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Readnoise and Dark Current in WFC3 Flight CCD Ambient Data

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ABSTRACT

Readnoise and dark current levels of the CCD flight detectors have been measured from data taken during an initial verification test at GSFC of the WFC3 UVIS channel. Even at the relatively warm operating temperature of the test (-74^{o}C), the readnoise and dark current are well within contract-end item (CEI) specifications. The readnoise values are in the range of ~3 electrons, and generally within 15% of the pre-ship values measured at Ball. The dark levels, 0.55 to 0.95 e^{-}/pix/hr, are in good agreement with the pre-ship values. The data also reveal the presence of a light leak in the set up, when the night lights in the test facility were left on. This was remedied by taking additional data later during testing with the night lights off.

Introduction

An abbreviated, preliminary UVIS "mini-ambient" test has been performed at the Goddard Space Flight Center (GSFC) in Dec 2003 - Jan 2004, as a check of the instrument performance; a full ambient test will be run at a later time. During these initial tests, WFC3 was located in the GSFC SSDIF (Space Systems Development and Integration Facility) clean room, with the UVIS detectors cooled to -74^{o}C. In this ISR, we discuss the results obtained from two particular tests; 1) the dark current measurements and 2) the readnoise measurements. The dark and readnoise Science Mission Specification (SMS), VE01S01, was run on 10 Dec, providing 2 biases and 2 darks (1000 and 3600 sec), each

with a gain of 1.5. Two more 3600-second dark current images, with various SSDIF lights out, were taken on 22 January.

Readnoise from overscan

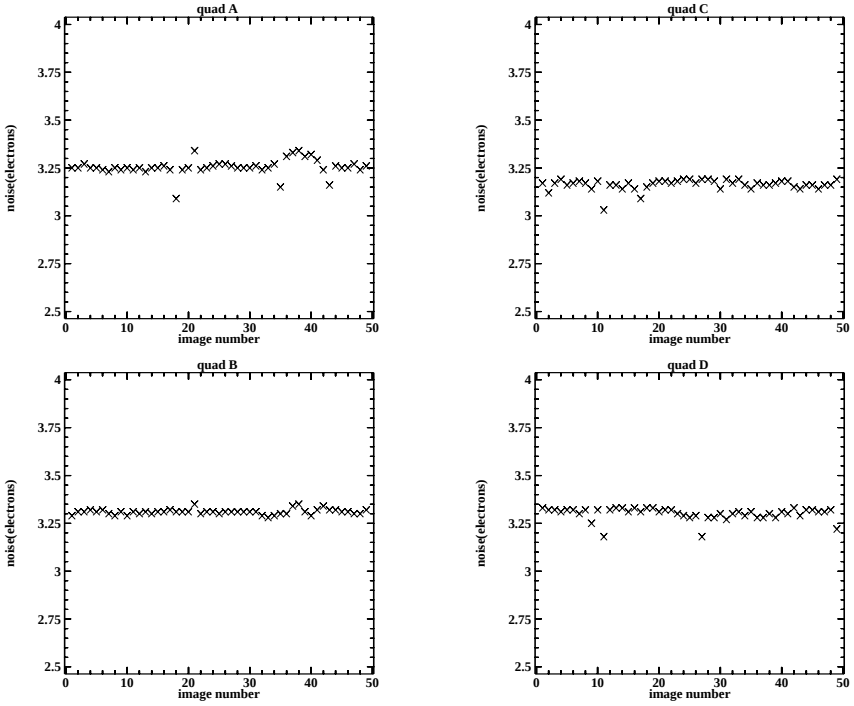
The virtual overscan region for each CCD channel (avoiding the first and last 3 columns and using only rows 100-2000) was examined in both bias and dark datasets. The standard deviation of the overscan region pixels was measured and converted to electrons assuming gain=1.5 e^-/ADU; the results for each image are summarized in Table 1 below. The files listed are, in order, the two darks and two biases associated with the readnoise test (SMS VE01S01), four full-frame bias images taken during other tests, and two additional darks taken with the various SSDIF lights off. For comparison, the readnoise measured on the detectors at DCL (GSFC Detector Characterization Lab) prior to integration into the instrument is also listed.

Readnoise measurements based upon the overscan region do not necessarily have to be limited to dark and bias frames, but can be performed on any image with an overscan. For this reason, readnoise was measured using all images taken during the ambient calibration testing that had a gain of 1.5 e^-/ADU. The individual measurements are plotted in Figure 1 as a function of image number while the average results are listed in the penultimate row in Table 1. Average readnoise values were 3.25, 3.31, 3.16, and 3.30 electrons for amps A,B,C, and D, respectively, with standard deviations of 0.03, 0.01, 0.02, 0.02 electrons. There were no obvious problems with the images with the exception of a handful of readnoise outliers in amps A, C, and D, so those values are included in the means.

