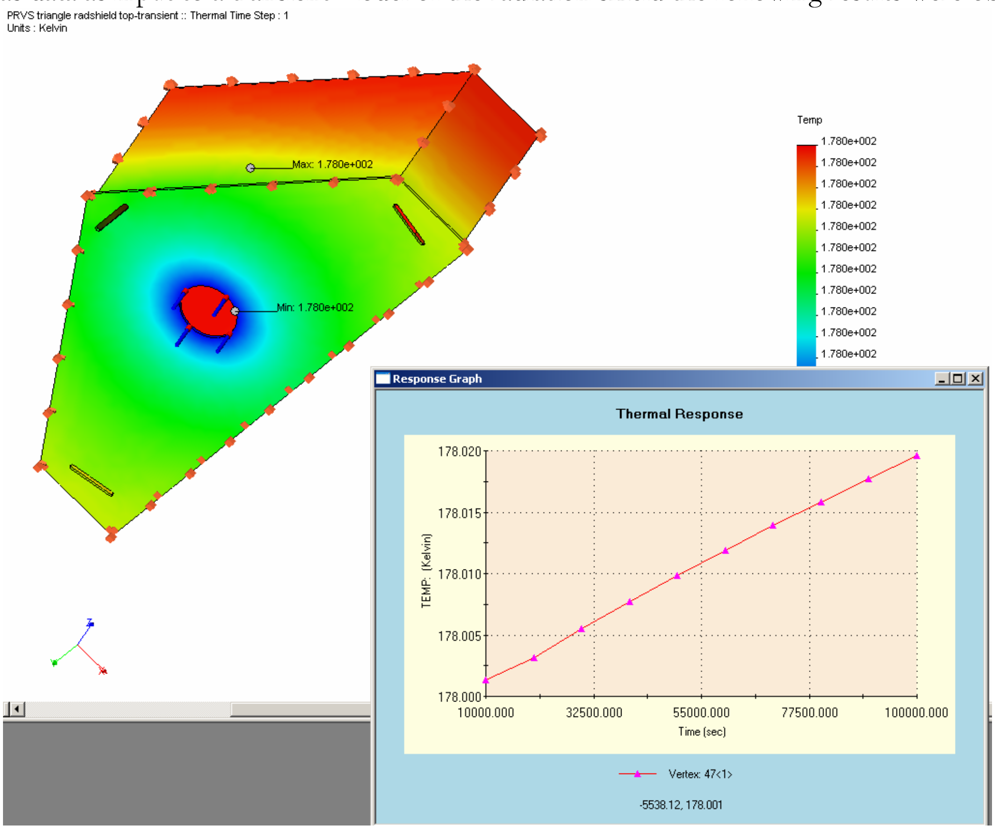
5.9.3 Dynamic thermal response

A model was analysed for the transient response of the vacuum vessel to a 1K step change in ambient temperature with the following results.



As can be seen, the 50% decay time is 31,000 sec or 8.6 hours. Initial rate of change 64mK/hour.

Using this as data as input to a transient model of the radiation shield the following results were obtained.

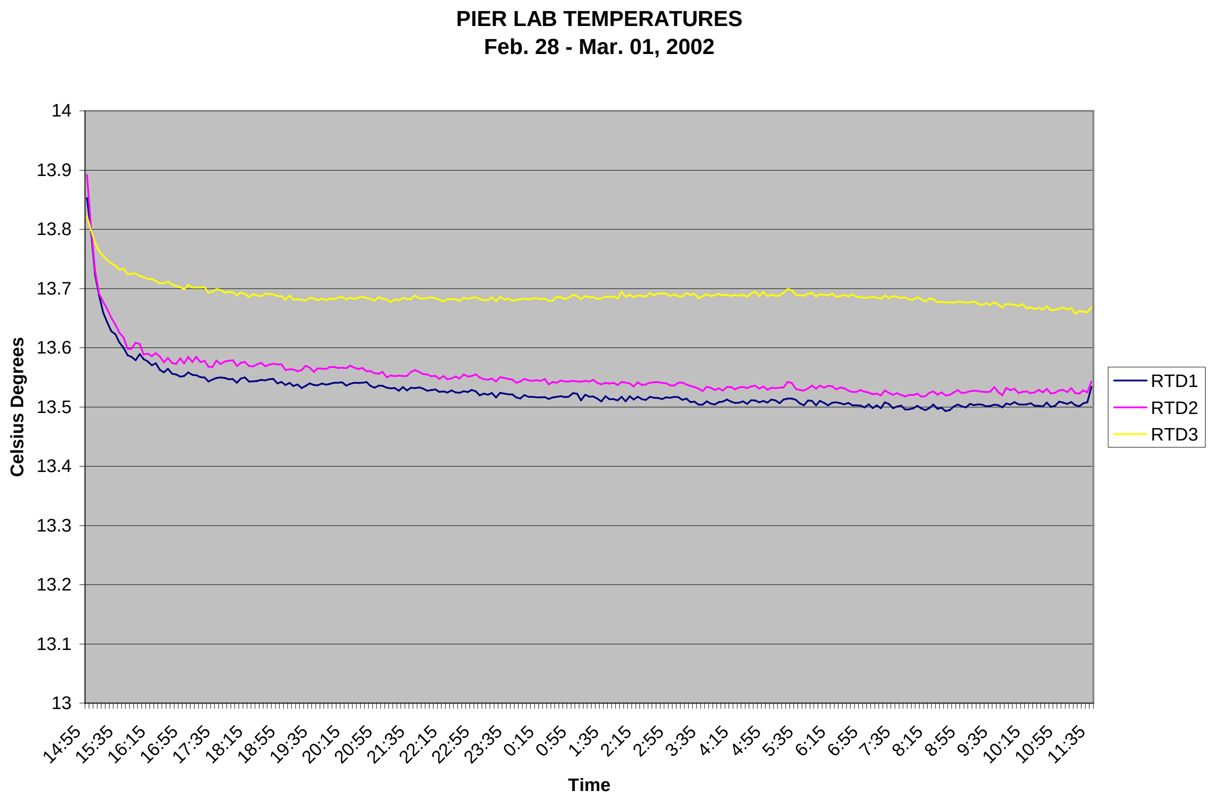


As can be seen, the response in the time frame considered is linear at 3.25x10-7 K/sec or 1.2mK/hour.

Based on this temperature change, it is clear that the thermal stability of the optical support structure over 1 hour will be adequate since all its heat loads come from the radiation shield.

5.9.4 Pier lab stability data

Some stability data was obtained for the pier lab where the bHROS instrument is installed. If this is typical, then clearly the short term stability (say 1 to 10 hours) of the current design is adequate since the variation is less that 1K over two days. More data would be useful on the pier lab stability over the long term (1 year).



5.9.5 Other de-stabilising influences

The other potential de-stabilising influences are tabulated below.

Source	Effect	Comment
Change in ambient	Heat load variation causing temperature gradients variation	Analysed above
Variations in refrigeration	Change in base temperature but controlled by servo in this design	Can be caused by leakage of the helium circuit or changes in ambient
Heat from mechanisms	Heating of optical bench on irregular basis	Not significant
Heat from detector	Variations in detector assembly temperature	Detector assembly will be insulated and independently controlled
Poor control of base temperature	Can vary the temperature of the bench in the short and long term	Need good temperature data and PID control. Can be limited by limiting power to heaters.

