SALT HRS Team Response to CDR report

The SALT HRS team is pleased to provide the following response to the SALT HRS CDR report. The structure of the response is similar to the CDR report in that we provide detailed responses to the 'Agreed Statement by Panel' given in Section 3 of the report, but prior to this more general responses to the Results and Recommendations (Section 4) and the Appendices. We will certainly correct those typographical items in Appendix 1 (under 3. Miscellaneous) that relate to the CDR documentation and release final documents onto the web site by the end of June 2005.

Response to Section 4: 'Results and Recommendations'

The SALT HRS team was extremely pleased with the Review Panel's recognition of the integrated approach that had been taken in building up the SALT HRS team. This had been very carefully considered throughout the long-drawn out design phase and has lead to an excellent relationship amongst all the key personnel and also with the preferred optical fabricator. We were also pleased to note that the services of the Project Manager, Graham Hodge (of Unilogix), were specifically noted in the report. We believe that this has been, and will continue to be, vital for the SALT HRS project.

Radial velocity stability
We have responded to the issues of radial velocity stability in our response to the 'Agreed Statement by Panel' and have noted that the SALT Project Scientist is willing to consider utilizing contingency funds to support this aspect of the post-CDR design. We again note that we are keen to provide advice to any group that becomes involved in precision radial velocity astrophysics.

Schedule
We recognise that the overall schedule is optimistic, but we have based this on our best estimates (and advice) on construction times and we wished to deliver a high resolution spectrograph to the SALT community at the earliest opportunity. The University of Canterbury will increase its staff effort if required. The PI intends to devote sufficient time to the HRS project and will negotiate his other duties within the Department of Physics and Astronomy appropriately. However, SALT must recognise that at the time of preparing this response full funding for SALT HRS was not available. Consequently the SALT consortium must realise that if funds do not become available very soon then the PI and some of the other University of Canterbury personnel currently assigned to SALT HRS will have to be diverted to other duties. The University of Canterbury cannot operate in an on/off mode at the request of SALT.

The University of Canterbury cannot commit to a definitive project schedule without SALT committing to a funding schedule. From time to time, the University of Canterbury will have to recalculate the impact of funding availability on the remaining portion of the project, with the final HRS delivery date being recalculated by this process. SALT must also accept responsibility for any budgetary consequences due to lack of adequate funding being available once construction commences.

Cost estimates
The cost estimate for HRS following the CDR process, including the changes suggested by the Review Panel, is $2.45M (nominal $, including a 10% University of Canterbury contingency) and represents a $US310,000 increase over the baseline budget (excluding Board risk of $500,000) approved by the SALT Board in November 2004. This revision

represents a much higher fidelity figure, based on a more mature and finalised design than that presented in November 2004. Because of the perceived diminished risk of the detector subsystem, for which $300,000 ($250,000 in Mar 99 $) was specifically allocated for detector contingency, we request that this detector contingency be allocated to the instrument as a whole. The revised HRS cost estimate, including all contingency/risk provisions, stays within the November 2004 Board approved ceiling of $2.285M (Mar 99 $), which corresponds to $2.65M in nominal dollars.

Contract management

The SALT Project Scientist makes a specific reference to the large increase in management costs for contract work by the University of Canterbury and indicates that it is surely only for the benefit of the University of Canterbury. The PS further notes that this should come from the 45% overheads being charged on salaries for the first generation instruments.

The University of Canterbury wishes to make two points in relation to this. First, there is a benefit to SALT in having a well-negotiated contract and this is currently being undertaken through the exchange of draft agreements between SALT and the University of Canterbury. This will ensure that there is a better understanding of the key issues on both sides. Second, the University of Canterbury only reluctantly agreed to the 45% overheads limit imposed by the SALT Board. Overheads are treated differently in the different countries involved in the SALT partnership and the 45% falls well short of covering the infrastructure costs for the University of Canterbury. The University of Canterbury has agreed to not charge the PI time (and the overheads associated with this) in line with the other first generation instruments for SALT. This has been, and will continue to be until SALT HRS is commissioned, a significant cost to the University of Canterbury. The teaching and other duties of the PI must be met from funds within the Department of Physics & Astronomy.

The University of Canterbury is negotiating the SALT-University of Canterbury Agreement in good faith and acknowledges the current lack of SALT funds. It should also be recognised that the Construction Agreement being negotiated is more of a collaborative than a commercial contract.

Response to Appendix 1: 'CDR Reviewers Comments'

There are many detailed comments made by some of the reviewers on a document by document basis and we have noted these in some of our responses to the 'Agreed Statement by Panel' and in the revised design. It was not felt appropriate to respond to each of these on a point-by-point basis.

