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Testing the On-The-Fly-Calibration System with WFPC2 Data

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ABSTRACT:

We present the methodology and results of the SSD testing performed on WFPC2 observations, calibrated via the new On-The-Fly-Calibration system. A regression set of 83 images was tested, including most WFPC2 modes, along with ~900 recent observations, which were selected randomly on a daily basis.

Introduction:

The OTFC system was developed as a way to significantly reduce the data volume in the HST Archive (Hanisch, et al., 1997), as only uncalibrated data are stored and are calibrated on-the-fly upon request. For WFPC2, the savings in storage can be nearly a factor of 10 (including compression), and the savings will be even greater for other instruments (e.g. ACS). To satisfy retrieval requests for calibrated data, OTFC automatically calibrates the archived raw data with the most up-to-date reference files, tables, and software.

This leads to another motivation for an OTFC system: the scientific need to recalibrate data to take advantage of various and continuing improvements to reference files and tables. In the past, instruments that undergo evolution of calibration files or calibration software often required that users carry out their own recalibrations, or wait until the data could be reprocessed and re-archived by STScI. With OTFC, STScI carries out the recalibration before delivering the data to the user.

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Additionally, problems with specific datasets, such as erroneous keyword values, etc., will now be fixed before data is delivered to users. Instead of reprocessing such data, STScI populates a table (the Keyword Exception Table, or the Data Exception Table), and the OTFC system corrects the keyword, and processes the data correctly.

It should be noted that for WFPC2 observations that have been in the archive for less than about 2 weeks, OTFC will probably calibrate that data with a less than optimal dark file. This results from the fact that it takes over a week for individual darks to be taken, archived, retrieved, and then combined into a pipeline dark. Thus, darks prepared for the week any given observation was taken are not available to either the normal OPUS pipeline, or OTFC, until about 2 weeks after that observation was made.

Many groups at STScI contributed to the development and testing of OTFC. This TIR presents only the SSD/WFPC2 checks performed.

Preliminary Work:

Prior to OTFC's public release in December 1999, all calibration switches for all archival WFPC2 images were checked for correctness. The calibration switches for WFPC2 (e.g., DOPHOTOM, BIASCORR, DARKCORR, etc., total of 8) are set according to the specific image type (e.g., external, earth-calib, kspots, etc.) and exposure time (shorter or longer than 10 seconds). In contrast to some of the other HST instruments, WFPC2 has a relatively limited number of image types, so that by using appropriate database queries, all switches for all images could reasonably be checked. Any such problems identified were either fixed via reprocessing and rearchiving the image at STScI (thereby fixing the calibration switches in the raw headers), repaired by inserting appropriate entries into the KET/DET, or deemed no longer an issue: new pipeline code since the image was last processed in OPUS would now automatically fix the problem.

In addition, further checks were performed on any keyword used to set the calibration switches, e.g., mode, gain, filter names, and so on. For example, all external exposures equal to or shorter than 10 sec. require a shutter shading correction; for the code to determine the proper shading file to use, the shutter keyword must be populated correctly. NULL, as was used early in the mission, is not an acceptable option (in this case, the images were reprocessed and rearchived, though they could also have been fixed via the KET).

Where possible, the calibration-related keywords were checked against an independent source. For example, filter names in the raw science header were cross-checked with filter numbers available in the standard header data and filter combinations were manually evaluated for any obviously non-physical combinations (two filters on the same wheel, polarizer used without second filter, etc.).

A crucial step in OTFC is the selection of the best reference files to use during calibration; reference file keywords were carefully checked for all archival images. This included comparing used reference filenames (used at the time of the original OPUS processing) and the new (as recommended by **bestref**) reference filenames. For example, some early images initially processed without the necessary reference files (they were manually forced through calibration in OPUS; used reference filenames were null or n/a). These images all have the appropriate reference files now, so that if they were requested through OTFC, they would calibrate without difficulty. All such images were also requested through OTFC at least once, to ensure that the new files would be picked up without difficulty.

