Report on the SALT High Resolution Spectrograph Critical Design Review and Recommendations

David A. H. Buckley
SALT Project Scientist

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The Critical Design Review of the R4 design for SALT High Resolution Spectrograph (hereafter HRS) was held from 12th to 14th April 2005. The formal review meeting, during which the HRS project team gave presentations on all aspects of the instrument, was held on Tuesday 12th April at the University of Canterbury, Christchurch, New Zealand. This was preceded on 11th April with a visit to *KiwiStar Optics*, a division of Industrial Research Laboratories (IRL), a so-called crown research institute of the New Zealand Government, in Lower Hutt, Wellington. *KiwiStar Optics* are the preferred optical fabricator for HRS and the visit was to allow members of the CDR review panel to assess their capabilities and experience. The CDR review panel also visited (on Tuesday afternoon) the workshops and labs of the University of Canterbury Physics and Astronomy Dept., where many of the mechanical and control systems of HRS would be fabricated and the instrument integrated and tested. On 13th April the review panel visited Mt. John Observatory, the observing out-station of the University of Canterbury, to see first hand some of the instruments and telescopes which they have built. The review panel then met the following morning (14th April) and drafted a report with a list of recommendations and comments, which is included here.

The HRS Critical Design Review was attended by 8 members of the HRS instrument team, the optical design consultant (from *Prime Optic*s), 2 representative from the preferred optical fabricator (*KiwiStar Optics*), 5 representatives of the SALT Science Working Group (SSWG) and 4 external reviewers, the latter being the same reviewers present for the PDR in July 2004. This report summarizes the assessments provided by the reviewers, both in terms of a jointly drafted report by the review panel, done at the time of the meeting, and individual comments provided by the reviewers, which are appended. Recommendations regarding the further development of the SALT HRS are given in the final section (§4).

The four external members of the review panel were Drs Hans Dekker (ESO), Bernard Delabre (ESO), Steve Shectman (Carnegie Observatories) and David Walker (UCL), whose combined experience in optics, instrument design and construction, particularly of high resolution échelle spectrographs, was well suited to reviewing SALT HRS. All of the external reviewers were present for the previous PDR, and two of them (Drs Delabre and Shectman) were reviewers for the previous (failed) R2 design of HRS, in Sept 2003.

1. Reviewers

Name	Role	Name	Role
Gordon Bromage	SSWG: UK	Wolfram Kollatschny	SSWG: Göttingen
David Buckley	SALT Project Scientist	Phillip MacQueen	SSWG: HET
Hans Dekker	External Reviewer	Blair Savage	SSWG: Wisconsin
Bernard Delabre	External Reviewer	Steve Shectman	External Reviewer
		David Walker	External Reviewer

2. HRS PDR Agenda

The agenda for the PDR meeting is summarized below.

Tuesday 12th April

1.	HRS Introduction and Instrument Description	Peter Cottrell
2.	Optical Design	Stuart Barnes, Damien Jones & Michael Albrow
3.	Mechanical Design	Graeme Kershaw, Nigel Frost
4.	Assembly & Testing	Graeme Kershaw
5.	Control	Ross Ritchie, Geoff Graham
6.	Software	Michael Albrow
7.	Detectors	Peter Cottrell
8.	Tour of Physics & Astronomy Dept. workshops/labs	
9.	Management, Schedule, Budget	Peter Cottrell, Graham Hodge

Wednesday 13th April

10.	Teleconference with Spectral Instruments	Robert Current, Charles Slaughter
11.	Visit to Mt John Observatory	

3. Review Assessment by Panel

Following the formal presentations by the HRS Team, the Review Panel met the on the morning of Thursday 14th April for approximately five hours to discuss and assess progress on HRS. The Review Board deliberated on the presentations and all the available PDR CDR documentation and then responded with a general report containing comments and recommendations regarding the future development of HRS. This report is presented here, while individual comments from reviewers are included in Appendix 1.

