IR CAMERA

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1 Introduction & Scope

This document sets out the tasks required for successful commissioning of the VISTA IR Camera at the telescope prior to acceptance and operational handover of the system to ESO. It lists assumptions made about pre-requisites for commissioning the camera that must be achieved by the telescope commissioning team before the camera commissioning phase can commence. At the time of the camera FDR it is intended that this document should be a complete preliminary issue which will be developed in more detail, under discussion with the VPO telescope commissioning team as the camera build process progresses.

2 Acronyms and Abbreviations

2MASS	2 Micron All Sky Survey
ADxx	Applicable Document number xx
ADC	Analogue-Digital Converter
AG	Auto-Guider
AIT	Assembly Integration and Test
aO	Active Optics
BPM	Bad Pixel Map
CCD	Charge-Coupled Device
ESO	European Southern Observatory
FDR	Final Design Review
FOV	Field of View
HOCS	High Order Curvature Sensor
ICS	Instrument Control Software
IRAF	Image Reduction and Analysis Facility
IRACE	Infra Red Array Control Electronics
LCU	Local Control Unit
LOCS	Low Order Curvature Sensor
LUT	Look-Up Table
M1	Primary Mirror
M2	Secondary mirror
PA	Position Angle
PSF	Point-Spread Function
RDxx	Reference Document number xx
SDSU	San Diego State University (technical CCD control electronics)
TCS	Telescope Control System
VDFS	Vista Data Flow System
VISTA	Visible and Infra-Red Survey Telescope for Astronomy
VLT	Very Large Telescope
VPO	Vista Project Office
WFS	Wave-Front Sensor

3 Applicable and Referenced Documents

	Title	Number & Issue
AD01	IR Camera Technical Specification	VIS-SPE-ATC-06000-0004 v2.0
AD02	IR Camera Telescope Mounting Procedure	VIS-PRO-RAL-060xx-00xx
AD03	IR Camera Cooldown Procedure	VIS-PRO-RAL-060xx-00xx
AD04	IR Camera Startup Procedure	VIS-PRO-RAL-060xx-00xx
AD05	IR Camera Prep-lab checkout procedure	VIS-PRO-RAL-06111-0002 to be developed during AIT phase
RD01	VISTA Telescope Operations Manual	VIS-MAN-ATC-?????-????
RD02	IR Camera AIT Plan	VIS-PLA-RAL-06091-0001
RD03	Filter Holder Design	VIS-TRE-RAL-06013-2005
RD04	VISTA aO Operations	VIS-TRE-ATC-?????-????? (WJS)
RD05	Scattered Light Analysis	VIS-ANA-RAL-06013-2002

4 Assumptions and Pre-Requisites

The following items are assumed to have been successfully completed before the telescope is deemed ready for camera commissioning:

1. Camera check-out in the instrument prep. lab. within the VISTA enclosure has been successfully completed according to AD05.
2. Telescope pointing software has been checked and calibrated using the VISTA test camera.
3. Telescope M1 actuator LUTs have been set up and tested using a Shack-Hartmann sensor mounted within the VISTA test camera.
4. The aO performance of the M2 unit has been verified using the Shack-Hartmann sensor within the test camera.
5. All construction activities in the vicinity of the VISTA enclosure have ceased such that dust has been allowed to settle.
6. RD01 exits in a suitable draft form to allow operations on-sky to proceed safely and with reasonable efficiency.
7. **presumably there are more of these!**

5 Commissioning Activities

The following table lists all anticipated commissioning activities, subdivided by broad topic. A detailed timeline for these activities will be developed following the FDR.

