Visible & Infrared Survey Telescope for Astronomy

IR CAMERA

Document Title:	**IR Camera System Assembly Integration & Test Plan**
Document Number:	**VIS-PLA-RAL-06091-0001**
Issue:	**2.0**

Document Prepared By:	**Martin Caldwell** **IR Camera Systems Engineer**	**Signature and Date:**	M Caldwell Martin Caldwell 2003.11.19 18:02:52 Z
Document Approved By:	**Martin Whalley** **Cryostat WP Manager**	**Signature and Date:**	Signature Not Verified Digitally signed by Martin Stephen Whalley Date: 2003.11.20 15:28:53 Z
Document Released By:	**Kim Ward** **IR Camera Project Manager**	**Signature and Date:**	K. Ward Kim Ward 2003.11.19 17:48:55 Z

Document Checked By:	**Gavin Dalton** **IR Camera Scientist**	**Signature and Date:**	Signature Not Verified Digitally signed by Gavin Dalton Date: 2003.11.20 17:29:32 Z

Change Record

Issue	Date	Section(s) Affected	Description of Change/Change Request Reference/Remarks
Draft 0.1	02/08/02	All	New document
Draft 0.2	09/08/02	All	Renumbered and updated.
Draft 0.3	10/09/02	all	Change of instrument layout, and proposed test sources. Comments from SM.
0.4	15-10-02	marked	Change in proposed test source, new cryostat AIT, WFS/FPA/Filter super-assembly
0.5	30-10-02	Marked	Comments from GD
0.6	15-11-02	"	Comments from PDR dry-run presentation.
1.0			PDR issue
1.1	240203	Marked	Update in light of optical alignment plan (AD6)
1.2	24-7-03	All	Update to use of different cryostat configurations
1.3	24-10-03	all	Section 5= verification matrix, moved to Verification plan. Test matrix revised. Draft for pre-FDR reviewing
2.0	14-11-03	-	FDR issue

Notification List

The following people should be notified by email that a new version of this document has been issued and is available on the IR Camera document database:

RAL: M Whalley
R Edeson
K Ward
A Richards
G Dalton
G Woodhouse
G Toplis
D Tye

ATC:
M Leclerc
A Gallie

A Longmore
A Born
S Beard
M Strachan
Durham: P Clark
P Luke

TABLE OF CONTENTS

1 SCOPE

This document plans out the flow of integration and the tests at each stage to assemble the camera hardware and test it up to UK acceptance.

As an input it takes the requirements from the Verification Plan of AD08 (in particular the items of the verification matrix which require tests). As an output it proposes the test matrix for UK acceptance of camera requirements and performance.

The plan places requirements on the test plans for the sub-systems at unit level. Details of these sub-system unit level tests are devolved into the sub-system documents (requirements specifications & designs), but their required inputs to camera-level AIT are summarised here.

2 ACRONYMS & ABBREVIATIONS

AIT	Assembly Integration and Test
AG	Auto-guider.
AT	Alignment Telescope

ATC	Astronomy Technology Centre
CIQ	Camera Image Quality
FOV	Field OF View
FPA	Focal Plane Assembly
FWA	Filter wheel assembly
HOWFS	High order wavefront sensor
IR	Infrared
LED	Light Emitting Diode
LOWFS	Low-order wavefront sensor
LOCS	Low-order curvature sensor
MLI	Multi-Layer Insulation
NA	Numerical Aperture
RAL	Rutherford Appleton Laboratory
TBC	To Be Confirmed
TBD	To Be Determined
UoD	University of Durham
VISTA	Visible and Infrared Survey Telescope for Astronomy
VPO	VISTA Project Office
WFE	Wave-Front Error

3 APPLICABLE DOCUMENTS

AD01	Camera Technical Specification	VIS-SPE-VPO-06000-0007
AD02	IR Camera System Design Description	VIS-DES-RAL-06013-0001
AD03	IR Camera System CIQ Budget	VIS-BDG-RAL-06013-1001
AD04	IR Camera AIT Procedures	VIS-PLA-RAL-06091-0008
AD05	Electrical design	VIS-DES-RAL-06013-0002
AD06	Optical alignment plan	VIS-PLA-RAL-06091-0002
AD07	AIT Plan MS Project File.	VIS-PLA-RAL-
AD08	Verification Plan	VIS-PLA-RAL-06090-0001

IR camera sub-system specs.

No.	**Title**	**Doc. No.**
AD11	IRACE Technical Spec.	VIS-SPE-ATC-06020-0005.
AD12	Window Req'ts. Spec.	VIS-SPE-RAL-06062-0001
AD13	Baffle sub-system Reqts. Spec.	VIS-SPE-RAL-06064-0001
AD14	Lens assembly sub-system Reqts. Spec.	VIS-SPE-RAL-06020-0010
AD15	Sensors sub-system Reqts. Spec.	VIS-SPE-RAL-06040-0001.
AD16	Filter wheel sub-system Reqts. Spec.	VIS-SPE-RAL-06050-0001

AD17	Focal plane assembly sub-system Reqts. Spec.	VIS-SPE-RAL-06030-0010
AD18	Camera handling equip't sub-system req'ts spec	VIS-SPE-RAL-06013-3001
AD19	Computer equipment sub-system requirements spec.	VIS-SPE-RAL-06082-0001

IR camera sub-system AIT plans.

No.	**Title**	**Doc. No.**
AD20	Cryostat AIT Plan.	VIS-PLA-RAL-06068-0001.
AD21	Window AIT Plan.	VIS-SPE-RAL-06062-0001
AD22	Baffle AIT Plan.	In DES document
AD23	FPA AIT Plan	VIS-SPE-RAL-06020-0010
AD24	Filter wheel AIT Plan.	VIS-SPE-RAL-06040-0001.
AD25	Lens assembly AIT Plan.	VIS-SPE-RAL-06050-0001
AD26	WFS Snsors AIT Plan	See DES document

Reference documents.

RD01	IR Detectors Procurement & characterisation (PDR)	VIS-PLA-ATC-06032-0001
RD02	AIT Schedule MS Project file.	VIS-PLA-RAL-06091-0010
RD03	Test source optical design	VIS-PLA-RAL-06091-1001
RD04	IR Camera test procedures	VIS-PRO-RAL-06091-0008

4 General Approach.

The approach to planning in the current phase has the following features.

- To have as much verification & testing as possible done at 'unit level', i.e. within each sub-system AIT activity, prior to integration to the camera.
- To commission & test the cryostat as a sub-system under WP 'Cryostat AIT', separately from the subsequent camera AIT, with the critical items absent (optics & detectors) to minimise risks. It is a major task and so is included in this plan.
- The integration of detectors & cold testing in the FPA is formally part of WP 'FPA AIT', but due to the activities required it is entwined with camera level AIT and so it is included here.
- To minimise the required number of cold runs at camera level. Extra runs may be needed but are considered as margin & contingency.
- To combine as many tests as possible per cold run to minimise the time taken, and to make the optical alignment measurements as early as possible. This makes best use of opportunities for iteration of these alignments on later cold runs.

- To test the gravity flexure responses at the same time as optical alignments, to make efficient use of common test set-ups & procedures.
- To have final acceptance testing occurring concurrently with the assembly and integration activity, rather than later as a separate 'acceptance phase' on the full system as in the original plan. This is to save time and to increase efficiency because some of the test equipment set-ups are the same for both integration and test procedures. For this approach it is required that: (a) the relevant items are in the final configuration (b) the case is made for the test being representative enough for acceptance purposes.
- Once the full configuration is reached, the remaining acceptance tests are made in a a phase 'all-up testing'. These tests include EMC of final system, observatory handling equipment tests.
- Post-delivery test phase for systems checking on arrival at Paranal (in prep-lab), prior to integration to the telescope.

5 Main phases of camera AIT

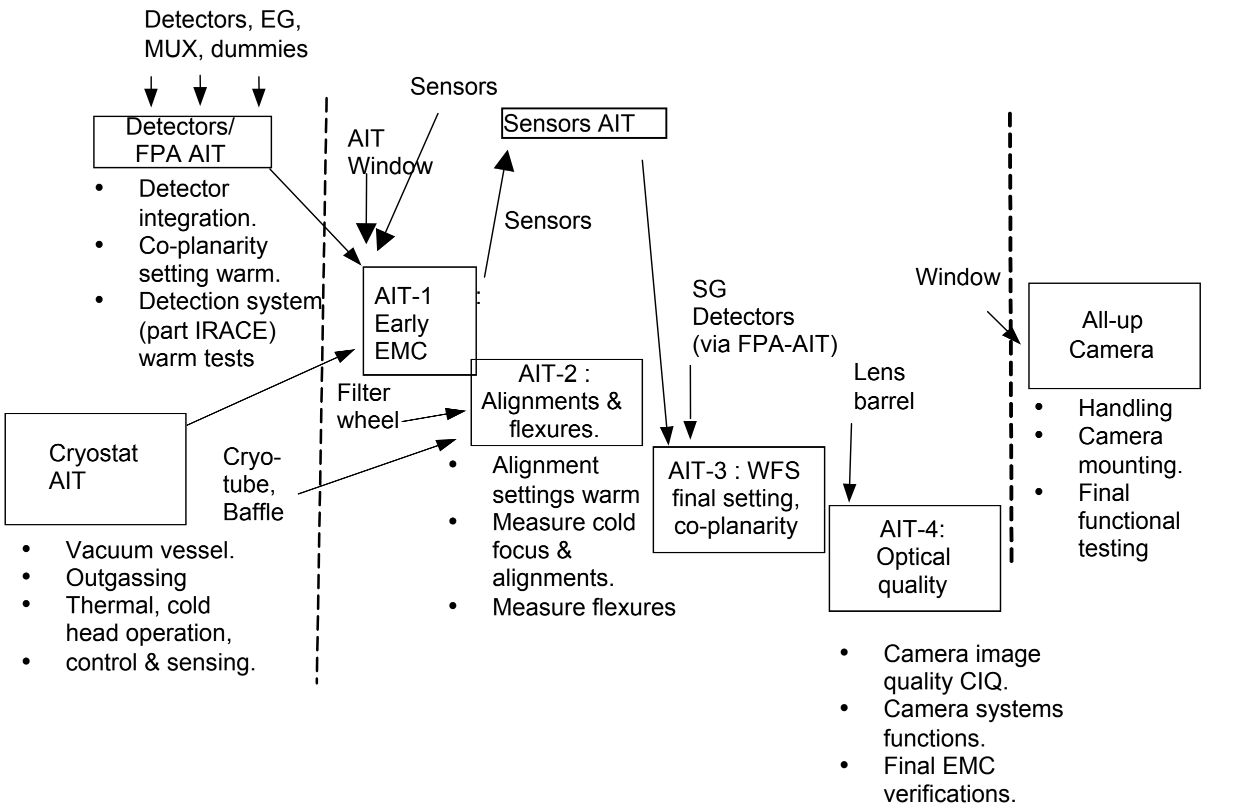


Figure 5-1. AIT phases.

