VISTA INFRARED CAMERA PDR, DECEMBER 10th-11th 2002

Report of the Review Panel

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Terms of Reference

The VISTA IR Camera Preliminary Design Review (PDR) is a preliminary review of the design of the infrared camera for VISTA.

The remit for Part 1 (technical) of the review panel is to:
- Verify the conformity of the Preliminary Design including accompanying analyses and trade-offs etc with the Technical Specification
- Assess and report on the realisation of the preliminary design for the infrared camera
- Comment on omissions, areas of perceived risk and further developments that the panel think are necessary

General comments on the Review Process

The documentation set was very extensive and was based on ESO requirements. Unfortunately, because the review itself was not organised on the ESO model, this gave inadequate time for the reviewers to obtain an in-depth appreciation of the complete project, and the project team inadequate time to respond to the many submitted questions. Nevertheless, from the documentation the reviewers did subject each specific area to a detailed critique in line with the terms of reference, which, along with the overview of the project, was thoroughly covered at the review itself.

For future reviews the VISTA Project Office (VPO) needs to decide precisely what type of review it wishes to conduct and decide on the level of documentation and schedule accordingly. This is as much for the project's sanity as the reviewers.

Having said that, the supplied document set was impressive, not only in terms of quantity but also quality and comprehensiveness. The team had obviously worked very hard to iron out discrepancies, which in fact were very few. The web browser supplied with the CDs was very useful, but again, a hint for the future for such a tome of documentation would be for a simple 'idiots guide' to what the document set includes and a 'read this first' section to get one into the overview simply and speedily.

The Review Item Discrepancy form supplied was, in principle, an excellent concept that could have led to a thorough close-out of all issues with quality assurance carried through. However, the time limitations prevented its use being effectively utilised by both parties and this needs thinking through for future reviews and more importantly, how the Review Item Discrepencies raised for the PDR will be closed-out.

The panel wish to thank the members of the team for their presentations and all the arrangements for the review.

General comments on the overall proposal

The panel was impressed with the staff involved and the level of co-ordination and co-operation of the team on what is a distributed project. The relationships with the detector supplier, Raytheon, appeared particularly healthy and a number of worries panel members had expressed prior to the review were removed at the presentations.

Overall, in the technical areas the project is predominantly at a PDR level with most areas being in a state for final design and detailing. There appear to be no show-stoppers and the project is compliant in almost all areas. For most of the remaining systems, the majority are to be clarified rather than non-compliant. However, while small, the out-of-compliance areas are very important, indeed some critical, and must be solved urgently. Crucially the team also needs to rapidly address aspects of design with maintenance requirements in mind and cost drivers versus trade-offs of design to spec.

The sensitivity requirements for the IR camera are well met, indeed, if the detectors perform as the manufacturer's claim, even the goals will be well exceeded. This would be excellent; giving adequate margin for survey speed should unforeseen problems arise downstream. However, the current optical design remains marginal for the camera image quality (CIQ) requirement of 0.32 arcseconds, where the design is out of spec by 5%. While the team presented ideas about bringing this into compliance, there is not a single clear path to guaranteeing this. At some point simple solutions may have been used up but out-of-compliance still remains and the next step solutions look costly, a dialogue with the VPO will be needed to address possible specification softening. Concern remains about both wavefront sensors and urgent attention to resolve this issue is needed.

The VISTA-IR camera utilises a novel design for a K-band infrared camera of omitting a cold stop and using internal baffles to control stray and scattered light. The resulting large window size means it is hard to keep it warm – even with the planned dichroic baffle coating it is predicted to mist over in humid conditions. This must be prevented and a solution found.

The panel raises a note of caution regarding overall systems engineering, specifically in ensuring that the software aspects are fully brought into the hardware considerations in addressing compliance. As for most modern systems, both must function before the overall system operates satisfactorily. There is at least one other recent major telescope project where these lessons learned should be taken well and truly to heart. The most obvious specific example for the IR Camera that triggered the panel's concern is the low order wavefront sensor (LOWFS), where although the optical/mechanical components are compliant, the overall operation on turnaround time (software driven) is totally non-compliant. There now needs to be a correlation of top-down and bottom-up systems work.