Ref	Activity	Actions
1	**1st Mounting of Camera to Telescope**	
1.1	Cooldown in prep. lab according to AD03	Check documentation and verify that the cooling timescale is consistent with the turnaround time specified for the camera.
1.2	Mount camera on telescope according to AD02	Check documentation and verify that the camera can be mounted on the telescope within 4 hours. Verify that the camera actually fits on the telescope! Verify that the camera is secured to the telescope and that all transient fittings are cleared. The telescope balance should presumably be checked at this point.
1.3	Power up camera according to AD04	Verify documentation
1.4	Camera Health Check	T sensor readings, Vacc gauge readings, detector health checks, WFS/AG health checks. Filter wheel operations check.
		It should now be OK to move the telescope and commence daytime on-telescope operations.
2	**Closed Dome Operations**	N.B. Some of these tasks will already have been done in the lab., but they should be repeated in the telescope operating environment. (i.e. M1 support control loop and telescope drives running etc...). This next set of tasks does not necessarily have to be complete before commencing on-sky work.
2.1	Science Detector Bias Frames	0s (min read time) exposures with dark filter in place and various dome/camera services operating. Check bias repeatability and coarse pick-up (e.g. can we do this while moving the windshield/moon screen/dome.)
2.2	AG/WFS Detector Bias Frames	As above for WFS/AG chips.
2.3	Science Detector Dark Frames	Start with window cover on, then with dark filter in and dome lights off, then with dark filter in and dome lights on. Probably need to do sets of 10 exposures in increments up to 30 minutes each, so this task could easily take 2 full days to complete. We should also verify the stability of the dark frames following power cycling of the detector system.

2.4	AG/WFS Detector Dark Crosstalk	Repeat one set of item 2.3 with AG/WFS running during the exposures to look for crosstalk. –Note that there is no real point in checking the dark current for the AG/WFS chips as the exposures are so short.
2.5	Flat-Field Screen Illumination setup	Slew telescope to dome flatfield screen position. For each science filter and the AG/WFS chips we need to experiment with illumination levels and exposure times to define suitable settings for domeflat observations. N.B. This implies that some level of control of the illumination setting is available. Output of this process will hopefully answer the question of whether or not we can achieve meaningful flatfields with the dome screen.
2.6	Flat-Field measurements	Take a fixed number, say 10 exposures of the screen in each filter setting to determine a baseline flatfield for each filter. Repeat these for the rotator at each of the four cardinal points (and probably the semi-cardinal points as well) to check for possible movements of the filters within the holders. We should also make a point of checking the stability of the flatfields between slewing the telescope around the sky and between movements of the filter wheel (to check repeatability of the filter positioning).
2.7	Baseline Linearity Measurements	Repeat flatfield measurements with successive, increasing exposure times to go from low counts to full ADC capacity to check linearity in each passband.
2.8	EMC check on flatfield images	Probably worth doing this again at some level with the AG/WFS running just in case there is different behaviour at high count rates. This should just be a box-ticking exercise…
2.9	FITS Header Check	The above datasets should provide adequate information to check that the basic telescope data is being correctly written to the FITS headers.
2.10	Bad Pixel Maps	Generate BPMs for each science array and the sensor arrays.
		This should be pretty much everything related to observations that needs to be checked out in the dome without the sky, but a subset of the above measurements should be repeated regularly during commissioning to assess temporal stability. This in turn implies that at least some of the data frames should be kept at hand!
3	**Open Dome Operations – First Light**	*This phase is intended to cover the first few nights on sky. The exact order of execution of the tasks below is expected to depend on the level of progress made at each step. We should be able to assume that the M1 LUTs are sufficiently well determined so that we can operate with M1 in open-loop at this stage without huge difficulties.*

3.1	Twilight Sky FlatFields	Probably won't get to this on the first night, but this would, in principle, be the first thing that could be done on sky, and which doesn't require anything else to be known to be working properly. Need to figure out what (if any) exposure times would be appropriate to obtain sky flats for a given telescope alt,az and sun position. Again, this could be turned into a LUT for flat-fielding. An alternative approach would be to develop an automatic process based on a simple minimum exposure measurement of the sky counts seen in a 'representative' region of the science array. The aim here should be to set things up so that there is never any 'fishing' involved in getting good sky flats. This should be done at the beginning and end of the night. N.B. there may be some correlation of K-band flatfield times with ambient temperature!
3.1	Initial Focus Setting	Once it's dark enough we should be able to acquire a bright star in either K_S or H_2 and get a rough focus position. (It may be possible to do this with the AG CCDs as well, but we can probably get there earlier in the night with the H_2 filter… At this point we should probably assume that the telescope is going to be pointing well enough to at least get a rough focus.
3.2	Pointing Model Update	Centre the star on one of the four central science arrays and check the zero-point of the pointing model. This is almost certainly going to be slightly off first time round due to any number of effects. Reset the zero-point to the new value using the appropriate aperture offset for the chip in question. This should set the telescope pointing model. It should now be possible to move the star (either by a preset or by 'hand paddle') to the centres of the other central arrays and repeat this check-and-set process.
3.3	Rough Saturation Magnitudes	Determine basic saturation exposure times for some known stars (e.g. from 2 MASS) to speed up further focus and calibration runs. Note that these will not remain accurate as the WFS LUTs converge and the SIQ reaches it's optimal value.
3.4	Basic Checks of Pointing Model	The next step is to slew the telescope to a large number of bright stars on the 'pointing grid' at a large number of positions on the sky. It would probably be useful if these could be selected at systematic altitude positions for each azimuth position. (N.B. Don't want to go below the pole yet!). For the 1st pass this should just be a visual evaluation (with notes) of the quality of the model to determine whether or not an update of the model is the highest priority. (Note that this is all done with M2 in open loop, so we may well need to refocus for some altitude angles).