The main phases of camera-level AIT are shown in figure 1. They occur due partly to schedule constraints and partly to organisation of the required tests. In particular the WFS Sensors are supplied to the Camera partially complete for AIT-1 (early EMC testing), but then must depart again during AIT-2 to complete their unit-level AIT.

6 Requirements on sub-system AIT tasks.

General: the tests to be made at unit-level on each sub-system are detailed in the sub-system requirements specifications AD's 11 to 19. The descriptions given here are to summarise the key outputs from those tasks which are needed as inputs to their camera-level integration and test tasks.

6.1 Cryostat AIT.

This section is intended to be a summary of the cryostat AIT plan in AD20.
The aims of cryostat AIT are the verification of:

- vacuum and LN vessels. In terms of structural integrity, safety, reliability (made by manufacturers as part of vessels sub-contracts).
- Cryostat pumping and cooling systems performance (Outgassing, thermal, hold times). Made after integration of vessels, vacuum equipement, coolers, thermal shields etc.
- Thermal characterisation: cold heads, heaters, pressure & T-sensors. Transients, gradients. Pumping, Cool-down and warm-up operations, safe modes.
- Early check of Micro-vibration effects.
- Early check/control of contamination (cleaning, bake-out).

The Cryostat-AIT includes pumping, LN, cooler and heater operations in cool-down and warm-up procedures and camera operating modes . Thermal performance testing may be at this stage, i.e. without the other sub-systems present, and thermal aspects then fully tested later.

Other aspects of cryostat performance such as camera handling, warm electronics accommodation, services interface to cable wrap, may also be covered in this phase for early verification or in later AIT phases. The cryostat articulation function (roll & elevation) should be tested at this stage as it is needed in Camera AIT at step AIT-2.

6.2 Handling equipment AIT.

This is closely related to cryostat AIT, and its basic tests will go hand-in-hand with the cryostat-AIT because the cryostat is likely to be built & tested (e.g. load cases) on the handling equipment.

6.3 Cryo- Window AIT

The window cell AIT plan is given in AD21.

The real window may not arrive at the camera until the all-up testing phase.

The '*dummy-window'* is a full-size glass window for verification of cell design. It is not reliable enough to be used in the camera-level AIT activities when the high-value items are present.

For the majority of the camera-level AIT a smaller, '*AIT-window'* is used. This is intended to be a re-use of the dummy lens glass, and it must be qualified in terms of its vacuum safety/reliability. The configurations used to achieve the required optical aperture with this window are given in the AIT procedures document AD04.

Tests on the *real window* at unit-level include:

- Window refractive index and dimensions (thickness & wedge error), made during manufacture.
- Interferometry measurements of WFE before mounting, made by the optics manufacturer
- Inspection of the window surface to verify the surface flaws requirement (needed to ensure vacuum strength), made by manufacturer. No proof test of pressure strength is planned.
- Metrology of the window in its cell, required to ensure correct centring, tilt & axial position of the window to the camera.

6.4 Cryo- Baffle AIT

The cryo-baffle AIT is described in AD22.

Tests on the baffle at unit-level include:

- Metrology/inspection to verify aperture sizes and co-alignments, and positioning relative to mechanical mounting interface (in warm state). Clearances of the baffle vane edges from the used beam must be tested in the final configuration in the camera. Sufficient clearance is used in the tolerancing of the design to make this issue non-critical.
- Compliance of black coatings (probably by witness sample), in terms of spectral response & contamination control.

6.5 Detectors & FPA-AIT.

The FPA-AIT activity involves the AIT of the FPA as an assembly, for delivery to the camera, as well as some test activities within the camera. The former task is described in the FPA AIT Plan in AD23 and the latter tasks are described in this document. The 'delivery' of the FPA to the camera occurs twice; firstly with EG detectors and later in final configuration with SG detectors. The following is intended to be a summary of the FPA-AIT plan.

Each detector is tested at Raytheon before delivery. It is then tested more extensively at ATC, with a test IRACE system, and using a test cryostat. The detector test cryo-stat includes a window to allow optical testing, and is relatively small such that it can accommodate only 1 detector at a time (RD01).

The data from detector-level testing is used in the design of the FPA full IRACE system.

The AIT of the FPA as a system requires cold testing, and for this the camera cryostat has to be used. In addition the detector array is not filled in a single operation but is built-up in stages as the detectors are delivered. These aspects mean that much of the FPA AIT has to be entwined with the camera AIT, and these parts are included in this plan. In particular this is for the test requirements of:

- Detector array performance in the cold state & with full IRACE.
- EMC testing in the cold state.

Also optical tests of the FPA:

- The co-planarity requirement between the detectors, including distortions of the mounting plate from warm to cold state;
- The tilt, decentre and axial (focus) displacement upon cooling of the detector relative to the FPA mechanical interface. This is required for optimum initial setting of the FPA at the start of the cryostat-level alignment phase (alignment plan AD6).

Other tests to be done in FPA-AIT are:

- repeats of earlier detector level tests as health-check.
- Operation of engineering grade (EG) detectors with IRACE system, for early tests of EMC issues in the representative camera configuration.

6.6 *Filter-Wheel*

Determination of filter focus shift for each filter set.
This may be done warm, with verification of cold values by analysis of manufacturer's measured refractive indices, TBC.

Interferometry for verifying correct WFE of each filter (stress-free mounting). To be repeated after non-operational cold cycle, done at filter tray level, for one set of filters only.

Motor operation, stability, repeatability, resonances (cold). Flexure (warm).

This may use an inertial dummy to allow a small existing cryostat to be used, or if schedule permits it may use the real wheel and be done in camera AIT.

6.7 *Lens assembly.*

Use of a dummy lens blank & cell for proof testing of lens mounting method.

For the delivered lens assembly: Measurement of lenses refractive indices, ROC's, thickness, wedge angles. Warm setting of separations, tilts & de-centres to compensate errors.

Cold test of the lens mount positions (lens seats) in axial, decentre and tilt, on dummy cell only. Analysis of lenses final positions with respect to the lens assembly external alignment reference co-ordinate system. Analysis of this data is required to determine the required internal alignment compensations and the assembly's WFE contribution & the optimum position when it is subsequently integrated to the camera.

6.8 WFS sensors

6.8.1 Optical characterisation.

A measurement of the best-plane position for each LOCS/AG sensor is required at unit level, with respect to the unit's external alignment references. This is required to enable correct focus positioning (axial & de-centre in cryostat) upon integration at camera level. Determination of the sensor FOV position (optimum line of sight of FOV centre pixel) is also required with respect to the external reference system..

In addition each unit is required to be swap-able with another without re-alignment. This requires that the units are identical (within tolerances) in the relation of their optical alignment to their physical mounting interface. This aspect must then be set by adjustment of each unit before delivery, probably using a common test jig.

The background to these requirements and tolerances involved are given in the alignment plan AD6.

6.8.2 Performance testing.

The verification of LOCS performances is to be made at unit level, using suitable test beams. (with aberration functionality). End-to-end testing (from sensors to image analysis LCU & software processing) to verify accuracy of Zernike determination.

Tests for AG are functional testing (including centroiding), but not requiring full test of accuracy (milli-arcsecond test source is not required).

HOCS.
Because in this case the optical hardware is part of the Filter Wheel and FPA sub-systems, it is tested at camera system level. This requires a representative and well-characterised F/3 test source, as does the CIQ measurement. It therefore has some synergy with the CIQ testing and it made in the same phase, as described later.

Tests applicable to the all sub-systems

- Contamination-control, by witness samples.
  - (Total budget ~ surface class 500 on optics, from stray-light analysis).
- Cold cycle (non-operational range), including thermometry data (FPA & filter wheel at camera-level)
- Characterisation of optical properties wrt physical co-ord system, by reference marks compatible with camera AIT.
- Mass properties.

7 Requirements on camera-level AIT

Having described the requirements on sub-system or 'unit-level' AIT tasks, the requirements on camera or 'system-level' AIT are summarised in this section. Some of these are requirement directly from the verification plan of AD08, while others are derived requirements (for example camera internal optical alignments).

7.1 Camera functional & thermal performances.

These tests are required in cold runs where all of the relevant sub-systems are present or else adequately represented by dummy units. The aims are:

1. Camera software & control systems functionality.
2. provide thermometry data which is then used to correlate the thermal model.
3. Functional tests of the filter wheel mechanism.
4. Functional & electrical tests of detector systems, including EMC verification for FPA, Sensors & Cryostat in final configuration.

7.2 Optical alignments.

Optical measurements & tests occur at various stages of the camera AIT. The measurement data needed for optical characterisation and sub-system alignments are built-up and iterated over the several cold-cycles of camera AIT (cycles AIT-1, -2, -3 and -4).

The logical sequence of alignment measurements and tests required during assembly of the camera optical sub-systems, is described in the Alignment Plan AD06. In summary

1. Alignment measurements: focus, tilt and de-centres are needed in:
   a. Setting up of camera reference axes (FPA axis to cass rotator interface).
   b. Co-alignments of LOCS/AG & FW to FPA.
   c. Cryo-stat mounting points, measurement of their alignments & flexures.
   d. Lens barrel alignment (to Cass rotator)
   e. Baffle clearances (de-centre).
   f. Window position.

The above alignment information is 1st made in the cold state on the cryostat's sub-system. mounting points. At the same time similar cold alignments information is measured during sub-systems AIT. These data are combined to determine optimum position for the sub-system ahead of its integration to the camera, and the required adjustments (e.g. shims) are implemented on first integration. Although some further fine iteration may then still be required, the aim of this approach is to minimise the number of camera cold runs required to reach final alignment. Alignment marks are used for initial alignment but in final configuration the measurements are through the actual sub-system optical paths where possible (making use of detector images).

