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WFC3/UVIS TV3 Post-flash Results

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Abstract

Given recent interest in potentially reviving the WFC3 post-flash capability, we have investigated the state of the ground system and have analyzed the post-flash images acquired during ground testing. Six images were taken with the flight detector on side 2 of the instrument. The post-flash illumination pattern is found to exhibit smooth, large-scale gradients of about +/-20% across the full field of view; however, those gradients were quite repeatable. Post-flash image ratios are flat to ~1%, with global offsets in the absolute flux level of 5-10%. The one post-flash image taken with the CCDs fully cooled had a higher flux (~80 e-/s) than the other images taken with the CCD only partially cooled (~60 e-/s). Assuming the former flux for on-orbit post-flash images, low post-flash levels of 10-20e- will be attainable with 0.1-0.3 sec post-flash durations at medium current. Given that 0.1 sec is the minimum allowable post-flash duration, should the on-orbit flux level be higher, it will be necessary to switch to the low current setting.

Introduction

Recent modeling of the WFC3 charge traps and their evolution over time has shown that images with low levels of background can experience a proportionally larger amount of CTE loss than images with high background levels (Anderson, 2012). Specifically, low S/N sources embedded in low backgrounds (< ~20e-) lose the majority of their charge to traps before readout while these same sources embedded in higher backgrounds (> ~20e retain most of their charge. Given the promise of mitigating CTE losses for faint sources by applying relatively low backgrounds, i.e., with only a low noise penalty, there is renewed interest in the WFC3 post-flash capability.

A post-flash is obtained by operating one of two available LEDs on the diode mounting plate of the post-flash ring assembly, one LED per instrument side (C.Long, 2012). The hardware is based on the ACS design, with the flash housing located between the CCD housing and the shutter blade; the light is reflected off the shutter blade down onto the CCDs. There are three available current settings 1, 10, and 11 mA, with allowable exposures times 0-409.5 sec, in increments of 0.1 sec (Draugelis, 2007).

Testing of the post-flash mode on the ground was limited as a decision was made to provide support for only one hardware-based method of CTE mitigation, either injection (CI) or post-flash. The pre-flight decision in favor of CI was taken based on the results from a detailed comparison of post-flash and CI using Fe55-irradiated detectors (Giavalisco, 2003). That study found that for the Fe55 sources, CI provided better mitigation of the effects of CTE loss on photometry and sensitivity with a lower noise penalty than a post-flash (~15 e- rms noise for CI ~10,000 e versus ~45 e- rms noise for 2,000 e- post-flash).

The basic post-flash commanding was developed before flight – the current ground system for WFC3 allows for post-flashing all target types except BIAS (Welty, 2012). Some key post-flash-related engineering parameters as well as header keywords are built into the ground system as well. During the WFC3 thermal vacuum ground tests, only a minimal number of post-flash images were taken to verify the mode's operation as remaining resources were focused on CI tests. However, successful macro timing tests of all three current levels at minimum (0.1s), maximum (409.5s) and intermediate post-flash times were performed on the test bench (there was no LED attached but hand and voltmeter readings were taken).

Given the recent evidence that a low level of post-flash may be able to significantly reduce CTE losses for low S/N source with a relatively small noise penalty, the ground post-flash images are analyzed in more detail here in preparation for comparison to upcoming on-orbit tests of the mode.

Data

During the WFC3 ground testing, a small number of post-flash DARK images were acquired to verify basic operation of the mode. The images were obtained manually using the commands listed below (Hickey, 2012); note that they were 100 sec internal darks and not 'externals' as the IMAGETYP header keyword states.

ICCDFULL ABCD DARK NONE (full frame, four-amp readout, dark, no charge injection)
ICCDEXP '61G' 'M3' 'AU' 100.0 (100 second exposure)
ICCDFLSH 3.0 MEDIUM (3 second flash at medium current)
ICCDREAD (readout)