SALT HRS CDR

Agreed Statement by Panel

1. Optical System Design and Related Issues

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

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.

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

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.

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.

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.

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

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

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

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 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.

2. Optical Manufacturing and Sub-system Test

2.1 Camera
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.

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

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.

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.

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

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.

3. Mechanical System

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

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.

Rotation alignment (manual) of the slit plate should be incorporated in the instrument design. Similarly, the team should consider whether there is a need for manual adjustment of the polar rotation of the VPH gratings in their cells.

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

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 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.

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.
- 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).
- 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?).
- Ghost image spec needs defining in terms of an emission line.
- Vacuum enclosure – state explicitly that the 'pressure is maintained' passively, with infrequent (how often?) pumping.
- 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!
- Spectrograph throughput excluding telescope – need to state the input-pupil for which the stated values apply (maximally-illuminated pupil).

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.

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.

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.

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

9. Miscellaneous
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.

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.

After seeing Hercules, the Panel recommends that the colour of HRS be not green.

4. Results and Recommendations
The Review Panel were favourably impressed by the quality and detail of both the CDR documentation and the presentations delivered at the CDR itself. By virtue of their nature, design reviews concentrate on perceived shortcomings, flaws, etc., rather than emphasizing the positive aspects. Although the Panel's report (above) emphasizes the former, the overall impression by the Panel was that HRS has evolved into an excellent design capable of achieving forefront science on SALT, and satisfying its diverse user community. Furthermore, the panel were impressed with the caliber of the personnel involved in the project and were also favourably impressed following their visit to the preferred optical fabricator, *KiwiStar Optics*. It would seem that the latter are well equipped to undertake the manufacturing of optical components and their mountings.

It is the belief of the Review Panel that there are no major issues with the design of HRS and that the project is in a good shape. A number of recommendations regarding design issues (optical and mechanical), fabrication and assembly have been made, which the project team should address before the design is finalized and construction begins. The mostly minor corrections (e.g. in part 3 (Miscellaneous) of Section 3 in Appendix 1) should also be made.

In addition to the comments on radial velocity stability (both in section 1. and 4. of the panel's report), I would emphasize that the review panel were not specifying a solution, rather identifying a shortcoming. 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. None of these options have major technical or large cost ramifications (anything will affect the cost!), and the benefits in terms of increased capabilities of HRS make these additions very desirable from the beginning. The Project Scientist would favourably consider utilizing contingency to fund this additional functionality, if needed.

The overall instrument construction schedule may well be somewhat optimistic, although there is perhaps ability for the University of Canterbury to increase its staff effort, if so required. However, the optical procurements and fabrication are likely to be the pacing items for the overall schedule. I trust that the PI can devote sufficient time to the HRS project, and that he and his team will receive the full support of the University of Canterbury Physics and Astronomy Department now that HRS is entering the crucial fabrication phase. I am extremely pleased that the PI is retaining the services of an excellent project manager in Graham Hodge of *Unilogic*.

The cost estimate (excluding contingencies) of HRS at CDR is now $2,122,854 (Mar 2005), which is $183,274 more than the previous cost estimate (Nov 2004). Some of these increases have arisen from devaluation of the $US with respect to the $NZ, which affects labour charges (+$25K, including 45% overheads) and some subcontracts (+$55K). Other increases are due to increased project and contract management charges (+$84K, including 45% overhead) and some increased capital expenditure (+$10K). The CDR cost estimate is still within the agreed baseline cost ($2.17M) approved by the Board in Nov 2004 (excluding risk controlled by the SALT Project Scientist), although if the UC-controlled contingency funds are used to fund these increases, there will only be a small amount remaining.

I am somewhat concerned over the large increase in management costs, particularly an additional ~$49K for legal and contract requirement work by the University of Canterbury in negotiating the HRS contract between SALT and UC, which is surely only of benefit to the latter. Following the precedents set by the other first generation instruments, these costs (and maybe those relating to other legal costs) should be covered by the 45% overhead being charged on salaries.