7.3 Opto-mechanical performances (thermal & flexure).

These require measurement of key optical alignments under the influence of thermal and gravity-vector effects. The key tests are:

a) FPA co-planarity, in operational cold state.
b) Key alignments (sub-system motions wrt camera interfaces), in de-centre, tilt and focus, at different camera roll/elevation positions.

7.4 Camera Image Quality.

After final optimisation of optics settings, and integration of all cold & warm electronics, the end-to-end image quality is to be measured, using a point source and images read out from the detectors. The tests are made at operational T and are:

a. Focus check of all optical sub-systems.
b. CIQ on-axis, and at edge-of-field. At representative wavelength (~1 to 2um).

The characterisation may have to have some limitations in scope:

- The point-spread function may not be obtained in great detail because the focused spot is confined to a few pixels, while scanning a test source in steps << 1 pixel is possible only randomly, using e.g. mechanical pointing drift in the test beam set-up.
- The set-up and alignment of the test beam optics is not trivial at this f-number, and it must be close to diffraction limited and characterised in order to reach the test accuracy required for CIQ verification.
- For the edge-of-field test the test beam might not be able to fully replicate the aberrations of the VISTA telescope, so the accuracy of the test may be limited. Clearly the aberrations should be made as representative as possible, and they may be characterised by using the LOCS/AG sensor. They could thus in principle be 'calibrated out' but this approach introduces its own error effects.

There is also the possibility to make double-pass interferograms of the camera optics (using a return sphere temporarilty mounted in the filter wheel), and this would be particularly useful for providing information on higher-order WFE effects in the lenses. However it is expected that the chromatic effect between the interferometer wavelength (633nm) and the VISTA design band mayl make such a test of limited usefulness.

7.5 WFS Sensors functional testing.

The AG , LOWFS and HOWFS performances are to be verified at sub-system level (AD08). Some functional checks, such as re-checking performance at limited accuracy & range, should be possible at camera-level. These tests will use the same test beam as for CIQ, and so have some of the same limitations. The ability to measure aberrations could also give some benefit to test beam and CIQ characterisation.

7.6 EMC tests.

The EMC requirements are on ‘internal’ and ‘external’ effects (AD08).

7.6.1 Internal

The internal effects are those concerning the operation of the camera as a system, which could be compromised by EMC issues between sub-systems. The requirement is to avoid such effects by design, best practise and following ESO guidelines (Electrical system design AD05). In AIT the requirement is to verify the compatibility by operating the critical sub-systems together in the camera at the earliest opportunity. Specifically:

- Full IRACE operation.
- Operation of LOCS/AG and VIRGO’s together (including any synchronisation functions).
- Filter wheel operation.
- Full functional testing of all operations in the final all-up configuration

7.6.2 External

The external EMC effects relate to the possible interactions between the camera and its environment, related to camera emissions and susceptibility. Although the specification calls for full demonstration of compliance to an EMC standard, due to the expense of the large amount of analysis and testing that would be required, a shared risk approach is to be adopted. This involves in the 1st instance analysis of the key risk areas in collaboration with the telescope and enclosure workpackages, followed by specific tests of those areas if the analysis shows they are critical. Example areas could be:.

- Camera susceptibility to dome modem.
- Camera emissions verified on-telescope, i.e. during commissioning.

7.7 All-up functions testing.

In addition to the preceding camera functional testing (e.g in cryostat AIT) these are functions tests to be made on the all-up system (the final phase of camera-AIT) to prove the end-to-end operations, including control and software functions.

7.7.1 Handling and mounting repeatability.

This refers to the handling operations on the all-up camera, as required at Paranal in the prep lab and in integration to the telescope. The understanding is that all such operations should be rehearsed, with camera in operational state, to verify the procedures during AIT. This is to include mounting and de-mounting to a mock-up of the cass rotator flange, to demonstrate the performance in repeatability of camera alignment (this is part of the camera CIQ effect).

7.7.2 Other all-up functional tests

- Camera operating modes with deliverable software.
- Mass and balance properties.
- Stray-light verification
- Maintenance operations (TBC).

8 AIT PLAN.

This section gives the AIT plan devised to meet the requirements summarised above within the constraints of schedule and budget. After giving the plan in this section, in the next section its compliance with the requirements will be summarised in terms of a compliance matrix of the proposed tests.

As well as the text description given here, task lists are given in schedule form (MS Project file) . For the Cryostat AIT and other sub-systems AIT this is given in the overall Project Plan. For the camera-AIT items of AIT-1, -2, -3 ,-4 there is an AIT MS project plan on Sharepoint (RD02). For the main critical alignments and tests, the procedures are given in RD04.

8.1 Cryostat AIT.

This is described in detail in the Cryostat AIT Plan of AD20 and the description given in this section is a summary of main activities.

Items to be tested are the cryostat integrity & functioning as given in the above requirements section.

The starting points are the vacuum and LN2 vessels, which will have been vacuum and safety tested to BS standards by the manufacturers. It is likely that for the cryostat this will include handling equipment AIT since this equipment is needed for all cryostat vessel operations.

8.1.1 Configuration.

The initial tests will involve only the lower & mid sections of the cryostat (in which case a blank plate replaces the cryostat tube). Subsequently the cryostat tube will be added & the blank plate may be re-used in place of the window or the dummy window.

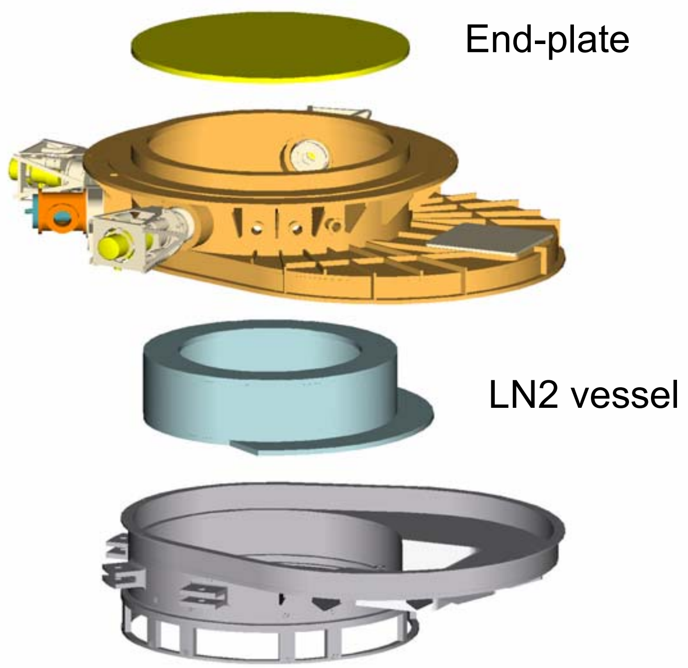


Figure 8-1 Configuration for Cryostat-AIT

The LN vessel will be integrated, along with the shields, the vacuum equipment, coolers, and associated sensing and control hardware.

For thermal tests several of the key optical sub-systems may be added. This will only be done after the integrity & contamination aspects of the cryostat are proven. Dummies will be used in the place of the high risk or long-lead time items, in particular detectors , sensors & window.

The following plan for Camera AIT involves 4 cold-cycles in different configurations, termed AIT-1, AIT-2, AIT-3 and AIT-4. As well as the text description given here there is a task list given in schedule form (MS Project file) on Sharepoint (RD02).

8.2 AIT-1 : Early EMC and initial optical measurements.

8.2.1 Configuration

- For early EMC testing: WFS Sensors & FPA sub-systems are present.
- FPA= 2 EG's, 2 MUX's, 12 dummies (6 optical).
    - Full IRACE, driving various configurations of detection

FW = Real wheel or a dummy plate, with 4x4 apertures in place over FPA, to achieve a representative environment for radiative EMC.

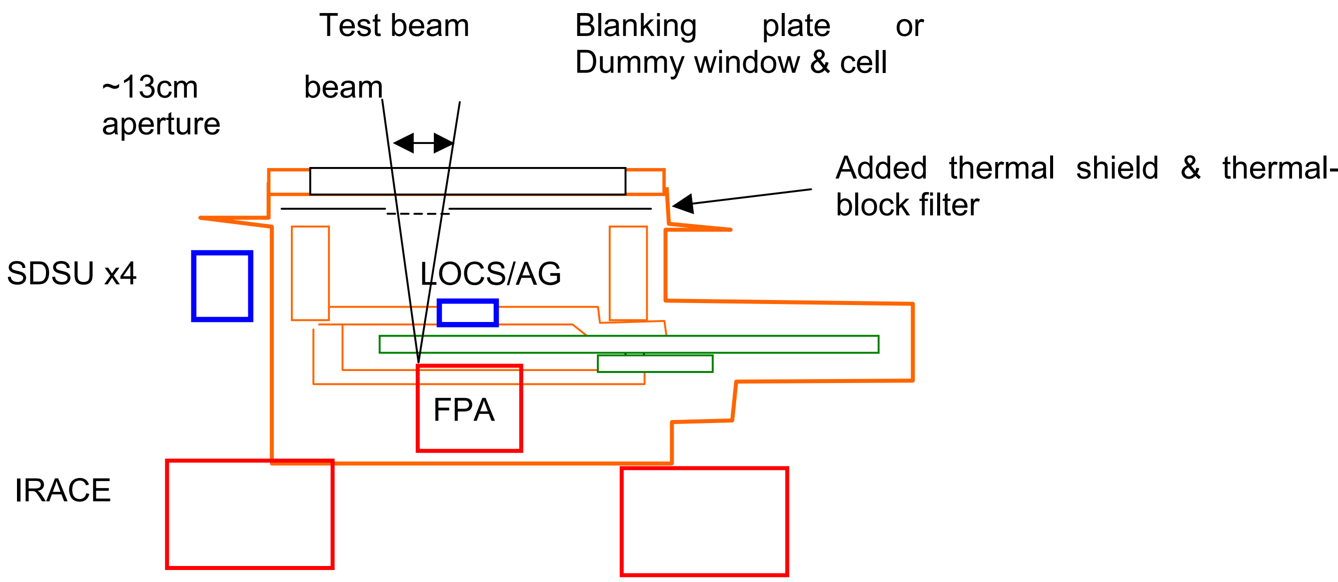


Figure 8-2 Configuration for AIT-1. Detailed drawing is given in AD04.

