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Instrument Science Report WFC3 2007-07

WFC3 System Throughput on the UVIS Build 2 detector

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Apr 26, 2007

ABSTRACT
The UVIS spare detector (UVIS build 2) is currently installed in WFC3 during ambient ground testing. We have performed testing of the end-to-end system throughput on the UVIS channel, and find that it performs better than expectations. The result is that the unfiltered (clear) performance of the UVIS spare detector is much closer to that of the flight detector (UVIS build 1). Comparing the 4 chips on the two detectors, chip 2 of the flight detector still offers the best performance, but the performance of the other 3 chips (chip 1 on the flight detector and chips 1 & 2 of the spare detector) are comparable.

Background

The Wide Field Camera 3 (WFC3) is currently undergoing ground testing under ambient conditions. Due to investigations of a lien against the UVIS flight detector (UVIS build 1), the UVIS spare detector (UVIS build 2) is currently installed in the instrument. Among the tests performed in ambient is a preliminary look at the end-to-end system throughput (i.e., the throughput of the entire instrument excluding the filter). These tests are performed at NASA/GSFC using an optical stimulus (called “CASTLE”) that can deliver flux-calibrated monochromatic light to the WFC3 focal plane with a variety of source sizes. The end-to-end system throughput tests are performed with a 200 micron fiber, producing a spot approximately 20 pixels across on the WFC3 CCD. This large spot allows the throughput to be measured more accurately, because it averages over pixel-to-pixel variations in response and allows a large number of counts in the measurement (generally >> 10,000 e-) without approaching the saturation limit of the CCD (80,000 e-). The current tests are very similar to the tests performed during the first thermal vacuum (TV) campaign (see Brown & Reid 2005, ISR WFC3 2005-02 for details). The original TV tests in 2004 encountered CASTLE problems, causing lost measurements at specific wavelengths, such that the test had to be repeated several times to get a clean measurement of the system throughput. The ambient tests run on 2007 April 15 ran flawlessly for each chip. The purpose of this report is to report the preliminary analysis of these tests, and to compare the results for the UVIS spare detector against the UVIS flight detector.

Each UVIS detector consists of two chips. There are various ways the detectors and their chips can be identified, so I summarize this information here. Confusingly, the FITS files for images obtained on the UVIS channel put chip 2 in extension [SCI,1] and chip 1 in extension [SCI,2]. On UVIS build 1, chip 1 is #178 and chip 2 is #18, where these numbers refer to identification numbers used by the GSFC Detector Characterization Lab (DCL). On UVIS build 2, chip 1 is #50 and chip 2 is #40. These chip identifications have been verified by comparing DCL images of the detector (B. Hill, private comm.) against flat-field images taken during the current ambient campaign.

Another factor to keep in mind is the absolute gain. Brown & Reid (2005, ISR WFC3-2005-02) assumed a gain of 1.5 e-/DN when measuring the system throughput of UVIS build 1. Subsequent analysis of the gain (Baggett 2005, ISR WFC3-2005-08) showed that the absolute gain of UVIS build 1 on amps A, B, C, and D, was actually 1.53, 1.52, 1.56, and 1.55 e-/DN, respectively. The system throughput tests for chips 1 and 2 are performed on quadrants read by amps A and C, respectively; these gain values have been assumed for UVIS build 1 in the analysis here (i.e., the chip 1 throughput has been scaled by 1.53/1.5, while the chip 2 throughput has been scaled by 1.56/1.5). Preliminary analysis of the gain values for UVIS build 2, taken during the current ambient campaign, are 1.58, 1.55, 1.65, and 1.61 (for amps A, B, C, and D; S. Baggett, private comm.). Those factors have been applied here to the throughputs for UVIS build 2.

Yet another factor worth checking is the flat-field, which has a fair amount of structure in the UV (see Bushouse 2005, ISR WFC3 2005-21). Inspecting a UV (F275W) flat field obtained in the current ambient campaign, the detector locations used for the throughput measurements with UVIS build 2 appear to be representative of the detector. Performing the same inspection on a UV (F336W) flat field obtained during the 2004 TV campaign, the throughput measurements were also done in regions representative of the detector.