Table 1. Readnoise values in electrons per pixel per read, assuming gain=1.5 e^-/ADU.

amp A	amp B	amp C	amp D	file type and name
3.25	3.32	3.17	3.34	bias - iv010101r
3.25	3.29	3.17	3.33	dark (1000s) - iv010102r
3.25	3.30	3.13	3.33	dark (3600s) - iv010104r
3.27	3.32	3.16	3.32	bias - iv010106r
3.24	3.30	3.17	3.32	bias - iv050106r
3.24	3.29	3.15	3.30	bias - iv050101r
3.24	3.33	3.15	3.33	bias - iv050111r
3.27	3.32	3.06	3.33	bias - iva001rzr
3.25	3.30	3.13	3.32	dark (3600s) - iva001txr
3.27	3.30	3.12	3.30	dark (3600s) - iva001tyr
3.25	3.31	3.30	3.30	ave readnoise based on 49 full frame images standard deviations of means: 0.01 to 0.03 e^-
2.45	2.50	2.92	3.01	DCL (-83^{o}C)

Figure 1: Readnoise values for all gain=1.5 e^-/ADU full-frame images taken during the Dec 2003 ambient testing.



Readnoise from bias image differences

The pair of bias images taken as part of the readnoise test (SMS VE01S01) were first overscan-corrected. As a sanity check, two cases were run: the correction was performed with calwf3 (in STSDAS/IRAF), and the STScI IDL pipeline (Hilbert, 2004, in prep.). calwf3 performs an overscan correction based upon simultaneous fits to both the parallel and serial overscans, while the IDL pipeline fits the average overscan column with a linear function and removes it row-by-row from the science area pixels.

For both the calwf3 and IDL pipeline-corrected files, pixels in the science image area were sigma-clipped once (10 sigma), the standard deviation of the remaining good pixels measured, divided by the square root of 2, and converted to electrons assuming a gain of 1.5 e^-/ADU. Results are tabulated in Table 2; values were the same to within 0.005 e^- regardless of the calibration pipeline used. As with the mini-ambient readnoise values in Table 1, these readnoise values are greater than those calculated from the earlier DCL data. This is because of the differing set-ups for the two datasets. The DCL data gives the readnoise resulting from only the detector and a minimum amount of electronics, while the mini-ambient data gives the readnoise from the full instrument.

Table 2. Readnoise measured from the science area in bias image differences

Amp	A	B	C	D
Readnoise (e^-/pix/read)	3.27	3.35	3.19	3.36

Dark level

Individual Images

The four dark current frames were overscan-corrected and bias image corrected, where the bias image was an average of the two overscan-corrected biases from SMS VE01S01. Pixels in the science area, omitting ~10 pixel border around each quadrant in order to avoid any possible edge effects, were sigma-clipped once (sigma=10), and converted to electrons/pix/hour assuming gain=1.5 e^-/ADU. Table 4 lists the dark current rate measured in each quadrant of each dark current image. The first two files in the table, iv010102 and iv010104, were taken early in ambient testing via SMS VE01S01. The last two darks were taken towards the end of testing: the cleanroom lights were off for iva001txr but the nightlights were on, while all lights, including the nightlights, were off for iva001tyr. There was some elevated background visible in the first pair of darks; a full-frame image of the 3600 sec dark, with scattered light, is shown in Figure 2 below. As can be seen in the dark current rates listed in Table 3, the cleanroom nightlights appear to increase the observed signal rate by a factor of 2 to 3, or 1.0 to 1.5 e^-/pix/hour. This may

have implications for WFC3 on-orbit operations, in that WFC3 would need to avoid any possible light contamination from other instruments.

The two darks with low background do not appear to have significantly different dark current levels, though more data (both darks and biases) would help verify the dark current stability. Means of the values from the low-background darks in Table 3 have been listed as the GSFC dark current values in Table 4.

