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WFC3 Thermal Vacuum Testing: UVIS Crosstalk

S. Baggett[1], R.J. Hill[2], G.Hartig[1], A.Waczynski[2], Y.Wen[2]
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ABSTRACT

The integrated WFC3 instrument recently underwent testing under thermal vacuum (TV) conditions in the GSFC SES (Goddard Space Flight Center Space Environment Simulator). This report summarizes the behavior of the UVIS channel crosstalk features seen in the TV data as compared to the behavior seen in previous data taken under ambient conditions in early 2004 and provides an update on the hardware investigation underway at the Detector Characterization Lab (DCL) at GSFC . The crosstalk in the TV images has been found to be essentially identical to the crosstalk in ambient images: 1) levels are low, +/- a few DN on average though individual pixels can exhibit crosstalk up to +/-10DN, 2) the effect is highly nonlinear, 3) the crosstalk is bias and gain dependent, and 4) the behavior of the crosstalk as a function of binning and readout combination remains unchanged. The hardware testing at DCL has found that the CEB test set and the flight-like harness generate crosstalk which does not behave exactly like the crosstalk in the flight channel. Further investigation into the cause of the crosstalk will require use of the flight hardware.

Introduction

Early in 2004, WFC3 underwent its first end-to-end testing, under ambient conditions in the GSFC SSDIF (Space Systems Development and Integration Facility). At that time, images of sources were found to cause low level electronic mirror images in other amplifier outputs and

[1] Space Telescope Science Institute
[2] NASA/Goddard Space Flight Center

the effect was investigated as thoroughly as possible. Results from the analysis of the ambient data have already been reported (Baggett et al., 2004) and can be summarized as follows.

There appear to be two types of crosstalk. In the first type, source pixels with any exposure level give rise to mirror images in all amps (in a full-frame, four-amp readout) while in the second type, only heavily saturated pixels cause crosstalk, and only in the alternate amp of the CCD containing the source. Both types of crosstalk are highly nonlinear and depend upon the gain and amplifier ADC bias offset level in use: changes in the bias level of the source amp and changes in the gain of the source and/or victim amps changes the sign, shape, and/or magnitude of the crosstalk. Changes to the bias level of the victim amp do not appear to have any effect on the crosstalk.

The ambient data also showed that the crosstalk was dependent upon the binning and number of amps used during readout. Specifically, binned two-amp read outs do not exhibit any type of crosstalk; binned four-amp read outs do not exhibit the type 1 crosstalk but do exhibit type 2. In unbinned two-amp read outs, the crosstalk appears in only one other amp; unbinned four-amp read outs - expected to be the nominal default mode on orbit - show crosstalk in all other amps (see Figure 1 below).

Thermal vacuum testing of the integrated instrument was performed in late 2004. Part of that testing consisted of a check of the crosstalk behavior, to allow a comparison to some of the images taken during ambient conditions. This report compares the crosstalk features in TV to those found in the ambient data and summarizes the current state of the hardware investigation at the Detector Characterization Lab (DCL) at GSFC.