The final uncertainty worth noting is the detector temperature. Nominally the UVIS detector is run at -83 C, but during the current ground tests the detector was run at -54 C, due to issues with the thermoelectric cooler. This may significantly affect the detector QE, particularly at the red end of the response curve.

Results

The results of the ambient tests on UVIS build 2 are given in Table 1 and Figures 1 through 4. As explained above, the throughputs have been corrected to account for the absolute gain on each amp. The throughputs also include a quantum yield correction. The quantum yield correction results from the fact that in the UV, there is a finite chance of producing two electrons on the CCD for one incoming photon. Without a quantum yield correction, a CCD with high quantum efficiency in the UV could appear to have an unphysically high efficiency exceeding unity. The quantum yield correction at a given wavelength w is w/w_c, where w_c is the critical wavelength, 339.68 nm (there is no correction for $w > w_c$).. As with UVIS build 1, the results are close to expectations in the optical (based on component measurements in the lab), but significantly different in the UV. This is due to a problem with the DCL measurements of the detector QE in the UV (see Brown & Reid 2005). The measured throughput of UVIS build 2 on both chips is similar to chip 1 on UVIS build 1.

Table 1: Throughput measurements for UVIS build 2

wavelength (nm)	observed chip 1 throughput	expected chip 1 throughput	ratio	observed chip 2 throughput	expected chip 2 throughput	ratio
200	0.14	0.08	1.76	0.14	0.10	1.38
205	0.13	0.09	1.46	0.14	0.12	1.19
210	0.15	0.11	1.40	0.16	0.14	1.14
215	0.18	0.12	1.46	0.19	0.16	1.18
220	0.24	0.14	1.77	0.26	0.18	1.45
225	0.28	0.16	1.70	0.28	0.21	1.35
230	0.31	0.19	1.67	0.32	0.24	1.32
235	0.34	0.21	1.61	0.34	0.27	1.26
240	0.35	0.24	1.48	0.36	0.30	1.17
245	0.36	0.24	1.46	0.36	0.31	1.15
250	0.35	0.25	1.42	0.35	0.31	1.11
255	0.35	0.25	1.39	0.34	0.31	1.09
260	0.34	0.25	1.34	0.32	0.31	1.05
270	0.30	0.25	1.22	0.29	0.30	0.97
280	0.30	0.26	1.14	0.29	0.31	0.93
290	0.33	0.29	1.15	0.32	0.34	0.93
300	0.36	0.30	1.17	0.34	0.36	0.94

wavelength (nm)	observed chip 1 throughput	expected chip 1 throughput	ratio	observed chip 2 throughput	expected chip 2 throughput	ratio
320	0.36	0.31	1.17	0.35	0.36	0.95
340	0.37	0.31	1.20	0.35	0.36	0.97
360	0.32	0.28	1.15	0.31	0.32	0.96
380	0.34	0.28	1.24	0.33	0.32	1.05
400	0.38	0.33	1.13	0.37	0.35	1.05
450	0.41	0.38	1.07	0.40	0.39	1.03
500	0.42	0.40	1.05	0.42	0.40	1.04
550	0.44	0.42	1.05	0.44	0.42	1.04
600	0.44	0.43	1.03	0.44	0.43	1.03
650	0.44	0.42	1.05	0.44	0.43	1.03
700	0.42	0.38	1.09	0.41	0.39	1.06
750	0.35	0.33	1.06	0.33	0.33	0.99
800	0.27	0.27	0.99	0.28	0.27	1.01
850	0.21	0.23	0.91	0.21	0.22	0.95
900	0.18	0.19	0.95	0.17	0.18	0.93
950	0.11	0.13	0.84	0.11	0.13	0.87
1000	0.05	0.03	1.53	0.05	0.03	1.53