In conclusion I believe that all of the requirements for a successful Critical Design Review have been met. In light of the unanimous opinion of the Review Panel, I recommend that the SALT Board grants approval to the HRS Principal Investigator and his team to complete the fabrication, assembly and commissioning of the HRS.

Finally, I wish to record my appreciation to the HRS Principal Investigator and his Team for the work they have done to date, which has resulted in this successful CDR. I am also indebted to the reviewers, particularly the four external review panel members, for giving up their valuable time in helping us in the process of developing an excellent SALT instrument.

Appendix 1: CDR Reviewers Comments

The following are detailed additional comments from reviewers. Important issues in the following table are shaded in grey.

Document	Comment
Calibration AE00017 p.3	One of the science goals is planet detection It is a bit surprising that the project goes to the trouble of vacuum isolation (which makes it unique for a large telescope) without implementing also an iodine cell and/or simultaneous ThAr lamp at 1st light.
Flat-fielding AE00018 p.6	The dynamic range in an unfiltered QTH flat between 370 – 890 nm will be > 100. This can be reduced by filtering (blue filter with calculated red leak) large differences will still occur when using a single filtered lamp. Better is to use a blue and a red lamp for flat-fielding the two arms separately. In that case one may also choose different exposure times.
VPHG efficiency and -alignment BP00019 p. 8 AP00031 p. 9	VPHG blaze efficiency can be tuned by tilting. This allows to correct for manufacturing errors in the location of the blaze wavelength, due to slight errors in dN and DCG thickness. In the case of HRS this is not possible because it would upset the astigmatism balance. Wasatch only measure 0-order transmission and the 1st-order diffraction efficiency must be inferred from this. If higher orders are possible, this may lead to errors in the inferred VPHG blaze locations and efficiency. In view of this and of the DCG manufacturing tolerances, it would be better to use a more direct way of measuring 1st order efficiency.
Budget BP00021 p.19	There seems to be no allocation for the cost of mechanics?
ThAr lamp AS00023 p.3	In our experience it is not necessary to continuously run the ThAr. Normal operating current is 2 mA and lifetime is 5000 mAh. So, the lamp would have to be replaced after 2500 h or 100 days. More info can probably obtained from the HARPS team who reach an RV accuracy of < 1 m/sec and instrument drifts of < 30 cm/sec during one night
Power and hazards AS00023 p. 7	Electrical power consumption is quite high at 3 kW. What happens if cooling fails?
Camera focus AS00023 p. 8	Spectrum position is going to change when you refocus with a pupil mirror. Since we believe that you will need a larger focus range than calculated, calibration may be affected if you would have to refocus during the night. This concerns wavelength calibration and fringing effects in the red.
Vacuum quality AS00023 p. 8	Is the detector system delivered with its own cryostat? We did not see any specs for vacuum cleanliness or sorption pumps in the CCD specs. Where does the 6 months maintenance interval come from? How is the interface CCD/field lens done? Where is the vacuum O-ring? Its location may also affect outgassing rate significantly. How long will the pipe from the Aluminizing plant be?
Resolution test AP0031 p. 10 p.5	Single ThAr line. There will be a lot of scatter, depending on how this line is sampled. This would be disturbing in high R mode. Better use a set of lines (100 or so – in all orders) located at x% of the FSR or Y pixels from the blaze, and define resolution as the median value.
UV QE AP0031 p. 10	QE at 350 nm seems not very ambitious. At ESO we have measured 70-80% on a number of EEV chips for *Omegacam.* http://www.eso.org/projects/odt/documentations/omegacam_poster.pdf
Radial velocity precision AP00031 p. 14	I am confused about the requirements. A precision of 30 m/sec, which is 1% of a resolution element at R=100 000, is quite easy to achieve give the proper calibration strategies and data reduction. However, it is not really sufficient for front-line RV work. Do you mean drift? In that case the time scale should be specified: per hour, per night …
Line profile stability AP00031 p. 14	How does one measure changes in the profile at the level of 1%? Is it meant the line profile **after sampling** by the detector?
Scattered light AP0031 p. 14	Stray light is relatively strongest in the blue part of the spectrum. If the source is red, it will be high, if it is blue (O-star) it will be low. Specifying relative to local continuum only makes sense if one also specifies the spectral type or color temperature of the object
Slit transfer optics AE00005 p. 21	The use of two doublets seems not necessary. One lens group could probably do the job. Interior surfaces could be coated with dual-layer sol-gel by Cleveland crystals (since protected)
Cross-talk between R and B arms AE00005 p. 5 fig 24	What is meant by cross-talk between R and B arms?

