

Calibrating WF/PC-1 Data

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45.1 Overview of Pipeline Processing

The data were received from the Space Telescope Data Capture Facility by the Post Observation Data Processing System (PODPS). There they were passed to Routine Science Data Processing (RSDP)—referred to as the *pipeline*—to be processed and calibrated. All of the steps performed by the pipeline were recorded in the trailer file for the dataset. Figure 45.1 shows an example of a trailer file and identifies comments made during the following pipeline steps:

1. The data were partitioned (separated into individual files, e.g., the engineering and science data are separated).
2. The data were edited to insert fill values in place of missing data.
3. The data were evaluated to determine discrepancies between the subset of the planned and executed observational parameters.
4. A list of calibration reference files to be used in the calibration of the data was created based on the executed observational parameters. This step did not generate comments in the example trailer file.

5. The data were converted to a generic format and the header keywords populated.
6. The data were calibrated using a standard WF/PC-1-specific calibration algorithm (STSDAS task **calwfp**).

Figure 45.1: Sample Trailer File

```

DPPBAN-***** TRAILER FILE *****
DPPSTA----- DATA PARTITIONING STARTED -----
DPPSTR-DATA PARTITIONING STARTED: 23-AUG-93 14:12:38
DPP OBS-Observation Identification: Program Number 1DR , Observation Set Number 08 , Observation Number 06
DPPCAT-Msg Artifacts Catalog: DCF Msg 12 contained data for Info Set File with Root Name of W1DR0806T
DPPIST-Missing pkts processing is complete, processed 3200 science pkts, detected 0 as missing
DPVWML-Weighted Quality Measure of 0 was calc for errors reported in Quality & Acctg Capsule entries for Info Set
DPPNPR- 3201 packets expected, 3201 packets received ( 1 SHPs, 0 UDLs, 0 Bad pkts) for Info Set W1DR0806T
DPPEND-DATA PARTITIONING ENDED: 23-AUG-93 14:23:31 .
DPPFIN----- DATA PARTITIONING COMPLETED -----
CPEOST----- DATA EDITING STARTED -----
CPESTR-DATA EDITING STARTED 23-AUG-93 14:23:47 FOR W1DR0806T.
DPE4PC- 0 fill source packets were inserted by PODPS.
DPE4DC-In W1DR0806T, 0 source packets were found that contain fill data inserted by the ST DCF.
DPERSC-CP34SE: ...and 0 packets were found to have segments without Reed Solomon corrections
CPEEND-DATA EDITING ENDED 23-AUG-93 14:23:47 FOR W1DR0806T.
CPEOEN----- DATA EDITING COMPLETED -----
CPGOVS----- DATA EVALUATION STARTED -----
DPVSTR-DATA EVALUATION STARTED 23-AUG-93 14:23:55 FOR W1DR0806T.
DPVEND-DATA EVALUATION ENDED 23-AUG-93 14:24:22 FOR W1DR0806T.
DPVWML-Weighted Quality Measure of 0 was calc for discrepancies between predicted & actual Flags & Indicators for Info Set
DPVOKK-Info Set quality was OK as Weighted Quality Measure of 0 did not exceed Quality Threshold of 9
CPGOVE----- DATA EVALUATION COMPLETED -----
CGAI00-----
CGAI01-----WIDE FIELD AND PLANETARY CAMERA GENERIC CONVERSION BEGINNING-----
CGAI00-----
CGAT01-Routine CGWFPC, version 32.0.D , will perform generic conversion
CGAT02-GENERIC CONVERSION BEGINNING: processing information set W1DR0806T
CGAT03-CGWFPC START: 23-AUG-93, 14:24:22
CGAW06-No error values detected in flags and indicators
CGAI06-SHP generic conversion has completed successfully
CGAC02-Generated new WFPC reference file catalog : CCC:[SIS.WFPC]W1DR0806T.CTX
CGAI08-SCI generic conversion has completed successfully
CGAI22-DQM generic conversion has completed successfully