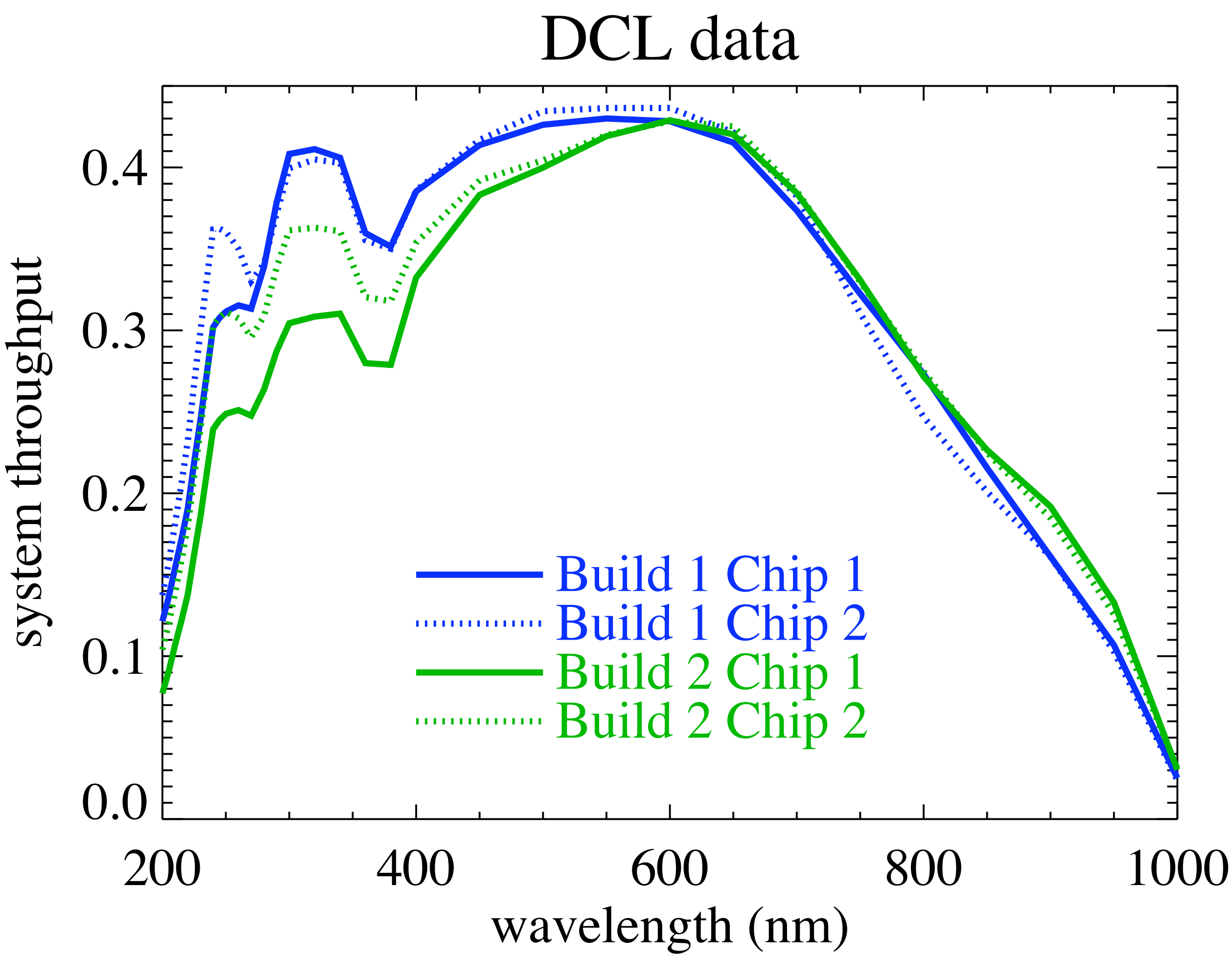

Figure 1: The expected system throughput for the UVIS flight detector (Build 1) and the UVIS spare detector (Build 2), based upon data from the Detector Characterization Lab (DCL) for the CCD chips, and data from Ball Aerospace for the optics. The system throughput is the throughput through the clear aperture (no filter, not the F200LP). The quantum yield correction has been applied. Based upon these curves, we expected the Build 2 performance to be significantly worse than the Build 1 performance in the UV.