8.2.2 FPA sub-system testing

This is detailed in AD23 and only a summary is given here. Individual array detectors undergo functional testing at unit-level using the dedicated cryo-stat at ATC, before integration to the FPA (part of Focal plane work package, WBS item 6.6). The 16 SG detectors arrive gradually & may be integrated to the FPA in several batches.

For this reason there is a design goal to allow integration of detectors with minimum dis-assembly of the cryostat or optical bench assembly. The FPA removable for this purpose as well as for minimising risk to detectors in certain operations. The handling issues for detectors may lead to use of a spare detector mounting plate (TBD).

In the current plan just two cycles of FPA AIT are assumed. The first occurs here in AIT-1, and involves an FPA configuration with two EG's, two MUX's and up to 12 dummy detectors (TBD). The 2nd occurs in AIT-3 and involves all 16 SG detectors.

The FPA tests in AIT-1 are the first cold tests of detectors with the full IRACE system. There are a minimum of 4 operational devices, but by placing these not all in the same FPA row, the operation will include the master & slave IRACE aspects.

8.2.3 EMC

The main aspect of EMC to be tested here is the operation of the WFS CCD detector system alongside the IR Science detectors. Some VIRGO detectors are already in the camera at this stage for FPA testing (previous section) and the LOCS/AG units are brought to the camera specially for this EMC test before being removed again to complete their AIT.

8.2.4 Optical measurements

8.2.4.1 FPA Co-planarity.

The co-planarity is set-up in manufacture by metrology and by fine machining of the bump mounts on the detectors and the mounting plate. It is verified in the warm state during detectors integration in the FPA AIT activity. The resulting co-planarity of the detectors must also be verified in the cold state, and the 1st opportunity is in AIT-1. Since not all of the detectors are present dummy detectors are used.

The test method in the cold cryostat-level case is to use optical sensing of the detector front surfaces, both the fiducial marks (for focus and de-centre) and reflection (for tilts) (alignment plan AD6).

Because the SG detectors are not present at this stage, this is not a final acceptance test. Rather its purpose is to confirm that (a) there are no effects in the mounting plate concept that cause non-compliance (b) that the test procedure is optimum for the later acceptance test.

The determination of overall position of the FPA's optimum focal plane is made as part of the camera-level optical alignments (next section).

8.2.4.2 Optical alignments.

The required measurements in AIT-1 are for the cold locations of key items. The measurement points are mostly at the mount locations are for sub-systems to be later integrated in the cryostat. They are made firstly in the warm state, and then re-measured in the cold state. They are needed at this stage to allow corrections to be made in time for later cold-runs when the units must be set as close as possible to final configuration.

The measurements are in initial or as-built alignment of:

- Co-ordinate axes set-up (cass rotator references)

- FPA to cass rotator.
- Sensors mounts to FPA.
- barrel mount to cass rotator.
- FW clearances to detectors (if FW is present)

The measurements are in Focus, de-centre and tilt, and the required accuracy requires a focused test beam of numerical aperture ~F/3 . (Alignment plan).

The measured data is then used along with equivalent unit-level metrology data to determine the correct shimming for each item to its final optimum position. Because the Cass rotator is the principal reference to which the other optics are aligned, its alignments do not enter into the error effect on image quality.

8.2.4.3 Optical test configuration: tilt & de-centre.

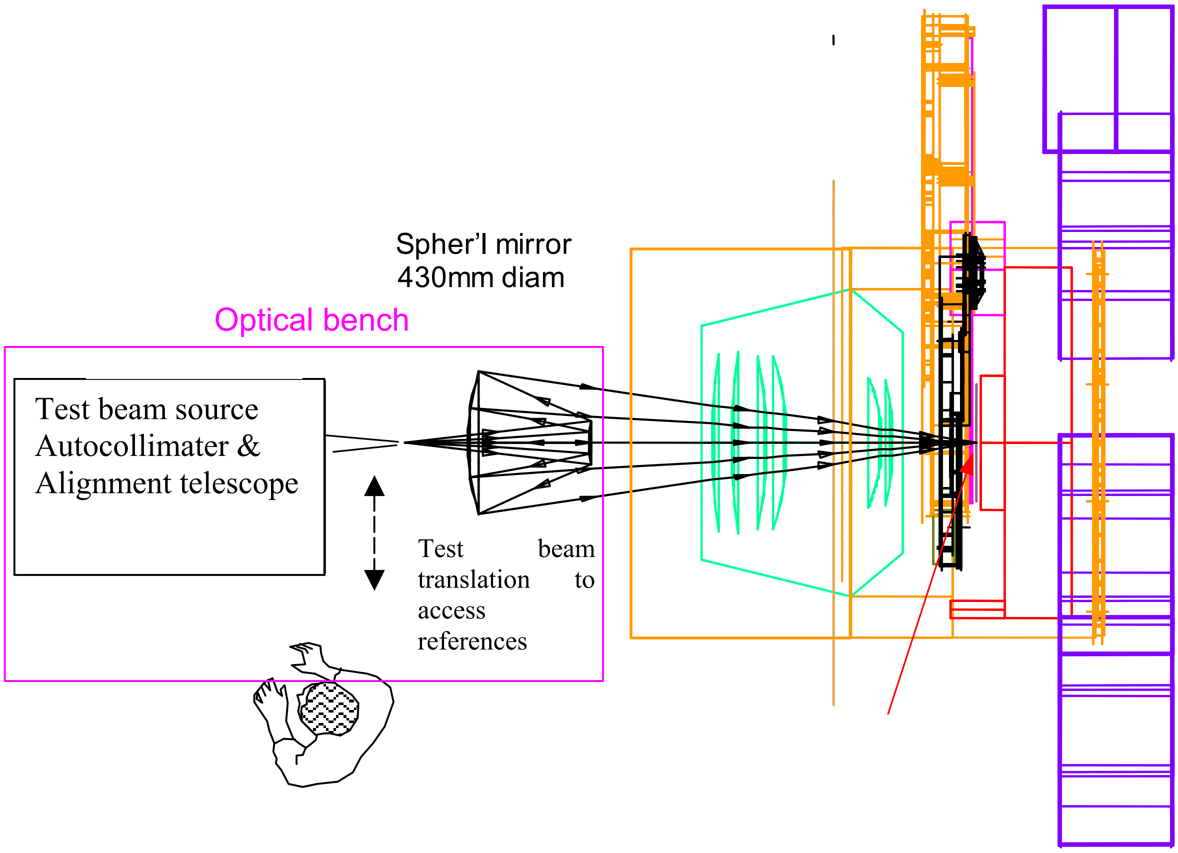
The tests use the camera in its horizontal position because the optical test gear & procedures are simpler. The test set-up is shown in the figure 8-3, and is defined in more detail in the alignment plan AD06 and the AIT procedures AD04. The 2-mirror test source optical design is given in RD03.

Using an alignment telescope (AT) viewing into the camera, the alignments of various parts of the system are sensed as follows:

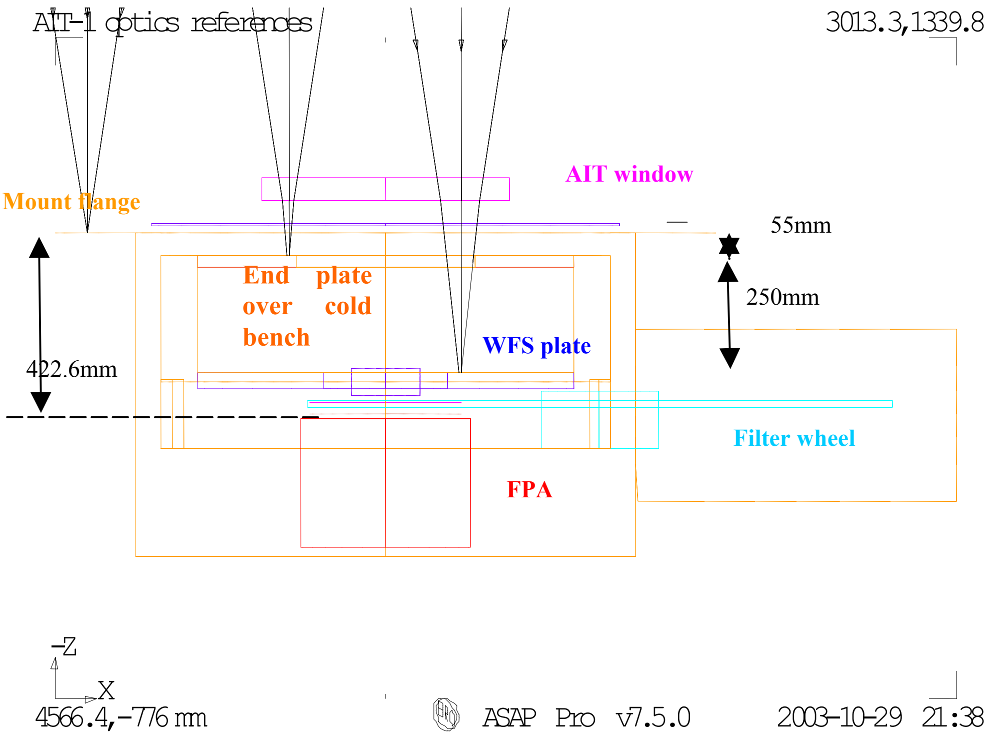
- Decentre: Viewing of a reflective cross-hairs mark located on the item. This has accuracy which varies with the distance of the target. Viewing may need to be via the 2-mirror test source to obtain the required measurement sensitivity.

- Tilt: View of beam reflected from plane mirror on the item. This mirror can be part of the same cross-hairs target as used in de-centre tests.

By placing such references on relevant items and locations, and traversing the test beam between them, the required alignments and separations can be measured in all degrees of freedom.


Spher'l mirror
430mm diam
Optical bench
Test beam source
Autocollimater &
Alignment telescope
Test beam translation to access references

(a)


AIT-1 optics references
3013.3,1339.8
AIT window
Mount flange
55mm
End plate over cold bench
250mm
WFS plate
422.6mm
Filter wheel
FPA
-Z
X
4566.4,-776 mm
ASAP Pro v7.5.0
2003-10-29 21:38

(b)

Figure 8-3 Test configuration, focus tilt & de-centre. (a) general arrangement, plan view, (b) beam access positions of references (from AD04).

1. This is the best orientation for assembly, particularly if the baffle tube is integrated in one piece, and because it provides access to both ends of the camera.

