NAOMI WFS Acceptance Tests at the University of Durham **wht-naomi-45**

Document number AOW/GEN/RAH/14.0/06/00 WFS acceptance tests
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The ID numbers are those used in Dr. Andy Longmore's Microsoft Access database (see AJL file: integration_tests.mdb) which summarises the WPD requirements.
Most of the acceptance tests listed in the database have been included in this document; some selection of tests has been performed. The pressures of the schedule may lead to significant reductions. In later versions of this document the author plans to attach priorities to the tests and indicate test sequences for more efficient operation, i.e. tests with similar configurations and requirements should be grouped together. Notes in this draft have partially addressed the need for grouping but a scheme that readily identifies similar tests is needed.

ID	Objective	Requirements	Description of Test	Date & Examiner	Pass/ Fail	Comments
4	Verify that the WFS will operate with atmospheric coherence lengths > 8 cm at 0.55 ? m.	?? WFS ?? OMC ?? Engineering level GUI ?? Liquid crystal turbulence simulator	1. Set up WFS to view point source through turbulence simulator with DM flattened and FSM at midrange. 2. Demonstrate that satisfactory Hartmann spot data can be obtained over required range of turbulence conditions, changing between lenslets 1 and 2 in accordance with turbulence strength.			
7	Verify that the DM segments map onto the WFS subapertures.	?? WFS ?? OMC ?? NCU ?? Engineering level GUI	1. Flatten DM and set the FSM to midrange. Align WFS to on-axis NCU DL point source. 2. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion. 3. Adjust x-y position of the DM as required for the best overall registration of the DM image with the lenslet array. 4. Verify that in near-pupil viewing mode that light does not spill over into other subapertures except as allowed by test ID number 120. Note: Tests ID 7 and 20 should be combined.			
10	Verify that CCDs operate with 8 x8 (6 x 6) and 4 x 4 pixels (unbinned)	?? WFS ?? OMC ?? NCU ?? Engineering level GUI	1. Flatten DM or install dummy DM. Set FSM to midrange. Align WFS to on-axis NCU DL point source. 2. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion. 3. Adjust WFS pickoff to centre Hartmann spots in array. 3. Adjust NCU brightness and WFS integration time to give high photon rate without saturation.			

			4. Operate in required readout modes and show that the data streams can be reconstructed into the appropriate images.			
11	Verify that the CCDs operate in a quad cell mode (2 x 2 binned pixels).	?? WFS ?? OMC ?? NCU ?? Engineering level GUI	1. Flatten DM or install dummy DM. Set FSM to midrange. Align WFS to on-axis NCU DL point source. 2. Set up WFS in quad cell mode with lenslet array 1 and ADC set to zero dispersion. 3. Adjust WFS pickoff to centre Hartmann spots in array. 4. Adjust NCU brightness and WFS integration time to give high photon rate without saturation. 5. Verify that the data stream can be reconstructed into the appropriate image.			
12	Verify that the CCD configuration is changeable without loosing lock.	?? WFS ?? OMC ?? Engineering level GUI ?? Liquid crystal turbulence simulator	1. This test should be performed on completion of test ID 4. 2. With lenslet 1 and 4 x 4 pixels close the DM and FSM loops for simulated r_o TBD (>15 cm suggested). 3. Demonstrate that one can change to quad cell mode and 6 x 6 pixels without loosing lock.			
20	Pickoff must allow acquisition of WFS source	?? WFS ?? Engineering level GUI	1. Acquire WFS calibration source by moving pickoff. 2. Verify that images of source can be centred in CCDs field of view.			
22	Verify that the acquisition accuracy is < 3.4 ?m.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	1. Flatten DM or install dummy DM. Set FSM to midrange. Install NCU FP mask. 2. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion. 3. Acquire and centre in CCD FOV a selection of pinholes from over the field presented by the FP mask. 4. Verfify that acquisition accuracy meets requirements from WFS pickoff readouts and calibration data for FP mask.			
23	Dithering range of 1.7 mm (5 arcsecond) with $\pm$ 3.4 ?m repeatability is required.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	1. Flatten DM or install dummy DM. Set FSM to midrange. Install NCU FP mask. 2. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion. 3. Select pair of pinholes in FP mask with separation			