3.5	Rotator centre check	If the pointing model is OK for the current position we should be able to execute the procedure for determining the rotator centre. –This is probably a pre-requisite for the next step, as the AG certainly won't perform correctly if we're not rotating about the correct axis.
3.6	AG focus check	Assuming that we have a stable pointing model, correct rotator centre and reasonable focus we should now be able to acquire a guide star on one of the AG CCDs. There are probably many reasons why the star position predicting software won't behave properly at this point, so it's probably best to start be acquiring the star from a full frame read of the chip and then selecting the box by hand. Once we've got a star we can perform a first direct check of the AG focus relative to the science array focus (although we're running M2 in open loop here, so it may not be perfect). *Single filter assumed at this point, probably J.*
3.7	2^{nd} AG focus cross-check	Repeat 3.5 for the 2^{nd} AG chip and compare the focus values obtained. Any discrepancy at this point can either be interpreted as an offset between the two units OR a tilt of M2, so it will be necessary to investigate the optimum focus positions for various points in the science field to determine the nominal focus and M2 tilt settings.
3.8	AG open loop operation	Now we sit and watch the star on the AG display, and check the measured FWHM and centroid values with the telescope in open loop tracking.
3.9	AG closed loop operation	At this point we should be able to activate the AG loop and check that no gross motion of the science field is observed. We should also be able to apply small (~1") offsets to the telescope position using 'hand paddle' operation and verify that the AG software correctly determines the offset and generates the appropriate correction signal.
3.10	LOWFS acquisition and simple open loop.	Once the AG is working at an acceptable level in closed-loop mode, we should attempt to acquire stars on each of the LOWFS units and take basic images. It should be possible to estimate the defocus positions of all four CCDs and run the fitting software to determine the current M2 errors. For a 1^{st} pass these errors should be input to the M2 unit control system 'by hand' as a simple check. A simple determination of image quality across the science field should be made before and after this correction is applied.
3.11	First Light Image	At this point we should probably attempt to obtain a simply dithered image of some familiar object. This image may be of use to the VDFS for testing purposes, but since we're not