Spot-checks of the USEAFTER keyword mechanism in **bestref** were also done. In **bestref**, the best reference file recommended for calibration is identified as the reference file with a USEAFTER date as close in time before the observation was taken. Various types of reference files, with a variety of USEAFTER dates, were checked against the images claiming them as the best reference files; that is, the USEAFTERs of the reference files were verified to be propagating correctly into the appropriate images. In addition, a spot-check of images from a variety of epochs verified that the reference files being recommended as best were indeed those intended as best.

Finally, all known WFPC2 image header keyword problems, such as those traditionally tracked in the WWW WFPC2 History file (`http://www.stsci.edu/instruments/wfpc2/Wfpc2_memos/wfpc2_history.html`), were checked. Even if the keywords involved were not strictly calibration-related (e.g., pointing keywords), fixes were installed in the KET to correct the headers. OTFC will thus provide not only the best possible calibration of the data but also corrected header information.

Selection of the Regression Test Datasets:

For our test, we have selected a large, representative sample of WFPC2 observations taken over the instrument’s lifetime, all of which were re-calibrated “by hand”, and also retrieved thru a test OTFC system. The resulting calibrated datasets were carefully checked against each other to ensure consistency between the two methods, and thus prepare the way for the official release of OTFC to the public. In this and the following section, we describe the selection criteria for our test observations.

Normal WFPC2 Observations:

The WFPC2 was designed to operate in many different observational modes, representing various combinations of filters, exposure times, gain, shutter, serial clocks, etc. Although not technically a mode, exposure time was a selection criterion since short exposures will be affected by shutter shading effects, thus we wanted to make sure we included such exposures in our testing. We compiled a list of the distribution of WFPC2 modes in the HST Archive. This list is available at:

`http://www.stsci.edu/instruments/wfpc2/Wfpc2_memos/wfpc2_exposures.html`

From this list we selected at least one dataset for each mode with 100 or more observations in the archive. Note: for OTFC testing purposes, we consider a WFPC2 mode to be specified by filters, gain, serial clocks, area/full readout, and exposure time. Observations of this type were included in our daily testing, as described later in this section. This list of WFPC2 datasets, however, does not include information as to whether or not any given dataset has a corrupted header, incorrect header keyword values, or other pre- or post-processing problems. In order to check if OTFC will correctly process such data, we compiled separate lists of datasets with known problems.

KET/DET Observations:

The KET (Keyword Exception Table), is a listing of all observations in the archive with incorrect keyword values, such as wrong filter number, shutter value, etc. This list contains approx. 700 datasets. The vast majority are incorrect filter names, which occurred with rotated filters early in the mission, and pointing related keywords. We selected 8 observations from this list.

The DET (Data Exception Table), contains 11 WFPC2 images are in the bypass-calibration table. These 11 images contain garbled observation dates, including several with corrupted data, and are flagged to bypass calibration. See Table 1, where pstrtime=predicted observation start time (yyyy.ddd:hh:mm:ss), and expstart=exposure start time. One of these images is in the regression set.

Note: although these observations are in the DET, users can still retrieve the raw data and attempt to repair/reprocess that data on their own.

Calibration Switches:

Hundreds of WFPC2 observations have erroneous calibration switches. These switches tell the calibration software to either perform or omit a certain calibration step. Thirteen observations with this error are in the regression set.

Observations using less than One Chip:
Users of WFPC2 have the option of only reading out a subset of chips. To ensure that OTFC can handle such data, we selected 7 single-chip observations.

Table 1. WFPC2 Observations in the OTFC Bypass-Calibration Table.