The panel also gained the impression of a clear difference of approach adopted by RAL in that the requirement for a 25 year lifetime seems to have been translated akin to a space mission, where routine maintenance, the usual design parameter space for ground-based instruments, is not part of the plan (see above). While the space approach is meritorious, the extent to which this may be a design cost-driver or has major implications for the assemble/disassembly and maintenance/cleanliness issues remains unclear. On the other hand, we were informed that the lifetime for the microswitches (UK ATC) was only around eight years, a good number for a ground-based system but clearly at odds with a 25 year no-replacement lifetime. This aspect of specification, lifetime and maintenance needs urgent dialogue between the Camera team and the VPO. It is critically important that the instrument does not fall between two stools: not quite being developed to space standards but not having a maintenance design philosophy built-in either.

Finally, the team needs to maintain a close link with the VPO to determine whether some of the tech specs that have been set somewhat arbitrarily have become cost drivers for the project.

The individual areas of the project are discussed below:

Optical considerations

The optical design is fundamentally sound, albeit currently marginal for the 0.32 arcsecond CIQ requirement as noted above. It appears that there has been a potential lost opportunity to progress optical design alternatives post-CoDR (July 2001) that might have resulted in cost savings or better performance (see separate report by Richard Bingham). The Co-DR gave confidence that the agreed design could be extended to meet the specification and this path was pursued. There is now no longer opportunity (or available cash) to pursue alternative designs or to make major tweaks to what was presented.

On the other hand, there appears to be some slack in the tolerancing specs for the optics that might be able to be fed back into assist the overall CIQ and to save money. This should involve the consideration of part-made reoptimisation, when some optical surfaces have been completed and measured. In particular, tolerancing of the aspheric surface requires that the tolerances be related to cost. In principle, the optical tolerances should be relatively relaxed for expensive or special production processes on certain of the camera's components and tightened for routine processes. This principle does not appear to have been applied. Similar ideas will also apply to the quality of the material used for the large window of the cryostat and its production tolerances.

"Blanket" optical tolerances that are the same on a number of surfaces or lenses could also be re-considered to see whether it is possible to relax them locally, for example, on surfaces that are relatively close to the detector.

Ideas for general mechanical stiffening should also help in tackling the CIQ figure, but after the cheap solutions have been explored, should out-of-compliance still remain then more expensive (in cash and time) solutions will need dialogue with the VPO to determine the best course of action: further spend or relaxation of requirement.

"Blanket" optical tolerances that are the same on a number of surfaces or lenses could also be re-considered to see whether it is possible to relax them locally, for example, on surfaces that are relatively close to the detector.

The top-level optical error budget could well include a factor combining a contingency allowance and measurement errors. This allowance need not have a difficult impact on other tolerances, as it could be quite small and added quadratically.

The documentation showed that a very detailed optical error budget had been pre-determined at the system level and did not stand up to the optical tolerance analysis in several areas. In practice, the optical designers should work to an overall budget that they can subdivide to individual dimensions. The panel was pleased to note that this point was accepted during the review.

The optical tolerance analysis as presented included the telescope in the ray-trace, but did not consider the tolerances in the telescope itself. The result will be more accurate if the tolerances in the telescope itself are included in an overall analysis, so that the aberrations that they cause in the telescope are correctly propagated into the camera.

The design of the temperature-compensated mount for the lenses and window is uncertain. The scheme presented verbally at the review was a different one from that in the review papers, which in turn differed from previous VISTA work, and there was an unanswered question at the review regarding the polymer material for the compensating rods. This area therefore stands at a conceptual level (also see RIDs).

No data was documented on (a) optical coatings or (b) the details of the emissivity of the fused silica optical material (also see RIDs) and so these properties could not be reviewed.