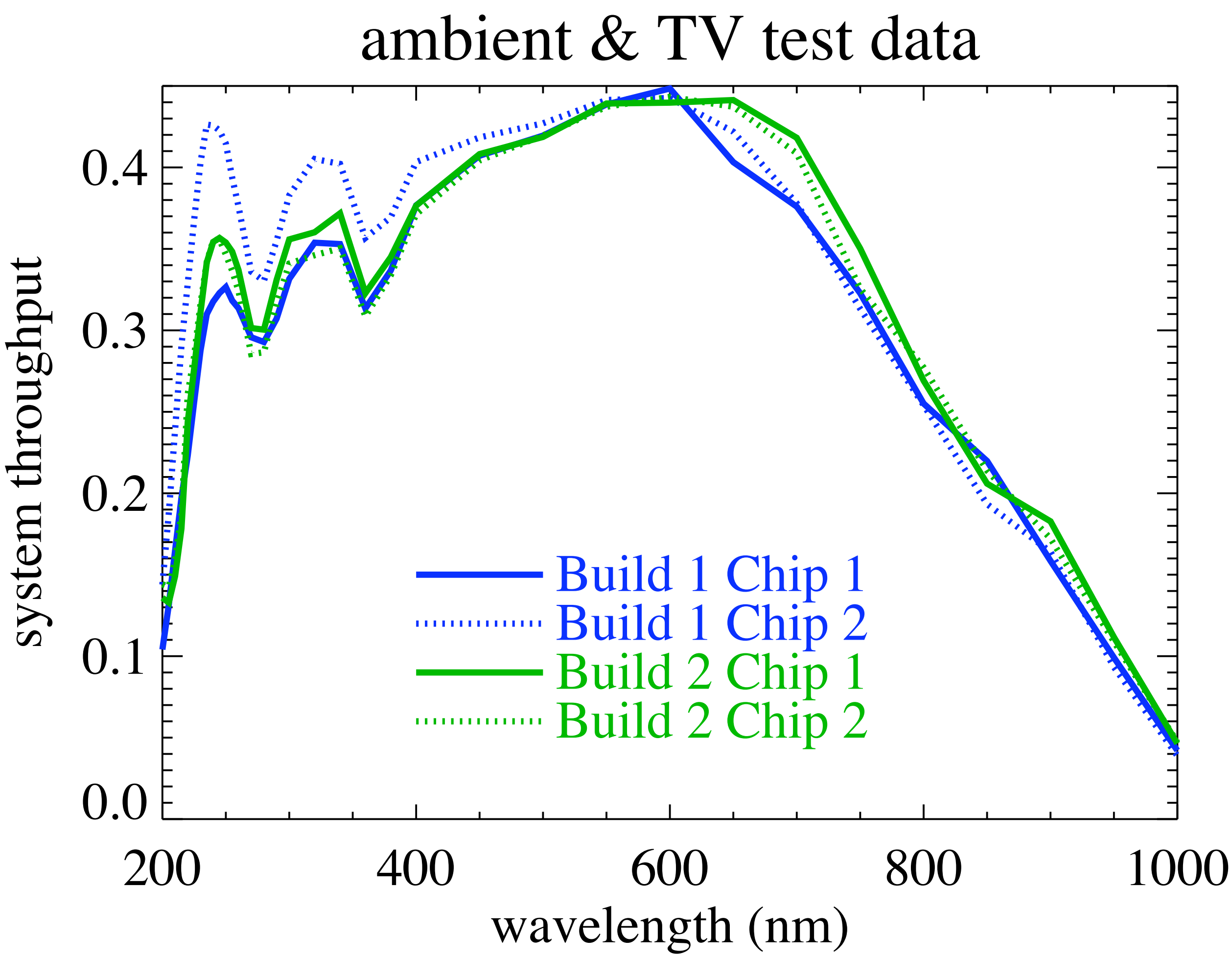

Figure 2: The measured system throughput for the UVIS flight detector (Build 1) and the UVIS spare detector (Build 2), based upon end-to-end throughput tests in 2004 thermal vacuum tests (for Build 1) and 2007 ambient tests (for build 2). The system throughput is the throughput through the clear aperture (no filter, not the F200LP). The quantum yield correction has been applied, and all curves have accounted for the absolute gain differences between detectors. Both chips on Build 2 are at levels similar to Chip 1 on Build 1.

