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Results of WFC3 Thermal Vacuum Testing: UVIS Readnoise and Dark Current

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ABSTRACT

The dark current and readout noise levels for WFC3's UVIS channel were tested during thermal vacuum testing in September and October, 2004. Measured readnoise values were comparable to those measured during mini-ambient testing (Baggett, 2004 and Hilbert et al., 2004), below the CEI specification of 4 e^-, and just above the goal of 3 e^-. Measured RMS dark currents were 0.16 - 0.5 e^-/pix/hour, lower than those from mini-ambient testing, and well below the CEI specification of 20 e^-/pix/hour.

Introduction

After two instrument level testing sessions in ambient conditions, WFC3 underwent thermal vacuum testing in September and October, 2004. The instrument level UVIS readnoise and dark current were measured using a series of images similar to those taken during ambient testing.

Data

Data used for these analyses were taken in the UV01 test. The series of images included 15 bias images, 13 long (3000 second) dark current images, and 1 shorter (1000 second) dark current image. All files were full-frame, 4 amp readouts, taken at a gain of 1.5 e^-/ADU. Detector temperature was -82^{o}C for most of the images, while a small subset were taken with the detector at -93^{o}C. Characteristics of the data are detailed in Table 1.

# Images	Image Type	Exposure Time (sec)	Detector Temperature (^{o}C)
13	bias	0	-82
12	long dark	3000	-82
2	bias	0	-93
1	short dark	1000	-93
1	long dark	3000	-93

Table 1. Summary of data files used in the calculation of readnoise and dark current.

Analysis

Readnoise

As with the readnoise tests performed during mini-ambient and ambient testing, readnoise values were calculated from the T/V data using two different methods. The first method calculated readnoise using the serial virtual overscan pixels for each CCD channel. The standard deviation of the overscan pixels in each quadrant was measured and converted to electrons assuming a gain of 1.5 e^-/ADU. The mean and median readnoise values for each quadrant are listed in Table 2. These values are comparable to those measured during mini-ambient testing (Baggett, 2004), and 3% - 6% higher than those measured during ambient testing with the same method. (Hilbert, 2004) However, ambient testing data were taken at a gain of 1.0 e^-/ADU, compared to the 1.5 e^-/ADU of the T/V data. Previous analysis of data taken at various gain settings shows that this 3% - 6% difference in readnoise could be explained by uncertainties in the ratios of the gain values relative to the 1.5 e^-/ADU gain setting. (Baggett, 2005) The on-orbit default gain is expected to be 1.5 e^-/ADU.

The second method used to measure the readnoise used pairs of long (3000 second) dark current images. The difference of two dark current images was taken, the difference image was sigma clipped 3 times at the 3σ level, and the standard deviation of the science area pixels in each quadrant was calculated. A total of 12 dark current images were taken for this test, which were arranged into 6 pairs of images. The readnoise values measured from the image pairs are comparable to those measured in ambient testing using the overscan pixel subtraction method. Results are listed in Table 3.

Quadrant	Mean Readnoise (e^-)	Stdev of Readnoise Values (e^-)	Median Readnoise (e^-)	Minimum Readnoise (e^-)	Maximum Readnoise (e^-)
A	3.12	0.03	3.18	3.08	3.20
B	3.23	0.04	3.24	3.07	3.26
C	3.11	0.03	3.12	2.99	3.13
D	3.24	0.02	3.25	3.16	3.27

Table 2. Mean readnoise values from a set of 29 images, calculated using overscan region pixels. Sigma clipping the input files at the 3σ level before calculating readnoise values had no effect on the results. These values are comparable to those measured during mini-ambient testing.

	Quadrant A (e^-)	Quadrant B (e^-)	Quadrant C (e^-)	Quadrant D (e^-)
Image pair 1	2.99	3.05	2.95	3.08
Image pair 2	2.99	3.07	2.94	3.07
Image pair 3	2.99	3.05	2.95	3.08
Image pair 4	2.99	3.07	2.95	3.07
Image pair 5	2.99	3.06	2.92	3.06
Image pair 6	3.01	3.07	2.98	3.08

Table 3. Readnoise values for each quadrant of the UVIS detector from sigma-clipped differences of long dark current images. These readnoise values are comparable to those measured in ambient testing, and ~10% lower than those measured with the same technique in mini-ambient. This is due to the more aggressive sigma-clipping applied to the data here.

Dark Current

Dark current for the UVIS channel at nominal temperature was calculated from the 12 long (3000 seconds) dark current images taken as part of the UV01 test. First, each file was overscan corrected. The dark current was then measured using the science pixels, by calculating the mean signal in each quadrant, and scaling the signal to an exposure time of one hour. This calculation was done both with and without sigma clipping the science pixels, in order to remove hot and dead pixels. When sigma clipping was performed, the science pixels were clipped 3 times at the 3σ level. A typical dark current histogram (prior to sigma-clipping) from one quadrant of the detector is shown in Figure 1.