At a more detailed level, the optical analysis could reasonably include more attention to (a) the lack of axial symmetry that pertains in the lens surfaces when some tolerance perturbations have been applied, (b) distortion, and (c) secondary spectrum. Also, consideration should be given to the values adopted for the "primary" wavelengths in each waveband (unless the analysis never calls for ZEMAX features that use the primary wavelengths).

The panel was concerned about the alignment repeatability process and procedures. The team needs to think carefully about what is really needed here, just what has to be recalibrated following any disassembly or mirror aluminising. Some tests and recalibrations are in fact rather easily undertaken on the telescope by looking at stars and so do not need further work. Further clarification about the entire procedures, including measurements on the sky, need to be addressed (see later).

Extensive work has been carried out on the scattered and stray-light analysis but the team are warned not to become complacent in this area as ‘unexpected’ light leaks invariably happen (holes, cabling, etc) and it is not obvious within the project that the system has taken this aspect on-board. It now needs to continue along with this work rather than freeze it as a ‘done deal’ and we recommend that a specific individual be charged with ensuring that as the design is detailed no unwanted light sources are introduced (such as a warm electrical component, a hole in bulk-head for a cable, from behind the focal plane array, etc). There is also a concern that the PDR lens barrel design uses smaller lens pockets (i.e. worse) than those assumed by the stray-light model. Lens outer diameters must be proven acceptable for stray-light, increasing them if necessary, before issuing the tender for lenses.

The baffle design is a critical component and it does appear to satisfy the strict requirements placed on it. Two coatings and suppliers have been identified that seem to meet the specs and urgent testing is now needed to confirm complete suitability.

Dust on the M1, M2 surfaces and the outside window of the camera have been excluded from the stray-light camera budget, but must be taken into account for the overall system sensitivity. It appears that the telescope and camera window front surface will dominate very quickly after degradation sets in following aluminising. In this light, the timescale (and procedures) for mirror and camera window cleaning needs to be determined. (Though this is partly outwith the scope of the camera project, the information should be provided).

Currently the camera top ring needs to have reduced emissivity by a significant factor to get within spec. This has been sketched out and looks like it should be adequate but clearly needs detailed design.

The moonlight analysis showed that a minimum height of the moonscreen was a requirement: this impacts on the height of the enclosure and needs to be taken on-board with the telescope via an interface document.

The Focal Plane Unit

The key to the focal plane is the detectors. The change of anticipated detector provider since the CoDR has led to a different layout of the focal plane array that has been incorporated into a new design. Regarding the detector specifications, Raytheon expressed bullish confidence that they expect to meet all requirements with room to spare, indeed exceeding the goals in a number of areas. Raytheon expressed the view that the tightest tolerance for them is the flatness per detector (<12μm) and the coplanarity across the entire set (2 parallel planes less than 25μm apart). The panel was convinced that considerable care has gone into the design of the detector mounting assembly by Raytheon to ensure compliance with tolerances and the issues of the re-mounting requirement for any detector. The panel congratulate the Vista project in making the detector mounting integral and the responsibility of the detector supplier. Indeed, Raytheon have clearly worked very closely with RAL in terms of the mounting of the focal plane unit and there is obviously an excellent working relationship.

Nevertheless, given the history of IR-array QE's at short wavelengths, it is important that direct QE measurements should be undertaken on the engineering arrays asap.

Concern was expressed regarding particulate contamination post-delivery and installation in the camera – how to keep it as clean as it needs to be requires further thought. Process control and handling requirements also need further work.

There was a detailed discussion regarding the selection of CMOS op-amps used for the pre-amp at the focal plane. Gain and bandwidth of the op-amps have to be carefully matched to the actual speed of the analogue output of the detector, which is specified by the manufacturer to be 400 kHz, a value that is usually optimistic. There is still some margin to meet the VISTA spec of reading out the complete focal plane in one second, which requires only a bandwidth of 0f 260 kHz. With the two CMOS op-amps tested so far, achieving high speed and low temperature operation currently seem incompatible. A key question was whether the spec has been over-interpreted and in reality the problem may not be so critical, but the temperature requirement is still a concern that still needs qualifying. If the pre-amp has to be warmer its location, photon contribution and additional noise pick-up due to longer cables needs to be addressed. This is not a show-stopper as a backup could be to use J-FET buffers inside the cryostat and use external op-amps but these bring other problems in turn.