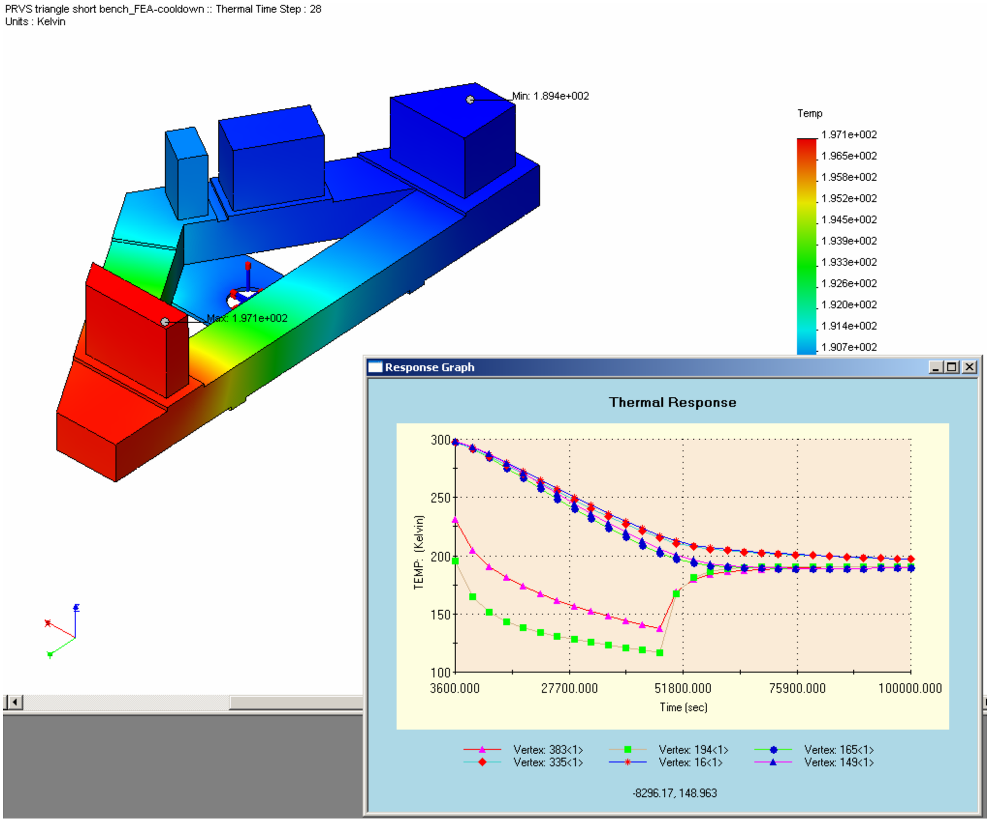
5.9.6 Expected temperature stability of the optical bench

The medium to long terms temperature stability will be dictated by the stability of the control loop electronics and temperature sensing. It is expected that 0.1K will be achievable. Short term (up to 8hours) stability of 0.01K is expected due to the high thermal inertia and de-coupling from ambient.

5.10 COOL DOWN TIME

5.10.1 Optical bench

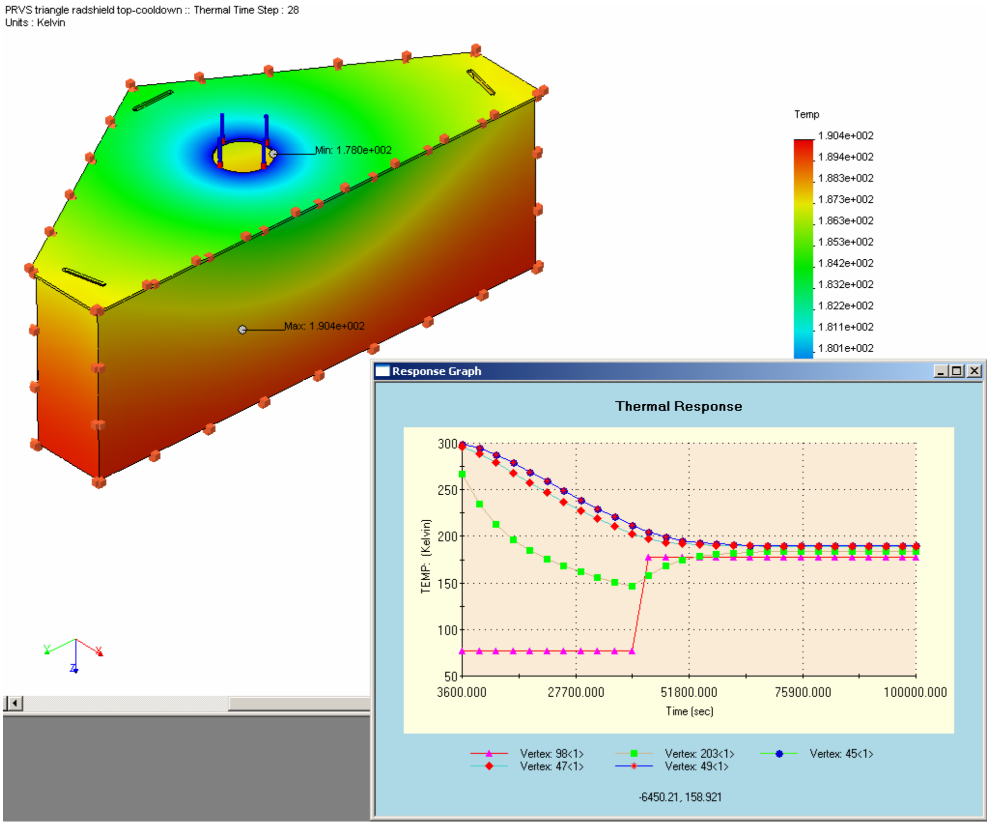
The plot below shows the estimated temperature distribution after 28 hours with a 13 hour LN pre-cool followed by thermal control near the LN fill. Response curves are shown for selected points on the structure (time steps are 1 hour). At the end of this time temperature difference across the bench is 8K.



If we assume that the instrument must meet the full stability specification of 0.05K above the set temperature for the bench, the cool-down is estimated to take another 46 hours, 74 hours in total. This is within the 96 hour requirement.

5.10.2 Radiation shield

The plot below shows the estimated temperature distribution after 28 hours with an 11 hour LN pre-cool followed by thermal control near the LN fill. Response curves are shown for selected points on the structure (time steps are 1 hour). At the end of this time temperature difference across the bench is 3K.