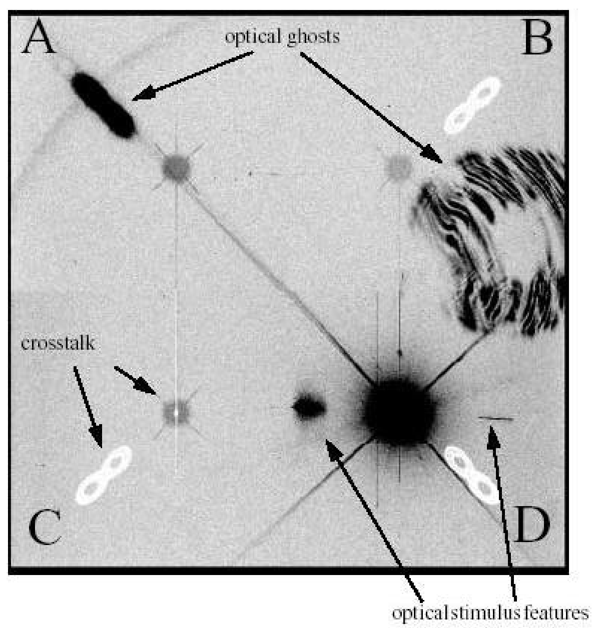


Figure 1: Crosstalk features due to a saturated PSF in quadrant D are visible as circular spots in the center of quads A,B,C. Crosstalk due to the optical ghost in quad A can be seen in quads B,C,D. The image is a gain 1.5, full-frame unbinned four-amp readout obtained during ambient testing, and has been displayed with an extreme hard log inverted stretch in order to highlight the crosstalk features.

Observations

The TV crosstalk check was executed as TV SMS script UVIS31. The intent of the proposal was not to duplicate the extensive ambient image suite but to spot-check key aspects of the crosstalk behavior. The basic test consists of 7 images, with the PSF placed at UV13 in quadrant D; the laser attenuation was set to produce a highly saturated PSF in all images except the first one, where the atttenuation was set to produce a source ~100x fainter. The dataset allows for checks of the crosstalk behavior in a full frame 4-amp read out, in binned frames (4-amp and 2-amp read out), in all gain settings, and in an image at a different exposure level. The test was performed at an ADC bias offset of 0, which was used for most of the ambient testing, and at bias offset of 3, the expected default offset on-orbit.

Table 1. List of TV crosstalk images, showing database entry number, root and filename, read out amps, gain, x & y axis sizes, x & y binning, and ADC bias offset level. Images were taken Oct8/9, 2004, with F625W, 10 sec exposures, source placed at UV13 (quadrant D) in each.

Entry	rootname	filename	amps	gain	xaxis	yaxis	xbin	ybin	offset
18264	IU310101	CSII04282161510_1	ABCD	1.5	4206	4140	1	1	3
18265	IU310103	CSII04282162432_1	ABCD	1.5	4206	4140	1	1	3
18266	IU310105	CSII04282163932_1	ABCD	1.5	2102	2070	2	2	3
18267	IU310106	CSII04282163932_2	BD	1.5	1402	1380	3	3	3
18268	IU310107	CSII04282163932_3	ABCD	1.0	4206	4140	1	1	3
18269	IU310109	CSII04282165240_1	ABCD	2.0	4206	4140	1	1	3
18270	IU31010A	CSII04282165240_2	ABCD	4.0	4206	4140	1	1	3
18398	IU310101	CSII04283093410_1	ABCD	1.5	4206	4140	1	1	0
18399	IU310103	CSII04283094332_1	ABCD	1.5	4206	4140	1	1	0
18400	IU310105	CSII04283095832_1	ABCD	1.5	2102	2070	2	2	0
18401	IU310106	CSII04283095832_2	BD	1.5	1402	1380	3	3	0
18402	IU310107	CSII04283095832_3	ABCD	1.0	4206	4140	1	1	0
18403	IU310109	CSII04283101140_1	ABCD	2.0	4206	4140	1	1	0
18404	IU31010A	CSII04283101140_2	ABCD	4.0	4206	4140	1	1	0

Analysis

A visual comparison of the images showed that the TV data with a bias offset level of 0 matched the ambient data (see Figure 2 below), with negative crosstalk due to the optical ghosts and positive crosstalk due to the PSF. The TV exposure level was somewhat higher than in ambient, causing some minor changes in the extent of the crosstalk, e.g., features in quad A/C due to the low level ghost in B/D are somewhat more extended in the TV data than in the ambient data, and crosstalk from the outer regions of the PSF is more extended than it was in the ambient data. Though not crosstalk-related, the faint arc feature in quadrant A, running from lower left to upper right through the figure-8 ghost, appears shorter in the TV data than it was in ambient; the reason for this is not clear.