The panel questioned the long-wavelength response/cutoff of the detector/filter combination with respect to the background light seen by the system. Is it too late now to change the detector spec or even worthwhile? The worry is that the 2.5 micron detector cutoff specified was chosen to guarantee the maximum science light in the traditional K band (which has a long cutoff at 2.4 microns) rather than minimise unwanted light in the science band. The choice should be made to maximise signal-to-noise and should allow some margin due to potential problems with filters and baffles. In this context the panel also note that the baseline filter set has K-short rather than traditional K.

The panel strongly suggested lowering the operating temp of the detectors from 77K to something like 65K or even lower because there is a notable improvement in cosmetics with lower temperature. On the other hand, the QE will also start to drop at some point so there is a trade-off to determine the optimum temperature. Raytheon believe that at least down to 65K the QE should be OK. (The project team believe that 65K is readily achievable in terms of cooling – indeed, less heating of the block would then be required.)

EMC between the CCD and IR detectors is always a worry and needs early testing. The most critical is EMC from the autoguider and curvature sensors to the science detectors. Possible options are (i) to interleave the autoguider and FPA and relax the guiding requirements to 3Hz while reading out FPA and then switch back to 10Hz (but this brings up a severe controller issue for both the FPA and the CCD), (ii) drop the CCD clock voltages. This latter solution brings other effects but was reported as working well for WFCAM where the CCDs are much closer to the science arrays than in VISTA. This area is not believed to be a show-stopper given the mitigation paths, but could prove costly in time and redesign. Although tests will be undertaken soon it is likely that the proof of the pudding will only be demonstrated in the final cryostat. The team need to maintain close links with the WFCAM project.

Regarding the EMC between the autoguider and low-order curvature sensing the obvious solution is to interleave the operation, but this may then need two CCD controllers to meet the non-missed-beat spec.

Regarding operability of the arrays, it would be beneficial if a damaged array could be isolated cold and observations continue rather than having to warm-up and replace the single array because the entire focal plane became unusable.

Wavefront sensors

The low order wavefront sensor appears to meet the accuracy requirements but not those for latency (software time >3 hours!). A new code was written following the failure of the EF package but the team admitted that no attempt has been made to speed up and optimise the code as yet. A number of solutions that would reduce the data reduction time to around 5 secs appear to be possible but have not yet been tested. It was confirmed that image generation is the slowdown and the team should look to use a better technique post PDR. A small team of gurus must meet early in the New Year to thrash out this area and decide a way forward with clear decision points.

The HOCS is as yet unproven; possible problems include wavelength, level of defocus, and the fact that the Simplex algorithm does not seem to cope with such a large parameter space (Z4-Z25). Investigations are ongoing and a backup is to revert to a Shack-Hartmann system, but this would come at a significant cost of cash and redesign time. It was agreed that a GO/NOGO date for a decision should be set for the end of March 2003. It may be that in the meantime the team could look at the extra <u>cost</u> of meeting the current technical requirements with a S-H compared with what the current system is expected to be able to deliver and then maybe live with it. The team confirmed that a very preliminary simulation of a S-H system gave 12nm worst case and most Zernike's better than 10nm with a 2 minute integration time. Following this one obvious suggestion is to look at the integration time itself; maybe this could be extended to 2 minutes rather than the current 60 sec requirement. The whole HOWFS area needs urgent work to resolve the issue and needs closing out. Close dialogue is clearly needed with the VPO on this.

Mechanical considerations

Good FEA work was presented showing that the overall mechanical system is under control and where a number of design improvements can be simply made. However, no earthquake modelling and its impact on the system was presented, which was an omission for a PDR. This now needs attention.

A cost benefit and risk analysis for the need for a spare window ingot needs to be undertaken; the dummy will meet most of the needs for the AIT.