CGAT04-GENERIC CONVERSION TERMINATING: successful completion
CGAT09-CGWFPC END: 23-AUG-93, 14:29:08
CPGOEN----- GENERIC CONVERSION COMPLETED -----
#####
##### This observation was reprocessed through the RSDP pipeline
##### because they were unreadable on the DMF disks. This allows
##### the data to be ingested into DADS for later/future retrievals
#####
##### 26-APR-1995 Mk
#####
CPEOST----- DATA EDITING STARTED -----
CPESTR-DATA EDITING STARTED 26-APR-95 18:05:56 FOR W1DR0806T.
DPE4PC- 0 fill source packets were inserted by PODPS.
DPE4DC-In W1DR0806T, 0 source packets were found that contain fill data inserted by the ST DCF.
DPERSC-CP34SE: ...and 0 packets were found to have segments without Reed Solomon corrections
CPEEND-DATA EDITING ENDED 26-APR-95 18:05:56 FOR W1DR0806T.
CPEOEN----- DATA EDITING COMPLETED -----
CPGOVS----- DATA EVALUATION STARTED -----
DPVSTR-DATA EVALUATION STARTED 26-APR-95 18:16:57 FOR W1DR0806T.
DPVEND-DATA EVALUATION ENDED 26-APR-95 18:17:10 FOR W1DR0806T.
DPVWML-Weighted Quality Measure of 0 was calc for discrepancies between predicted & actual Flags & Indicators for Info Set
DPVOKK-Info Set quality was OK as Weighted Quality Measure of 0 did not exceed Quality Threshold of 9
CPGOVE----- DATA EVALUATION COMPLETED -----
CGAI00-----
CGAI01-----WIDE FIELD AND PLANETARY CAMERA GENERIC CONVERSION BEGINNING-----
CGAI00-----
CGAT01-Routine CGWFPC, version SOGS35.3.A , will perform generic conversion
CGAT02-GENERIC CONVERSION BEGINNING: processing information set W1DR0806T
CGAT03-CGWFPC START: 26-APR-95, 18:17:10
CGAW06-No error values detected in flags and indicators
CGAI06-SHP generic conversion has completed successfully
CGAC02-Generated new WFPC reference file catalog : CCC:[SIS.WFPC]W1DR0806T.CTX
CGAI08-SCI generic conversion has completed successfully
CGAI22-DQM generic conversion has completed successfully
CGAT04-GENERIC CONVERSION TERMINATING: successful completion
CGAT09-CGWFPC END: 26-APR-95, 18:20:33
CPGOEN----- GENERIC CONVERSION COMPLETED -----
CCAI00-----
CCAI01-----WIDE FIELD AND PLANETARY CAMERA CALIBRATION BEGINNING-----
CGAI00-----
CCAI07-CALIBRATION BEGINNING: processing information set W1DR0806T
CCAI11-CCWFPC START: 26-APR-95, 18:45:08
CCAIRI- --- Message From: CALWFP While Processing:
CCAIRI- --- Message: WF/PC Calibration Starting: CALWFP Version 1.2.1
CCAIRI- --- Message From: CALWFP While Processing: W1DR0806T
CCAIRI- --- Message: Starting CALWFP: Input = wcal:w1dr0806t Output = wcal:w1dr0806t
CCAIRI- --- Message From: CALWFP While Processing: W1DR0806T
CCAIRI- --- Message: Start Process Element 1
CCAIRI- --- Message From: CALWFP While Processing: W1DR0806T
CCAIRI- --- Message: Start Process Element 2
CCAIRI- --- Message From: CALWFP While Processing: W1DR0806T
CCAIRI- --- Message: Start Process Element 3
CCAIRI- --- Message From: CALWFP While Processing: W1DR0806T
CCAIRI- --- Message: Start Process Element 4
CCAIRI- --- Message From: CALWFP While Processing: W1DR0806T
CCAIRI- --- Message: WF/PC Calibration Ending for observation
CCAI10-CALIBRATION END: 26-APR-95, 18:54:35

```

1 Partitioning

2 Editing

3 Evaluation

4 Conversion

5 Comments, if any

6 Calibration

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The calibration software used by the pipeline is exactly the same as that provided within STSDAS (**calwfp**). The calibration files and tables used were taken from the Calibration Data Base (CDBS) at STScI and were the most up-to-date calibration files available at the time the data was processed. All CDBS files are available to users through the HST Data Archive.