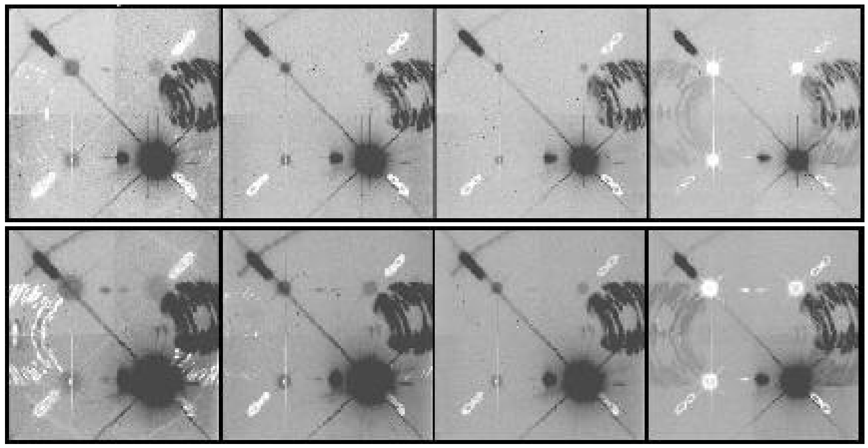


Figure 2: Crosstalk patterns as a function of gain. Top row is ambient data, bottom row is TV data, both with bias offset of 0; gains are 1.0, 1.5, 2.0, and 4.0, left to right.

An image was also taken at each gain setting using a bias offset of 3, as that is likely to be the offset used on-orbit. As expected from ambient data results, changing the offset level dramatically changes the sign & magnitude of the crosstalk (see figure below). Also, as expected, a gain 1.5, offset 3 image taken during ambient matched the corresponding TV image.

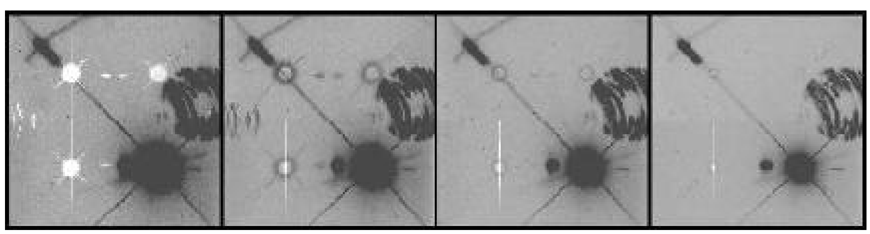
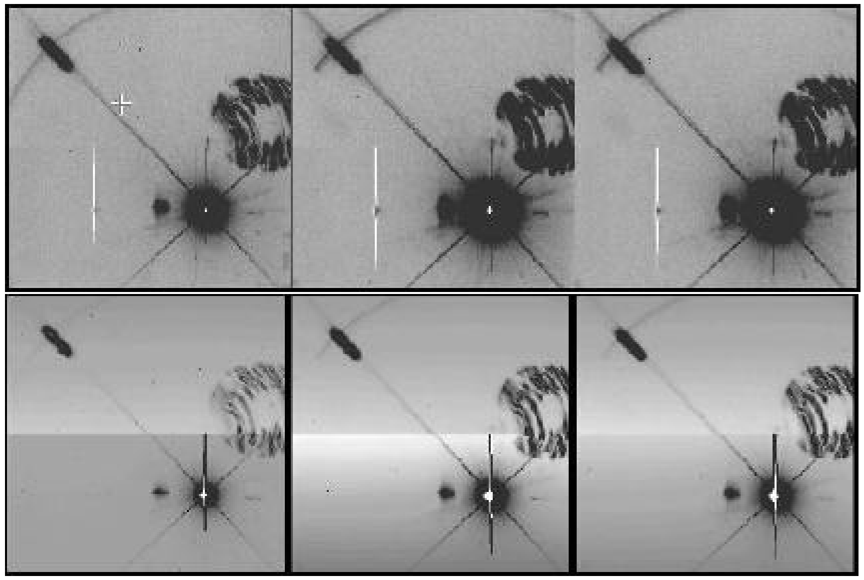


Figure 3: TV crosstalk patterns as a function of gain, with offset level of 3 (gain 1.0, 1.5, 2.0, and 4.0 from left to right).