Table 3. Dark current levels in individual images, assuming gain=1.5 e^-/ADU.

channel	ave (e^-/pix/hr)	stddev (e^-/pix/hr)	file
Darks from SMS VE01S01			
A	2.48	0.007	iv010102r_03344214759
A	1.75	0.003	iv010104r_03344225202
B	2.87	0.007	iv010102r_03344214759
B	2.45	0.006	iv010104r_03344225202
C	1.63	0.007	iv010102r_03344214759
C	1.55	0.003	iv010104r_03344225202
D	1.81	0.007	iv010102r_03344214759
D	1.35	0.003	iv010104r_03344225202
Darks with SSDIF lights off and nightlights on (txr) and off (tyr)			
A	0.81	0.003	iva001txr_04022202333
A	0.60	0.003	iva001tyr_04022213303
B	0.94	0.003	iva001txr_04022202333
B	0.51	0.003	iva001tyr_04022213303
C	0.67	0.003	iva001txr_04022202333
C	0.55	0.003	iva001tyr_04022213303
D	0.68	0.003	iva001txr_04022202333
D	0.78	0.007	iva001tyr_04022213303

Summary

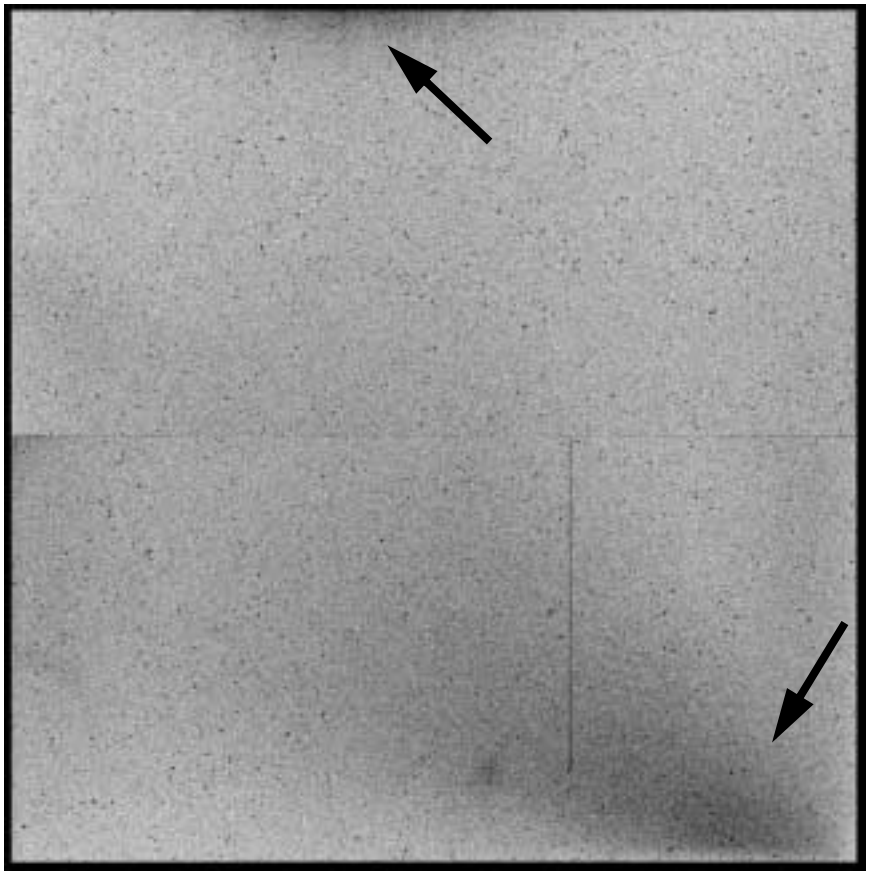
The average dark current levels measured at various phases of testing are reported in Table 4. The GSFC row represents the best average results (using values from iva001txr and iva001tyr) from the ambient testing; the pre-ship values were measured at Ball Aero-

space (Argabright; WFC3 Pre-Ship Review) prior to the delivery of the flight CCDs to GSFC. The dark current values measured on the CCDs prior to placing them in the flight enclosures at Ball are shown in the DCL column (from DCL WebWeb pages). The DCL values for amps A and B are artifically elevated due to an error in the experimental setup. The CEI specification for dark current allows a maximum dark current of 20 e^-/pixel/hour.

Table 4. Average dark currents (e^-/pix/hour) at various phases of testing.

Amp	A	B	C	D
GSFC ambient (-74^{o}C)	0.71	0.73	0.61	0.73
Ball pre-ship (-79^{o}C)	0.95		0.74	
DCL (-83^{o}C)	6.77	5.65	0.40	0.44

Figure 2: First long dark exposure, taken Dec 2003, dark areas are background scatterred light.



Conclusions

Overall, the results confirm that the WFC3 UVIS flight channel meets the CEI specifications that set limits of 4 e^-/pix/read of readout noise and 20 e^-/pix/hour of dark current. The measured readnoise is roughly 3 electrons, which is within 15% of the pre-ship measurements performed at Ball. The dark current levels, in the range of 0.5 to 0.9 e^-/pix/hr, are also in good agreement with the pre-ship Ball values. There was obvious scattered light in two of the darks, but the extreme background was virtually absent when the lights in the SSDIF were turned off.

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