45.2 Calibration of WF/PC-1 Data

WF/PC-1 science data was calibrated in the pipeline using **calwfp**, available under the **hst_calib** package. By using this IRAF/STSDAS task, the data can be recalibrated using the same software used in the routine calibration pipeline.¹

The calibration software takes as input the raw WF/PC-1 data file pairs (Table 44.1 on page 44-2) `d0h/d0d`, `q0h/q0d`, `x0h/x0d`, `q1h/q1d` and any necessary calibration reference images or tables. The software determines which calibration steps to perform by looking at the values of the calibration switches (e.g., MASKCORR, BIASCORR, etc.) in the header of the raw data (`.d0h`) file. Likewise, it selects the reference files to use in the calibration of the data by examining the reference file keywords (e.g., MASKFILE, BIASFILE, BIASDFILE, etc.). The appropriate values of the calibration switches and reference file keywords depend on the instrumental configuration used, the date when the observations were taken, and any special pre-specified constraints. They were initially set in the headers of the raw data file in the RSDP pipeline during generic conversion; for recalibrating, they can be redefined (using **hedit** for example) and **calwfp** run on the raw files.

To determine what calibration steps the pipeline applied to the data and which calibration reference files were used to calibrate the data, examine the values of the calibration switches in the header of the raw (or calibrated) data. Prior to calibration, the calibration switches will have the value YES, NO, or PERFORM. After calibration, the switches for completed steps will have been assigned the value COMPLETE in the header keywords of the calibrated data file.

As with other header keywords, the calibration keywords can be viewed using any of several tasks, for example, **imhead**, **hedit**, or **hselect**. Alternately, the **chcalpar** task in the STSDAS **tools** package can be used to view the calibration keywords directly.

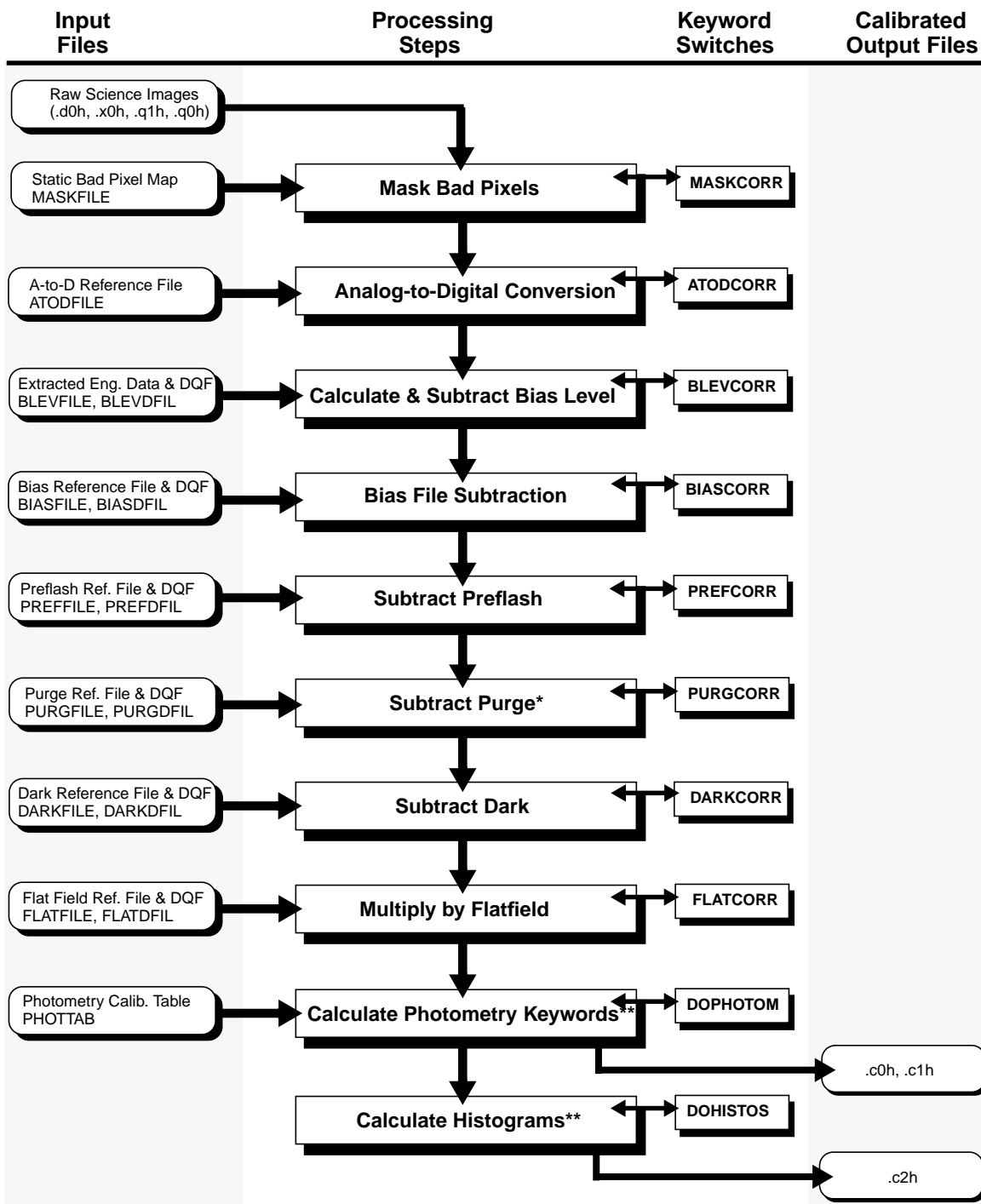
1. Online details about the WF/PC-1 calibration pipeline are available from within the IRAF help system using the `opt=sys` argument, type: `help wfpc opt=sys`