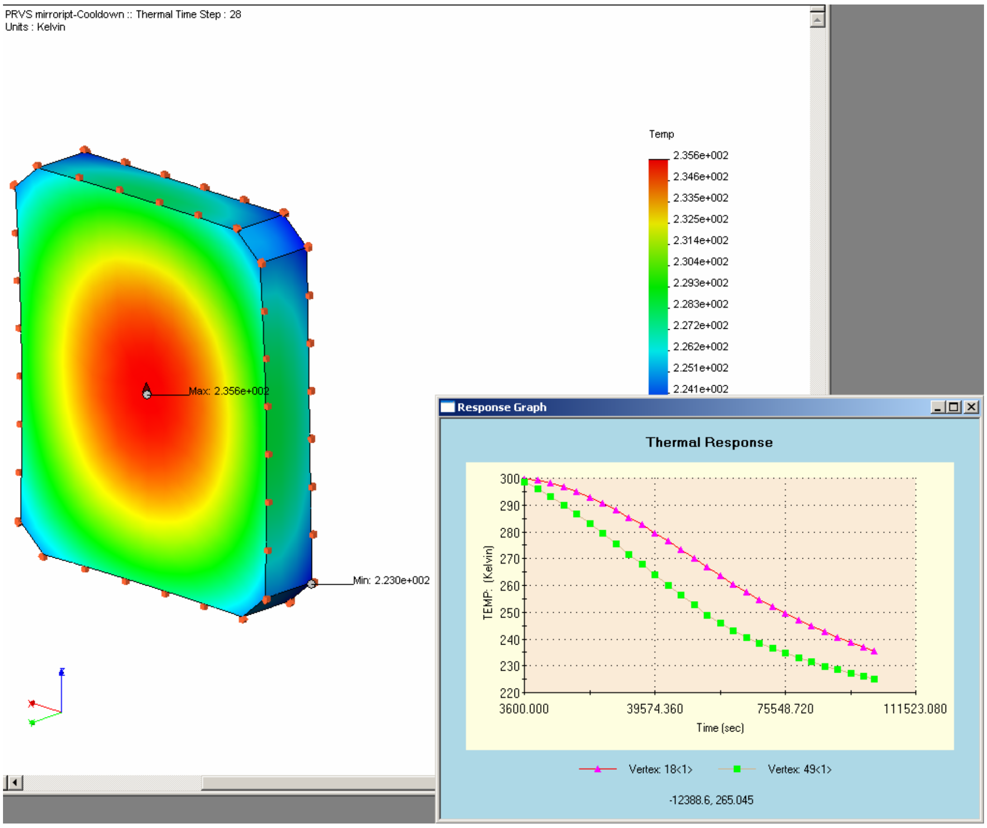


5.10.3 Warm up

The warm will be possible in 24 hours, using the temperature control heaters and controlled back fill of the vacuum vessel.

5.10.4 Collimator cool-down

The cool-down of the collimator was modelled assuming that it is radiatively coupled to the bezel (black anodised or painted to give an effective emmissivity of 0.8). The bezel temperature profile is approximated to the cool-down curves estimated for the optical bench. The results are shown below as thermal response cool-down curves for the edge and the centre of the mirror optical surface. This is expected to be the slowest cooling of all the optical elements due to its mass.

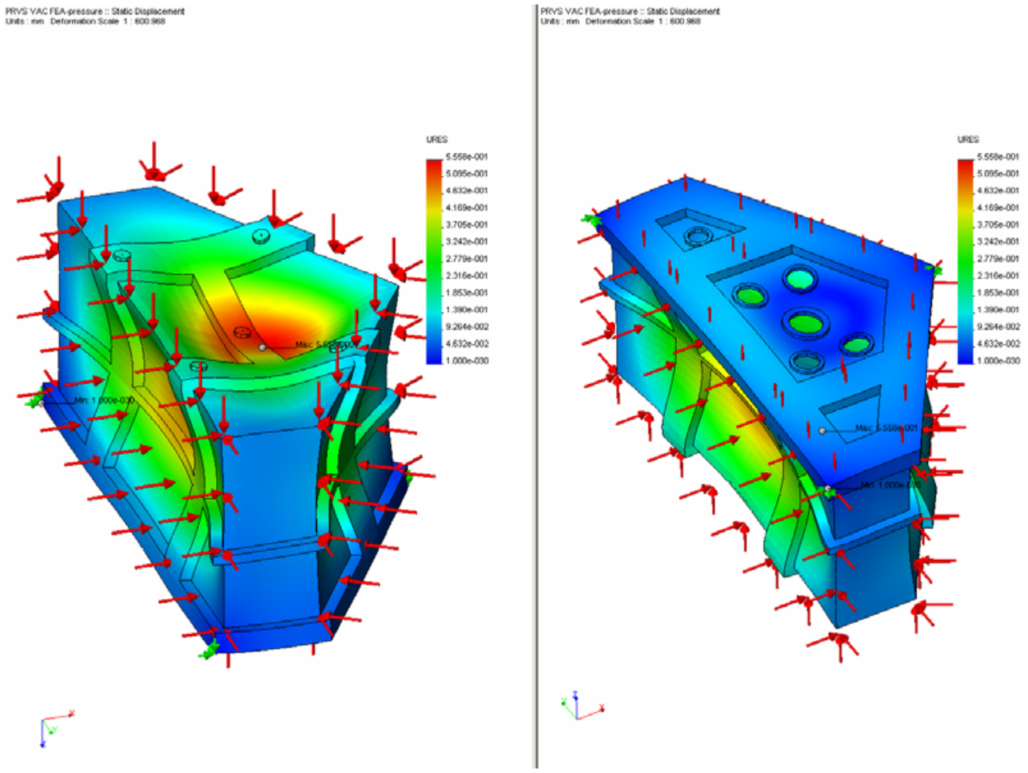


The collimator lags the optical bench by some 30K after 28 hours at 236K. Extrapolated temperature after 48 hours is 215K.

6. STRUCTURAL ANALYSIS

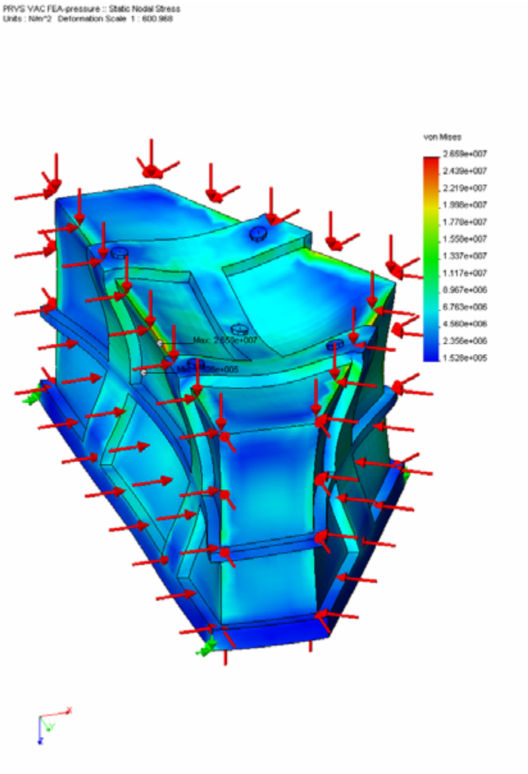
6.1 VACUUM VESSEL DEFORMATION UNDER LOAD

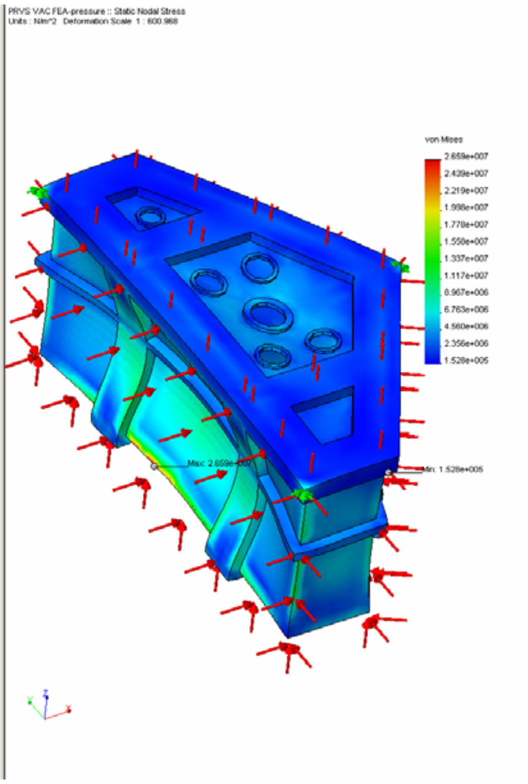
The vacuum vessel was analysed for an external pressure of 1 atmosphere simulating use at sea level. The results are shown below. It can be seen that maximum deflections are 0.5mm, well within the requirement of 2mm.