The lens assembly is not included because a direct optical path to the FPA is needed (for the FPA tests of section. For thermal & flexure reasons a dummy lens assembly is needed. This should have representative, mass, balance & thermal transmission. It may be implemented as an aperture with glass plate, possibly re-using the dummy lens unit (TBC). It would have to be flat & sufficiently parallel-sided for the angular measurement needs to be unaffected.

8.2.4.4 Optical test configuration; Focus & co-planarity.

For sufficiently accurate focus testing of the above, the numerical aperture provided by an AT is in some cases insufficient because the working distance is large.

Also for the later CIQ tests a point source with large NA approaching that of VISTA is needed, and it makes sense to try to use this source also for focus sensing at this earlier stage.

This test optics uses point source + two mirrors, (aspheric M1, large sphere M2), optical design given in RD03. It is also used later, for CIQ testing. In order to keep the test optics to a manageable size, the working distance is minimized to ~ 1 m , by using a 'short' cryostat configuration in AIT-1. This requires its own thermal design to ensure that the temperatures of units are sufficiently representative. The configuration for focus testing is as per that of figure 8-3 above, but with the beam position including illumination of the FPA. The details of this are given in the AIT procedures AD04.

8.3 AIT-2 Cryo-stat & FPA alignment stability.

The cryostat mountings must be adequately stiff and stable with respect to warm/cold state and flexure. The main aim of this test phase is to verify the flexure performance, i.e. the changes in alignment with instrument orientation.

8.3.1 Cryostat configuration

For the purpose of flexure testing the mount points must have the representative loads applied, and ideally these are the sub-system itself. In the case of the lens assembly this is not possible without disturbing the view to the lower sub-systems, hence the representative dummy unit is to be included instead.

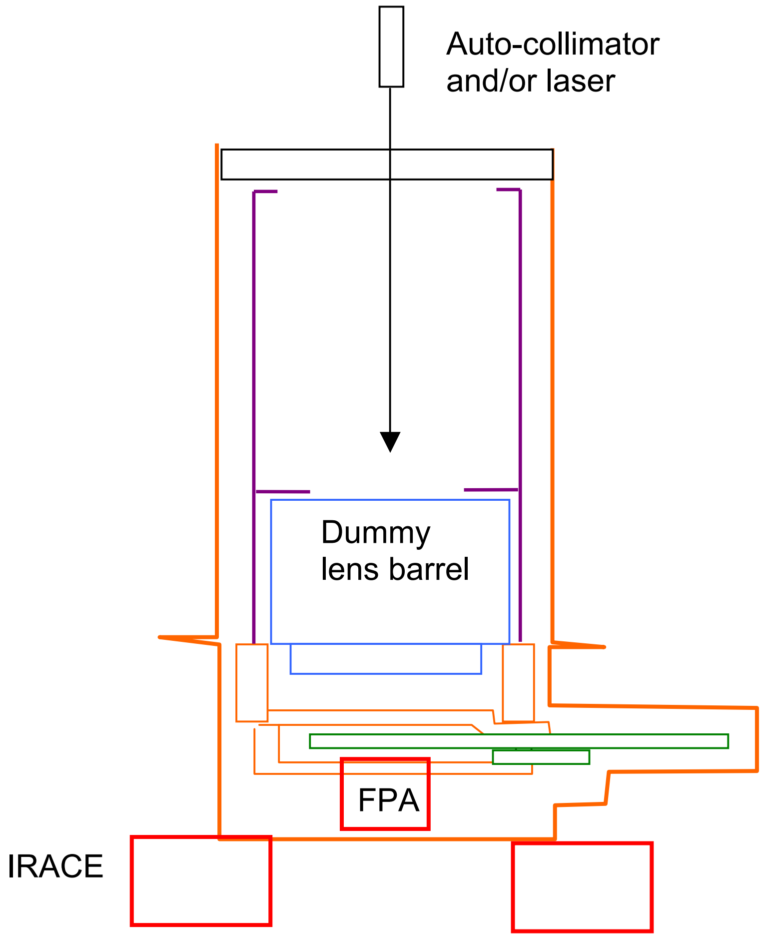


Figure 8-4 Configuration for AIT-2. Detailed drawing showing which references are accessed is given in AIT procedure AD04.

The main measurements used to verify flexure are angular alignment; in addition de-centre is measured. Axial shifts (focus) cannot be measured to high accuracy, but will be derived from the tilt & de-centre measurements using FEA & geometric modelling.

8.3.2 Handling configuration

The flexure testing requires tilt in both axes, as well as roll about the line of sight, and several points in each range for full characterisation of the behaviour on the telescope. Exceptions to some or all of these tests may occur if structural analysis shows the test unnecessary, with significant margin. Examples could occur for flexure between or within units which are small and mounted close together.

The aim is to make flexure tests at this early stage using the AIT stand. This is practical because

a) the optical test gear required is relatively simple (plane mirror + alignment telescope).
b) all alignment measurements are between references on the camera, so the stand absolute stability required is not onerous. However any short-term instabilities (drift, vibration) would have to be small enough to not disrupt the tests.
c) The AIT stand may in any case required to move the camera between the horizontal and vertical positions, for the purpose of LN2 filling.

8.3.3 Tests

This configuration is the first one that is close to a full camera assembly. The tests are

- Full thermal operation & performances.
- Camera handling trials.
- FW operations, mechanism.
- further system EMC (filter wheel)
- Optical alignments:
    - Cryostat mounts metrology (further iteration from AIT-1).
    - Flexure tests (tilts & de-centres only) using autocollimator, and laser mounted on-camera.
    - Filter positions, clearances.
    - Baffle & alignment.

8.3.4 Optical test set-up

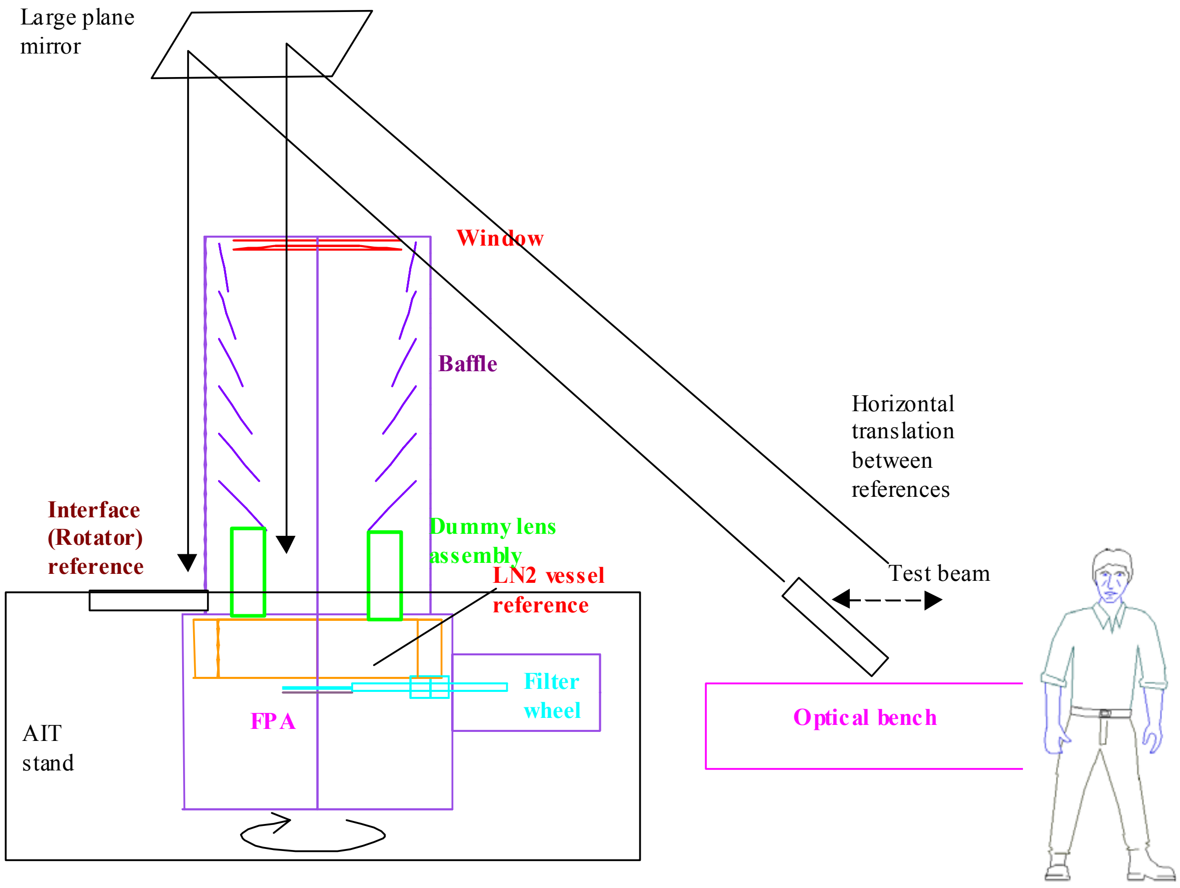


Figure 8-5 AIT-2 optical test configuration, for cryostat mounts, flexures (alignment plan AD06).

This configuration & sensing method is equivalent to that used for alignment measurements, but with the camera re-oriented over a range of gravity vectors (horizontal to vertical). The figure shows the vertical case, but also several intermediate positions are used. To test flexure over elevation in X & in Y, the roll adjustment of the AIT stand is used.

The AIT stand allows the camera to be positioned in a roll angle of 0 or 90 about the horizontal before elevation is applied, but not to be rolled while elevated. It therefore allows the camera to be elevation within its Z-Y and Z-X planes only. Cryostat mounts & sub-systems focus settings.

To avoid working at height in the near-vertical case shown, a large fold mirror is used. This mirror has to have size that is at least half of the cass rotator radius plus margin, but only in one axis (i.e. it is a long mirror). The sighting of references over the distances involved requires suitable test gear, but is no more challenging than the methods used in eg spacecraft optical instrument AIT.

In addition the flexures are sensed in an end-to-end sense using alignment lasers mounted on the window cell top ring, producing spot images read out on the science detectors.

Due to the size and complexity of an F/3 focused beam in the flexures configuration, it is not possible to directly test focus versus flexure. However as an alternative two lasers in a triangulation geometry will be mounted on the camera. This should allow focus changes to be sensed, although at TBD accuracy.