For the thermoelastic analysis, realistic CTEs for the expected operating temperature range need to be included in the model. The results presented at the review suggested that the G10 trusses needed to be redesigned to relieve high stresses caused by thermal deformations. With realistic CTEs, or integrated CTEs, these stresses may be considerably reduced. An analysis of stresses in the camera during cooldown should also be undertaken.

Thermal considerations

Cooling of the detectors appears to be readily adequate, going colder also appears not to be a problem. All the cooling is provided by three cryo-coolers in the baseline design and the panel recommends that the third cryo-cooler is retained until it is proven that it could be removed while still retaining adequate margin.

As noted in the introduction, humidity and temperature requirements are only mostly compliant. Window condensation occurs for RH>72% and condensation on cryostat tube if RH > 82% for the cold condition. Modelling suggested that the latter can mostly be eliminated by using MLI or shielding and external black paint on the cryostat. The exception is the very tip of the cryostat in the cold condition, which would still condense. The addition of MLI or shielding brings essentially no change to the window problem. While this condition may be rare at Paranal, a solution must be found. As noted in the optics section, the surface contamination levels are very stringent and so the window should never expect to get wet, certainly not on the telescope where cleaning is almost certainly going to be a problem (cleaning is much simpler during testing in the UK where the conditions for misting might be more readily found unless the environment is humidity controlled). Loss of additional telescope downtime is also to be avoided. The most favoured path to the solution appears to be blowing dry air across the window surface in high humidity conditions but this has not yet been worked through to an acceptable solution and so the entire area remains a high concern.

Shown the cooling curves for the lenses, the panel requires the team to demonstrate that the thermal gradient of the worst lens is within tolerance for non-damage of the lens during cooling.

Software

The control system looks straightforward but the data handling is challenging. The team seems to have taken on-board the ESO requirements and a pragmatic approach to solutions using ESO-provided components. The control and data-flow architecture looks well understood along with their interfaces.

Consideration has been given to the higher processing power for the LOWFS and this still needs to be closed out.

Prototyping needs to be done as soon as possible to mitigate problems downstream and the project seems to have this under control.

There is a need to ensure that the guide stars can be selected automatically rather than need to have operator intervention – it is not clear that this is currently feasible and must be addressed with the VLT group and solved.

Because this is the first ESO instrument, the knowledge of the software effort remains uncertain but the proposed phased plan looks sensible.

Since CoDR considerable risk has been removed from the camera software package by having the on-board wavefront sensors controlled from the VISTA telescope software.

The panel expressed caution about the potential for non-sidereal tracking to suck up significant effort, especially if it needs exploring the use of the autoguider software. The VPO needs to determine the requirements for non-sidereal tracking and determine whether this requirement or goal should be pursued further.

AIT, operability and maintenance on the telescope

The AIT plan for lab commissioning is well progressed and a detailed test matrix was provided. However, there was concern that the lack of experience of such an instrument and how it works on a telescope might have meant that the most optimum plan has yet to be reached. This area needs further discussion with the science leaders. The team will keep open the most optimum and safest final plan for the population of science grade arrays into the focal plane and will work with Raytheon on further optimising delivery schedule.

The handling is not as far advanced as other work and the AIT stand design is challenging and not yet finalised. Critical aspects of camera to telescope mounting need to be very careful thought through and it was far from obvious that this area is as well progressed as one would expect at PDR. It is not clear that the risks associated with the camera-telescope insert/retraction have currently been fully thought through and the team would need to make a convincing case to show why lead-ins were not an integral part of the design. Indeed, the whole concept of handling on site as opposed to lab testing needs further thought and dialogue with the VPO to determine the cost/complexity drivers.

The ‘final’ tests in the UK will include the acceptance tests and the baseline plan is that the team do not expect to open the camera up again and it will be shipped intact to the telescope. This has implications on the shipping size of components, specifically the transport stand. A cost-benefit and risk analysis of the ship-intact versus ship-in-bits has not been undertaken but needs to be formally undertaken as there are system-wide implication including type of flexure tests etc.