6.2 VACUUM VESSEL STRESSES UNDER LOAD

The vacuum vessel was analysed for an external pressure of 1 atmosphere simulating use at sea level. The results are shown below. It can be seen that maximum stresses are 27Mpa, well within the requirement of 64Mpa (SF4 on yield for 6061 T6).


PRVS VAC FEA-pressure :: Static Nodal Stress
Units : N/m^2 Deformation Scale 1 : 600.968
von Mises
2.659e+007
2.439e+007
2.219e+007
1.998e+007
1.778e+007
1.558e+007
1.337e+007
1.117e+007
8.967e+006
6.763e+006
4.560e+006
2.356e+006
1.528e+005

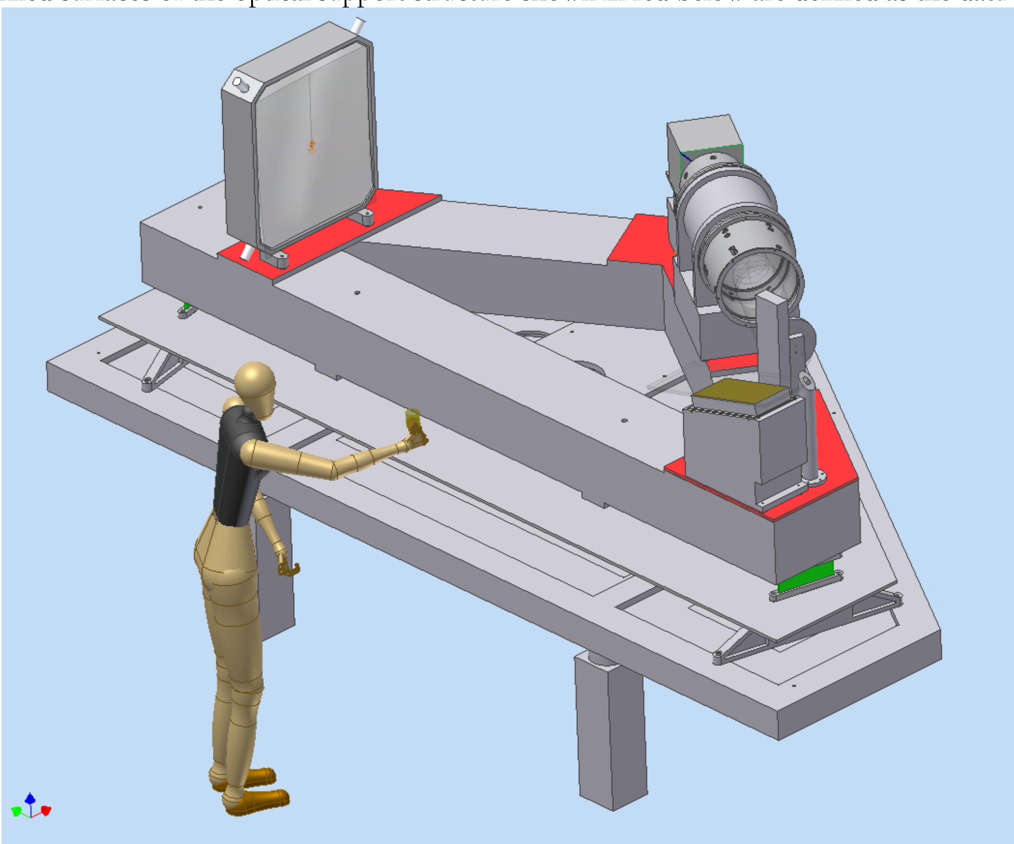

PRVS VAC FEA-pressure :: Static Nodal Stress
Units : N/m^2 Deformation Scale 1 : 600.968
von Mises
2.659e+007
2.439e+007
2.219e+007
1.998e+007
1.778e+007
1.558e+007
1.337e+007
1.117e+007
8.967e+006
6.763e+006
4.560e+006
2.356e+006
1.528e+005
Min: 1.528e+005

7. TOLERANCE ANALYSIS

In this section, a bottom-up estimate of the static misalignment of the optical elements is presented. In each case tolerances are given in local XYZ co-ordinates. This is a right handed co-ord system looking at the optic along the optical axis which is the –Z direction. X is horizontal.

7.1 DATUM SURFACE DEFINITION

The machined surfaces of the optical support structure shown in red below are defined as the datum.

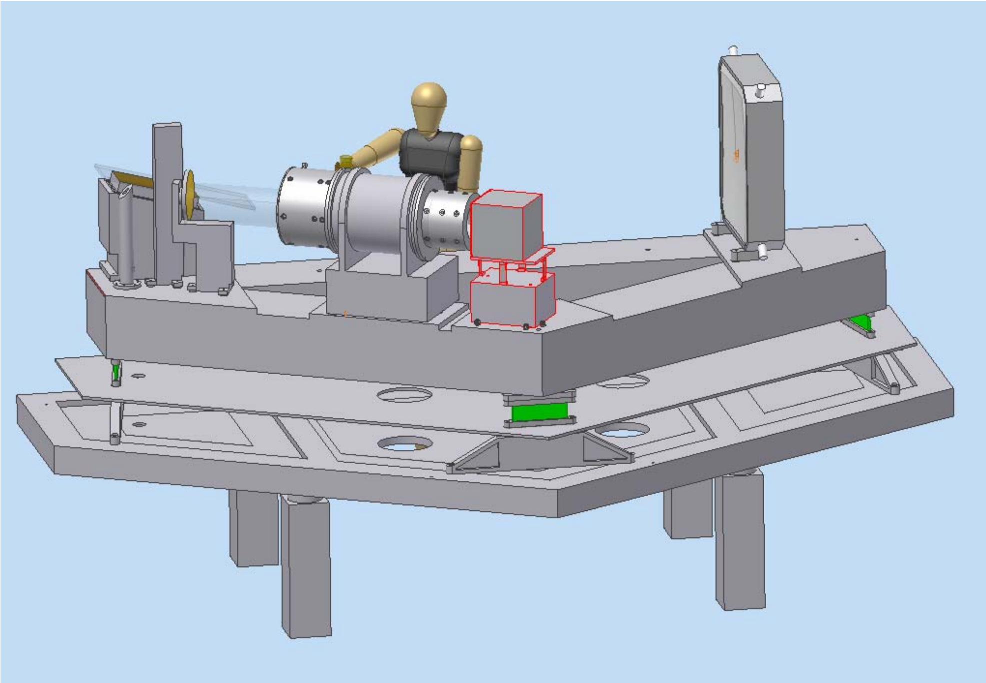


The pads on which the optical modules are mounted have individual position and tilt tolerances detailed in the table below.

