SPACE TELESCOPE SCIENCE INSTITUTE
Operated for NASA by AURA

Instrument Science Report WFC3 2008-13

WFC3 TV3 Testing: UVIS-1' Gain Results

S. Baggett
June 20, 2008

ABSTRACT

Thermal-vacuum (TV3) level tests using the integrated WFC3 instrument, with the UVIS-1' detector in place, were performed at Goddard Space Flight Center (GSFC) during the spring of 2008. Flatfield data were acquired to allow an absolute gain measurement using the mean-variance method at the nominal gain 1.5 setting, in both unbinned and binned modes. The CCDs were at the nominal operating temperature of -83C. The gain in unbinned mode was measured at 1.56, 1.56, 1.58, and 1.57 e^-/DN for quadrants A,B,C, and D, respectively, with errors ~0.01 e^-/DN; these values are within 1-2% of those measured for UVIS-1 during TV1. The TV3 gain values for the binned modes were within 1% of the unbinned mode gain, specifically, 1.56, 1.55, 1.58, and 1.57 e^-/DN for 2x2 mode and 1.55, 1.55, 1.56, and 1.56 e^-/DN for 3x3 mode, for A,B,C, and D, respectively, with errors ~0.01 e^-/DN.

Introduction

The WFC3 instrument, with the UVIS-1' flight detector in place, recently underwent thermal-vacuum (TV) testing in the GSFC Space Environment Simulator chamber. Flatfield illumination was provided by the WFC3 optical stimulus (CASTLE), an apparatus that simulates the HST OTA, including the major aberrations. Flatfield data for the gain determinations were taken at the nominal setting (1.5 e^-/DN) in unbinned and binned modes (1x1, 2x2 and 3x3). The gain 1.5 setting is the default setting as it provides the best compromise between sampling the entire full-well of the detector, given the 16-bit A to D

converter, and providing a reasonable sampling of the low read noise. The three off-nominal gain settings (1.0, 2.0, and 4.0 e^-/DN) were measured during a previous TV test with UVIS-1 (Baggett, 2005); they were not remeasured at this time as these modes will be unavailable to observers. The binned modes have been measured, however, as they will be supported and available for use. While binning, the co-addition of either 2x2 or 3x3 pixels before reading out the effective pixel value, reduces the spatial resolution, it improves the signal-to-noise ratio by minimizing the readout noise, which can be useful with faint targets for example. This report presents the results of the TV3 gain analysis.

Method

The gains were measured via the standard mean-variance technique: the inverse slope of the mean signal level plotted versus the variance yields the gain. As presented previously (Baggett, 2005), the derivation is based upon the assumption that there are only two sources of noise: photon shot noise and detector read noise. In that case, the total noise can be written as $N = \sqrt{p^2 + R^2}$, with all parameters in units of e^-. Converting to units of DN via the gain (e^-/DN), the equation can be rewritten as $(N/g)^2 = (p/g)^2 + (R/g)^2$, where the noise squared term is the variance. When the mean signal, μ, is measured in DN, the photon noise, *p*, is simply $\sqrt{g \cdot \mu}$ which when substituted into the noise equation yields $\sigma^2 = (1/g) * \mu + (R/g)^2$. The inverse slope is the gain.

The images used were taken March 12, 2008 and April 10/11, 2008 (listed in Table 2, Appendix A). All images were processed through calwf3 version 0.8 (21-Dec-2007 release); the CCDTAB and OSCNTAB were those in place in the pipeline in early 2008 (r6p1618ci_ccd.fits and q911321oi_osc.fits, respectively). Only the overscan correction was applied. Average and difference images were formed for each pair of flatfields at a given exposure level and the mean-variance plots were constructed from the means of the average images and the variances of the difference images (standard deviation squared and divided by two).

Statistics in the unbinned data were measured in twenty-six 400x400 pixel regions per image pair per detector quadrant, for a total of >300 regions per quad. No individual pixels were masked although a small number of regions (< 5 out of the more than 300) were discarded due to excessively high variance, traced to cosmic ray events. Statistics for the binned data were computed in twenty-six 200x200 pixel regions (2x2 binned images) and twenty-six 133x133 pixel regions (3x3 binned images). In the initial mean-variance plots for the binned data, there were obvious outliers found to be due to the influence of e.g. bad columns or cosmic ray events on the now-smaller image sections being used. For this rea-

son, 3 iterations of 3 sigma clipping were done to mask pixels (for the binned images only).