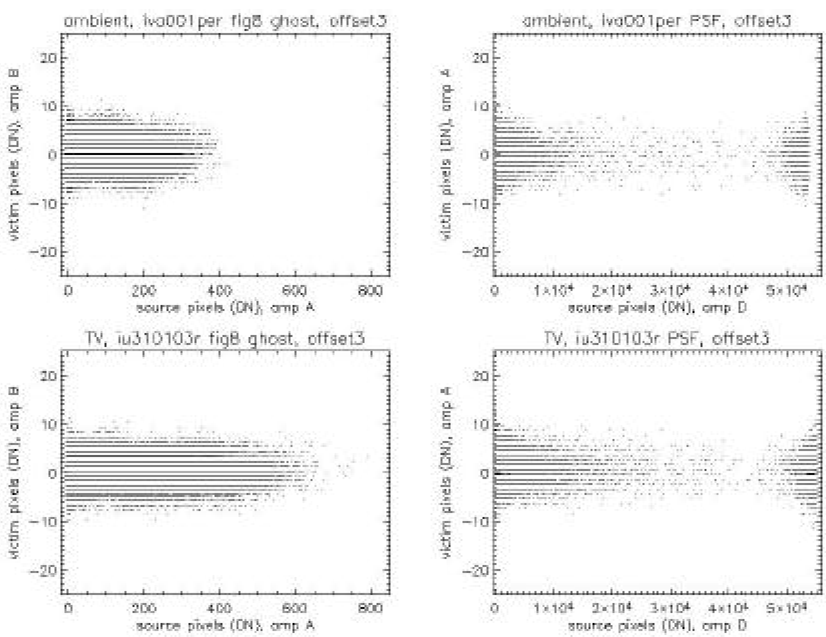
A comparison of ambient and TV binned data, taken with four-amp and two-amp read outs, also showed no surprises. As in ambient data, a 2x2 binned four-amp read out has type 2 crosstalk (due to saturated source pixels and falling in the alternate amp of the CCD containing the source) and no type 1 crosstalk, while a 3x3 binned two-amp read out has no detectable crosstalk at all. Figure 4 presents the ambient and TV images; as noted in the gain comparisons, since the exposure level in TV was somewhat higher than in ambient, the crosstalk extends somewhat further in the TV images.

Figure 4: Crosstalk in binned data. Four-amp 2x2 binned and two-amp 3x3 binned images are in the top and bottom rows, respectively. Ambient images are on the left, TV in the middle (bias offset 0) and right (bias offset 3).



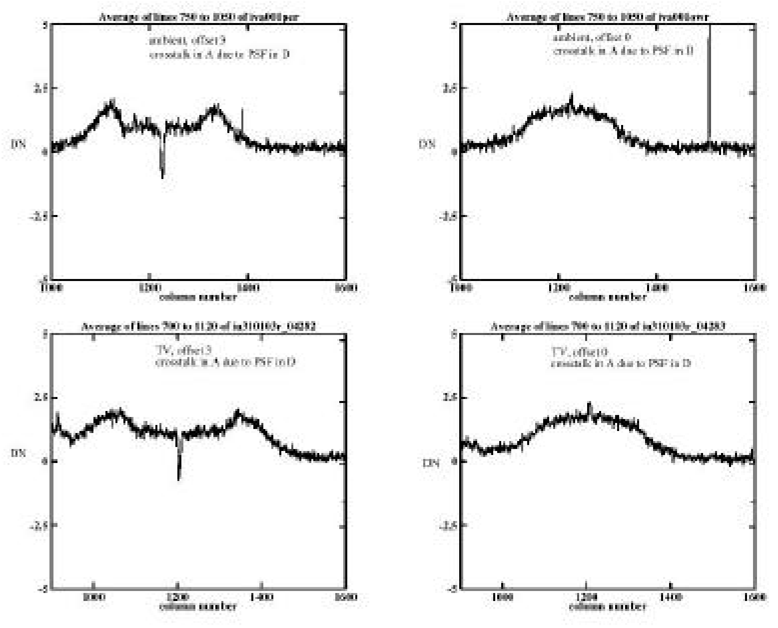
A comparison of the magnitude of the crosstalk in the ambient and TV data showed that the effect remains highly nonlinear: the crosstalk level fall within +/- 10DN regardless of the level in the source pixels. Figure 5 shows the crosstalk pixel levels as a function of source pixel level, for faint and bright source regions in an ambient and TV image; similar results were seen for the TV image taken at 100x fainter exposure level.