AE00005 p.25	The thickness of main collimator and pupil mirror seems too thin. Ratio 1:6 or 1:8 is generally preferred
AE00005 p. 30, 31	The asphere should be placed on a CaF2 surface. This can be diamond-machined at low cost and requires no post-polishing
Mylar strip on echelle AD0006 p. 61	Mylar might not give sufficient surface quality. Have you considered alternatives? Have you considered diamond machining for the collector mirror?
CCD flat-fielding AE00005 p.33	The emitting area that is finally seen by the CCD is less than 1 inch wide, so it does not nearly fill the pupil and the flat-field will not be very "flat". Could the emitting area be wider? At ESO we use a blue filter (400-450 nm) since in the UV one is more sensitive to contamination effects
Rotation alignment AE00005 p.38	Is it possible to rotate the slits? Necessary to be able to fully eliminate variable line tilt along the orders.
Thermal analysis AE00005 p.55	The calculated camera sensitivity is only 3 µm/degC. That is very small and we believe that possibly dN/dT may not have been included in the simulations. If this is the case, then pupil mirror may have to be moved so much that aberration balance on VPHG is disturbed. Either place camera focus inside the camera or T-stabilize the spectrograph right away. Have you taken dν/dT of the cross disperser into account? This would be dictated by the expansion of the substrate, BK7
Echelle efficiency AE00005 p.58	Missing in the component efficiency list
Homogeneity AE00005, general (cameras)	$2x10^{-6}$ seems to be too strict, certainly for the lenses closer to the focal plane and will drive cost. Part of delta N is only tilt or can be refocused.
VPHG coating, 15-16 substrate, p. 38 AD0006	FuSi may be a better choice for the blue VPHG. UVB VPHG blaze curve could be tuned more to the UV – this is also a science issue. Was the shape (circular) and the free aperture discussed with Wasatch? From p.15 it is not clear if the VPHG is coated, or the lens. MgF2 could be improved upon
CCD FF lamp AD0006 p. 65	150 W is overdoing it by a large factor. On UVES we use a 10 W with an ND2-ND3 and 50 nm interference filter.
Acceptance test AA0007 p. 10-11	The star test is a good choice. However, only on-axis test is not sufficient to detect decenter error. One should also test in the field.
Tolerance analysis AA0007	Have homogeneity requirements for the glass been analyzed?
Ghosts AA0007 p. 14	Have you analyzed ghosts between the CCD surface and the VPHG in higher orders (reflectance? Dichroic ghosts – they can be reduced by using a thick dichroic mirror and a good A/R on the back, esp. in the transition region.
Detector specs AE00001	A spec for detector PSF is missing. On thick chips one may have to trade this off against dark current. If a PSF spec cannot be imposed at this stage, one should at least measure it, for instance by looking at skewed cosmics
Overheating prevention CG0025 p. 7	It is generally considered bad practice to have any SW in the safety loop. Will the equipment shut down automatically in case of overheating? Can damage occur due to SW failures (p. 14?) Have you considered using slip clutches on motors? (p. 15)
Operational safety CG0025 general	Hazards are considered by themselves and emphasis seems to be on development up to commissioning. At ESO it is demanded to analyze chains of events that may lead to a catastrophic incident (defined as severe injury or instrument out of operation for more than 1 week), e.g. (no coolant) .AND. (failure of staff to react to alarm signal) .AND. (no auto-shutdown) At least three failures must be required before a catastrophic incident can occur.