Results

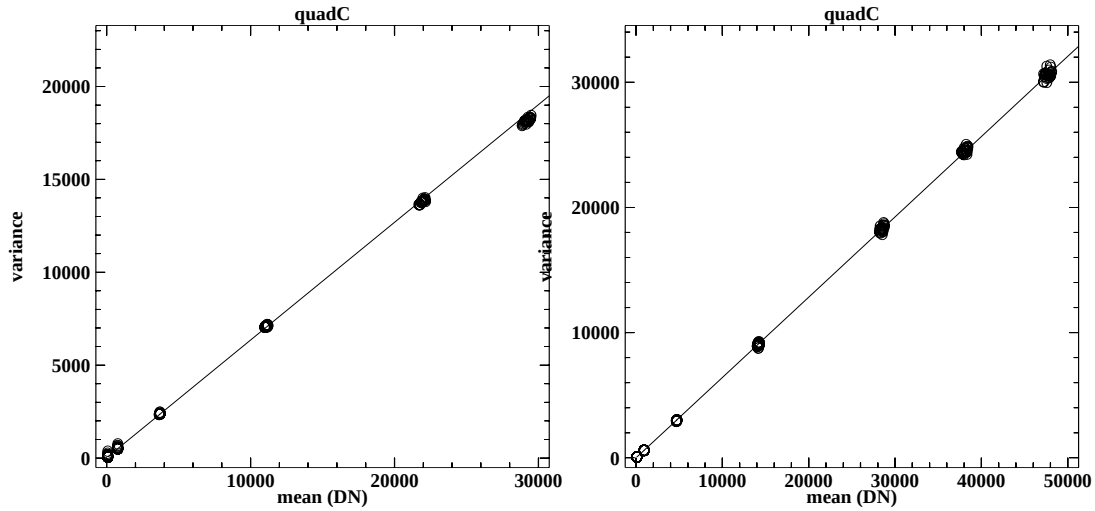
Figure 1 shows the quad C results for the unbinned mode; the final fit has been restricted to ~30K DN to avoid any potential non-linearity effects at the next highest exposure level, 39K DN (expanding the fits to 39K DN raised the resulting gains by ~1%). The final TV3 gains for UVIS-1' were 1-2% higher than those measured during TV1 testing with UVIS-1 (Baggett, 2005).

One of the binned-mode mean-variance plots is shown in Figure 1 (quad C, 3x3 binning). In the binned modes, the quadrants showed good mean-variance behavior out to ~60-62K DN, quadrant C out to ~55 KDN. To stay well within the linear regime and treat all quads equally, the gain was measured on data out to ~50K DN; values are tabulated in Table 1. The binned mode gains are within 1% of the unbinned mode gains, within the noise of the analysis.

Table 1. UVIS-1' gain results for the commanded gain 1.5 setting.

	unbinned		**2x2 binning**		**3x3 binning**	
quadrant	**gain**	**fit error**	**gain**	**fit error**	**gain**	**fiterror**
A	1.56	<0.01	1.56	<0.01	1.55	<0.01
B	1.56	<0.01	1.55	<0.01	1.55	<0.01
C	1.58	<0.01	1.58	<0.01	1.56	<0.01
D	1.57	<0.01	1.57	<0.01	1.56	<0.01

Figure 1: Mean-variance plots for quad C, for unbinned mode (left) and 3x3 binned mode (right).



Acknowledgements

Thanks are due to all the WFC3 team members, at GSFC and STScI, who supported the thermal vacuum testing.

References

Baggett, S., “WFC3 Thermal Vac Testing: UVIS Gain Results,” ISR 2005-08, Feb 2005.

Appendix A.

Table 2. Files used for absolute gain determinations. Images were all full-frame, four-amp readouts, with offset=3, CCD temperature of -83^{o} C, gain setting of 1.5. Unbinned data were done with WFC3 electronics side 1 (MEB1) while binned data were done with side 2 (MEB2). Flats were taken with F606W, using the CASTLE tungsten lamp with OSFILT0 and OSFILT2 set to OPEN; the OSFILT1 setting is recorded in the osfilter column. Tabulated are the imagenames, tv number, observation date and time, exposure time, CASTLE OSFILT1, binning mode, and median level (in DN).