Figure 5: Crosstalk levels in ambient and TV, top and bottom plots respectively. Levels (in DN) in the crosstalk pixels are plotted as a function of source pixel level.



Finally, Figure 6 presents an average cut through the PSF crosstalk in an ambient and TV image, at the two different bias offset levels. As can be seen from the plots, the levels and shapes are the same in ambient and TV data, the average crosstalk level is +/- 2 to 3 DN and can be positive as well as negative.

Figure 6: Average crosstalk levels in cuts taken across the PSF. Top plots are based upon ambient data, bottom plots on TV data. Offset is 3 (left plots) and 0 (right plots).



Status of hardware investigation at DCL

A variety of tests have been run at the Detector Characterization Lab (DCL) in an attempt to identify the source(s) of the crosstalk. The UVIS surrogate detector enclosure was used along with a flight-like harness and the CEB test set (modified to include capacitors to reduce the common-mode susceptibility); the results can be summarized as follows.

1) No crosstalk is observed internal to the CEB test set (signal injected at the CEB input, without a harness).
2) Crosstalk can be detected when the harness is included (signal injected into the harness running from the detector enclosure to the CEB). However, the behavior differs significantly from that observed in the flight channel: the crosstalk is always at a low, negative, channel-dependent level, the crosstalk does not cross CCD chips, and the magnitude of the features are proportional to the injected signal and decay with time. One similarity with the flight channel was noted: the crosstalk level decreased at slower clock speeds (none at all is seen when the serial speed is 44µs), such that no crosstalk is expected for binned images; no crosstalk is seen in binned two-amp read outs in the flight channel ambient and TV tests. However, the crosstalk in the flight hardware exhibited changes in sign when the clock speed was decreased (by using and increased

clamp time) before eventually vanishing, while the crosstalk seen with the CEB test set was always negative and linear with signal.

3) Crosstalk is also detected when the UVIS surrogate detector enclosure is included; the levels in the various amps are about equal and at the level seen in the CEB crosstalk in the previous test.
4) The level of the crosstalk increases by about a factor of 4 when the capacitors (added to correct the common-mode susceptibility) are removed from the input amplifiers.

The crosstalk seen in the DCL testing does not behave like the crosstalk seen in the flight hardware; the CEB test set and flight-like harness behave differently than the flight CEB and harness. Further testing to track down the source(s) of the crosstalk seen in the flight channel will require access to the flight hardware.

Conclusions

The behavior of the UVIS crosstalk in the TV data appears to be the same as it was in the ambient data. The crosstalk is highly nonlinear, with relatively low levels of typically a few DN (though it can range up to +/- 10DN). The bias and gain dependencies found in the ambient data are found in the TV data. The crosstalk behavior as a function of binning and number of amps used to read out the frame remains the same as in ambient as well. The hardware investigation at the DCL has shown that crosstalk from the CEB test set and the flight-like harness behaves differently than the crosstalk in the flight channel; further testing to determine the source(s) of the crosstalk will require access to the flight hardware.

Acknowledgements

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References

Baggett, S., Hartig, G., and Cheung, E., "WFC3 UVIS Crosstalk Images," WFC3 ISR 2004-11