There are history records at the bottom of the header file of the calibrated data (as well as the calibration reference file headers). These history records sometimes contain important information regarding the reference files used to calibrate the data in the pipeline.

The flow chart below summarizes the sequence of calibration steps performed by **calwfp**, including the input calibration reference files and tables, and the output data files from each step. The purpose of each calibration step is briefly described in the accompanying table; a more detailed explanation is provided in the following section.

Figure 45.2: Pipeline Processing by calwfp



* Purge subtraction was never implemented
 ** This step does not change the science data

Table 45.1: Calibration Steps and Reference Files Used for WF/PC-1 Pipeline Processing

Switch	Processing Step	Reference File
MASKCORR	Update the data quality file using the static bad pixel mask reference file (MASKFILE), which flags defects in the CCD that degrade pixel performance and that are stable over time.	mask file (r0h)
ATODCORR	Correct the value of each pixel for the analog-to-digital conversion error using information in the A/D lookup reference file (ATODFILE).	atod file (r1h)
BLEVCORR	Subtract the mean bias level from each pixel in the science data. Mean values are determined separately for even column pixels (group parameter BIASEVEN) and odd column pixels (BIASODD) because bias levels exhibit column-wise pattern that changes over time.	extracted engineering file (x0h/ q1h)
BIASCORR	Subtract bias image reference file (BIASFILE) from the input science image and update output data quality file with bias image data quality (BIASDFIL).	bias file, bias DQF file (r2h/b2h)
PREFCORR	Correct for uneven illumination pattern produced by preflash by subtracting preflash reference file (PREFFILE) scaled by preflash lamp exposure (PREFTIME keyword). If no preflash was done, a correction called CTE fixup is done to correct charge transfer problem across gate.	preflash file, preflash DQF file (r3h/b3h)
PURGCORR	Remove residual effects of superpurge, which removes residual image from highly overexposed source. This step was not implemented in pipeline.	purge file (r4h/b4h)
DARKCORR	Correct for dark current by scaling dark image reference file and subtracting it from science data. Dark image is multiplied by total dark accumulation time (keyword DARKTIME).	dark file (r5h/b5h)
FLATCORR	Correct for pixel-to-pixel gain variation by multiplying by inverse flatfield image.	flatfield file (r6h/b6h)
DOSATMAP	Create an output data quality file (.c3h) that flags pixels that saturated the A/D converter. This is redundant because saturated pixels are flagged in the DQF (.c1h).	
DOPHOTOM	Determine absolute sensitivity using throughputs in photometry calibration table (PHOTTAB). This step does not change science data values.	phottab (cw0)
DOHISTOS	Create 3-row image (.c2h) for each group. Row 1 is a histogram of raw science values, row 2 the A/D corrected data, row 3 the calibrated image.	