Dataset Name	Proposal	Target	Pstrtime	Expstart
U29J1801T	5584	LMC-30DOR-C-POS7	1995.008:07:38:39	17 Nov 1858 12:00
U2A31V08P	5570	EARTH-CALIB	1994.162:10:01:39	30 Nov 1989 11:00
U2G40602P	5663	NGC5139	1994.206:13:25:38	30 Nov 1989 11:00
U2I10207T	5678	HD32228	1994.262:23:57:39	30 Nov 1989 11:00
U2MM0K03T	6140	EARTH-CALIB	1995.058:05:23:39	30 Nov 1989 11:00
U2PQ0702T	6276	NGC6251	1995.179:01:57:39	30 Nov 1989 11:00
U2SA8402T	6119	LO1	1995.228:03:33:39	30 Nov 1989 11:00
U2SL0F07T	6250	INTFLAT	1995.276:00:48:39	30 Nov 1989 11:00
U2SL1708T	6250	INTFLAT	1996.034:01:49:39	30 Nov 1989 11:00
U2XK2G03T	6187	EARTH-CALIB	1996.025:20:20:39	30 Nov 1989 11:00
U3EK0307M	6909	EARTH-CALIB	1996.231:02:15:39	17 Nov 1858 12:00

With a sample of “problem” datasets already selected, we then chose 25 “normal” datasets with various combinations of filters, obs. mode, etc., to fill out the test suite. These 83 datasets form our regression test set, and this set is listed in Table 2.

Selection of the Daily Testing Set:

Along with the regression set, we also tested, on average, several images per day, before and after the public release of OTFC. These images were randomly selected from the archive, with the only criterion being that the OTFC processed data and the normal pipeline processed data used the same reference files. This was done to provide additional testing without tedious manual recalibrations.

Finally, we reviewed the master list of all WFPC2 data in the archive, and we identified several very infrequently used modes and filter combinations that had not yet been selected. While not strictly part of the daily testing, this gave us a further 16 datasets to check.

Table 2. Regression Test Set.

Dataset Name	Image Type	Gain	Serials	Filter 1	Filter 2	Shutter	Exptime	Readout Mode
U20L0U02T	KSPOTS	7	OFF	NULL	NULL	NULL	2.60	FULL
U21Y0103T	BIAS	15	OFF	F437N	F1042M	A	0.00	FULL
U21Y010AT	INTFLAT	15	OFF	F555W	NULL	A	23.0	FULL
U21Y0205T	VISFLAT	15	OFF	F439W	NULL	A	80.0	FULL
U21Y0503T	VISFLAT	7	OFF	F555W	NULL	A	0.110	FULL
U21Y0707T	KSPOTS	15	OFF	F437N	F1042M	NULL	1.00	FULL
U21Y0A01T	BIAS	7	OFF	F673N	NULL	NULL	0.00	FULL
U21Y0A09P	INTFLAT	15	OFF	F555W	NULL	B	23.0	FULL
U21Y0B01T	VISFLAT	15	OFF	F555W	NULL	A	3.00	FULL
U21Y0B02T	VISFLAT	15	OFF	F555W	NULL	B	3.00	FULL
U21Y0B05T	VISFLAT	15	OFF	F439W	NULL	NULL	80.0	FULL
U21Y0L02T	DARK	7	OFF	F437N	F1042M	NULL	80.0	FULL
U22P0106T	NGC188	15	OFF	F555W	NULL	A	1.0	FULL
U22T0102T	NGC5139	15	OFF	F547M	NULL	NULL	26.0	FULL
U22T0206T	A+81D266	15	OFF	F130LP	F122M	NULL	26.0	FULL
U22T5101T	NGC5139	15	OFF	F300W	NULL	NULL	600.0	FULL
U22T5102T	NGC5139	15	OFF	F547M	NULL	NULL	26.0	FULL
U22U6501T	M67	15	OFF	F555W	NULL	B	40.0	FULL
U2310C05T	A+81D266	15	OFF	F170W	NULL	B	3.00	FULL
U2310T01P	KSPOTS	7	OFF	F437N	F1042M	NULL	2.60	FULL
U2310T02P	DARK	15	OFF	F437N	F1042M	NULL	20.0	FULL
U2320101T	EARTH-CAL	15	OFF	F218W	NULL	NULL	500.0	FULL
U2320404T	EARTH-CAL	15	OFF	F656N	NULL	B	0.350	FULL
U2320601T	EARTH-CAL	15	OFF	F336W	NULL	B	0.160	FULL
U23I0107T	DARK	15	OFF	F437N	F1042M	B	1.0	FULL
U23T0201T	GAL-CLUS	7	OFF	F702W	NULL	NULL	2100.0	FULL
U23X0102T	2141+175	7	OFF	F702W	NULL	NULL	140.0	FULL
U2410507P	ETA-CAR	15	OFF	F375N	NULL	B	0.110	FULL
U2410509P	ETA-CAR	7	ON	F375N	NULL	B	4.0	FULL
U2440101T	NGC1976	7	OFF	F656N	NULL	NULL	350.0	FULL