This scheme of optical tests is summarised in the table at the end of this section.

8.3.5 Issues on how representative are the tests for acceptance purposes

The flexure testing in this phase is the basis for acceptance of the flexure behaviour, in particular its impact on the CIQ performance versus elevation.

The limitations of the testing in terms of representing the operating configuration are:

- The CIQ is not measured directly, except in horizontal position. This means that to show compliance a combination of test data & analysis is used. The test data includes the horizontal CIQ's plus the flexure alignment data versus elevation & roll. This data includes tilt, de-centre & focus (via laser triangulation).
- The camera is not in the final configuration. In particular the real lens barrel and window are absent. However the lens barrel is represented by its dummy having the correct mass properties. The AIT-window may also need correct mass properties but is less critical for flexure as it is mounted directly to the cryostat and not via the cold optics.
- Thermal configuration. This is also affected by the dummy units. However the thermal conditions are not expected to have any direct impact on flexures.
- Number of orientations used. The full range of camera orientations is not tested, in order to allow a reasonably simple & compact AIT stand to be used. However the gravity vector is represented along all principal axes, over full angle range, with a reasonable number of angle steps being used.

8.4 AIT-3: Final co-planarity and LOCS/AG focus.

After AIT-2 the finally configured LOCS/AG units become available. They are integrated to the camera, along with an updated FPA (now containing a full set of 16 SG detectors).

The tests needed at this stage are:

- FPA final co-planarity.
- LOCS/AG final alignment.

The details of how these tests are made are given in the AIT procedures AD04.

8.4.1 Configuration.

For the detailed co-planarity and focus tests the F/3 test source is again needed, so the configuration returns to that of AIT-1 (‘short’ configuration, cryostat tube removed)

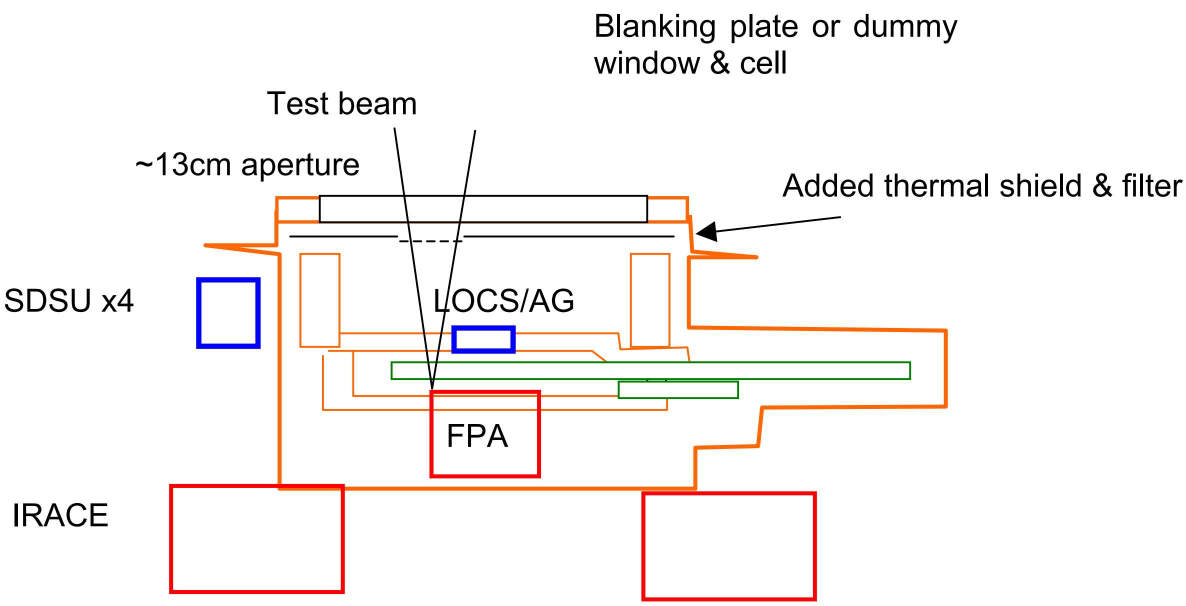


Figure 8-6 Configuration for AIT-3 (Detailed drawings showing actual reference points used are in AD04).

8.4.2 Tests.

- ‘Fuller’ EMC testing.
- Final FPA co-planarity.
    - Method as for AIT-1, now with SG detectors
- LOCS/AG : focus (to ~25um), FOV position setting.

– Requires scanning of source laterally from SG detectors to AG detectors, i.e. over ~ 100mm.
– Requires readout of both SG's and AG detectors.
– Careful use of filters & wavelength to ensure chromatic effects are correctly accounted for.

8.4.3 Issues on how representative are the tests for acceptance purposes

The main issue for representative testing is the thermal environment in the 'short-cryostat' configuration as compared to the operational case.

The goal is that the temperatures of the key items will be as close as possible to operating points. This will be done by dedicated thermal design for this configuration (including shields). Because the CTE effects of materials become less significant at lower temperatures it is anticipated that with this approach the temperature differences of the test from the operational temperatures will be acceptable.

In addition the temperature gradients between the detectors and the LOCS/AG unit must be low enough that the focus tests are valid.

8.5 AIT-4: lens barrel, CIQ and WFS functions.

The main testing in this phase is :

: lens barrel alignment

: On-axis optical image quality.
: edge-of-field image quality
: WFS functions, HOCS performance and LOCS & AG re-checking.

8.5.1 Configuration

The lens barrel is now available, and is added to the camera as shown in the figure below. to accommodate the lens barrel with minimum cryostat length. This is needed to allow the F/3 test source to be used.

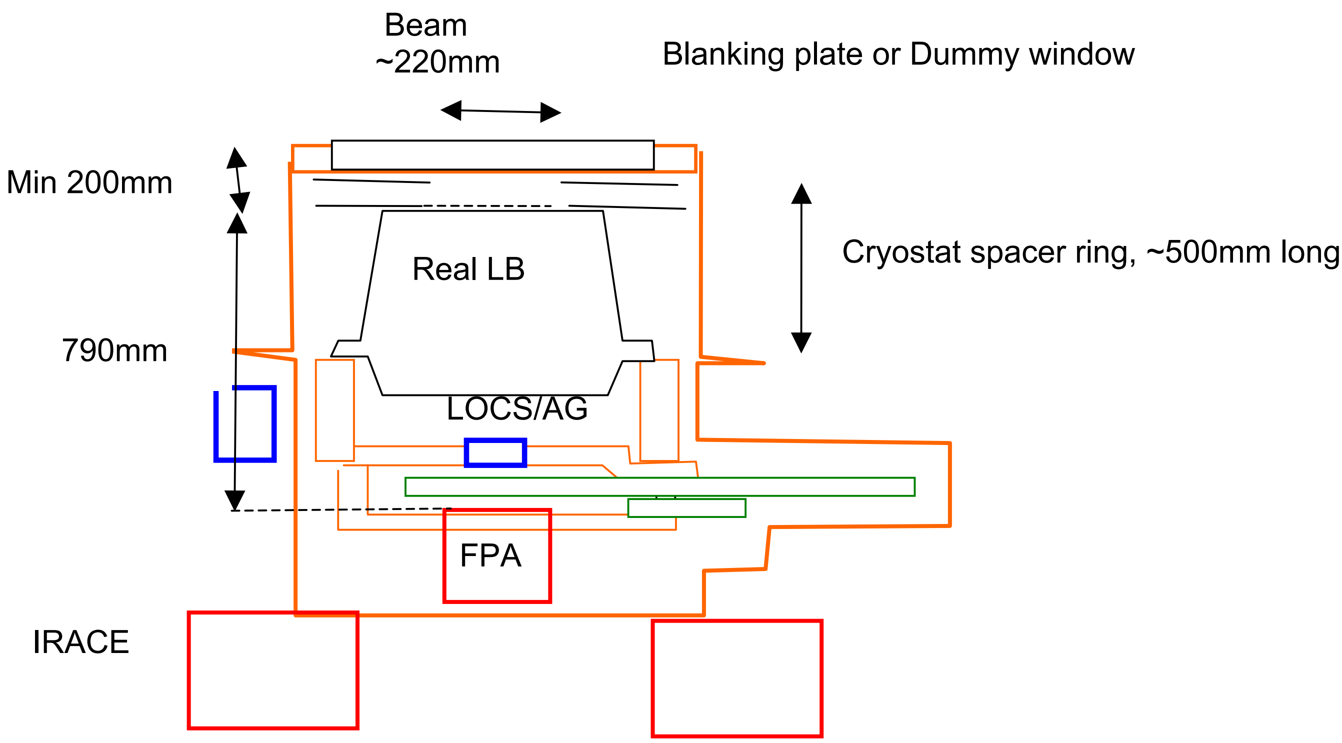


Figure 8-7 Configuration for AIT-4. (Detailed drawings of the optical arrangements used are in AIT Procedures of AD04).

8.5.2 Optical test configuration.

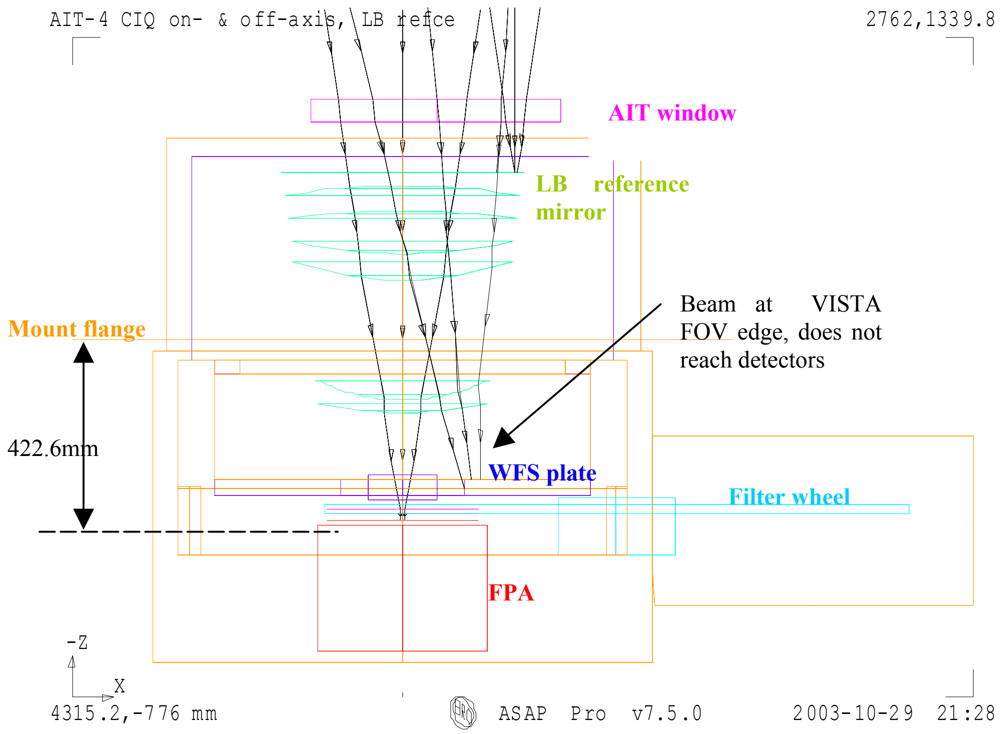


Figure 8-8 CIQ test configuration (from AD04)

Lens barrel alignment is measured relative to the cass rotator, using method and references similar to that used for the mount in earlier tests.