Mounting pad	Tilt (µradians)	Height (mm)	Module position feature (mm)
Input/echelle	200	0.05	0.05
Collimator	200	0.05	0.05
Camera	200	0.05	0.05
Detector assembly	200	0.05	0.05

7.2 DETECTOR ASSEMBLY

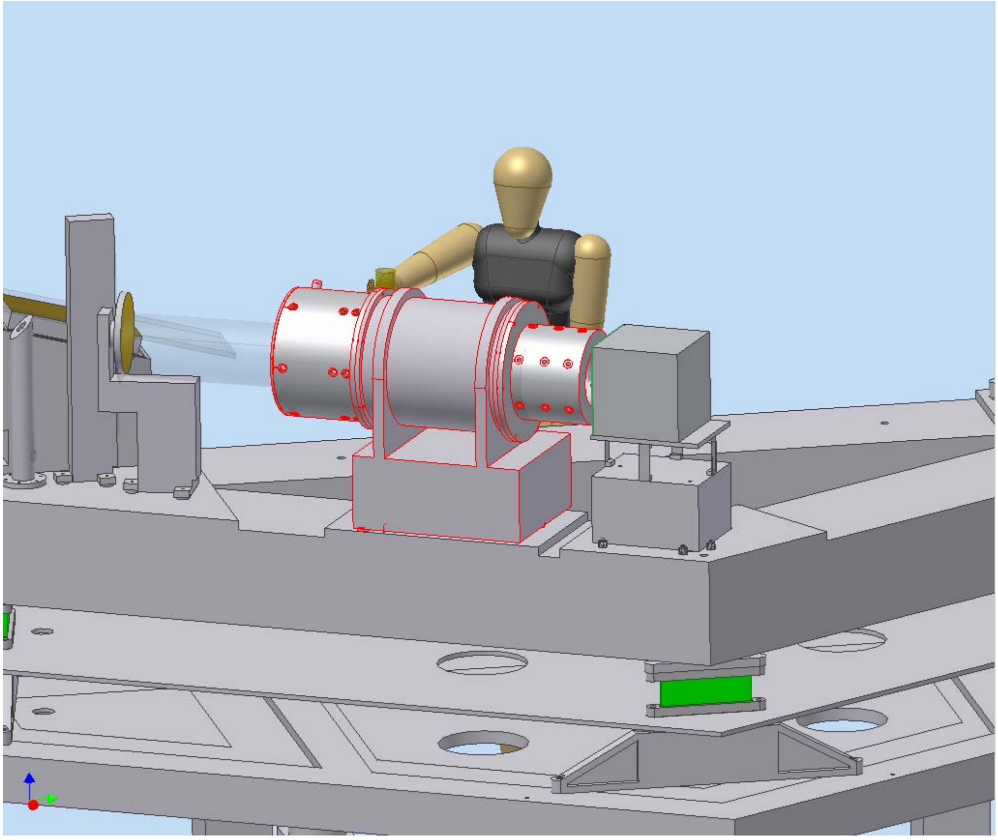
This includes the detector box, its thermal mount and the interface mount to the bench, outlined in red in the picture below.



Item	Tilt X (μradians)	Tilt Y (μradians)	Tilt Z (μradians)	Dec X (mm)	Dec Y (mm)	Spacing (mm)
Mounting surface	200	200	200	0	0.05	0
At det				0.07	0.07	0.07
Locating features	100	100	100	0.05	0.05	0.05
At det				0.035	0.035	0.035
Mount geometry	100	100	100	0.05	0.05	0.05
At det				0.035	0.035	0.035
Flexure fits	100	100	100	0.02	0.02	0.02
				0.019	0.019	0.019
Flexure geometry	100	100	100	0.02	0.02	0.02
At det				0.015	0.015	0.015
Flexure fits	100	100	100	0.02	0.02	0.02
				0.011	0.011	0.011
Mounting plate geometry	100	100	100	0.02	0.02	0.02
				0.011	0.011	0.011
Detector box fits	0	100	100	0.02	0	0.02
Detector to box	100	100	100	0.1	0.1	0.1
Totals (rss)	331	346	346	0.159	0.165	0.159

7.3 LENS BARREL

To simplify the tolerancing and to reflect the natural grouping of sub assemblies this table has three sub totals for the entire lens tube, lens groups 1 and 2 and individual lenses. This is outlined in red in the picture below.

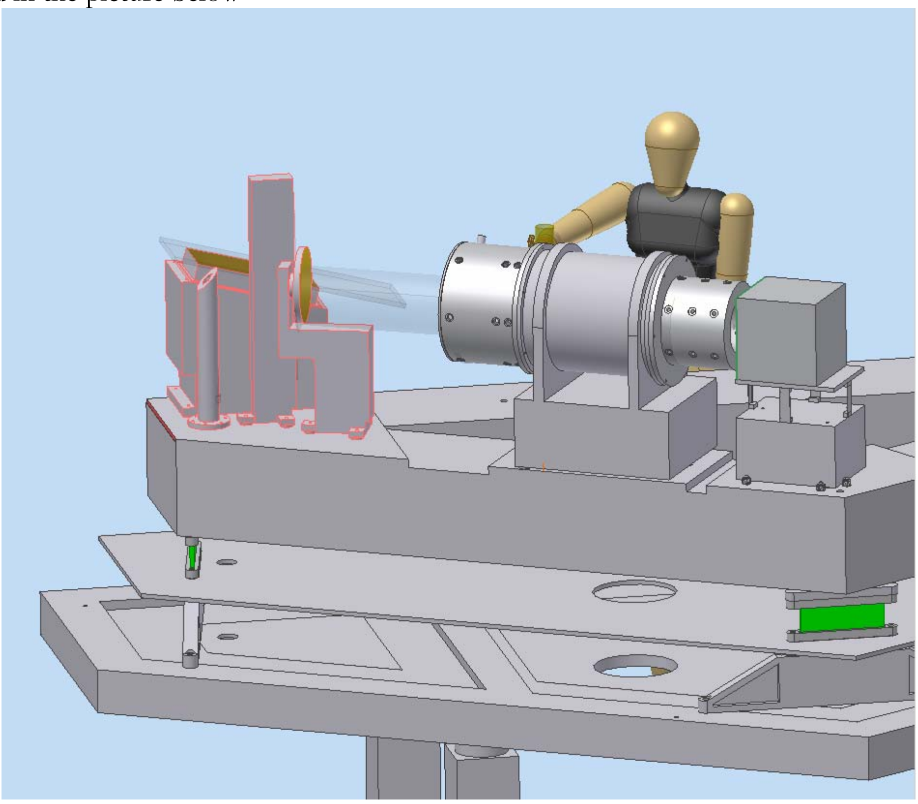


Item	Tilt X (μradians)	Tilt Y (μradians)	Tilt Z (μradians)	Dec X (mm)	Dec Y (mm)	Spacing (mm)
Lens barrel						
Mounting surface	200	200	200	0	0.05	0
Mid barrel				0.07	0.07	0.07
Locating features	100	100	100	0.05	0.05	0.05
Mid barrel				0.035	0.035	0.035
Mount geometry	100	100	100	0.05	0.05	0.05
Mid barrel				0.035	0.035	0.035
Total (rss)	245	245	245	0.11	0.12	0.11
Lens group 1 and 2						
Tube mount geometry	50	50	0	0.020	0.020	0.05
Fit	0	0	0	0.020	0.020	0

Lens bezel geometry	50	50	0	0.02	0.02	0.05
Total (rss)	71	71	0	0.035	0.035	0.071
Lenses 1-6						
Radial definer mount	0	0	0	0.05	0.05	0
Plunger/spring	0	0	0	0.041	0.041	0.041
Axial spacer	20	20	20	0	0	0.05
Totals (rss)	20	20	20	0.041	0.041	0.064