imagename	tvnum	observation date	exptime	osfilter	binning	mean (DN)
iu051b02r_08072025818	50946	2008-03-12 2:53:25.06	146.1	ND3	1	75.92
iu051b04r_08072031956	50947	2008-03-12 3:09:51.05	146.1	ND3	1	75.74
iu051b05r_08072031956	50948	2008-03-12 3:15:03.05	146.1	ND3	1	75.785
iu051b07r_08072034134	50949	2008-03-12 3:31:29.06	146.1	ND3	1	75.82
iu051b08r_08072034134	50950	2008-03-12 3:36:41.06	146.1	ND3	1	75.87
iu051b0ar_08072040312	50951	2008-03-12 3:53:07.05	146.1	ND3	1	75.73
iu051b0br_08072040312	50952	2008-03-12 3:58:19.05	146.1	ND3	1	75.605
iu051b0dr_08072042450	50953	2008-03-12 4:14:45.06	146.1	ND3	1	75.52
iu051b0er_08072042450	50954	2008-03-12 4:19:57.06	146.1	ND3	1	75.775
iu051b0gr_08072044126	50955	2008-03-12 4:36:23.05	146.1	ND3	1	75.575
iu051b0jr_08072051343	50957	2008-03-12 5:08:30.06	167.2	ND2	1	784.
iu051b0lr_08072053459	50958	2008-03-12 5:24:44.04	167.2	ND2	1	783.7
iu051b0mr_08072053459	50959	2008-03-12 5:29:45.06	167.2	ND2	1	783.85
iu051b0or_08072055615	50960	2008-03-12 5:46:00.04	167.2	ND2	1	783.2
iu051b0pr_08072055615	50961	2008-03-12 5:51:01.06	167.2	ND2	1	783.1
iu051b0rr_08072061240	50962	2008-03-12 6:07:16.04	167.2	ND2	1	783.55
iu051b0ur_08072063305	50964	2008-03-12 6:29:23.05	76.4	ND1	1	3753.
iu051b0wr_08072065348	50965	2008-03-12 6:44:06.06	76.4	ND1	1	3750.5
iu051b0xr_08072065348	50966	2008-03-12 6:47:34.06	229.3	ND1	1	11276.5
iu051b0zr_08072071710	50967	2008-03-12 7:04:47.05	229.3	ND1	1	11275.
iu051b14r_08072074105	50970	2008-03-12 7:37:52.04	48.4	OPEN1	1	22231.
iu051b29r_08072120132	50997	2008-03-12 11:57:13.06	48.4	OPEN1	1	22293.5
iu051b16r_08072075347	50971	2008-03-12 7:46:58.06	64.4	OPEN1	1	29609.
iu051b17r_08072075347	50972	2008-03-12 7:50:16.04	64.4	OPEN1	1	29597.

imagename	tvnum	observation date	exptime	osfilter	binning	mean (DN)
iu051b1ar_08072081153	50974	2008-03-12 8:08:06.06	80.6	OPEN1	1	37058.5
iu051b1cr_08072083015	50975	2008-03-12 8:22:54.06	80.6	OPEN1	1	37028.
iu051b1fr_08072084853	50977	2008-03-12 8:41:16.04	88.7	OPEN1	1	40825.
iu051b1gr_08072084853	50978	2008-03-12 8:44:58.06	88.7	OPEN1	1	40794.5
iu050202r_08101205248	57311	2008-04-10 20:50:28.04	48.1	ND3	2	95.93
iu050204r_08101205858	57312	2008-04-10 20:56:38.06	48.1	ND3	2	96.095
iu050206r_08101210351	57313	2008-04-10 21:01:31.05	48.1	ND3	2	95.915
iu050208r_08101210842	57314	2008-04-10 21:06:22.04	48.1	ND3	2	95.995
iu05020ar_08101211335	57315	2008-04-10 21:11:15.06	48.1	ND3	2	96.07
iu05020cr_08101211828	57316	2008-04-10 21:16:08.06	48.1	ND3	2	95.855
iu05020er_08101212321	57317	2008-04-10 21:21:01.05	48.1	ND3	2	95.6
iu05020gr_08101212814	57318	2008-04-10 21:25:54.04	48.1	ND3	2	95.995
iu05020ir_08101213307	57319	2008-04-10 21:30:47.06	48.1	ND3	2	95.875
iu05020kr_08101213800	57320	2008-04-10 21:35:40.06	48.1	ND3	2	95.92
iu05020nr_08101215240	57322	2008-04-10 21:50:15.06	53.1	ND2	2	955.5
iu05020pr_08101215823	57323	2008-04-10 21:55:58.04	53.1	ND2	2	955.3
iu05020rr_08101220249	57324	2008-04-10 22:00:24.06	53.1	ND2	2	955.55
iu05020tr_08101220715	57325	2008-04-10 22:04:50.04	53.1	ND2	2	954.55
iu05020vr_08101221141	57326	2008-04-10 22:09:16.06	53.1	ND2	2	954.9
iu05020xr_08101221607	57327	2008-04-10 22:13:42.04	53.1	ND2	2	954.75
iu05020zr_08101222413	57328	2008-04-10 22:18:06.04	265.5	ND2	2	4780.
iu050210r_08101223226	57329	2008-04-10 22:23:48.06	265.5	ND2	2	4781.5
iu050214r_08101224357	57331	2008-04-10 22:35:44.06	76.	ND1	2	14400.5
iu050215r_08101225009	57332	2008-04-10 22:38:20.06	76.	ND1	2	14390.5
iu050217r_08101225009	57334	2008-04-10 22:43:32.06	151.8	ND1	2	28832.
iu050224r_08102002805	57362	2008-04-11 0:20:55.05	151.8	ND1	2	28796.5
iu05021br_08101231022	57336	2008-04-10 22:56:02.04	21.6	OPEN1	2	38274.5
iu05021cr_08101231022	57337	2008-04-10 22:57:44.06	21.6	OPEN1	2	38216.5
iu05021er_08101231022	57339	2008-04-10 23:01:08.06	27.	OPEN1	2	47845.5
iu05021fr_08101231022	57340	2008-04-10 23:02:55.06	27.	OPEN1	2	47885.
iu05021hr_08101231022	57342	2008-04-10 23:06:29.05	29.7	OPEN1	2	52644.
iu05021ir_08101231022	57343	2008-04-10 23:08:19.06	29.7	OPEN1	2	52564.5