Dataset Name	Image Type	Gain	Serials	Filter 1	Filter 2	Shutter	Exptime	Readout Mode
U2480F01T	WFC2-CEN	15	OFF	F555W	NULL	B	1.00	FULL
U24Z0101T	M101	7	OFF	F502N	NULL	B	2000.0	FULL
U26M1201T	NGC1860	15	OFF	F450W	NULL	A	80.0	FULL
U28U6N01T	DARK	7	OFF	F1042M	F437N	A	1800.0	FULL
U29N0B01T	BIAS	7	OFF	F502N	NULL	B	0.00	FULL
U29N0B03T	INTFLAT	7	OFF	F555W	NULL	B	10.0	FULL
U29N2P09T	KSPOTS	15	OFF	F555W	NULL	B	1.00	FULL
U2BX0601T	NGC1952	7	ON	F170W	NULL	B	2000.0	AREA
U2EB0101T	SL-17	7	OFF	F702W	NULL	A	800.0	FULL
U2EB0302T	SL-5	7	OFF	F702W	NULL	B	800.0	FULL
U2EQ0201T	JUPITER	7	OFF	F673N	NULL	B	0.230	AREA
U2EU0402T	NEPTUNE	7	OFF	FQCH4N15	NULL	A	350.0	FULL
U2FU0401T	TX0828+193	7	OFF	F555W	POLQ	B	1000.0	FULL
U2H50805T	MARS-OPP	7	OFF	F336W	NULL	A	6.00	FULL
U2IH0104T	HD39060	15	ON	F555W	POLQN33	A	26.0	FULL
U2KE0403T	COMET-B	7	ON	F675W	NULL	B	10.0	FULL
U2L90305P	MARK463E	7	OFF	F439W	POLQN33	A	230.0	FULL
U2LS0202M	NGC6995-A	7	OFF	F502N	NULL	B	2000.0	FULL
U2MM0F09T	EARTH-CAL	15	OFF	F502N	FR533N18	B	1.20	FULL
U2OL0O0CT	DARK	7	OFF	F1042M	F437N	A	1800.0	FULL
U2QQ8001T	VISFLAT	7	OFF	F336W	NULL	A	600.0	FULL
U2SA8101T	K1-14	15	OFF	F814W	NULL	A	500.0	FULL
U2SU030BT	MMJ6504	7	OFF	F606W	NULL	B	2.0	FULL
U2UT1101T	UVFLAT	7	OFF	F160BW	NULL	A	1000.0	FULL
U2W90404R	A1689-4	7	OFF	F814W	NULL	B	1200.0	FULL
U307140AT	NGC2300	15	OFF	F814W	NULL	A	230.0	FULL
U30K0106T	HR-8728	15	ON	F555W	NULL	A	40.0	FULL
U30T0101T	V1L4	7	OFF	F300W	NULL	A	500.0	AREA
U30T0201P	V2L8	7	OFF	F300W	NULL	B	500.0	AREA
U31T0803T	HDF-123634	7	OFF	F814W	NULL	A	900.0	FULL
U31Z0201T	3C303.1	7	OFF	FR680N	NULL	B	1400.0	FULL
U37G030AR	TER8	7	OFF	F555W	NULL	B	0.50	FULL