7.4 INPUT GROUP

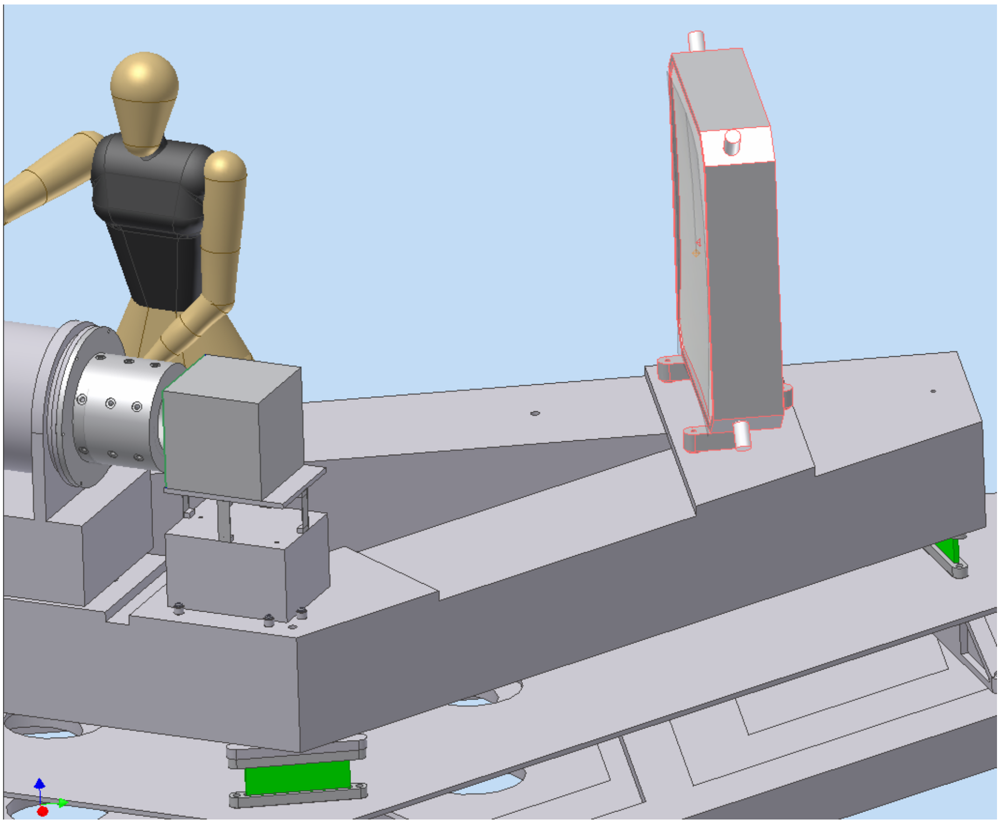
The input group includes the input fold, echelle, spectrum mirror, slit and dispersing mirror. These are outlined in red in the picture below



Item	Tilt X (μradians)	Tilt Y (μradians)	Tilt Z (μradians)	Dec X (mm)	Dec Y (mm)	Spacing (mm)
Mounting surface	200	200	200	0	0.05	0
Locating features	100	100	100	0.05	0.05	0.05
At optic				0.070	0.070	0.070
Mount geometry	100	100	100	0.05	0.05	0.05
Total (rss)	300	300	300	0.099	0.11	0.099

7.5 COLLIMATOR

The collimator assembly is outlined in red below.



Item	Tilt X (µradians)	Tilt Y (µradians)	Tilt Z (µradians)	Dec X (mm)	Dec Y (mm)	Spacing (mm)
Mounting surface	200	200	200	0	0.05	0
Locating features	200	200	200	0.05	0.05	0.05
At optic				0.070	0.070	0.070
Mount geometry	100	100	100	0.05	0.05	0.05
Plunger/spring				0.05	0.05	0.05
Total (rss)	300	300	300	0.11	0.11	0.11

7.6 EFFECT OF TOLERANCES

The effect of these tolerances on image quality is not assessed here. The bottoms up estimates are generally of the order of ±0.1mm decentres and ±300µradians tilts.

The sensitivity analysis carried out in document TRE-00003-0001 used ±0.2mm decentres and ±200µradians tilts. Some iteration is required to settle the manufacturing tolerances (PDR phase) but the image quality degradation looks to be acceptable.

8. MASS ESTIMATE

The mass of the instrument is estimated here for the baseline design.

Item		Mass (Kg)	Mass (Kg)	Mass (Kg)
Vacuum vessel				
Vessel base				
	Base component	186		
	Close cycle cooler +AV	20		
	Turbo pump +valve	10		
	Vacuum Accessories	10		
	Subtotal	226	226	
Vacuum vessel mid section		208	208	
Vacuum vessel top section		313	313	
Subtotal			**747**	**747**
Cold structure				
Radiation shield				
	Radshield base	77		
	Radshield mid section	63		
	Radshield top	298		
	LN cans	14		
	Subtotal	379	**298**	
Optical bench				
	Optical bench	200		
	Support flexures	5		
	Input module	1.4		
	Slit module	2 (est)		
	Collimator module	91		
	Spectrum mirror module	7.5		
	Disperser module	8.2		
	Camera module	47		
	Detector module	19		
	Subtotal	381		
Wicks	Wicks	30		
	Subtotal	411	**411**	
		Subtotal	**709**	**709**
Legs		45		**45**
Fasteners		50		**50**
			Total	**1541**

The mass estimate is well within the 3000Kg specification. The largest individual element requiring disassembly in the pier lab (vacuum vessel top is 313Kg). This is well within the capacity of the overhead hoists.

9. ASSEMBLY PROCEDURE

The assembly procedure is fairly straightforward as this is essentially a bench spectrograph. Many components and sub-modules require lifting apparatus and handling interface to the same. All modules above 5Kg will be fitted with lifting points for swivel hoist rings. In the UKATC instrument lab, a travelling overhead crane is available with plenty of headroom.

At the Gemini telescope, options for craneage are more limited, particularly within the pier lab where there is a pair of overhead hoists on a fixed rail. The vacuum vessel and radiation shield have been split to accommodate the underhook height in the lab. With this scheme, the instrument must be positioned with the CofG of the vacuum vessel top and radiation shield directly under the rail.

A suggested position and orientation for the instrument is shown in the picture below. The locus of the crane in this case is compatible with removing the collimator and grating modules. It is possible to get castor attachments and braces for the legs to allow position of the instrument for this operation.

The modules can be handled using the overhead hoists. The addition of an appropriate portable boom hoist would be of benefit. In either case, it would be advisable to modify the hooks and associated hardware to remove or cover oil and paint.