We hope that these responses are satisfactory to the SALT Project Scientist, the external reviewers and the SALT Science Working Group.

Peter Cottrell
SALT HRS Principal Investigator
June 21, 2005

Response to Section 3: 'Agreed Statement by Panel'

1. Optical System Design and Related Issues

A. The Panel expresses confidence that the optical design is fundamentally sound.

B. The team should check that the thermal effect on refractive index of the camera lenses has been correctly considered. The effect of re-focus on the aberration-balance of the pupil-mirrors should be quantified.

We have checked this. It was done in Section 5.4 Thermal Analysis.

Cost: none
Schedule: No effect
Decision: Accept/~~Reject/Defer[date]~~

C. The Panel recommends that active control of the temperature of the spectrograph environment is implemented at first-light.

We agree and have investigated suppliers in New Zealand and South Africa, the latter through existing SALT contacts. We are of the opinion that it should be undertaken in New Zealand so that appropriate modification of the basic unit can be undertaken (fitting of electrical and vacuum feed-throughs) and monitoring of its capabilities can be undertaken before shipping to South Africa.

Cost:$5,000
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

D. The team is advised to specify the AR coatings on the camera lenses to optimise overall throughput. This should take into account the range of angles of incidence at each surface, and the proportion of the area of the pupil corresponding to each angle. The coating bandwidth specified should take into account the shift in band with incident angle.

The average polychromatic angles of incidence requirement will be determined for each lens and the specification document updated.

Cost: $2,000
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

E. (linked to **K**) It is recommended that the team should consider whether there should be available different-width slit-masks optimised for either i) high throughput, or ii) optimal integrity of radial velocity. These might need to be remotely interchangeable.

We propose to implement a single high precision radial velocity mode. This mode will be additional to the modes already proposed and will involve dedicated image slicers. These image slicers will be optimised for radial velocity precision. This mode will incorporate fibre double scramblers. Implementation of this mode will have a significant cost including a design study of the optimal configuration. We will continue to offer sufficient physical space for an iodine cell as a possible future upgrade.

Cost: $50,000 (estimate including labor)
Schedule: extra 40 working days
Decision: Accept/~~Reject/Defer[date]~~

<u>SALT HRS precision radial velocity mode:</u>

The requirements for precision radial velocities are:

1) ***high resolving power***
2) ***high throughput***
3) ***good instrument stability***

Given the throughput and resolving characteristics of SALT HRS gains in radial velocity precision will only be possible by enhancing the instrumental stability. As a fibre fed, vacuum enclosed, thermally and mechanically isolated instrument, SALT HRS has high intrinsic stability. The varying nature of the SALT entrance pupil will cause variations of the instrumental profile due to incomplete fibre scrambling. SALT will incorporate an optical calibration system that will ensure that wavelength calibration is performed using light whose distribution mimics that of the telescope. However, given the recommendations of the SALT HRS CDR review panel, namely…

The panel's recommendation is for HRS to have an assured high radial velocity precision *at first light*, better than the current 30 m/s in the FPRD, which is very conservative. Possible approaches for consideration would be: 1) an iodine cell, 2) simultaneous ThAr injection (both recommended by the panel), and 3) double fibre scrambling.

… it is clear that at least one additional fibre feed mode should be provided. This mode will be optimized for high precision radial velocities.

Physical space has been made in the current redesign for an iodine cell. However, the SALT HRS team does not intend to implement this at first light, but it would be happy to assist other groups interested in implementing this option.

It is proposed to incorporate a fibre double scrambler in a single high precision radial velocity mode. The advantages of double scrambling have been demonstrated in the laboratory (Hunter and Ramsey, 1992) and most recently by HARPS. It is clear that double scrambling will remove most effects of the SALT HRS moving pupil (Sessions MSc thesis). A design for a fibre double scrambler is outlined below.

It will not be possible to use the prime focus calibration optics for simultaneous thorium argon injection. A benchtop source will be required. This is likely to be the same source used for calibrating the direct injection fibre feed. The size and location of the simultaneous thorium argon injection fibre will limit the inter-order space available for a sky fibre. The reduction in efficiency of the sky mode can be minimized by injecting light at the highest resolving power(smallest fibre) possible.

The optimal resolving power for this mode and the design of the fibre image slicers has yet to be undertaken. The use of a slightly undersized entrance slit is recommended. The height of the sky fibre can also be reduced in order to locate the simultaneous thorium argon lamp fibre.