			closest to 1.7 mm. 4. Establish pickoff positions that centre each pinhole in CCDs' FOV. 5. Dither between these pinholes and determine repeatability from Hartmann spot positions at ends of each dither cycle.			
24	Dithering range of 6 mm (18 arcsecond) with $\pm$ 8.5 ?m repeatability is required.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	This test is similar to the previous test (ID 23) except that the dither range is increased accordingly.			
25	Dithering amplitude accuracy shall be $\pm$ 17 ?m ($\pm$ 0.05 arcsecond) or better.	??	This test should be combined with tests ID 23 and 24. These tests establish repeatability. To establish accuracy one compares the commanded pickoff positions with the actual as determined by the spot positions as seen by the CCDs.			
29	Pickoff z-axis shall provide field curvature compensation.	?? WFS ?? Engineering level GUI	Verified as part of any test involving z-axis motion, e.g. ID 159.			
30	Maximum z-axis speed shall be > 1.9 mm/sec.	?? WFS ?? Engineering level GUI	Measure time for z-axis motion of 19 mm.			
39	WFS must register with OMC with a 3-axis repeatability < 50 ?m.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	1. Install dummy DM with fiducial. Set FSM to midrange. Align WFS to on-axis NCU DL point source. Set NCU to high brightness. 2. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion. 3. Adjust WFS pickoff to centre Hartmann spots in array. Adjust integration time to give go best signal to noise ratio without saturation. 4. Measure spot positions, mean separation, pupil image of fiducial in front of dummy DM. 5. After taking all precautions, lift the WFS using the handling gear provided and carefully replace. 6. Repeat step 4 and calculate replacement accuracy from spot position and pupil changes.			
40	WFS must pivot about f/16.8 focus in both axes.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	This capability is verified as part of the OMC/WFS initial installation and alignment.			
41	Phase-gradient measurement accuracy of 0.018 wave	?? WFS	1. Flatten DM or install dummy DM. Set FSM to midrange. Align WFS to on-axis NCU DL point			

	(?=2.2 ?m) rms required with 1500 photons/subaperture .	?? NCU ?? OMC ?? Engineering level GUI	source. 2. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion. 3. Adjust WFS pickoff to centre Hartmann spots in array. 4. Adjust NCU brightness and WFS integration time to give photon rate. Record spot centroid positions. 5. Tilt FSM angle* 20.8 ?rad (4.3 arcsec) and measure spot centroid positions. Repeat several times and determine the dispersion. (* Mirror surface tilt corresponding to required phase gradient accuracy.)			
42	Phase-gradient measurement accuracy of 0.14 wave (?=2.2 ?m) rms required with 40 photons/subaperture.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	1. Flatten DM or use dummy DM. Set FSM to midrange. Align WFS to on-axis NCU DL point source. 1. Set up WFS in quad cell mode with lenslet array 1 and ADC set to zero dispersion. 2. Adjust WFS pickoff to centre Hartmann spots in array. 3. Adjust NCU brightness and WFS integration time to give photon rate. Record spot centroid positions. 4. Tilt FSM angle TBD and measure spot centroid positions. Repeat several times and determine the dispersion.			
43	Verify phase gradient range is at least ± 1.5 waves/subaperture (?=2.2 ?m) with 4 x 4 pixels for r_o=8 cm and 8 x 8 pixels for r_o >13 cm.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	1. Flatten DM or use dummy DM. Set FSM to midrange. Align WFS to large NCU source which simulates time-averaged source degraded by strong turbulence. 2. Set up WFS in 4 x 4 pixel mode with lenslet array _ and ADC set to zero dispersion. 3. Move WFS pickoff along x-axis until edge of pixel array is reached in each direction. Note that ± 1.5 waves/subaperture corresponds to a pickoff motion of ± 0.41 mm. Record pickoff positions at array edges. 4. Repeat for y-axis. 5. Align WFS pickoff to NCU DL point source and select lenslet 1 and 8 x 8 pixel mode. 6. Repeat steps 3 and 4 for this configuration.			
51	Spot displacements due to	?? WFS	1. Set up WFS in 4 x 4 pixel mode with lenslet array 1			