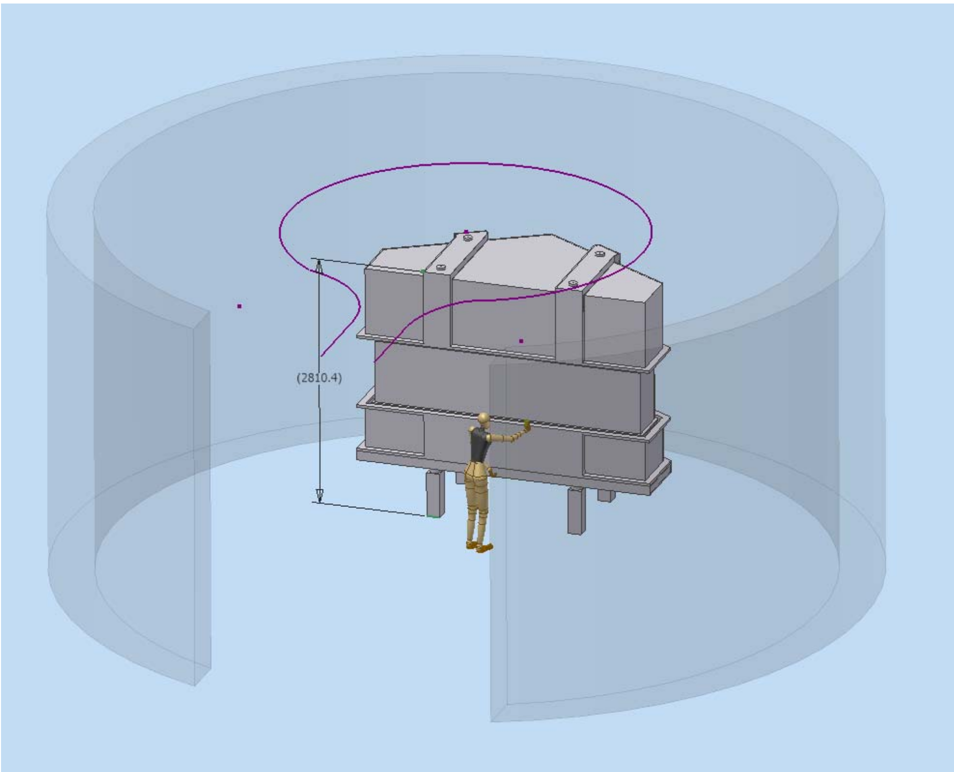


Figure 20. Removing vacuum vessel top section

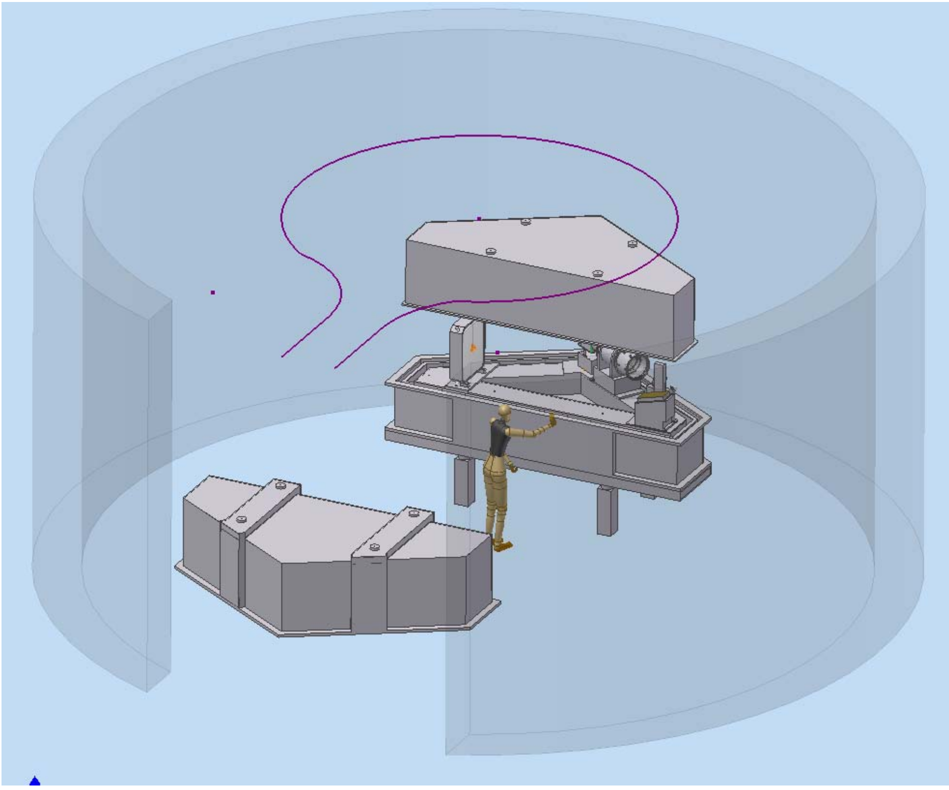


Figure 21. Removing radiation shield top section

9.1 SWIVEL HOIST RINGS

All handling interfaces will be designed for swivel lifting eyes. Interfaces will have a flat land greater than 'D' in the table below. Tapped holed shall use inserts and be 2 diameters deep. All lifting points will be static load tested to 1.25x maximum calculated load. See appendix 'Swivel hoist rings'.

10. APPENDIX

10.1 ANTI-VIBRATION SUPPORTS

This data sheet is an example of a commercially available solution. Other options/manufacturers may be found during further development of the design.

Optical Supports

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System 1

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Discounted Inventory
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Free-Standing Individual Posts

Gimbal Piston™ Isolators and Rigid Supports

Free-standing posts are a convenient alternative to posts with tiebars when open access between the pos is necessary. Though generally configured in sets of 4 and 6 legs, other configurations include 3 and 5 legs.

The independent posts offer the maximum flexibility in post positioning with respect to the optical Top.

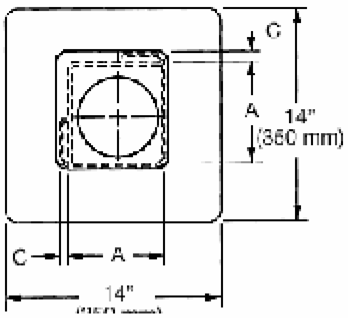
Free-standing posts are especially convenient for supporting large coupled table systems.

Click here for a larger image.

Features

- Patented Gimbal Piston™ or rigid leveler
- Baseplate with leveling screws are available as an option. (Change the fourth digit of the catalog number from "3" to "4".)
- Oversize steel base plate for maximum stability

Dimensions and suggested layouts for Free-Standing Individual Posts



Posts may be used in group of 3, 4, 5, 6, or more.

10.2 ALUMINIUM EXTRUSIONS

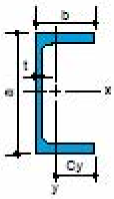
This data sheet is an example of a commercially available solution. Other options/manufacturers may be found during further development of the design.