A tentative high precision radial velocity mode is as follows:

1) 500um (or 350um) object fibre. Fibre double scrambler. Image sliced. Slightly undersized (by ~10%) entrance slit.

2) 500um (or 350um) sky fibre. Fibre double scrambler. Image sliced. Identical slit as for object fibre. An ~50% (TBC) undersized slit in spatial direction.

3) Simultaneous thorium argon calibration fibre. A means for controlling lamp intensity is required. Interchangeable neutral density filters may be appropriate. A mode may also be made available where this fibre is not used.

In order to accommodate the high precision radial velocity mode the slit plate will be modified. A possible layout is shown in Figure 1. Note that this design assumes the same form of image slicers are used as in the medium resolving power mode.

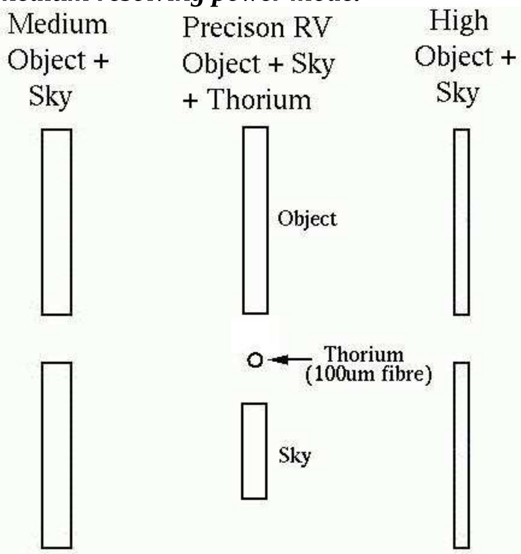

Figure 1: Modified SALT HRS slit plate. The precision RV mode will use the same type of image slicers as for the medium resolving power mode [TBC]. The object slit width is slightly undersized. The sky slit is undersized in both directions allowing placement of a calibration fibre between the two slits. The calibration fibre will be the equivalent of a 100micron fibre fed at f/3.8.

<u>SALT HRS fibre double scrambler:</u>

Each fibre (long and short) is butted against a hemispherical silica lens with a 1.25mm radius of curvature. The two lenses are placed 1.25mm apart. In order to minimize additional loses due to focal ratio degradation the output from the double scrambler will slightly underfill a 500um fibre (i.e., the image is ~480um). The output focal ratio is f/3.5. The FRD of the short fibre gives an output of f/3.9 into the spectrograph.

[see Hunter & Ramsey, "Scrambling properties of optical fibres and the performance of a double scrambler", PASP, v104, pp1244-1251, 1992.]

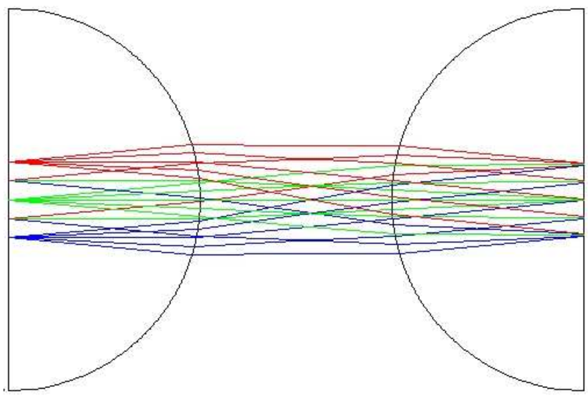

Figure 2: Schematic of a fibre double scrambler for SALT HRS. Each lens is a silica hemisphere with a radius of 1.25mm. Light exits a 500um fibre and enters the first lens from the left. A shorter 500um fibre will be used to couple the output of the double scrambler to a dual fibre image slicer.

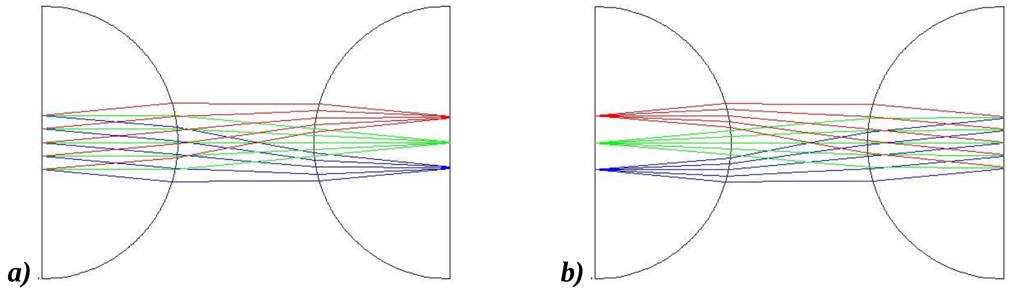

Figure 3: The scrambling of the angular and radial distribution of rays is shown. In a) the angular distribution of rays are converted into radial positions, while b) shows the radial distribution being converted into an angular distribution.