2. Some further notes made during discussions:

1. Coma compensator in cameras may help to alleviate tolerances.
2. The 6.4 mm fiber bundle for the exposure meter could be replaced by a liquid light guide with higher efficiency. However, there may be vacuum feed-through issues with a liquid light guide.
3. Need better definition of quick-look and pipeline data reduction software? To which quality must data be calibrated to?

4. Low level traps need controlling.
5. Need to interact with supplier for detailed planning of optics manufacturing. Final M&T optimization can only be done when the glass melt data are there. Acceptable to delay one camera with respect to the other one.
6. Alignment of collimator should be done with an interferometer.

3. Additional comments from SSWG reviewers:

1. Achieving High Throughput.
High throughput is an extremely important deliverable for the HRS. The project might consider implementing a program to make sure that the delivered HRS has as high a throughput as possible.

A comparison of the VLT UVES and the HET HRS illustrates the problem (see pg. 10 of 3200AE0017: SALT HRS Instrument Description). Although both spectrographs seem to have similar properties in the red, the throughput of the VLT UVES is twice that of the HET HRS at 600 nm.

For the SALT HRS to be scientifically competitive, it must have a high throughput. It is often extremely difficult to ensure that an instrument will have high throughput unless extra special care is taken at all times along the path from design to the final assembly of the instrument. It would be valuable to have a throughput optimization program for the HRS. As we heard at the CDR, it appears possible by working with the CCD vendor to improve the detector QE by nearly a factor of 2 at 380 nm. That is a huge gain for some astronomical programs such as the one by B. Wakker to determine the distances to the high velocity clouds via the Ca II ISM lines. Although such significant gains are unlikely to be found elsewhere, I wonder about such things as the coatings of the optics, the alignment, and the proper handling , storage and protection of the optics after fabrication. Even small throughput losses of 3%, 4%, 2%, 5%, and 4% from one optical element to the next can in the end be very important because of the large number of optical elements in the HRS. One mishandled optical element can cause a major throughput loss and it would be difficult to find it after the instrument is assembled.

2. The Image Slicer.
The image slicers appear to me to be potentially a weak link in the system. The spectroscopic spread function for the higher resolution modes will depend critically on how well the image slicers function. There could be a throughput problem for the higher resolution modes unless most of the sliced light passes through the subsequent slits required to achieve the resolution. It would be very unfortunate if a substantial throughput loss is required to cleanly achieve the resolution of 37, 000. Do the image slicers introduce significant scattered light that adversely affects the spectroscopic spread function? Is it possible to work with the image slicer vendor to get image slicers optimized for the SALT HRS? A little more money spent to get optimized image slicers might be well spent.

3. Miscellaneous
Occasional section labeling mishaps and strange number formatting (6 replaced by :) in some of the documents.

Some inconsistencies, or lack of clarification, regarding the stated highest resolving power (65,000 to 70,000). Instrument description says 70,000, ICD document says 75,000.

Radial velocity precision should be tightened up, with both a number to sign up to (e.g. with iodine cell or ThAr) plus a goal.

Optical Design Table 2 seems to miss out details of the pupil re-imaging optics, including the VPH lenses.

Close interaction will be needed between the HRS team and the FIF PI concerning the design of the ferrules to accommodate the newly devised 3-4mm diameter “windows”.

Table 4 in Instrument Description 3200AE0017 should include a column with SALT specs.

Some of the analysis work on the mechanical design (e.g. supporting FEA, as in the SOW) seemed a bit lacking. A little too much presented to be “taken on experience/trust” and less on quantitative modeling.

There should be flatness and cross-talk specs on the CCDs.