It was not obvious why the tech spec requires the instrument to be removed from the telescope for cooling (removal for scheduled maintenance was obvious but not for unplanned warm-ups). Provision of nitrogen cooling on the telescope needs to be reviewed in terms of operational constraints.

As noted previously, non-repeatability of camera installation need to have associated calibration procedures derived between the camera and telescope teams.

The team concurred that the focal plane assembly will be accessible from the rear but only a concept was provided. This must be brought into the general design.

Continuous pumping is an unusual route to take and the explanations were not wholly convincing. While this did not appear to be a cost driver the concept needs clarifying with respect to a more standard use of a turbo pump. If continuous pumping is retained, there may be different ways of operating the cryo-pump, such as shutting it off during observing and pumping during the day.

The derivation of the one-year tech spec on warm-ups etc could do with a review after the PDR. It was not clear how these had been derived and whether they had turned into major cost drivers for the project.

The maintainability question has already been raised as a serious concern in terms of the design philosophy and this needs urgent dialogue with the VPO.

The recommendations are:

VISTA Infrared Camera PDR
10 & 11 December 2002
Technical Requirements

Topic	Required Action	By Whom	By When
General Comments on Review Process			
1	The VISTA Project Office (VPO) needs to decide precisely what type of review it wishes to conduct **Action: VPO to review the management of reviews to allow sufficient time for documentation**	VPO	Feb 03
General comments on the Overall Proposal			
2	**Action: PM to review the maintenance requirements for the camera with VPO**	K Ward/ VPO	Feb 03
3	There is clearly a discrepancy between the CIQ and the preliminary design. **Action: Mitigation plan to achieve CIQ must be provided by Jan 03. In addition, mitigation for the wavefront sensing must be provided**	K Ward	Jan 03
4	There is o a non-compliance of the cryostat window, which is predicted to mist over in certain conditions. **Action: Systems Engineer should provide plan for solving the window misting issue**	Systems Engineer	Feb 03
5	The panel noted some instances where the software issues had not been coordinated with other systems issues. **Action: Systems Engineer is to ensure that software requirements are included in compliance matrix**	Systems Engineer	Feb 03
6		???	???
Optical Considerations			
7	There appeared little justification on the apparent lack of development of the optics barrel since CoDR **Action: UKATC to provide short paper noting the design considerations of the optics barrel covered since CODR**	UKATC	Feb 02

8	The panel was concerned about the alignment repeatability process and procedures. **Action: requirement to meet alignment requirements on site should be discussed and a plan formulated to allow partial disassembly and rebuild on site**	K Ward	Mar 03
9	Although two coatings and suppliers have been identified that seem to meet the specifications and urgent testing is now needed to confirm complete suitability. **Action: tests on coatings for the baffle should be completed ASP and discussions carried out with suppliers to ensure material meets requirement**	K Ward	Feb 03
10	It appears that the telescope and camera window front surface will dominate stray light issues very quickly after degradation sets in following aluminising. **Action: VPO needs to ensure a cleaning programme to assist with maintenance is included in overall planning**	VPO	Feb 03
11	Currently the camera top ring needs to have reduced emissivity by a significant factor to get within specification. **Action: Design of the camera top ring should be developed through this phase**	K Ward	Apr 03
12	The moonlight analysis showed that a minimum height of the moonscreen was a requirement. **Action: VPO Systems Engineer to ensure that an interface document between moonscreen and telescope is produced within 4 weeks**	VPO	Feb 03
The Focal Plane Unit			
13	It is important that direct QE measurements should be undertaken on the engineering arrays asap. **Action: PM is to ensure QE's are available from RVS as soon as possible**	K Ward	ASAP
14	Concern was expressed regarding particulate contamination post-delivery and installation in the camera – how to keep it as clean as it needs to be requires further thought. Process control and handling requirements also need further work. **(Action: PM is to ensure plans in place to ensure cleanliness of detectors)**	KWard	ASAP
15	There was a lengthy discussion regarding the op-amp in the pre-amp, which has been changed to meet the 400Hz speed requirement. **Actions: UK ATC to review the requirement for 400Hz as soon as possible. A reduction will simplify the requirement. In addition, the temp requirement needs urgent review in an attempt to avoid the use of J-FET buffers**	UK ATC	Feb 03
16	The panel questioned the long-wavelength response/cut-off of the detector/filter combination with respect to the thermal background. **Action: VPO are to review the cut-off requirements for the detectors**	VPO	Feb 02
17	The panel strongly suggested lowering the operating temp of the detectors from 77K to something like 65K or even lower. **Action: UK ATC should test the detectors at lower temperatures to assess effect**	UK ATC	On arrival of first eng grade