<u>Optical requirements:</u>

Fibres:	***2 x 500um (or 350um) fibres. ~30m in length***
	2 x 500um fibres. ~5m in length
	1 x [TBC] fibre. ~5m in length
Input/Output:	***4 x fibre entrance/exit windows (overcoated)***
	2 x 5mm ball lenses (overcoated)
Double scrambler:	***4 x hemispherical silica lenses. R = 1.25mm (overcoated)***
Image slicer:	***1 x double image slicer***
ThAr source:	***reimaging optics (input and/or output) [TBD]***
	continuously variable neutral density filter
	fold mirror (for switching between direct injection and high RV mode)

<u>Mechanical requirements:</u>
Additional FIF ferrules (x2)
Mount for fibre double scrambler
Additional position on fibre selector (identical to one of existing modes)
ThAr source filter wheel and fold mirror control (originally a static aspect of the instrument)
Modification to slit plate design

F. The team is encouraged to consider reducing the number of “air-glass” surfaces in the fore-optics design, and possible application of sol-gel coatings. Possibilities for reducing surfaces include a ‘mini lens’ cemented directly to the end of the fibre, and incorporating power in the tank window. [This last point is considered further under ‘Mechanical Design’.] The field lens should be further removed from the focal plane to avoid near-focus ghosts and flat-fielding issues due to migrating dust.

We agree. This will involve some extra design time.

Cost: $2,000
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

G. The blue VPH should be on a material with a higher internal transmission at 370 nm than BK7 (e.g. silica or BK7HT).

The substrate efficiency is negligible compared to the coatings, but we will investigate when completing the final specifications.

Cost: $500
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

H. It might be considered to shift the blaze of the UV VPHG more to the UV; this should be taken up with the SSWG.

The blue VPH is already slightly tuned towards the blue and we would not want to shift this much further towards the blue.

Cost: none
Schedule: no effect
Decision: ~~Accept~~/Reject/~~Defer[date]~~

I. Early ordering of both VPH gratings would allow including as-manufactured properties in the camera tool and melt adaptation.

We agree.

Cost: none
Schedule: no effect, except for sequencing
Decision: Accept/~~Reject/Defer[date]~~

J. A full end-to-end ghost analysis of the instrument is presently missing and should be conducted. Issues to be considered include ghosts in the fore-optics, CCD⇔VPH, CCD⇔echelle, and within the dichroic. Special attention should be given to low-reflectance AR coating optimised for the transition-region of the dichroic.

The ghost analysis has already been done and was included in the CDR package in the report from Damien Jones of Prime Optics. There were no significant ghosts. The AR coating for the dichroic was neglected in the optical specification, but will be included in the final specification.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

K. (linked with **E**) The panel believes that it would be prudent for the team to consider the simultaneous injection of ThAr, and/or the inclusion of an iodine cell, to realise the full radial-velocity potential of HRS at first-light.

***This was addressed under* E *above*.**

Cost: see E
Schedule: see E
Decision: Accept/~~Reject/Defer[date]~~

2. Optical Manufacturing and sub-system Test

2.1 Camera

L. The instrument team might want to consider a diamond-turned aspheric surface on the camera calcium fluoride element, with the possibility of post-polishing to remove any residual signature from the turning process.

We appreciate this information from the Review Panel, but at this stage the additional design costs would outweigh any cost savings.

Cost: none
Schedule: no effect
Decision: ~~Accept~~/Reject/~~Defer[date]~~

M. The current tolerancing on the camera lens elements are very tight. These might be relaxed by designating a specific single element (probably the front element) as a coma-corrector with lateral adjustment. All the other elements could potentially be mounted with no lateral adjustment.

The curvatures are the main concern. Damien Jones of Prime Optics will check the coma corrections.

Cost: $1,000
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

N. The team should investigate whether the homogeneity spec of 2 x 10^{-6} is too tight and could be relaxed. This might lead to significant savings in cost and schedule.

Damien Jones of Prime Optics notes: 'The rule of thumb for astronomical spectrographs is H2 (5e-6) at least and as this is a fast system, H3 (2e-6) is not unreasonable.' He has indicated that if we could obtain vendor homogeneity data he would model the deflections caused by any variations through the material. We are working closely with Prime Optics and KiwiStar Optics to ensure that the glass specifications are appropriate for our application.