45.3 Calibration Details

Each calibration step (and the keyword switches used to turn the step on or off) is described in detail in the following sections; the steps are performed in the following order:

1. Flag static bad pixels.
2. Flag saturated pixels.
3. Do analog-to-digital (A/D) correction.
4. Subtract bias level.
5. Subtract bias file.
6. Subtract preflash.
7. Subtract dark.
8. Multiply by inverse flatfield.
9. Calculate photometry keywords.
10. Calculate histograms.
11. Generate final science data quality file.

45.3.1 Static Mask

The static mask reference file contains a map of the known bad pixels and blocked columns. If this correction is performed (MASKCORR=YES), the mask is included in the calibration output data quality files. The mask reference file is identified in the MASKFILE keyword. The science data itself is not changed in any way; the STSDAS task **wfixup** can be used to interpolate across bad pixels flagged in the final data quality file (.c1h). Note, however, that the fixup is generally only done for image presentation; the interpolation can cause large errors in any photometry involving the flagged pixels.

45.3.2 Saturated Pixels

Pixels at the maximum level of the analog-to-digital (A/D) converter are automatically flagged in the calibration output data quality files (.c1h/.c1d). If the DOSATMAP correction is requested, an additional calibration output file is generated (.c3h/.c3d), containing a map of the saturated and missing pixels. Note, however, that this output file is redundant, since the same information is stored in the .c1h/.c1d.

45.3.3 A/D Fixup

All WF/PC-1 observations should have the analog-to-digital (A/D) correction performed. Due to a problem in the WF/PC-1 sample and hold circuitry, certain DN values are statistically more likely to occur than adjacent values. For this reason, a statistical correction is applied to the data using the A/D fixup file; there is no associated data quality file with the A/D reference file. Note that the correction is a statistical one—there will be some information that is not recoverable.

The A/D reference files may contain multiple look-up tables, which depend on the Bay 3 temperature (stored as degrees Celsius in the WBA3PCTM keyword of the observation). The first row in the A/D reference file consists of temperatures, while subsequent rows contain the lookup tables. That is, the second pixel in row one is the Bay 3 temperature associated with the second row A/D fixup values, the third pixel in row one is the Bay 3 temperature for the lookup table in the third row, and so on. However, since the Bay 3 temperature remained stable, only one lookup table is contained with the A/D reference file.

Note that the STSDAS task **mka2d** can be used to generate a lookup table. However, a table of the 48-bit errors are required as input (see *OV/SV Report*, Faber et al., 1992, Chapter 1).

45.3.4 Bias Level

The bias level is determined to first order from the extended register pixels which are in columns 3 through 14 of the extracted engineering files (.x0h/.x0d; if the image was done in area mode, the bias level is determined from the good pixels in column 1). Since the odd and even columns are at slightly (~0.6 DN) different levels (whose parity occasionally changes with a decontamination procedure), the bias level is separately determined and removed for even and odd columns (in **calwfp** versions after and including February 1992). The levels removed are stored in the group parameters BIASEVEN and BIASODD in the calibrated file, which can be examined with the IRAF task **hedit**. Note that the BIASEVEN keyword contains the average of the extracted engineering data (EED) columns 3, 5, 7, 9, 11, and 13 while the BIASODD keyword contains the average of EED columns 4, 6, 8, 10, 12 and 14.

45.3.5 Bias File

Once the bias level correction has been completed, any remaining bias pattern is removed by applying a bias file correction. The bias reference file is generated from a set of A/D and bias-level corrected zero-length exposures. The correction consists of subtracting the bias file from the observation and flagging in the .c1h/.c1d file any bad pixels noted in the bias file data quality file (.b2h/.b2d). Due to charge transfer problems, the bias calibration files do not make suitable corrections for dark current during readout, and this overhead time should be included in the DARKTIME used for dark correction.² (See *WF/PC-1 ISR* 93j-01).