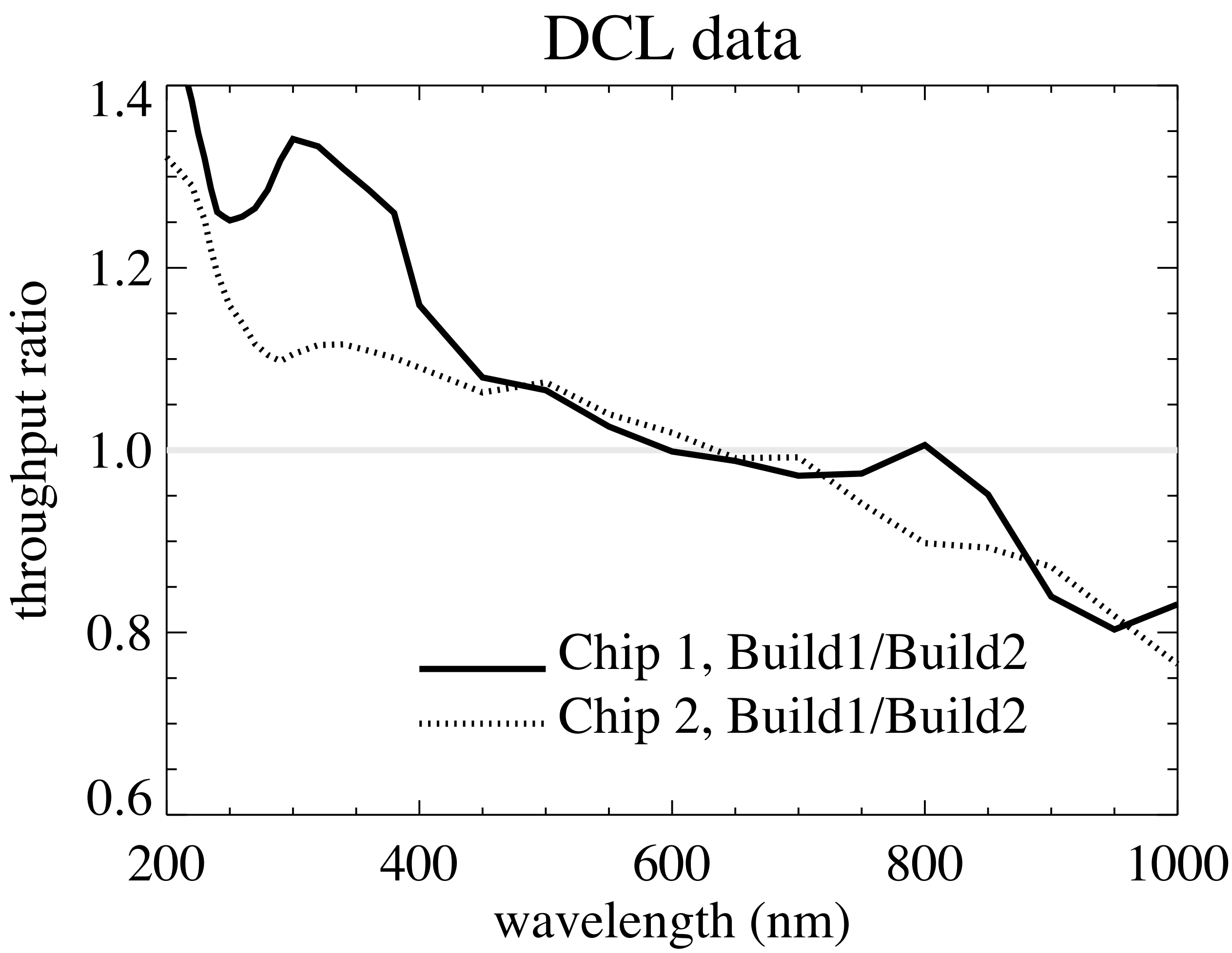

Figure 3: The ratio of throughputs for Build 1 and Build 2, on a chip by chip basis, based upon DCL data for the detector QEs and Ball Aerospace data for the optics. This is an appropriate comparison, because Chip 2 is the better performer in the UV in both datasets.