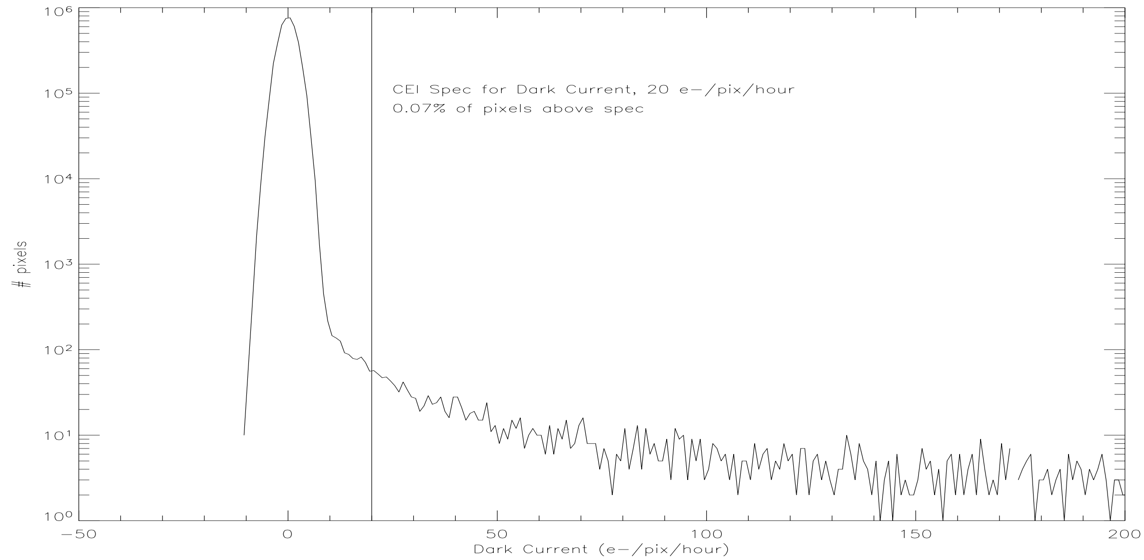

Figure 1: Dark current histogram for quadrant B of the UVIS detector. This histogram was created prior to sigma-clipping. The CEI Spec for dark current is 20e^-/pix/hour. In this histogram, 2,746 out of 4.2 million pixels (0.07%) have dark currents greater than spec.

Quadrant	**Mean Dark Current (e^-/pix/hour)**	**1σ Uncertainty (e^-/pix/hour)**	**Median Dark Current (e^-/pix/hour)**
No Sigma Clipping			
A	0.50	0.54	0.35
B	0.33	0.50	0.33
C	0.33	0.33	0.26
D	0.40	0.41	0.29
Sigma-Clipped			
A	0.16	0.09	0.14
B	0.32	0.10	0.27
C	0.34	0.10	0.30
D	0.41	0.11	0.39

Table 4. Dark currents for the 4 quadrants of the UVIS channel. The top four rows give the dark current calculated from the 12 dark current images without attempting to remove hot or dead pixels. The lower four rows give the dark current after the 12 files were sigma clipped at the 3σ level 3 times. Detector temperature was -82^{o}C.

The results from both sigma-clipped, and non-clipped images are shown in Table 4. All dark current values in Table 4 are less than those calculated during mini-ambient (0.50 - 1.0 e-/pix/hour) and ambient (~1.0 e-/pix/hour) testing. This is attributed to the detector temperature during T/V testing being roughly 10 degrees less than that in mini-ambient and ambient testing.

Quadrant	**Mean Dark Current (e-/pix/hour)**	**Median Dark Current (e-/pix/hour)**
No Sigma Clipping		
A	0.58	-0.21
B	0.61	0.28
C	0.76	-0.21
D	0.68	0.20
Sigma-Clipped		
A	0.21	-0.36
B	0.29	0.40
C	0.44	0.45
D	0.38	0.87

Table 5. Dark current rates calculted the same way as those in Table 4, but for data taken at a detector temperature of -93^{o}C, rather than -82^{o}C.

Table 5 lists the measured dark current for the files taken with the detector operating at -93^{o}C, rather than the nominal temperature of -82^{o}C. Again, the dark rates were calculated both with and without sigma clipping. These results have a higher level of uncertainty, as only one long dark current ramp was collected at -93^{o}C, compared to the 12 ramps collected at -82^{o}C.

The sigma clipping has a significant effect on the mean dark rate, at both -82^{o}C and -93^{o}C. At the colder detector temperature, sigma clipping lowers the mean dark rate by 40% - 50% in each quadrant. At -82^{o}C however, sigma clipping only significantly changes the mean dark current value in quadrant A, where the mean dark current decreases by 65%. In the other three quadrants, the mean dark current is unchanged after sigma clipping.

From Tables 4 and 5, it appears that the dark current of the detector does not change appreciably as the temperature decreases from -82^{o}C to -93^{o}C. The calculated dark current in each quadrant at -93^{o}C is within the 1σ uncertainty of the dark current in the same quadrant at -82^{o}C.

Conclusions

Readnoise values measured during T/V testing are comparable, and dark current levels are 60% - 80% lower, than values measured under similar conditions during mini-ambient and ambient testing. Readnoise values are 3 - 3.25 e^{-}/pix, and dark currents range from 0.16 to 0.87 e^{-}/pix/hour, depending on whether the data are sigma clipped before making the measurements. Both readnoise and dark current values measured in T/V testing meet CEI specifications. Dark currents remained constant within their uncertainties when detector temperature was varied between -82^{o}C and -93^{o}C.

References

Baggett, S. and B. Hilbert, **Readnoise and Dark Current in WFC3 Flight CCD Ambient Data**. (ISR WFC3-2004-01) http://www.stsci.edu/hst/wfc3/documents/ISRs/WFC3-2004-01.pdf 1 June 2004.

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