		running OBs at this point there may be data missing from the headers that would be required to run a simple verification of the pipeline just yet, although these could presumably be added by hand.
		We have now covered the basic steps to make sure that the basic functionality of the camera is present at some level.
4	**Telescope LUT Generation**	
4.1	HOWFS Open Loop Measurements	The aim here is to visit a large number of stars suitable for HOCS measurements at a wide range of alt,az,rot settings and at different points in the camera FOV. The rot and FOV x,y changes can be used to isolate effects that are due to residual optics imperfections in the camera itself. These residuals need to be added to the 'null' aberrations used by the WFS software subsystems. At each point we examine the residuals seen between the M1 LUTs that were obtained from the test camera and the HOWFS measurements. This step requires a substantial amount of on-sky time. Systematic deviations from the test-camera LUT should be investigated and understood at this stage before any attempt is made to update the LUTs. *Note that we have to be slightly careful about the fact that M2 is running in open loop at this point –It may be necessary to apply corrections to M2 based on LOWFS measurements during this process as the M2 LUTs will not yet have been changed. It is assumed that guiding will be available if required.*
4.2	HOWFS LUT update	Once we're happy that we understand any differences between the apparent numbers generated by the HOWFS and the test camera LUTS we should store the former somewhere safe and generate an update based on a similar process to 4.1
4.3	HOWFS Open Loop Measurements	Repeat 4.1 using our own LUT, but with M1 in open loop as a sanity check.
4.4	LOWFS Open Loop measurements	Repeat 4.1 using LOWFS measurements to study M2 behaviour and verify the static aberrations seen at the LOWFS positions (should also verify the variation of these across the LOWFS fields). *This can probably be done in parallel with 4.1, but is identified as a separate task for clarity.*
4.5	LOWFS LUT update	Update the LOWFS LUT.
4.6	LOWFS Open Loop Measurements	Repeat 4.4 with LOWFS measurements. *Again, this can probably be done in parallel with 4.3*
4.7	General Cross-Check	*It should now be possible to acquire a HOWFS star with the LOWFS and AG running in closed loop mode and track this star for several hours to allow monitoring of the interaction between the LUT open loop settings and the dynamic updates provided by the LOWFS sensor readouts. In particular, it*

		should be possible to verify that the LOWFS and HOWFS see a consistent picture of what is going on!
4.8	WFS and AG sensitivity	Determine sensitivity of AG and WFS to faint stars, crowded fields, and poor seeing. We should also contrive to generate ghost images of nearby bright stars/moonlight within the AG and LOWFS fields to investigate the behaviour under these conditions.
4.9	aO Performance Checks	Now that everything *should* be working to a reasonable level, we should spend some time adding deliberate errors to the M1 and M2 LUTsas described in RD04. Among other things, this will provide a verification of the behaviour of the software when one or more of the measurements goes ‘out of range’. We should also investigate and verify the performance of the system when one LOWFS is out of action for whatever reason, or is generating ‘suspicious’ data. –This should include observations where the LOWFS FOV is crowded. A secondary aspect of this is that we should be able to investigate and verify the system performance when one M1 actuator is non-functioning, and characterise the signals that might tell us that more than one actuator is non-functioning, or that there is a problem with the M2 unit. *Note that a) this bit should all be fairly obvious, but needs to be checked, and b) this could be considered to be an aspect of commissioning that falls under the telescope, rather than the camera, but there may be software tweaks required on the camera side, so we need to consider this activity here, even if it is* also *done somewhere else (e.g. with the test camera).*
5	**Camera Co-Ordinate System Setup**	
5.1	FPA array positions	Identification of the exact positions of the science arrays in the focal plane co-ordinate system using astrometric references.
5.2	AG array positions	Identification of the exact positions of the AG sensors in the focal plane co-ordinate system using astrometric references
5.3	LOWFS array positions	Identification of the exact positions of the LOWFS sensors in the focal plane co-ordinate system using astrometric references
5.4	HOWFS nominal position	Definition of the default position of the HOWFS measurement on one of the central arrays.
5.5	Astrometric solution	Determine generalised cubic distortion term for the camera using pre-defined fields of astrometric references. *This can be setup using the ASTROM package.*
5.6	Astrometric residuals	Determine a map of the astrometric residuals from the