Table 1 summarizes the acquired images along with post-flash duration, current, operating environment, date of the observation, temperature of the CCDs, and instrument side. For completeness, the table lists all post-flash images taken during all ground campaigns. *For the purposes of this study, we restrict ourselves to only the images taken with the final flight detector package (2008 timeframe) and to those taken on the instrument side being used on-orbit (MEB2).* The detector temperatures listed in the table are from the IUVDETMP spt file keyword and were confirmed using the ground testing shift reports. Due to a glitch in the ground processing, some temperatures were recorded in the IUVDETMP keyword with an artificial -77 degree offset, i.e., they read -127 and -160 in the image header but were actually taken with the CCDs at -50C and -83C, respectively. These corrections have already been made to the temperatures provided in Table 1. There was one image during 2008 taken at the operating temperature and with the instrument side in use on-orbit (-83C, MEB2); that image is highlighted in grey in Table 1. All other images were acquired with the detectors cooled to only -50C. The shutter blade used for the post-flash has been determined from the ISHRBPOS engineering mnemonic in the spt headers: values between 800-2100 and 33600-34900 indicate shutter blade A was in place while values between 17200-18500 and 50000-51300 indicate shutter blade B was in place.

Finally, we note that a small set of engineering parameters and header keywords were built into the ground system to support post-flash imaging. Table 2 summarizes the engineering mnemonics for post-flash and their mapping to the keywords in the various image headers.

Table 1. The manual successful post-flash images acquired during ground testing. Data are all 100 sec full-frame four-amp readout darks taken without any filters in place. The entry for the image taken under conditions closest to those on-orbit has been shaded grey.

Tvnum	Image name	Flash dur	Flashcur	Environ	Date	Temp (C)	Side	shut
9437	i61gm3aur_04218222117	3.0	MedCur	AMBIENT	2004-08-05 22:13:57	-49.6	MEB1	B
9463	i61gm3aur_04223015211	3.0	MedCur	AMBIENT	2004-08-10 01:42:48	-49.6	MEB2	B
9487	i61gm3aur_04237153652	3.0	MedCur	AMBIENT	2004-08-24 15:30:31	-49.6	MEB1	B
9492	i61gm3aur_04238085911	3.0	MedCur	AMBIENT	2004-08-25 08:53:51	-50.2	MEB2	B
10769	i61gm3aur_04255151415	3.0	MedCur	VACUUM	2004-09-11 15:05:18	-81.4	MEB2	A
10805	i61gm3aur_04256073038	3.0	MedCur	VACUUM	2004-09-12 07:22:34	-81.8	MEB1	A

45802	i61gm3aur_08020030320	3.0	MedCur	AMBIENT	2008-01-20 02:56:06	-50.	MEB1	B
45840	i61gm3aur_08021001853	3.0	MedCur	AMBIENT	2008-01-21 00:12:27	-50.	MEB2	B
48701	i61gm3aur_08053035912	3.0	MedCur	AMBIENT	2008-02-22 03:54:17	-50.	MEB2	A
48725	i61gm3aur_08053175613	3.0	MedCur	AMBIENT	2008-02-22 17:47:12	-50.	MEB1	A
49280	i61gm3aur_08066100814	3.0	MedCur	VACUUM	2008-03-06 10:01:07	-83.	MEB2	A
49362	i61gm3aur_08067111230	3.0	MedCur	VACUUM	2008-03-07 11:06:01	-83.	MEB1	A
59293	i61gm3aur_08134032101	3.0	MedCur	AMBIENT	2008-05-13 03:08:24	-49.4	MEB1	B
59327	i61gm3aur_08135030024	3.0	MedCur	AMBIENT	2008-05-14 02:53:26	-48.8	MEB2	A
59348	i61gm3aur_08183182848	3.0	MedCur	AMBIENT	2008-07-01 18:21:57	-50.	MEB1	B
59650	i61gm3aur_08185004152	3.0	MedCur	AMBIENT	2008-07-03 00:34:50	-50.	MEB2	A
59685	i61gm3aur_08228102233	3.0	MedCur	AMBIENT	2008-08-15 10:15:22	-20.8	MEB1	A
59719	i61gm3aur_08229041250	3.0	MedCur	AMBIENT	2008-08-16 04:05:32	-50.	MEB2	A

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Table 2. Post-flash related engineering mnemonics and header keywords.