Cost: $2,000
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

O. It is not recommended that test-plates be produced before the melt-data is known for the lens-glass. A specification should be imposed on the partial-dispersion (parallelism of refractive index curves) of the S-FPL51Y glass-type.

Following discussions with Damien Jones and KiwiStar Optics they were not concerned by the requirement for melt data prior to test-plate manufacture. If required KiwiStar Optics would make minor changes to the test-plates.

Cost: up to $2,500 (if reworking of test-plates is required)
Schedule: up to 5 days if reworking of test-plates is required
Decision: ~~Accept~~/Reject/~~Defer[date]~~

P. The assembled camera optics should be tested off-axis as well as on-axis and the results compared with a ray-tracing model of the test.
We note that the proposed star test needs modification.

Cost: $500
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

2.2 Mirrors and dichroic

Q. Mirrors and dichroic appear too thin, and 1:6 to 1:8 aspect-ratio is recommended.

We agree. Mirror specifications have been changed. Changing the dichroic thickness specifications has been made but the implications of these changes on the path-lengths will have to be compensated.

Cost: $5,000 (estimate)
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

2.3 General alignment

It is strongly recommended to use an interferometer for optical alignment with fringe-analysis software, in order to quantify wave-front aberrations at intermediate steps, and to compare with the ray-tracing model.

The collimator focus is quite insensitive to misalignment. The auto-collimated return spot should be within ±0.5 mm of the nominal location and this should be readily observable by using a travelling microscope. This is the only "intermediate step" where we can see that fringe analysis might be considered useful.

Cost: $2,000 (if required)
Schedule: no effect
Decision: ~~Accept~~/Reject/~~Defer[date]~~

3. Mechanical System

R. RTV mounting of mirrors (as distinct from lenses) is not optimum to achieve stability.

We have investigated alternative RTV products. RTV 255 and CY 51-019 compare very favorably with both Sylgard 184 &186 in terms of their mechanical properties, but have significant adhesive qualities. These products will greatly enhance the optical performance of both mirrors and lenses in SALT-HRS.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

S. The current interface of the bench and tank, relying on multiple attachments at the camera-lid, plus rollers on the opposite side, is over-constrained. It is recommended that alternative solutions are explored that remove the constraints imposed by the hard-line contact of the rollers. Possible solutions could be as simple as supporting the bulk of the mass of the bench with internal counterweighted levers.

Since the CDR review a redesign of the input/output lid has been completed. Maximum deflection of this lid is approximately 6 microns, atmosphere to vacuum (c.f. 23 microns at CDR). The camera lens mountings are now the only coupling points to the optical bench. A pair of weighted levers support the optical bench inside the tank, each taking approximately 150kgs of the load. Thrust bearings are used to decouple these levers from the tank. A full FEA of the optical bench has shown very favourable results (see figures and FEA below).

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

Figure 4: Final tank design showing lever and hinge arrangements for lids.

Figure 5: The optical bench support (from underneath) showing thrust bearing, with self-aligning bearing, support lever and knife edge pivot point.