		generalised distortion using pre-defined fields of astrometric references. –This provides useful information for the VDFS and a direct check of the co-planarity of the focal plane.
5.7	PSF measurements	Determine a map of departures from the canonical PSF obtained in good seeing conditions. –Expect to see radial variations, but should be able to go to second order.
5.8	Filter Defocus	N.B. The filters are supposed to be co-focal! However, it is possible that there may me *small* focus offsets between the science filters that can be compensated at the expense of a *small* degradation in the AG performance and a small change to the *expected* aberrations seen at the LOWFS detectors.
5.9	AG/WFS position predictor	Now that we have the coordinate system setup correctly, we should be able to speed up subsequent phases by using predicted positions for the AG and WFS stars. This needs to be checked out at different sky PA's as well. The stability of the offset between the WFS units and the FPA needs to be verified by repeated return to known positions from various large-angle slews.
6	**Photometric System Setup**	
6.1	Standard Stars	We need to obtain observations of many fields of standard stars at different airmass values to determine the photometric zero-points and colour terms for the science filters. The assumption here is that we can begin by using the WFCam standard equatorial fields. These will allow us to place standard stars on 4 science arrays simultaneously, and we should be able to use these to build up filled fields of standards. Particular attention should be paid to the colour terms emerging for different arrays here, as these can be indicative of 'red leaks' in the filters. Note that a quick and dirty zero point for J and K can be derived from the 2MASS data that will be available inside the VDFS. *N.B. this should include some attempt at verifying that the filter occupancies make sense, both at the level of the filter IDs of each set, and internal consistency within a set!*
6.2	Stability	We need to demonstrate the stability of the photometric system over many nights. –Ideally this should be done over nights with a wide range in ambient temperature.
6.3	Sky Background Levels	We should determine the sky background in each of the filters under various conditions: Dark moon, Half Moon, Full Moon, 0^{o} ambient, 15^{o} ambient, first half of night, second half of night, and through twilight as a function of sun angle below the horizon. This latter will allow optimisation of the observing hours and the utility of twilight flatfields.
6.4	Daylight Pointing	Verify that this gives an acceptable signal-noise ratio for stars

	Calibration Filter	of given K magnitudes, and specify suitable operations limits.
6.5	Flatfield Stability	Verify the stability of the flatfield in each filter as a function of sky position and PA. Again, this should be done over many nights.
6.6	Sky Background Map	RD03 gives the predicted pattern of diffuse scattered skylight that arises from the discrete filter panes in the filter wheel. The general form and amplitude variation of this pattern should be checked.
6.7	Ghosting Checks	The expected pattern of low-level ghost images due to the presence of bright stars in the field is well understood (RD05). This should be verified using bright stars at various positions in the field.
6.8	Dark Frames	Obtain dark frames immediately before an exposure and check for variations between these and the dark frames that were obtained during daytime operations or 'library' dark frames.
7	**Operations Verification**	
7.1	Jittering	Verify that the jittering procedures (small offsets) give the correct offsets for the science data, and that the AG and WFS stars are picked up correctly.
7.2	Dithering	Verify that the dithering procedures allow a filled tile to be recovered correctly with no gaps.
7.3	Timings	Verify and optimise the time overheads inherent in jitter and dither procedures. In particular, we should determine the optimal (time) route to obtain a single filled tile in four filters, and we should also consider the optimal (quality) route to the same end so that the end user is able to make informed decisions.
7.4	QA pipeline	Verify the speed and reliability of the QA pipeline.
7.5	OB processing	Can we actually run through a set of OBs without hiccups?
7.6	Long Term Stability Check	Repeated observations of a number of fields at different PAs and sky positions over many nights to verify long term stability of performance (flexure of FPA/filter wheel/baffle/M2 baffle, filter repeatability etc.)
7.7	Wind/Moon Screen	Determine suitable limits for the wind and moon screen to avoid vignetting or emissivity issues. Investigate photometric performance as we move close to the full moon with the moon screen in position.
7.8	Cassegrain Rotator Limits	Verify that the interaction of the OS and the Cass rotator limits functions correctly. Verify the zenith proximity limit for acceptable science data.
7.9	High Humidity Alarm	Verify that this behaves properly and that there is no misting issue.

7.10	Data Volume	Can we generate a full nights data in anger without exceeding storage capacity
7.11	Data Flow Rate	Are the unexpected bottlenecks in the data flow rate?
8	**Maintainance Issues**	*No particular order here!*
8.1	Camera Dismount Procedure	Verify the camera dismount procedure as in AD02
8.2	Cryopump Activity	Verify Cryopump activation and regeneration procedures.
8.3	Filter Exchange	Verify the filter change procedure and that update of the active filter information present in the database propagates correctly through the system.
8.4	Emergency Stop and recovery	We need to make sure that the camera behaves correctly under emergency stop conditions.
8.5	Power Failure and recovery	Verify that the power fail shutdown and recovery procedures work as intended.
8.6	Warmup Procedure	Most important is to verify that the detectors are warmed up in advance of the surrounding material to prevent surface contamination.
9	**Operations Manual**	Throughout the commissioning phase the camera operations manual will be developed and updated. A final pass through the operations manual should be performed as part of the final acceptance testing.

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