Beam-switching (i.e. splitting the observation) should be mentioned in the OCDD. Operational sequence (OCDD, Section 4.1) misses FIF feed mirror insertion and removal of SALTICAM mirror.

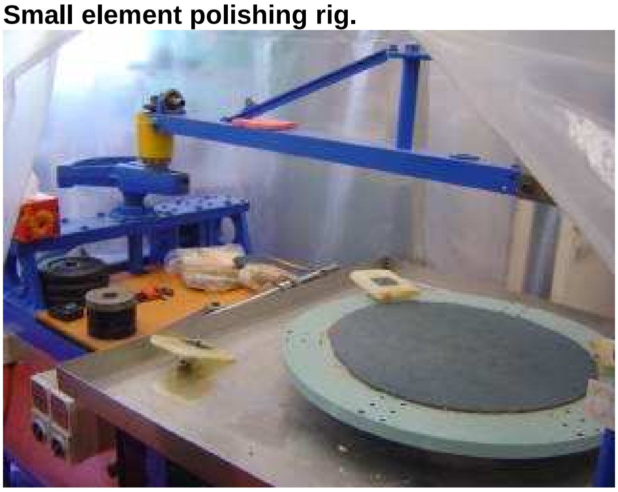
Management plan should include more detailed quarterly reports, covering financial, schedule and risk issues. Item 4 mentioned in Section 11 is missing from list.
Section 3.3.3 in Safety Review should include the fire hazard on the cryocooler lines.

Appendix 2: Visit to ***KiwiStar Optics, IRL*** (11th April 2005)

The CDR review panel, together with the HRS PI (Peter Cottrell), visited *KiwiStar Optics* on Monday 12th April. Peter Connor, representing *KiwiStar*, presented an overview of their corporate structure, optics experience and a description of several relevant projects. This was followed by a tour of the facilities by *KiwiStar* Wellington staff, which included optical fabrication and testing workshops/labs. The recently completed ~600mm diameter four-element Wynn-type prime focus corrector, built for the Anglo Australian Observatory to be used on the Subaru telescope, was shown to the panel.

Small element polishing rig.

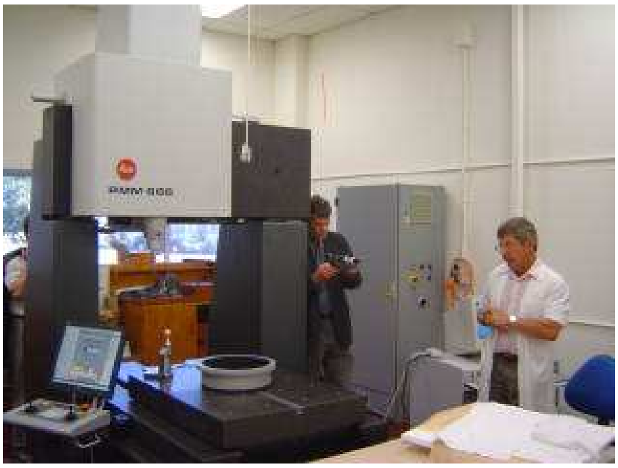
600 mm diameter Subaru corrector.



Large grinding & polishing table.

Subaru corrector.

Twyman-Green interferometer.



x, y, z measuring machine.

Appendix 3: Visit to Mt John Observatory

The CDR Review Panel also visited Mt John Observatory on 13th April to inspect several successfully completed projects constructed by some of the HRS team personnel in the Physics & Astronomy Department. These included the 1.0-m McLellan telescope and the HERCULES fibre-fed R2 echelle spectrograph, both built entirely in-house, with the optics fabricated by IRL/*KiwiStar Optics*. The new 1.8-m MOA telescope, with a ~500mm prime focus corrector built by *KiwiStar*, was also visited.

1.0-m telescope drive and polar axis.

1.8-m MOA telescope, with 500mm diameter prime focus corrector.

HERCULES vacuum tank.