8.5.3 CIQ testing.

The on-axis optical image quality is measured by reading out images from the central SG detectors.

Factors affecting CIQ measurement.
1. Measurement resolution.
The data on the focused spot shape (point spread function) will be limited since the spot is expected to cover just 3 x 3 pixels. It is difficult to scan the test source angle at the sub-pixel level, but as an aim the test source with be moved in steps of ~1/2 pixel size to generate a range of images. It is also difficult to eliminate the effect of test source focus position, so through-focus scans will be needed in addition to angle scans.

2. Representative aberrations.

This requires a change to the test optics in comparison to that used for focus tests. The telescope SA ~10λ must be added, and this is to be by change in separation of the M1, M2 mirrors. The source aberrations need to be independently verified, and this is best done by interferogram (at 633nm), using a return sphere placed at the source focus.

3. Representative wavelength.
A wavelength of ~1um will be used. This has to be in-band to achieve the correct CIQ (chromatic effects), but at the short-wavelength end so that diffraction effects do not dominate the CIQ measured. A double-pass interferogram of the system may also be made (at 633nm) if this is useful, e.g. for comparing with the test source calibration (providing chromatic effects do not make this test invalid).

Off-axis CIQ
This is needed because the on-axis test does not provide enough info on possible optics mis-alignments and other errors. The off-axis CIQ needs to be measured on at least four sides to constrain the characterisation model. It is planned that the off-axis position used is that which accesses:

- the SG detectors on the sides of the array, e.g. near the (x,y) positions (+X, 0), (+Y,0)
- the LOCSAG detectors (0, +Y), (0,-Y) .

The handling equipment allows 4 positions around the FOV to be measured with the same test beam, by rolling the camera about its axis in 90-degree steps (in the horizontal position). The corner SG detectors of the array are not included in CIQ test because that would require the handling stand functionality to include rotation to arbitrary roll angle.

Because the LOCS function test (later) is with the same beam as the CIQ test and there may be some synergy between these tests if the LOCS itself can measure the final beam properties, to some accuracy.

In addition to the above effects, in the off-axis CIQ measurement other factors limit the measurement accuracy:

1. Off-axis aberrations.
It is more difficult to represent the telescope aberrations in this case, requiring a bi-conic mirror in the test optics. The optical design is given in RD03.

It is required to use a source including the J wavelength bands, to test the CIQ . K or H bands are also desirable. For this purpose the point source will be a lamp (high temperature black body) plus pin-hole and filter arrangement, or a 1.06micron laser (suitably attenuated).

AG & LOWFS function test.
Once in the off-axis position, the source can be used for probing the corners of the detector FOV & the AG & LOWFS's, by rotating the camera.

8.5.3.5 CIQ stability.

Flexure.
Just as for the System Test No.1 metrology, the CIQ tests of this section would ideally be repeated with the camera tilted in order to show compliance with flexure requirements (affecting Image quality budget). However the baseline is not to include such a test but to use instead the extensive flexure info on tilts & de-centres + analysis.

Thermal. Ideally the CIQ measurement should be repeated after this cycle to verify the stability with respect to thermal effects. However this test is not planned because:

(a) there is insufficient time available for the extra cold cycle.
(b) There are sufficient cold cycles and measurements of alignments to infer the optical stability of all the key items, so this test is not strictly essential

If opportunity arises for this repeat of some or all of CIQ tests then it will be made.

8.5.4 WFS function tests.

The HOCS tests cannot be made at unit level since the HOCS design uses components on both the filter wheel & FPA. It can be made in a straight-forward way at system level in a similar set-up to the on-axis CIQ. In this configuration only focus, alignment & sensor operation can be tested. The test may require photometry of the point source at some level TBD. The test source has limited scope to create high order aberrations, so the test of the full HOCS including software & Zernike recovery may not be possible. In place of this an equivalent test may be feasible using the LOCS system at unit level, with the appropriate change of de-focus.

8.5.5 Issues on how representative are the tests for acceptance purposes

The main issues here are those relating to the acceptance testing of CIQ. In addition to the above test beam limitations, other issues are:

- Thermal. As in the previous ‘short cryostat’ configuration , sufficiently representative temperatures must be achieved at the key items (all cold units).
- The optics configuration is incomplete. The missing item is the real window. However it should be acceptable to have the window tested separately because:
    - The window is at ambient T, such that its unit-level tests for geometry, refractive index and WFE are valid.
    - The window alignment is not critical, such that it is sufficient to show by later alignment measurements that it meets the tolerance requirements.
    - Remaining ‘missing’ effects are the pressure-distortion of the window (relating to window shape and to birefringence) and its temperature gradients. However both of these are small effects on CIQ and are accurately characterised by the analytical models. The temperature distribution can be measured in a simple separate test using a thermal camera.
- Since the cryo-stat is re-configured after this test phase, it is important that non of the key items are dis-assembled, as this could invalidate the CIQ test. The plane ensures

that the FPA, Lens Barrel and WFS are left in place after AIT-4 until delivery. Any dis-assembly required would have to be done according to the maintenance procedures, as these are compliant with the CIQ budget (Alignment Plan AD06). However demonstration of this maintenance compliance, and of the thermal cycling effect, are not included in the plan.

8.6 All-up test phase.

The final configuration, shown below, is achieved by addition of:

- cryostat upper section.
- Cryo-Baffle.
- real window cell.
- Replacement of the 'test optics' FW tray with deliverable filter tray.

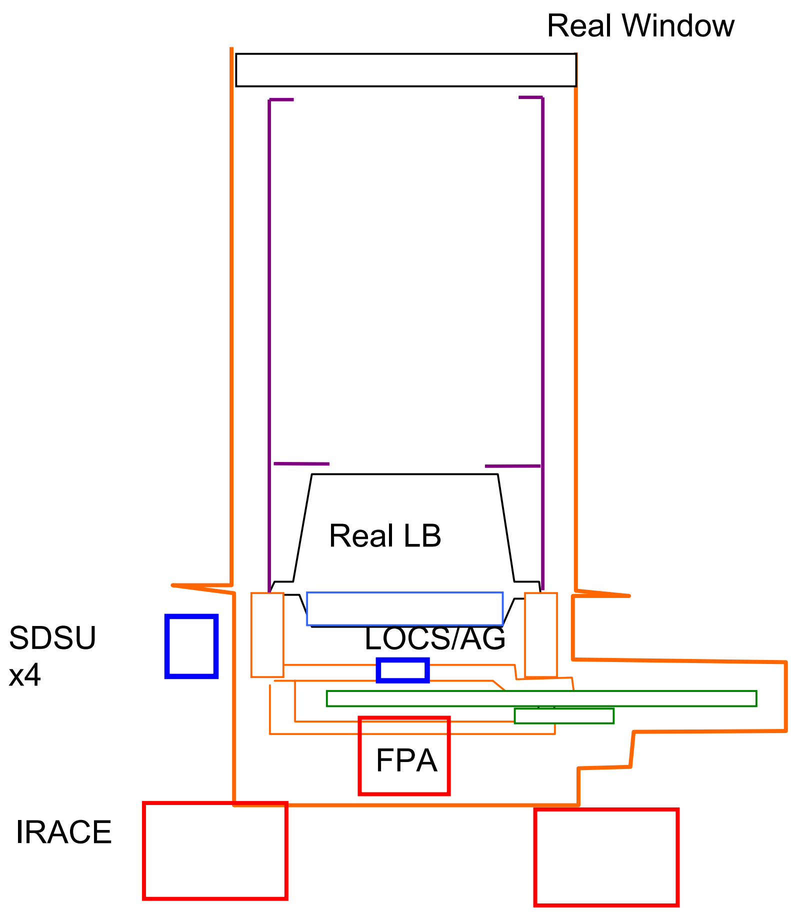


Figure 8-9 Configuration for All-up testing

Tests made are those that remain from the verification table, i.e. those not already covered in earlier AIT phases. These are acceptance tests of:

- Final EMC acceptance tests
- Camera handling.
- Final function testing.
- Camera/telescope mounting repeatability.

8.6.1 EMC testing.

The EMC mitigation plan is in the electrical design AD05.
The main features to be verified at camera-level are:

- Correct functioning of full IRACE system (part of FPA workpackage), and sensors system, in the cryostat environment with nominal operation modes of the other electrical systems all present.
- Correct functioning of any modes implemented in the design to mitigate EMC effects in order to meet the above system-level functions, e.g. synchronisation of readouts, operation of mechanism.

8.6.2 Thermal testing.

At camera level this includes:

Characterisation of operating temperatures, thermal gradients, cool-down rates, via T sensors.
This should be close to the operating T range, or else analysis used to relate the lab (e.g. room-T) environment to the operating ones.

A thermal cycle over the non-operating T range. Using normal cool-down procedure.

8.6.3 Mechanical testing.

This includes:

- Measurement of final mass & balance properties.
- Manufacture of final shim for telescope mounting, according to optical alignment data.
- Verification of the handling procedures for mounting to telescope, using the handling equipment, camera & dummy cass rotator structure (verification of the handling equipment will also be made progressively during the earlier tests, as there is opportunity to use it there & obtain early verification of its operations).This includes the camera mount repeatability test.
- Verification of camera re-build repeatability. The re-build repeatability requirements are included in the alignment plan AD6. The design approach assumes that the focus

testing equipment is not available at Paranal. The re-build repeatability relies on tolerance build of the critical components. It is to be verified by warm tests at the relevant stages of AIT.