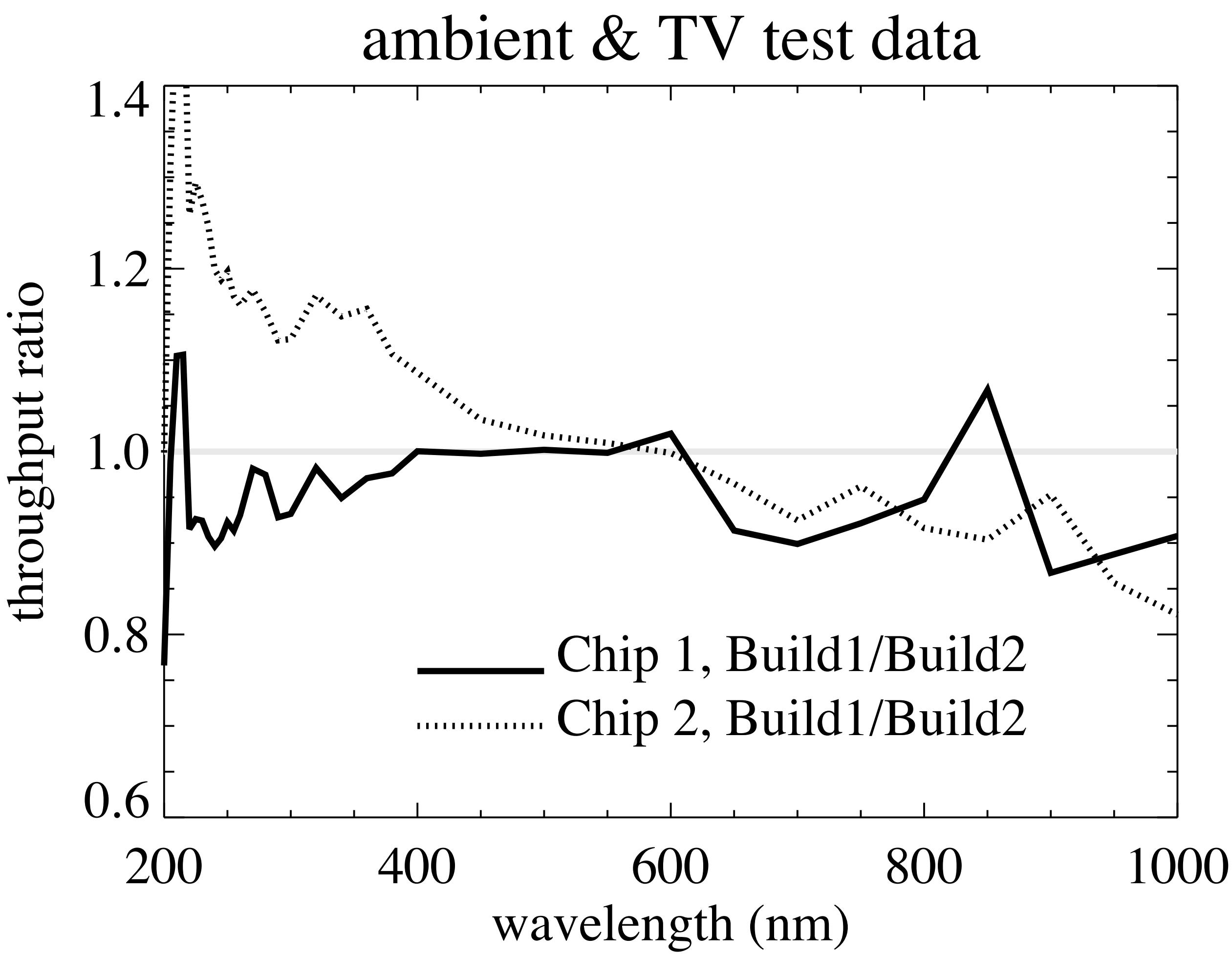

Figure 4: The ratio of throughputs for Build 1 and Build 2, on a chip by chip basis, based upon the measurements in the 2004 thermal vacuum tests (Build 1) and 2007 ambient tests (build 2).