All dimensions in inches and weight in pounds per lineal foot

ALUMINUM Alloy 6061-T6

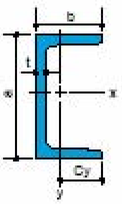
STRUCTURAL CHANNELS

25' lengths



Aluminum Association Standard

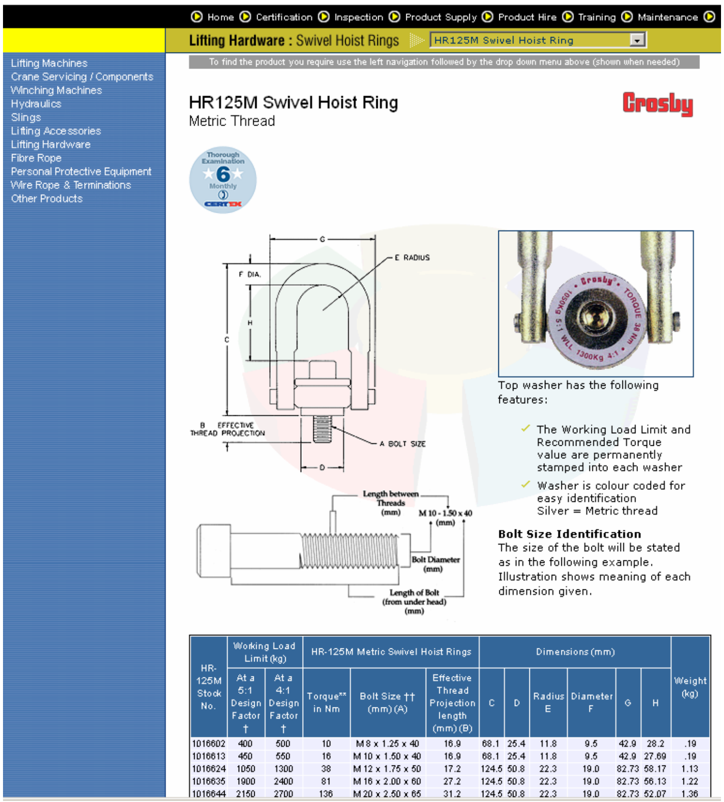
a	b	t	lb/ft	Area	Ix	Sx	rx	Iy	Sy	ry	Cy
2.00	1.00	.13	.577	.491	.288	.288	.766	.045	.064	.303	.70
2.00	1.25	.17	1.071	.911	.546	.546	.774	.139	.178	.391	.78
3.00	1.50	.13	1.135	.965	1.41	.94	1.21	.22	.22	.47	1.01
3.00	1.75	.17	1.597	1.358	1.97	1.31	1.20	.42	.37	.55	1.13
4.00	2.00	.15	1.738	1.478	3.91	1.95	1.63	.60	.45	.64	1.35
4.00	2.25	.19	2.331	1.982	5.21	2.60	1.62	1.02	.69	.72	1.47
5.00	2.25	.15	2.212	1.881	7.88	3.15	2.06	.98	.64	.72	1.52
5.00	2.75	.19	3.089	2.627	11.14	4.45	2.06	2.05	1.14	.88	1.80
6.00	2.50	.17	2.834	2.410	14.35	4.78	2.44	1.53	.90	.80	1.71
6.00	3.25	.21	4.030	3.427	21.04	7.01	2.48	3.76	1.76	1.05	2.13
7.00	2.75	.17	3.205	2.725	22.09	6.31	2.85	2.10	1.10	.88	1.91
7.00	3.50	.21	4.715	4.009	33.79	9.65	2.90	5.13	2.23	1.13	2.30
8.00	3.00	.19	4.147	3.526	37.40	9.35	3.26	3.25	1.57	.96	2.07
8.00	3.75	.25	5.789	4.923	52.69	13.17	3.27	7.13	2.82	1.20	2.53
9.00	4.00	.29	6.970	5.927	78.31	17.40	3.63	9.61	3.49	1.27	2.75
10.00	3.50	.25	6.136	5.218	83.22	16.64	3.99	6.33	2.56	1.10	2.48
10.00	4.25	.31	8.360	7.109	116.15	23.23	4.04	13.02	4.47	1.35	2.91
12.00	4.00	.29	8.274	7.036	159.76	26.63	4.77	11.03	3.86	1.25	2.86
12.00	5.00	.35	11.822	10.053	239.69	39.95	4.88	25.74	7.60	1.60	3.39



American Standard

a	b	t	lb/ft	Area	Ix	Sx	rx	Iy	Sy	ry	Cy
3	1.410	.170	1.420	1.21	1.66	1.10	1.17	.20	.20	.40	.970
3	1.498	.258	1.730	1.47	1.85	1.24	1.12	.25	.23	.41	1.058
3	1.596	.356	2.070	1.76	2.07	1.38	1.08	.31	.27	.42	1.136
4	1.580	.180	1.850	1.57	3.83	1.92	1.56	.32	.28	.45	1.120
4	1.647	.247	2.160	1.84	4.19	2.10	1.51	.37	.31	.45	1.197
4	1.720	.320	2.500	2.13	4.58	2.29	1.47	.43	.34	.45	1.260
5	1.750	.190	2.320	1.97	7.49	3.00	1.95	.48	.38	.49	1.270
5	1.885	.325	3.110	2.64	8.90	3.56	1.83	.63	.45	.49	1.406
5	2.032	.472	3.970	3.38	10.43	4.17	1.76	.81	.53	.49	1.522
6	1.920	.200	2.830	2.40	13.12	4.37	2.34	.69	.49	.54	1.410
6	1.945	.225	3.000	2.55	13.57	4.52	2.31	.73	.51	.54	1.435
6	2.034	.314	3.630	3.09	15.18	5.06	2.22	.87	.56	.53	1.534
6	2.157	.437	4.480	3.82	17.39	5.80	2.13	1.05	.64	.52	1.647
7	2.110	.230	3.540	3.01	21.84	6.24	2.69	1.01	.64	.58	1.570
7	2.194	.314	4.230	3.60	24.24	6.93	2.60	1.17	.70	.57	1.674
8	2.290	.250	4.250	3.62	33.85	8.46	3.06	1.40	.81	.62	1.730
8	2.343	.303	4.750	4.04	36.11	9.03	2.99	1.53	.85	.61	1.793
8	2.435	.395	5.620	4.78	40.04	10.01	2.90	1.75	.93	.61	1.885
8	2.527	.487	6.480	5.51	43.96	10.99	2.82	1.98	1.01	.60	1.957
9	2.430	.230	4.600	3.91	47.68	10.60	3.49	1.75	.96	.67	1.830
9	2.648	.448	6.910	5.88	60.92	13.54	3.22	2.42	1.17	.64	2.068
10	2.600	.240	5.280	4.49	67.37	13.47	3.87	2.28	1.16	.71	1.970
10	2.886	.526	8.640	7.35	91.20	18.24	3.52	3.36	1.48	.68	2.266
12	2.960	.300	7.410	6.30	131.84	21.97	4.57	3.99	1.76	.80	2.250
12	3.047	.387	8.640	7.35	144.37	24.06	4.43	4.47	1.89	.78	2.377
12	3.170	.510	10.370	8.82	162.08	27.01	4.29	5.14	2.06	.76	2.500
15	3.400	.400	11.710	9.96	314.76	41.97	5.62	9.63	3.11	.90	2.610

10.3 SWIVEL HOIST RINGS



HR-125M Stock No.	Working Load Limit (kg)		HR-125M Metric Swivel Hoist Rings			Dimensions (mm)						Weight (kg)
	At a 5:1 Design Factor †	At a 4:1 Design Factor †	Torque** in Nm	Bolt Size †† (mm) (A)	Effective Thread Projection length (mm) (B)	C	D	Radius E	Diameter F	G	H	
1016602	400	500	10	M 8 x 1.25 x 40	16.9	68.1	25.4	11.8	9.5	42.9	28.2	.19
1016613	450	550	16	M 10 x 1.50 x 40	16.9	68.1	25.4	11.8	9.5	42.9	27.69	.19
1016624	1050	1300	38	M 12 x 1.75 x 50	17.2	124.5	50.8	22.3	19.0	82.73	58.17	1.13
1016635	1900	2400	81	M 16 x 2.00 x 60	27.2	124.5	50.8	22.3	19.0	82.73	56.13	1.22
1016644	2150	2700	136	M 20 x 2.50 x 65	31.2	124.5	50.8	22.3	19.0	82.73	52.07	1.36

10.4 TEMPERATURE CONTROLLER

This data sheet is an example of a commercially available solution. Other options/manufacturers may be found during further development of the design.

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Model 332 Temperature Controller

Product Overview | Tech Specs | Ordering Information | Downloads

Front Panel Rear Panel

Model 332 Features

- Operates down to 500 mK with appropriate NTC RTD sensors
- Two sensor inputs
- Supports diode, RTD, and thermocouple sensors
- Sensor excitation current reversal eliminates thermal EMF errors for resistance sensors
- Two autotuning control loops: 50 W and 10 W
- IEEE-488 and RS-232C interfaces, analog outputs, and alarm relays

Product Description

Building on the best selling Model 331 Ten Controller platform, the Model 332 incorpo electronics for high resolution temperature and control. The Model 332 automatically current to support Cernox™ and other neg coefficient (NTC) resistors to as low as 50(332 also includes 50 W and 10 W heater o flexibility in cryocooler applications requirir for fine and coarse control. More...

- Sensor Inputs
- Temperature Control
- Interface
- Configurable Display
- Sensor Selection: Sensor Temperature R
- Sensor Selection: Typical Sensor Perform

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