8.6.4 Issues on how representative are the tests for acceptance purposes

Stray-light tests.
The all-up stray light test envisaged is a test for unexpected paths. This involves a configuration with the camera open, such that the lower-section end-plate is removed (but not the FPA),a nd possible also the window cell. Each end of the camera is illuminated with a suitable point-like source, which is moved over the all positions in radius. This is done while viewing the other end of the camera to check for unexpected light paths. Possibly an IR source e.g. a grey body may be used and detector read-out (where possible) plus thermal camera viewing is used to check the paths.

EMC end-to-end & 'external'

The end-to-end EMC tests alongside camera functional test operations in full operating modes including software.

The external EMC tests for UK acceptance may involve emissions and susceptibility. As explained in the requirements section the plan is not to demonstrate full compliance to an EMC specification, rather to plan specific tests in critical areas. Where these require large apparatus or have difficulties in achieving sufficiently representative environment, there will be request for postponment until telescope-level testing.

Handling equipment and telescope mounting test.
The AIT lab environment does not fully replicate the VISTA enclosure. In particular:

- the handling route from prep lab to telescope can only be represented in mock-up.
- The dummy telescope cass rotator flange used for the mounting tests is not made to the VISTA working height (~ 3m), but is instead closer to ground level. This should be acceptable providing the working height is chosen as close to that possible with the VISTA the cherry-picker platforms. In addition the working constraints of these platforms will be represented in the tests.

9 Test matrices for IR camera acceptance.

9.1 Optical alignment, build-up of test data.

Camera components	**AIT-1**	**AIT-2**		**AIT-3**		**AIT-4**	
		Warm	Cold	Warm	cold	Warm	cold
Detector co-planarity	Verify mounting plate (detector foci)		Further verify using detector tilts	Integrate all SG's	Final co-planarity (detector foci, tilts)		Re-check tilts
FPA (to cass rotator)	Measure FPA reference to cass rotator	Adjust at mount plate feet	Re-measure tilt, de-centre	Re-adjust if nec'y. Transfer FPA reference to SG's	Re-measure, inc. focus		
LOCS/AG (to FPA)	Basic fit-check. Measure WFS frame ref's	-	-	Set LOCS/AG position using data from both sides	Verify final LOCS/AG alignment		
Lens barrel (to FPA)	Meas LN2 ref's (time permitting	-	Meas LN2 ref's (except focus)	-	Meas LN2 ref's focus	Mount on Shim ring (tilt, focus), using data from both sides. Align in de-centre	Verify cold position. WFE,
Filter wheel (to detectors)	-	Dead-reckoning. Fine adjust at tray.	Verify clearances	-	Verify clearance to SG's	-	Can include in WFE, HOCS tests.

Baffle (to FPA)	-	Dead-reckoning	Verify clearances	-	-	Re-install	Verify final position.
Window	-	Dead reckoning	"	-	-	Re-install	Verify final position

For the main critical alignments the procedures are included in RD04.

9.2 Camera-level acceptance tests

Tests referenced as e.g. FPA-AIT are those which take place at sub-system level. Tests referenced as e.g. FPA test are those postponed from sub-system AIT to be made in this camera-level AIT.

Requirement tech spec section #	**Test/Measurement (from verification matrix, AD08)**	**AIT-1**	**AIT-2**	**AIT-3**	**AIT-4**	**All-up config**	**Ref sub-sys tests**
3.5 interfaces	" mount & mount repeatability					v	
"	End-to-end operations & software.					v	
" and 3.7 mass/balance	mass properties, on handling stand					v	
3.8 EMC	EMC early warning	v					
"	Full EMC (IRACE's & SDSU's)			v	v	v	
" Suscept'y	Probe camera with ESO or modem source					v	
" emissions	Tested at telescope level						
3.9 Isolation	Check each sub-system on integration	v	v	v	v	v	
3.10 Vibration	Early test via optical test equipment, precise test in CIQ	v			v		
3.11 Camera thermal performance	Cryostat thermal, vacuum functions	v	v		v		use of T sensors
3.12 Wavelength & throughput	None. Analysis of sub-system data						sub-sys AIT's
3.13 Elevation	Handling stand		v				
"	Cryost electrical function	v					
3.14 Imaging, CIQ							
" Optical alignments	Set ref. axes (cass rotator interface)		v				
"	Cryost internal mount points & flexures		v				
"	Filter wheel operation & alignment		v				
"	WFS mount –to- FPA cold charact'n	v					

" Sensors	" + WFS final registration to FPA			v			
"	Lens mount focus charact'n		v		v		
"	Baffle alignment		v				
"	Window alignment (warm)		v (dummy)			v	
" Opto-mech performance	FPA mounting plate deformation	v	v				FPA test
"	" + SG Detectors co-planarity			v			FPA test
"	As-built CIQ, near-axis & edge of FOV				v		Lens & FW assy test
"	WFS sensors, accuracy made at sub-system level, function checks				v	v	WFS-AIT
" air-mass >1.3	Cryostat Flexures, above tests, and analysis		v				Cryost-AIT
3.15 Detector alignment	sub-system plus above tests						FPA test
3.18 Stray-light	background level, by above thermal test +analysis						Baffle-AIT (coatings)
	emissivity, by above thermal data, baffle AIT & backgnd meas'ts		v			v	baffle test, flat-field
	ghosting, not tested						
	photon rate, angles <30deg					v	flat-field test
	light leakage: FW sub-system plus light-tightness check				v	v	Filters AIT
3.21 Data handling	SW sub-system acceptance						SW - AIT
3.22 WFS Sensors	Tests covered by sub-system and above CIQ sections						WFS-AIT
3.23 Operation	Camera/telescope handling.					v	HE test
"	End-to-end operations &					v	"
3.26	Turn-around time		v			v	"
3.27	Maintainability	v	v		v	v	"

For the main critical and tests, the procedures are given in RD04 for the camera-level tests, and in the sub-system DES or PRO documents for the sub-system-AIT tests.

10 Requirements flowing from AIT Plan

10.1 Handling equipment

Handling	AIT-1	AIT-2	AIT-3	AIT-4	All-up tests

feature					
Camera config'n	Short-cryostat, electronics part complete	Cryostat full configuration, electronics part complete	Short cryostat, electronics complete	Short cryostat	Full config'n
Camera orientation	Horizontal	Various	As per AIT-1	Horizontal	Horizontal
Height	Bench height with test source	Bench height when horizontal	"	As per AIT-1	Various, on crane
Multiple roll ?	0, 90, 180, 270 degrees	0, 90 degrees	"	"	No
Multiple elevation	None.	0 to 90 degrees, ~ 5 steps	"	None	No

10.2 Software

Sub-system being integrated.	**Cryostat-AIT**	**FPA-AIT**	**AIT-1**	**AIT-2**	**AIT-3**	**AIT-4**	**All-up config'n**
Cryostat sub-system	Cryostat cooler/heater control, Temp, Pressure readout & reporting. Warm-up functions. - Use Inst. LCU, or PC	As at left	As at left	Cryostat functions as at left, plus: Set points on control T's Data logging. Automated 'survival mode' on UPS power	As left		Fully functional camera ICS software. Functional testing. Automated features.
FPA Sub-system	No FPA	Test IRACE. Data display. Quick-look functions	Full IRACE.(driving various detector combos, up to 4)	As at left	Full IRACE, 16 SG detectors	As left	External I/F's tested with TCS 'simulation mode'
WFS Sensors Sub-system		No Sensors	Real TCCD (complete) or Test units Synchronisation	No Sensors	Full Sensors, TCCD, Image analysis.	Image capture, Science & WFS detectors.	No observer support.

			functions. Data display				
Filter wheel sub-system			No filter wheel	Filter wheel full function	Real TCCD's	HOCS testing LOCS,AG, HOCS Image analysis.	
Data Handling.		Data reduction, archiving requirements.(?) Use standard packages.	No Image Analysis LCU Data reduction, still with standard packages.	High level maintenance SW: Request single exposure. Request series of exposures & log instrument parameters, including tilt.			As at left. Maintenance SW, for use in commissioning.
EMC				Further synchronisation tests (including FW)	Full-function EMC characterisation.	Interferometer data processing (separate system).	
Test image requirements				Flexure tests: Quick-look image capture.	WFS alignment: LOCS/AG image capture & analysis.	Data reduction calculating CIQ from WFE & PSF (off-line ?)	

10.2.1 Maintenance & camera handling.

There are functions required for maintenance which may also give requirements on the software system:

10.2.1.6 LOCS/AG maintenance (replacement of unit).

In this operation, it is required to move the Filter Wheel to an arbitrary position, while the Camera is in the warm state and the cryostat is open.
Since the wheel cannot be moved manually, a software function to allow this operation is needed.

10.2.1.7 Disconnection of warm electronics boxes.

This may be needed during mounting to telescope, when some or all of the boxes may need to be removed. The Instrument LCU and Controllers boxes are likely to need disconnecting, and this will affect software requirements.

10.2.1.8 Integration on to telescope.

It is desired to monitor the status of the camera in terms of temperature and pressure, during the transitions between the telescope and the prep lab. This may be done using a support-equipment PC having a network link to the LCU.

10.3 Test source.

10.3.1 Optical requirements

F/3.25 beam, working distance ~1 metre (or ~ 2 metres).
Point source,

- diffraction limited at 2 microns (AIT-1, -3)
- Ability to add ~10 wavelengths of SA to replicate VISTA telescope (AIT-4)

Optical coupling to :

Phase-shifting interferometer.

Alignment telescope. This will be focussed at finite conjugate (min distance, TBC) such that f-number matches test source input.

Arc-lamp for 1 to 2micron wavelength testing (TBC).

The test source optical design is given in RD03.

10.3.2 Mechanical.

Source translated horizontally on table:

300mm travel, to ~20um repeatability (for co-planarity test, reference flat can calibrate mechanism run-out)
able to change height by 150mm (co-planarity test).
To ~20um over 100mm (for LOCS/AG alignment tests).
Fine-adjustment of pointing ~ 0.5 degrees (to accommodated flexures, locate reference mirrors)
Scan over ~1 pixel for PSF – to ½ pixel step size.
Orient in alt & azimuth orientations –not required.

__oOo__