imagename	tvnum	observation date	exptime	osfilter	binning	mean (DN)
iu050227r_08102002805	57364	2008-04-11 0:26:41.06	21.4	ND3	3	96.435
iu050229r_08102003428	57365	2008-04-11 0:33:04.04	21.4	ND3	3	96.465
iu05022br_08102003742	57366	2008-04-11 0:36:18.06	21.4	ND3	3	96.525
iu05022dr_08102004056	57367	2008-04-11 0:39:32.04	21.4	ND3	3	96.58
iu05022fr_08102004410	57368	2008-04-11 0:42:46.06	21.4	ND3	3	94.745
iu05022hr_08102004724	57369	2008-04-11 0:46:00.04	21.4	ND3	3	96.19
iu05022jr_08102005038	57370	2008-04-11 0:49:14.06	21.4	ND3	3	96.755
iu05022lr_08102005352	57371	2008-04-11 0:52:28.04	21.4	ND3	3	96.36
iu05022nr_08102005706	57372	2008-04-11 0:55:42.06	21.4	ND3	3	96.225
iu05022pr_08102010020	57373	2008-04-11 0:58:56.04	21.4	ND3	3	96.49
iu05022sr_08102010822	57375	2008-04-11 1:06:56.04	23.6	ND2	3	955.75
iu05022ur_08102011140	57376	2008-04-11 1:10:14.06	23.6	ND2	3	955.45
iu05022wr_08102011424	57377	2008-04-11 1:12:58.06	23.6	ND2	3	955.6
iu05022yr_08102011708	57378	2008-04-11 1:15:42.06	23.6	ND2	3	955.85
iu050230r_08102011952	57379	2008-04-11 1:18:26.06	23.6	ND2	3	955.8
iu050232r_08102012236	57380	2008-04-11 1:21:10.06	23.6	ND2	3	956.45
iu050234r_08102012708	57381	2008-04-11 1:23:54.06	118.	ND2	3	4781.5
iu050235r_08102012957	57382	2008-04-11 1:26:43.05	118.	ND2	3	4783.5
iu05023br_08102014135	57385	2008-04-11 1:39:59.05	33.7	ND1	3	14388.5
iu05023dr_08102014503	57386	2008-04-11 1:43:27.05	33.7	ND1	3	14399.5
iu05023fr_08102015044	57387	2008-04-11 1:46:21.06	67.4	ND1	3	28880.5
iu05023gr_08102015305	57388	2008-04-11 1:48:20.04	67.4	ND1	3	28880.5
iu05023hr_08102015526	57389	2008-04-11 1:50:19.05	89.9	ND1	3	38569.5
iu05023jr_08102015747	57390	2008-04-11 1:52:40.04	89.9	ND1	3	38559.5
iu05023nr_08102020315	57392	2008-04-11 1:57:22.06	112.4	ND1	3	48234.
iu05023pr_08102020559	57393	2008-04-11 2:00:06.06	112.4	ND1	3	48209.5
iu05023tr_08102020854	57395	2008-04-11 02:05:34.06	123.6	ND1	3	53058.0
iu05023vr_08102021149	57396	2008-04-11 02:08:29.06	123.6	ND1	3	53035.5