	aberrations on-axis must be < 20% of pixel size.	?? Engineering level GUI	and ADC set to zero dispersion. 2. Move pickoff to acquire WFS calibration source. 3. Adjust WFS pickoff to obtain best centration of Hartmann spots in array. 4. Adjust WFS integration time to give high photon rate without saturation. 5. Record spot centroid positions and determine displacement from centre of each pixel array.			
54	Transmission shall be >90% over 0.5 to 1.0 ?m spectral range.	?? WFS ?? OMC ?? NCU or suitable bright source at Nasmyth focus ?? ATC photometer	1. A “point” source of sufficient brightness is required at the input to the OMC, i.e. the Nasmyth focus. “Sufficient brightness” is defined as a good signal to noise level with the ATC photometer when its head is placed at the f/16.8 focus, i.e. the WFS input. 2. Measure the signal at the f/16.8 focus with the photometer head. 3. Move the CCD carriage to the rear limit of its travel. 4. Select the WFS doublet in the lenslet wheel. 5. Mount the photometer head to collect all light from the doublet. 6. The ratio of the second reading to the first is a measure of the transmission (excluding relay optics). 7. Perform this operation with different filters (subject to availability) to assess transmission variation with 0.5 to 1.0 ?m spectral region.			Measurement excludes relay optics.
67	Lenslets shall not scatter >2% into adjacent subapertures.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	1. Flatten DM and set FSM to midrange. 2. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion. 3. Align WFS to on-axis NCU point source. 4. In pupil-viewing mode verify correct registration of DM segments to lenslets. 5. Select a subaperture and tilt segments around this subaperture to limit away from subaperture. 6. Measure flux in adjacent subapertures and compare with flux in selected subaperture.			Difficult to distinguish between lenslet scattering and DM mis-registration.
80	Pupil shift and residual dispersion shall be <5% subap. and <0.04 arcsec at	?? WFS ?? NCU ?? OMC	Satisfactory procedure not yet defined.			Difficult to perform a credible test.

	45deg zenith: <8% subap, 0.06 arcsec at 60 deg zenith.	?? Engineering level GUI				
85	Remotely-controlled shutter with EPICS interface is required.	?? WFS ?? Engineering level GUI	Verify remote operation of shutter.			
88	Verify that two electronically switchable readout modes have been provided.	?? WFS ?? Engineering level GUI	Demonstrate synchronized mode switch (by inspection of output data stream?) while observing WFS calibration source.			
90	At 100 kilopixel/sec the readout noise shall be 3 e-/pixel or less.	?? WFS ?? Engineering level GUI	With the WFS shutter closed, set the readout rate, determine the dark field and readout noise level.			
91	At maximum rate, the readout noise shall be 7 e-/pixel or less.	?? WFS ?? Engineering level GUI	Similar to previous test (ID90) but at maximum readout rate.			
103	Reference wavefront tilt accuracy must be a factor of two better than WFS can detect.	?? WFS ?? Engineering level GUI	Confirm by calculation. Compare pickoff resolution to Hartmann spot centroid accuracy as determined in ID 41.			
105	WFS calibration source intensity must be $\geq$ 3 x 10^-8 W/steradian.	?? WFS ?? Engineering level GUI	1. With lenslet 1 and 4 x 4 pixel mode, acquire the calibration source and centre Hartmann spots in CCD FOV. 2. Measure number of photons /subaperture in 5 msec through broadest spectral filter with no ND. Number of photons should exceed 2500.			
107	WFS calibration source intensity must be uniform.	?? WFS ?? Engineering level GUI	1. With lenslet 1 and 4 x 4 pixel mode, acquire the calibration source and centre Hartmann spots in CCD FOV. 2. Switch to the pupil-viewing mode, increasing the integration time if required to obtain sufficient signal. 3. Record the pupil image and assess the uniformity.			
108	WFS calibration source must simulate G0-K0 star.	?? WFS ?? Engineering level GUI	Test required to analyse spectral characteristics.			Difficult to devise and perform suitable test.
111	Verify that WFS transfer curve linearity is <15% (except in quad cell mode).	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	1. Flatten DM or use dummy DM. Align WFS to on-axis NCU DL point source. 2. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion.			