Mnemonic	Keyword and header location	Sample value	Comment
IQFLSHEC	FLSHERR (spt)	'NoError'	Flash Error Code
IQFLSHAB	FLSHABRT (spt)	'-- '	Flash Aborted
IQFLSHCT	FLSHCUR (spt)	'MedCur'	Flash Current
	FLASHCUR (raw/flt)	'ZeroCur '	Post-flash current (zero, low, medium,high)
IQFLSHSF	FLSHSTAT (spt) FLASHSTA (raw/flt)	'Success' 'Successful '	Flash Status (Success/Fail) Status: successful, aborted, not performed
IQFLSHCD	FLSHCDUR (spt)	3.0	Flash Commanded Duration
IQFLSHAD	FLSHADUR (spt)	3.0	Flash Actual Duration
	FLASHDUR (raw/flt)	3.0	Exposure time in seconds: 0.1 to 409.5

Analysis

The bias overscan level was subtracted from the post-flash images; no dark correction was performed as its contribution is small: the exposure times are short (100 sec) and even at the warmer operating temperature, the dark rate is relatively low (0.01-0.02 e-/sec). One of the resulting post-flash images is shown in the left panel of Figure 1; the amp quadrants have been labeled. Overall, the illumination is relatively smooth though there are clear gradients across the field. The brightest areas, ~15% above the median, exist in the lower left corner of the B amp quadrant and upper left corner of the D amp quadrant, i.e., just right of the center of the WFC3 FOV. The lowest areas of illumination, ~25% below the median, are in the upper left corner of the A amp quadrant and lower left corner of the C amp quadrant. The average and median post-flash levels are summarized in Table 3, which lists image name followed by number of pixels, mean, standard deviation, and median for each chip (in units of DN), and the average of the chips (in units of e-/sec/pix). A modest 3-sigma clipping was performed in order to correct for the occasional cosmic ray or hot pixel. Most of the post-flash illumination levels were repeatable to within a few percent: excluding the one obvious outlier, the mean of the averages is ~58 e-/s/pix with a standard deviation of ~2 e-/s/pix, for medium current. No images were acquired using the low or high current settings.

The outlier is from the single cold post-flash image taken under thermal vacuum, not ambient, conditions. One possibility for the flux difference is that the LEDs were able to operate at a cooler temperature at ambient due to cooling via air currents (the instrument was under a dry nitrogen purge) and once under TV conditions, the LEDs were able to run at their normal, hotter temperature. Alternatively, the LED may generate more flux when colder: generic LED characteristic curves show that intensity increases as the ambient temperature drops (e.g., ledtronics.com, 2012). Further testing in-flight will be required to determine on-orbit flux levels for the WFC3 LEDs. Assuming they fall near the 80 e-/s range, post-flash levels of 10-20e- will be achievable with medium current and post-flash durations of 0.1-0.3 sec at the low end of the allowable post-flash duration time range. If the flux should be significantly higher on-orbit, it will be necessary to use longer post-flash durations at the low current setting in order to obtain 10-20e- post-flash levels.

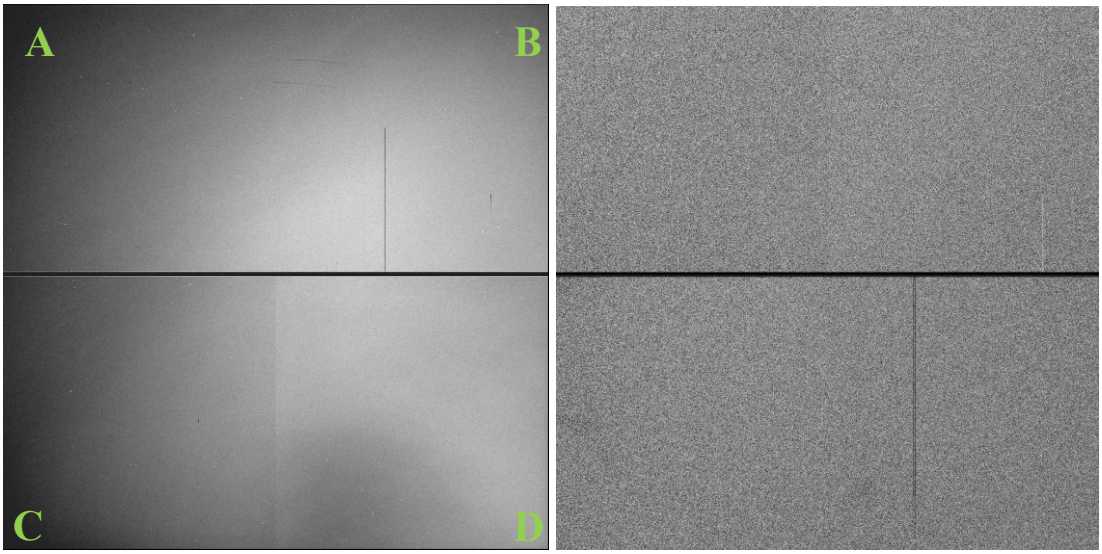

Figure 1. At left is a gray-scale image of the full-frame four-amp readout post-flash image taken on instrument side two with the CCDs cold (i61gm3aur_08066100814); stretch is +/-20%. At right is the ratio of that image to another post-flash image taken more than 150 days later, shown at a +/-10% stretch.