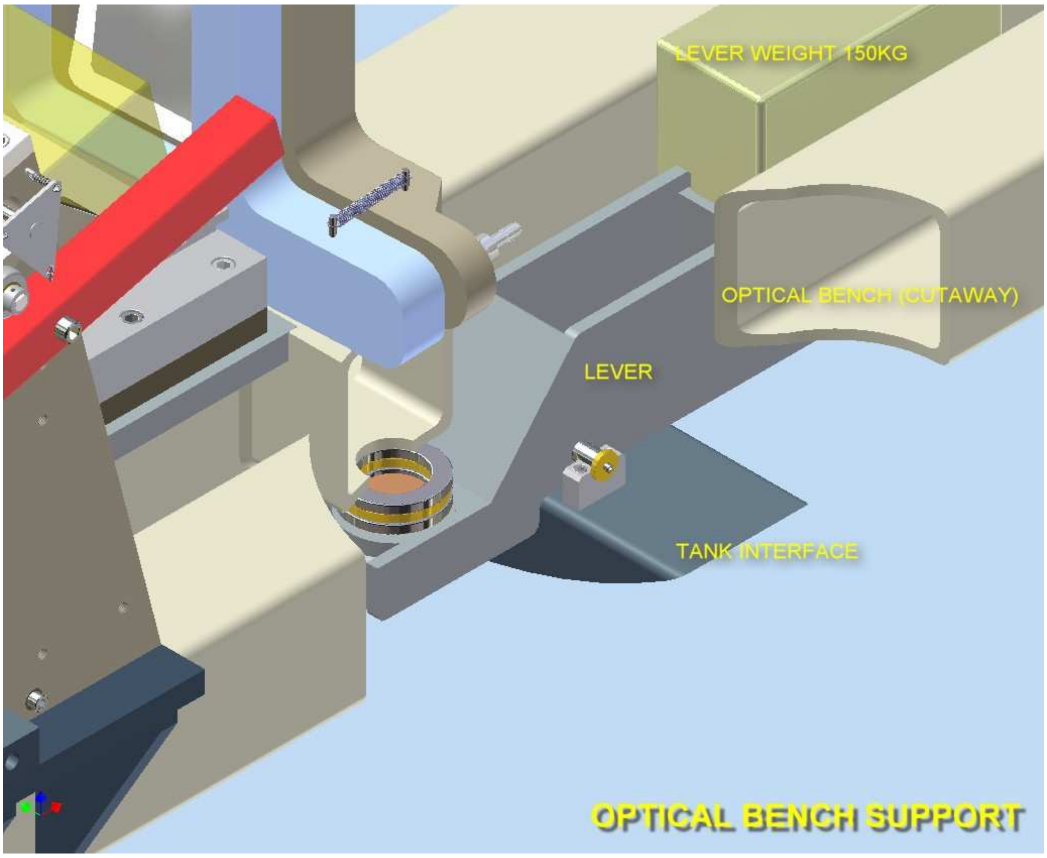

Figure 6: Optical bench support showing lever and weight. The echelle grating is at top left.

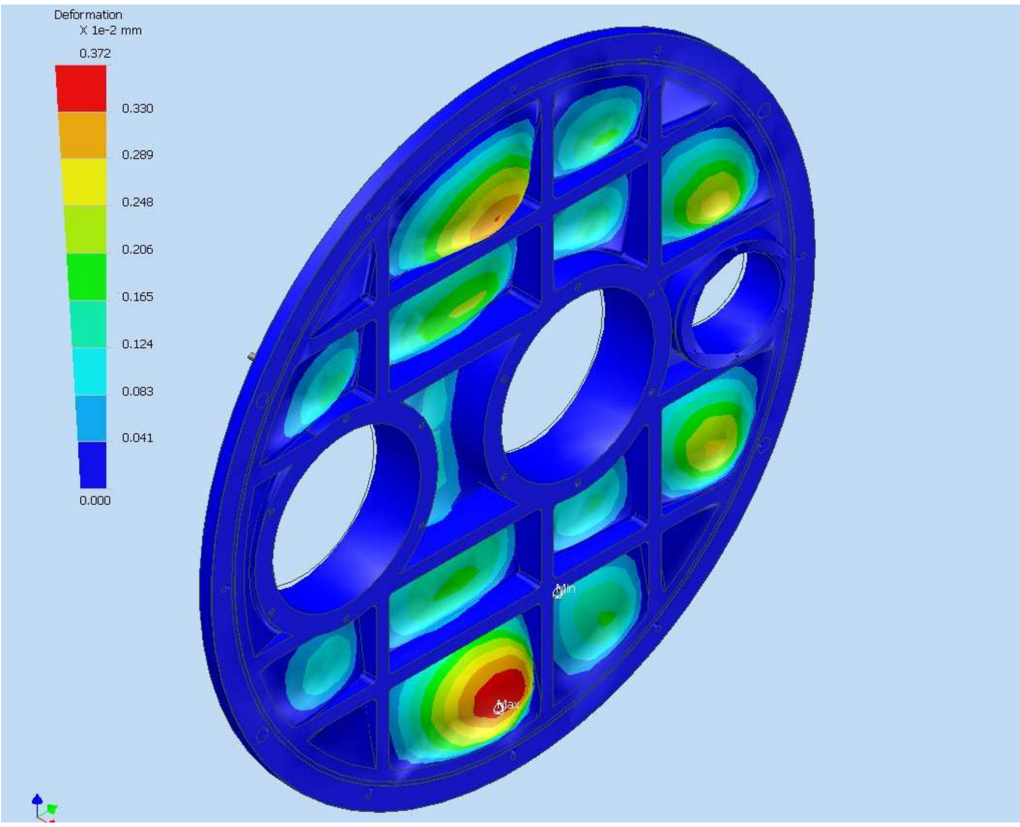

Figure 7: FEA of HRS tank lid for input optics and cameras.