18	EMC between the CCD and IR detectors is always a worry and needs early testing. **Action: The PM should ensure that a clear EMC plan is in place that is followed by everyone. In addition, he should follow the EMC issues being solved by WFCAM at present**	K Ward	Feb 03
19	It would be beneficial if a damaged array could be isolated cold and observations continue rather than having to warm-up and replace the single array because the entire focal plane became unusable. **Action: Systems Engineer to review outline design to see if cold isolation of one detector can be achieved.**	Systems Engineer	Mar 03
Wavefront Sensors			
20	The low order wavefront sensor appears to meet the accuracy requirements but not those for latency (software time >3 hours!). **Action: It is urgent that the area be reviewed by an action item involving all responsible members**	K ward	Jan 03
21	The HOCS is as yet unproven with problems with wavelength, level of defocus, and the fact that the Simplex algorithm does not seem to cope with. **Action: Again this area needs urgent planning and mitigation put in place. The action team noted above should deal with this**	K Ward	Mar 03
Mechanical Considerations			
22	A cost benefit and risk analysis for the need for a spare window ingot needs to be undertaken; the dummy will meet most of the needs for the AIT. **Action: Cost benefit analysis needs to be drafted by the PM and presented to the VPO for consideration**	PM	Jan 03
Software			
23	There is a need to ensure that the guide stars can be selected automatically rather than need to have operator intervention – it is not clear that this is currently feasible and must be addressed with the VLT group and solved. **Action: Project Scientist to resolve issue of guide stars and selection**	Vista Project Scientist	Feb 03
24	The panel expressed caution about the potential for non-sidereal tracking to suck up significant effort. **Action: VPO are to issue instructions on non sidereal tracking requirements and discuss implications with the camera team**	VPO	Feb 03
AIT, Operability and Maintenance on the Telescope			
25	The team will keep open the most optimum and safest final plan for the population of science grade arrays into the focal plane and will coordinate this plan with Raytheon. **Action: A clear AIT plan must be agreed ASP**	K Ward	Mar 03
26	The handling is not as far advanced as other work and the AIT stand design is challenging and not yet finalised. **Action: The PM Camera must review the handling requirements in line with the AIT plan and the on-**	K Ward	Mar 03

	site requirements		
27	The 'final' tests in the UK will include the acceptance tests required to provide assurance. The location of such testing was unclear. **(Action: See earlier actions concerning utilisation of UoD for AIT)**	K Ward	Mar 03
28	It was not obvious why the tech spec requires the instrument to be removed from the telescope for cooling **Action: VPO are to review the requirements within the specification for warm up/cool down mounted to the telescope**	VPO	Feb 03
29	As noted previously, non-repeatability of camera installation need to have associated calibration procedures derived between the camera and telescope teams. **Action: See earlier action on repeatability**	K Ward	Mar 03
30	The team concurred that the focal plane assembly will be accessible from the rear **Action: The focal plane design should include the ability to remove the FPA from the rear of the camera**	K Ward	Apr 03
31	Continuous pumping is an unusual route to take and the explanations were not wholly convincing. **Action: the requirements for cooling and pumping need to be reviewed in detail before the preliminary design is developed further**	VPO	Feb 02
32	The derivation of the one-year tech spec on warm-ups, etc could do with a review after the PDR. **Action: The VPO should review the timing of warm-up to see if any expense could be saved through an alternative strategy**	VPO	Feb 02