WFCAM Performance and summary of characteristics

1 WFCAM Sensitivity

The following table shows the K point-source magnitude giving a S/N ratio of 5 for the given area and integration time. Note that 0.2 sq. degree is the area achieved by WFCAM in a single pointing. Numbers are based on the following assumptions:

- flux has been binned in a 2" diameter aperture
- 20% overhead for target acquisition and microstepping
- latest estimates of WFCAM throughput and measurements of detector QE values down to 800 nm
- a Moffat profile has been used for the PSF, scaled to a seeing FWHM of 0.5 arcseconds
- the calculated image degradation due to optics/tolerancing has been convolved with this
- 10 hours observing per night has been assumed
- no allowance has been made for bad weather

	1 hour	**10 hours**	**10 nights**	**1 year**
0.2 sq. degrees	20.4	21.7	22.9	
1 sq. degrees	19.5	20.8	22.0	24.0
10 sq. degrees	18.3	19.5	20.8	22.8
100 sq. degrees		18.3	19.5	21.5

The numbers in the table are for K band only. The following are the conversions from this to limiting magnitudes at other wavelengths.

z’	0.88	K + 2.8
Y	1.02	K + 2.2
J	1.25	K + 1.2
H	1.65	K + 0.5

These improve earlier estimates but are still only approximate. The greatest uncertainties are due to

- the exact shape of the PSF and the encircled energy within the small binning aperture. In practice more sophisticated source extraction and photometry will be used than the single fixed aperture here.
- uncertain values of the sky backgrounds at z’ and Y
- variations which occur on a nightly and seasonal basis in the sky backgrounds. Note that J and H backgrounds can vary strongly due to variable OH emission. K band also contains variations due to OH and due to thermal background which varies strongly with telescope temperature and cleanliness of optical surfaces (emissivity). Typically all backgrounds decrease by a factor of ~2 between the beginning and end of the night.

2 Readout modes

The standard readout mode for the broadband observations is anticipated to be correlated double sampling (CDS) where the array is reset, a first read is done, wait for the exposure time, take a second read. The stored data is the difference between the two reads.

Three other read modes are specified. A multiple NDR mode to give lower read noise for narrowband work. A Read-Reset-Read scheme which reduces the ovserhead for multiple coadded exposures but may have problems. A window readout mode which it is anticipated will only be used for commissioning.

3 Filters

The filters installed on day one will be z', Y, J, H, K, br Gamma, H_2 S1, opaque blank. The blank will be used to make dark exposures.

4 exposure times and saturation

The expected broadband exposure time will be 5 seconds. Longer integrations will be built up by multiple coadditions of these. The maximum frame rate stored to disk is specified as 1 every 10 seconds - it is likely (but not guaranteed) that we will be capable of considerably faster rates than this.

The narrowband exposure times will likely be of order 30 seconds to a few minutes.

With a 5 second exposure the detectors will saturate at magnitudes J=11.5, H=11.5, K=11.1

The minimum exposure time will be approximately 0.65 seconds.

5 overheads

- filter changes will take 20 seconds.
- telescope short-slew and settle time is 5 seconds
- guide star acquisition time is 2 seconds
- exposure efficiency for 5 second exposures is 88% due to readout overheads.

The worst total observing efficiency will be for the LAS where it is estimated to be 66%.

6 Autoguiding and microstepping

A CCD in the centre of the science field provides autoguiding. The CCD is rotated by 45 degrees relative to the IR science detectors. Its position is fixed and so guide stars will be preselected so the system will know where the guide star will fall (X,Y position on CCD) within errors of a few arcseconds. The guide star will initially be located and then the telescope trimmed to move the guide star to the demand position.

Microstepping will be achieved by changing the guide position to a different pixel intersection.

7 Focussing

Regular focussing will be required due primarily to changes in telescope truss length (M1-M2 distance) with temperature and telescope attitude. Some automatic compensation will be included.

Since there is no WF sensor in WFCAM a new focussing algorithm will be implemented, using images taken on either side of focus. The procedure is as follows

- WFCAM focus observation is taken (~ 2minutes)
- focus reduction algorithm returns optimum focus position of M2
- operator enters or confirms this as new best focus

8 Pointing errors

- worst case 3 sigma error in guide star position on guider CCD after slew = 5"
- worst case error after guide star is re-positioned at demand position = 1"

9 PSF shape and encircled energy

WFCAM will operate with tip-tilt correction. This will correct tracking wobble and windshake, as well as some dome seeing possibly. Assuming a Moffat function fit to the resulting (essentially free-seeing) image gives the following probable enclosed energy fractions.

aperture diameter	enclosed energy
fwhm	29%
2*fwhm	62%
4*fwhm	87%
8*fwhm	96%
16*fwhm	99%

The PSF will be wavelength, off-axis angle and telescope attitude dependent. The likely variation will be of order 10-20% in fwhm for typical seeing.

10 Vignetting

There is vignetting variation across the focal plane. This vignetting is wavelength dependent. In the worst case, there is a 5% drop in throughput at the field corner compared to the centre.

11 Optical distortion

The maximum plate scale distortion is 0.4 to 0.5% for Y to K, at the field corner compared to field centre.

12 Focal Plane alignment

- The detectors will be aligned N-S/E-W to an accuracy of 0.3 deg
- The detector spacing will be 94%
- the available minimum overlap between adjacent exposures will be 0.7mm, 39 pixels or 16 arcsec. Microstep sequence must fit within this envelope.

13 Detector characteristics

These are based on analysis of one science detector and one engineering device.

13.1 Bad pixels

The biggest patch of bad pixels contains some 300 pixels in a rectangular patch. There is also a bad column in one quadrant. We have still to reliably determine the real total number of bad pixels, but will be of order 0.2%.

13.2 Persistence

Persistence after a saturated exposure is at a level of approximately 2.10^{-4} (in the next exposure) after 20 seconds.

13.3 Fringing

We have no data on this. Phil Lucas reports fringing at 1% peak-to-trough on a 2 minute exposure at J, flatfielded with a twilight flat, in Flamingos Hawaii-2 data.

13.4 Reset anomaly

There is a reset anomaly which means that a strong gradient remains from top to bottom of each quadrant after a CDS dark exposure. The anomaly appears to be very stable and was removed completely by subtraction of an identical exposure 15 minutes after the first. This suggests the effect should vanish with a sky or dark subtraction in real data.

13.5 signal crosstalk

The Hawaii-2 detectors consist of 4 quadrants, each with 8 channels. The channels consist of 128x1024 pixels. If there is a signal on any given pixel, crosstalk results in a spurious ghost signal at the identical pixel in other channels and quadrants. The level of the crosstalk has been measured at 2.10^{-3} for channels in the same quadrant. We have not made interquadrant measurements but the level should be the same or smaller.

13.6 Scattered light

Straylight analysis predicts no in-focus ghosts. There is however a large extended shoulder-halo around any point source which can be thought of as an extension to the psf. However the level in the halo is very weak at 10^{-5} of the peak source intensity.