Dataset Name	Image Type	Gain	Serials	Filter 1	Filter 2	Shutter	Exptime	Readout Mode
U38N0402M	IO-LON160	15	OFF	F410M	NULL	A	10.0	FULL
U3AV240FT	DARK	7	OFF	F1042M	F437N	A	1800.0	FULL
U3AV2503R	BIAS	15	OFF	F814W	NULL	B	0.00	FULL
U3AV3009R	KSPOTS	15	OFF	F555W	NULL	A	1.00	FULL
U3B3010DM	HEN401	7	ON	F606W	POLQ	A	200.0	FULL
U3EK0701M	EARTH-CAL	15	OFF	F343N	NULL	B	14.0	FULL
U3I2030CM	P041-C	15	OFF	F336W	NULL	A	35.0	FULL
U3I9050JR	G191B2B	15	OFF	F439W	POLQ	A	4.0	FULL
U3I90511R	G191B2B	15	OFF	F300W	POLQN33	A	4.0	FULL
U3I9A207R	G191B2B	15	OFF	F555W	POLQ	A	1.20	FULL
U3IK010BT	BD+75D325	15	OFF	F122M	F130LP	B	10.0	FULL
U3JG070BT	WD2126+734	15	OFF	F122M	F130LP	B	100.0	FULL
U3JJ5103R	SATURN-150	7	OFF	FQCH4P15	NULL	B	80.0	FULL
U3KG0107R	NGC6752-TO	15	ON	F439W	NULL	B	1100.0	FULL
U3LU0202R	XZ-TAU	7	OFF	F675W	NULL	B	6.0	FULL
U3M00209R	MARS-ATM	15	OFF	FR868N	NULL	B	1.0	FULL
U3MA0201R	UZ-TAU	15	OFF	F569W	NULL	A	10.0	FULL
U3MA020IR	UZ-TAU	15	OFF	F631N	NULL	B	1000.0	FULL
U41G021ZR	JUPITER	15	OFF	F336W	NULL	A	3.50	FULL
U460A202R	PKS0745-191	7	OFF	FR680N	NULL	A	1100.0	FULL
U4720101R	UVFLAT	7	OFF	F160BW	NULL	A	1000.0	FULL

Analysis:

The first rounds of OTFC testing were restricted to the regression set described above. A request list of the datasets was sent to the HST archive, whereupon we would receive the uncalibrated files, the original calibrated files, and the best reference files for each observation. Simultaneously, we would send the same request list to the then test OTFC system. From this we would receive only OTFC calibrated data.

The datasets from the archive, hereafter referred to as “pipeline” files, were then all carefully recalibrated “by hand”, updating calibration switches and reference filenames as necessary and using the most up-to-date reference files and tables. These newly calibrated pipeline files were then ready to be checked against the same datasets as processed by the OTFC system.

The first round of testing was a simple differencing of headers, and comparing data via the statistical results from **wstat**. The results from **wstat** were useful as a quick error check - if the statistics for a dataset were vastly different between the pipeline and OTFC, it was immediately apparent that there was a problem. The header differences would usually pinpoint any such calibration error. All properly re-recalibrated datasets agreed with the OTFC data.

The header differences would occasionally reveal other keyword problems that would not affect the calibration steps. One such discrepancy was that of the MIR_REVR keyword. The header differences indicated that all of the pipeline calibrated files had MIR_REVR set to ‘T’, while only about half of the OTFC set were ‘T’, the remainder set to ‘F’. Through much investigation, it turned out to be the IRAF task **strfits** that was causing the problem, and thus not related to OTFC or the pipeline.