T. Rotation alignment (manual) of the slit plate should be incorporated in the instrument design.

This was intended in the design and will require a once only adjustment.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

U. Similarly, the team should consider whether there is a need for manual adjustment of the polar rotation of the VPH gratings in their cells.

We agree and will provide the manual adjustment.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

V. All optical cells (and particularly the echelle-cell) should be designed to avoid protruding glass, which could otherwise be subject to accidental damage.

We agree and will incorporate with all glass elements to avoid damage and injury.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

W. The team might usefully consider whether flexural solutions to small-motion mechanisms could be advantageous to minimise hysteresis and wear effects (e.g. pupil mirrors, in the case that it is decided to keep the instrument at constant temperature).

The use of flexures in the design of the mirror mounts may not provide the level of support and location that can be achieved with pre-loaded self-aligning bearings. Our technical staff have had extensive experience with the use of self-aligning bearing supports in the past, particularly in the mounting of mirror assemblies in very large ring lasers designed and built in our workshop. They exhibit no hysteresis even when used with a 40 metre optical lever.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

X. The panel is not convinced that the present concept of stacked stages will provide adequate stiffness and stability. The team is encouraged to investigate integrated multi-axis flexural stages, such as are marketed for precision fibre-positioning.

We have re-investigated this aspect of the design. We have found X-Y flexure stages from ThorLabs that will replace the custom made table proposed for the fibre input. Also from ThorLabs is a precision rotating table that can take a 2.5kg vertical loading, which would be very suitable for this application. We still propose to keep the three stacked micropostioners, as they are the best solution for moving the fibres with respect to each other and the image slicers. We have extended the platform that they are attached to and have a clamp to hold the tubing that the fibres are inserted in – see Figure 8.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

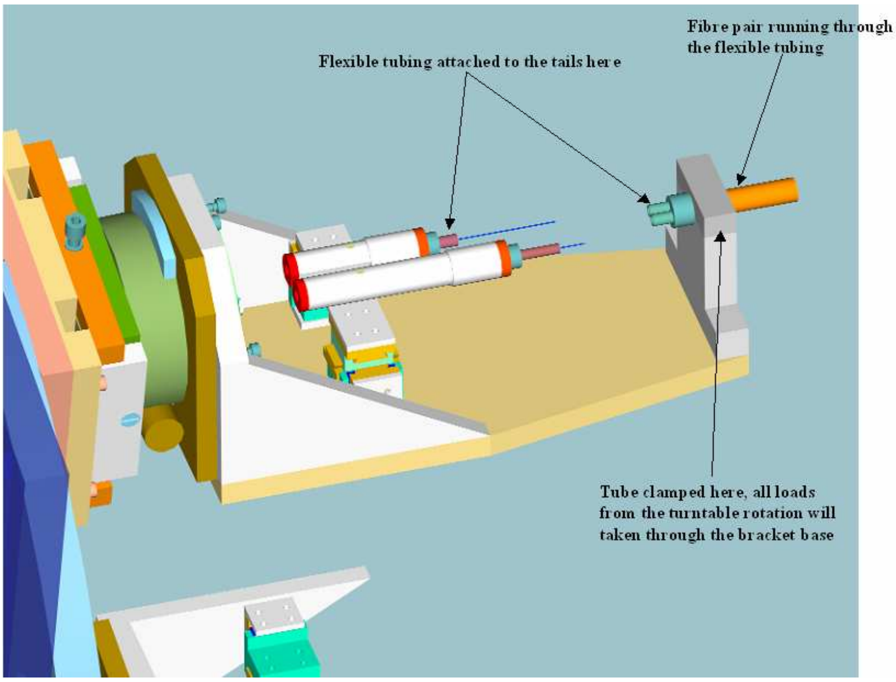

Figure 8: The revised input fibre assembly stage, showing the extended platform and clamping arrangement.

4. FPRD

This should define the quantitative criteria by which the instrument is judged for formal acceptance.

Several areas need strengthening or clarifying, such as the following (not an exhaustive list):

- Software specification is sketchy and should be more fully defined.
- The data-reduction software needs to be properly specified in detail.

The SALT HRS team believe that these specifications are sufficient at this stage. They were considered appropriate by SSWG following PDR and are also at about the same level as deemed acceptable for the PFIS CDR.

- How is the resolving power defined? ("ratio of wavelength to FWHM of [defined] stabilised laser line", sampled by three pixels, or whatever the team considers appropriate).

Resolving power defined by the measured ratio of wavelength to FWHM of a Th arc line, measured near the blaze wavelength of an order.