			3. Move WFS pickoff along x-axis in 5 ?m increments until edge of pixel array is reached in each direction. 4. Record WFS mean centroid position for each increment. 5. Plot mean centroid position against pickoff position. 6. Repeat steps 3-5 for y-axis. 7. Determine linearity of transfer curves.			
115	CCD pixel gain calibration shall be accurate to1% rms or better.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	1. Set up NCU to provide uniform extended source. 2. Flatten DM or use dummy DM. Set FSM to midrange. Align WFS to source. 3. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion. 4. Perform pixel gain calibration. 5. Tilt FSM by random amounts to shift position of extended source and repeat pixel gain calibration at each position. (Intent is to smooth out variations in extended source brightness.) 6. Repeat for various integration times, if possible.			Feasibilty depends on sufficient NCU brightness. Difficult to establish 15% accuracy.
116	CCD pixel background offsets shall be determined to within 1 e^- per sensor integration period.	?? WFS ?? Engineering level GUI	1. Close WFS shutter. 2. Measure stability of dark frame counts for various integration times, e.g. 3 – 30 ms, and confirm that the objective is satisfied.			
120	Lenslets shall be aligned in angle to better than 10 arcminutes relative to mapping of the DM segments.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	1. Flatten DM. Align WFS to on-axis NCU DL point source. 2. Set up WFS in 4 x 4 pixel mode with lenslet array 1 and ADC set to zero dispersion. 3. Adjust x-y position of the DM as required for the best overall registration of the DM image with the lenslet array. 4. Select DM segment at edge of WFS subapertures and offset all adjacent segments so that their respective Hartmann spots move out of the WFS field. 5. Determine the light spillover into adjacent subapertures as a result of misregistration (angular or otherwise). 6. Repeat the measurement for three other subapertures so that all four lie at the extremes of a cross. Light spillover into an adjacent subaperture should not			Requirement is achieved by shimming DM as required.

			exceed 0.7 % due to rotation alone.			
121	Lenslet accuracy shall be maintained when lenslets are changed.	?? WFS ?? Engineering level GUI	1. With lenslet 1 and 4 x 4 pixel mode acquire the WFS calibration source. Centre the source image by adjusting the pickoff position as required. 2. Record spot positions. 3. Rotate lenslet wheel and reselect lenslet 1. 4. Re-measure spot positions. 5. Repeat for other lenslets.			
132	WFS shall perform to specification with a temperature change of 1 deg C/hour.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	This test could be a continuation of ID 121 by monitoring the spot position, deviation and size with temperature.			
146	WFS vibration sources must contribute < 0.0035 arcsec rms uncorrectable tip/tilt jitter	?? WFS ?? NCU ?? OMC ?? Engineering level GUI ?? SBIG camera	1. Flatten DM and set FSM to midrange. 2. Install SBIG camera at the optical science port to view DL pinhole in FP mask. 3. Align WFS to suitable pinhole in FP mask without obscuring image of the SBIG camera. 4. Measure PSF width at science port with WFS power sources off. 5. Turn on WFS power sources. Measure PSF width again. Determine change in width.			Extremely difficult to detect.
147	Cleaning procedures for all optical components must be developed and demonstrated.	?? WFS	Cleaning procedures should first be demonstrated on witness samples wherever possible to reduce the risk of damage. An area of particular concern is the WFS pickoff mirror as no spare is available. Advise waiting until cleaning is required.			
159	Combined motion of all carriages in response to pickoff motion shall produce no detectable focus error at WFS.	?? WFS ?? NCU ?? OMC ?? Engineering level GUI	This test could be performed in conjunction with ID 22 by using the reconstructor to determine the focus change at each pinhole position.			
162	Verify proper function of encoder readout and use in any feedback.	?? WFS ?? Engineering level GUI	A separate test is not essential in that other tests should adequately demonstrate the encoder functions. Tests already performed at the ATC indicate satisfactory operation.			
163	Lifting frame and attachments must be provided for the WFS.	?? WFS ?? Lifting equipment	Demonstrated as part of ID 39.			
164	Verify fit of components in	?? WFS	Pack and inspect.			

	shipping containers and adequacy of protection.	?? Shipping containers				
165	Verify fit and functionality of any spares.	?? WFS ?? Engineering level GUI ?? WFS spares	Using full check list of spares, install each and show normal operation of WFS, e.g. using WFs calibration source.			
168	Temperature sensors will be provided to allow correction to unavoidable alignment changes caused by contraction or expansion.	?? WFS ?? Engineering level GUI	Test and monitor temperature sensors over a couple of 24 –hour periods. Confirm that readings are consistent with those from an independent thermometer.			