Even after we were satisfied that the headers were in agreement, etc., we were concerned that the **wstat** results did not *exactly* match. For example:

```
# Image statistics for 'OTFC/u21y0b02t.c0h' with no mask
#GROUP  NPIX   MIN     MAX     MEAN    MIDPT  MODE   STDDEV
[1] 640000 -0.781997 3066.41 576.181 643.98 667.15 196.97
[2] 640000 -1.43901  3780.89 2437.1  2681.7 2756.1 730.68
[3] 640000 -0.050978 3795.41 2478.48 2745.  2771.1 776.24
[4] 640000 -1.45318  3792.43 2405.79 2698.3 30.509 809.28

# Image statistics for 'PIPE/u21y0b02t.c0h' with no mask
# GROUP NPIX    MIN   MAX     MEAN    MIDPT  MODE   STDDEV
[1] 640000 -0.781152 3063.39 575.562 643.28 666.37 196.76
[2] 640000 -1.43694  3775.73 2433.53 2677.8 2752.2 729.62
[3] 640000 -0.050944 3790.95 2475.82 2742.  2768.  775.4
[4] 640000 -1.45206  3790.89 2404.09 2696.4 30.526 808.7
```

We suspected that these discrepancies were due to the noisy pyramid edges. But to be certain, we needed a testing method which would compare data values in the scientifically useful portions of the chips, thus ignoring the pyramid regions. J.C. Hsu developed a python routine, called **fitsdiff**, which would make a detailed comparison of the headers, group parameters, and the image data, in FITS format. Not only did this save the step of conversion to GEIS, but **fitsdiff** compared images pixel-by-pixel. This allowed a way to automate the testing procedure, specifying the number of pixels per chip to test (and thus separate out the pyramid regions), and gave us a way to test data on a weekly or even daily basis.

Our daily testing consisted of sending an SQL query to the archive requesting a list of all WFPC2 observations archived about 2 weeks prior. Ten datasets per day were selected from this list, and the data retrieved from the HST archive, and also from the OTFC system. Upon receipt of the data, the headers were checked to ensure that the reference files used by both the pipeline and OTFC were the same. The only reference files expected to differ were darks, as the most up-to-date darks are not usually available for about 2 weeks after any given observation was taken. This check was done to prevent manual recalibrations, and any datasets that did not have the same reference files were discarded from the test.

The data were then compared thru **fitsdiff**, which generated a large output file. The output contained any header differences, a pixel-by-pixel list of differing data values, the percentage difference, and the total number of pixels with differences for each dataset. We found no problems during our daily testing.

Conclusions:

We have tested ~980 WFPC2 datasets, calibrated with the normal HST pipeline, and the new OTFC system. A core regression set of 83 images were carefully selected to include the most used WFPC2 observational modes, and ~900 were randomly selected from the archive on a daily basis, and tested against the same sets of observations as processed by OTFC. From the results of the regression test, the daily testing, the database testing, and the **bestref**/USEAFTER checks, we found no major problems. Minor issues have arisen but these are being handled via additional KET entries or software fixes (details will be tracked in the WFPC2 History File: `http://www.stsci.edu/instruments/wfpc2/Wfpc2_memos/wfpc2_history.html`). In conclusion, we find that the OTFC system properly calibrates WFPC2 data, taking into account all known keyword, calibration switches, and other known data problems.

Other OTFC Documentation:

OTFC News, which includes links to design documents, users guide, requirements, etc.:
`http://www.dpt.stsci.edu/otfc/`

OTFC Project, including status, change system, getref/upref, pipeline, etc.:
`http://www.dpt.stsci.edu/otfc/otfc_index.html`

A few final items nearing completion:
`http://sesd.stsci.edu/~hopkins/STIS%20and%20WFPC2--Testing%20in%20the%20OTFC%20era.htm`

OTFC summary in the recent AAS meeting poster:
`http://www.stsci.edu/instruments/wfpc2/wfpc2_doc.html#Meet`

STScI OTFC Site:
`http://www.dpt.stsci.edu/otfc/external/otfc_index.html`

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