- A precise definition of stability of PSF is needed.
- Stability needs unambiguously defining (and is 30m/s right, what is the time-scale, how much is the tracker allowed to move, and is it with or without the iodine cell?).

We will split the stability requirement in two.

Intrinsic stability: ***The average measured centroid of a chosen set of Th arc lines from the direct injection calibration fibre will not shift by more than 0.001 pixels during 1 hour.***

Radial velocity stability: ***The minimum requirement is for 30 m s^{-1} radial velocity precision measured by the RMS scatter over a period of a day for observations of a sharp-lined dwarf star taken with a signal to noise S/N > 100 in the medium resolving power mode for a short exposure and at central***

track. This requirement will only be invoked if independent tests of the on-SAC calibration system have demonstrated that the far-field illumination patterns for a star and arc vary by no more than 5% at any position in the far field.

- Ghost image spec needs defining in terms of an emission line.

Peak intensities of any ghosts of an arc emission line are to be less than 0.1% of the measured central intensity of that line.

- Vacuum enclosure – state explicitly that the 'pressure is maintained' passively, with infrequent (how often?) pumping.

The pressure will be maintained through pumping on an approximately quarterly basis using a pump dedicated to this purpose.

- Stray light – the 5% value should be related to the ratio of the inter-order light to the average of the adjacent continuum spectra. The source characteristics and test-wavelength(s) must be stated. For example, looking at a red source (tungsten lamp) in the blue-end of the blue channel, you could have nearly 100% stray light!

A maximum of 5% stray light will be allowed, where stray light is defined as the ratio of the average interorder light from both sides of the spectrum to the continuum spectrum intensity at the following wavelengths and corresponding source temperatures:

$\lambda = 460$ nm $\quad T_S = 6{,}500$ K

$\lambda = 700$ nm $\quad T_S = 4{,}300$ K

- Spectrograph throughput excluding telescope – need to state the input-pupil for which the stated values apply (maximally-illuminated pupil).

This was always calculated with a maximally illuminated pupil.

Cost: none
Schedule: none
Decision: Accept/~~Reject/Defer[date]~~

5. Detectors

The team is encouraged to work with the CCD vendor to optimise the following issues:

- Low-level traps
- Cross-talk
- Radiation events
- UV QE
- CCD flatness, particularly for the Fairchild device.
- Readout-noise / binning effects
- Develop a grounding strategy for the CCD/instrument system

The team should also conduct a tolerance analysis of the CCD-flatness, and the parallelism and location of the CCD with respect to the reference flange and the axis of the toroidal lens. The results should be compared with the vendor's specifications. It may be necessary to re-optimise the field-flattener for the as-measured CCD flatness.

We are committed to working closely with the CCD vendor to deliver an excellent system to the SALT community.

In terms of the CCD flatness we have included this in a revised tolerancing study and will include the revised tolerance in the revised specifications for the CCD vendor.

Cost: $30,000
Schedule: unknown
Decision: Accept/~~Reject/Defer[date]~~

6. Test and Verification

The panel recommends that an adequate amount of time be allocated to Test and Verification at Christchurch before shipping. Time should be allocated for any re-work required following Acceptance Tests and before shipping.

We have added 20 working days after the pre-ship Acceptance Test for reworking the instrument (if required) prior to packing and shipping.

Cost: 20 days of labor for 5 people plus 45% overheads ($29,000)
Schedule: 20 days
Decision: Accept/~~Reject/Defer[date]~~

7. Management and Planning

The present manufacturing schedule of 1 year for the cameras appears optimistic. It would be acceptable to deliver one camera (most likely the red one) earlier than the other.

We note that the optical manufacturing schedules are optimistic, but all our discussions with the optical fabricator have indicated that they can deliver to this timetable. And we are certainly scheduling the delivery so that one camera is completed and tested before the other.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

8. Control

It is recommended that the control system should be constructed with [number?] of spare slots/channels for future upgrades.

The control system has built-in expandability.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

9. Miscellaneous

Y. The Team is encouraged to conduct a simple audit of the materials and lubricants etc to be used within the tank, to ensure that there are no major sources of out-gassing.

We will undertake this.

Cost: none
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~

Z. The efficiency of a liquid light-guide for the exposure meter might be better than a fibre light-guide. However, vacuum issues would need to be considered.

The exposure meter is being reconsidered. The most likely option is to use a fibre-coupled avalanche photo-diode with different transfer optics.

Cost: none, as redesign costs offset by less expensive components
Schedule: no effect
Decision: Accept/~~Reject/Defer[date]~~