Table 3. Illumination levels in medium-current post-flash images acquired on the ground; units are in DN unless otherwise noted. The entry for the image taken under conditions closest to those on-orbit has been shaded grey.

image	Chip 1 (A,B)				Chip 2 (C,D)				average
	Npix	Mean	Stddev	Median	Npix	Mean	Stddev	median	(e-/s/pix)
i61gm3aur_08021001853	8379928	110.4	13.7	109.8	8379882	111.1	13.0	111.	55.4
i61gm3aur_08053035912	8383573	116.9	14.	116.5	8381337	115.8	13.5	116.3	58.2
i61gm3aur_08066100814	8390477	157.5	18.1	157.1	8390232	157.3	17.1	158.	78.7
i61gm3aur_08135030024	8382244	121.6	14.5	121.	8380820	120.7	13.9	121.1	60.6
i61gm3aur_08185004152	8378587	119.7	14.4	119.5	8379635	118.9	13.7	119.5	59.6
i61gm3aur_08229041250	8382729	118.5	14.2	117.8	8381248	117.6	13.6	117.6	59.0

To investigate the stability of the illumination pattern, we ratioed all 2008 MEB2 post-flash images to the image taken Jan 21, 2008 (shutter B, taken at -50C) as well as to the image taken May 15,2008 (shutter A, taken at -50C); one of those ratios is shown in the right panel of Figure 1. As the figure shows, the ratio is extremely flat; all ratios were confirmed to be flat via horizontal and vertical cuts through images. Based on the limited ground data available, the illumination pattern appears to be repeatable though this will require verification on-orbit. The image ratio statistics summarized in Table 3 illustrate that although the ratios were flat, the absolute illumination level varied by 5-10%. The

outlier post-flash image is i61gm3aur_08066100814; as discussed earlier, it is the only image to have been taken under thermal vacuum conditions with the detector fully cooled to its nominal operating temperature of -83C. The resulting illumination level is ~35% higher than the level obtained in the ambient images.

Table 4. Image statistics of post-flash images ratioed to the image from Jan 21, 2008 (i61gm3aur_08021001853).

Image	Chip 1 (amps A,B)				Chip 2 (amps C,D)			
	Npix	Mean	Stddev	Median	Npix	Mean	Stddev	median
i61gm3aur_08053035912	8349945	1.063	0.1145	1.057	8352875	1.047	0.112	1.041
i61gm3aur_08066100814	8344395	1.433	0.1455	1.424	8345142	1.422	0.1428	1.415
i61gm3aur_08135030024	8350407	1.106	0.1178	1.098	8352482	1.091	0.1153	1.085
i61gm3aur_08185004152	8349344	1.089	0.1164	1.083	8352629	1.075	0.1141	1.068
i61gm3aur_08229041250	8349504	1.077	0.1156	1.071	8352009	1.063	0.1132	1.057

Conclusions

Given the renewed interest in the WFC3 post-flash capability, we have presented a brief summary of the mode and analyzed the available ground test images. A total of 6 post-flash images were acquired with the flight detector on side 2 of the instrument. The resulting illumination pattern is relatively uniform, regardless of shutter blade, but exhibits large-scale gradients of about +/-20% across the field of view. The gradients are very repeatable: image ratios are flat to ~1% ; offsets in the absolute level are ~5-10%. A larger global offset, ~35%, is present between the 'warm' (-50C) images and the one cold image taken at nominal operating temperature (-83C), attributed to differences in the LED performance under ambient and thermal vacuum conditions. Post-flash flux levels were ~60 and ~80 e-/sec for the images taken with the CCDs at 'warm' and nominal cold temperatures, respectively. Assuming the latter flux on-orbit, low post-flash levels of 10-20e- will be achievable with 0.1-0.3 sec post-flash durations at medium current. If the flux levels on-orbit should be higher, then it will be necessary to switch to the low current setting.

References

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