45.3.6 Preflash/CTE File

A preflash was applied to circumvent the low level non-linearity in the CCDs: during readout, very low-level charge ($< 250 e^-$ /pixel) was inefficiently transferred, smearing faint images. In addition, some charge ($\sim 50e^-$) was completely lost, which adversely affected the photometry of even uncrowded fields. The preflash, which was requested by the observer, was done by imaging the shutter through a red filter, thereby imposing a low-level signal (~ 30 to $40 e^-$ /pixel) on the image before the science exposure began.

The preflash reference files were generated from sets of bias files which were preflashed; the final reference files were scaled to 1 second. Since the two possible shutters (A or B) had different reflection patterns, there were separate preflash reference files for each shutter configuration (see note below). If the preflash time (PREFTIME) was larger than zero, the preflash reference file was multiplied by PREFTIME and subtracted from the image. The first row of each preflash file contains the charge transfer efficiency (CTE) correction (offsets for columns with poor charge transfer); if the preflash time was zero, the CTE fixup was done. Note that for preflashed images, the preflash reference file effectively includes the CTE fixup, so that the CTE correction is done during the subtraction of the preflash reference file.

For an external image, the SHUTTER keyword should indicate which shutter was in place during the preflash. The shutter used can be verified by extracting the engineering data to a table using the STSDAS **engextr** task and then using the **tdump** task to examine the table, for example:

```
st> engextr w0ts0n02t.x0h outtable=.
st> tdump w0ts0n02t row=77-78
```

The example above would write to the screen the values stored in rows 77-78 of the file `w0ts0n02t.tab` which contain the shutter status at the *end* of the image readout. Assuming that 1) there were no interruptions or multiple exposures before the readout, 2) SERIALS=NO, and 3) the observation is shorter than 300 seconds, the preflash shutter is the one opposite the shutter marked as closed in the table (e.g., if A is marked as closed in the extracted engineering table, B was used during the preflash).



For exposures longer than 300 seconds, shutter B always closed the end of the exposure, regardless of the shutter used for preflash, so that the above algorithm fails—however, the difference between the A and B shutter blade preflashes was relatively small, less than about 0.5 DN. Shutter B was usually used to preflash long exposures, and that is the assumption used in calibrations. If the shutter blade is likely to be important for the observations, contact the STScI help desk (help@stsci.edu) for help in determining the preflash shutter.

2. See *WF/PC-1 Instrument Science Report 93-01*.

45.3.7 Dark File

A dark correction is required to account for the thermally-induced dark current which occurred during the image exposure; many of the hot pixels are corrected with the dark file as well (however, see “Hot Pixels” on page 46-5). Usually, the dark reference file is generated from ten or more individual dark frames (long exposures taken with the shutter closed) that have each had the standard calibration corrections applied (ATODCORR, BLEVCORR, BIASCORR, and PREFCORR). In addition, each frame is examined and residual images are excluded by a mask. If the dark correction is requested, the dark reference file (which has been normalized to 1 second) is scaled by the DARKTIME keyword value and subtracted from the observation.



Note that the DARKTIME used in pipeline processing is only an approximation. For long exposures or data requiring very accurate dark correction, the darktime should be recalculated (see *WF/PC-1 Instrument Science Report 93-01*), inserted into the DARKTIME keyword, and then the images should be recalibrated. There was a problem in older data with the DARKTIME being improperly set for interrupted exposures; in these cases, the darktime must be manually computed from the WEXPODUR keyword and the DARKTIME keyword updated before recalibrating (see “Recalibrating WF/PC-1 Data” on page 45-20).

45.3.8 Flatfield

The data are multiplied by a normalized, inverted flatfield in order to remove any pixel-to-pixel variations in the cameras. Flatfields used in the pipeline calibration were generated from sets of *earthcals* (observations of the bright earth). The general procedure for creating a pipeline flatfield was to combine a chosen set of earthcals using the STSDAS task **streakflat**, then normalize and invert using **normclip**. The code allows for the fact that some of the earthcals had streaks due to features on the earth being smeared by HST motion in the images.

Acquiring enough properly exposed earthflats was time-consuming, primarily due to the large variation in the earth’s albedo. In addition, the earth is too bright for some broadband filters, requiring the use of a neutral density filter (either the F8ND or F122M), which added features of their own which must then be removed. For these reasons, only two complete flatfield calibrations were planned, the first was completed during Science Verification (“SV”) and early Cycle 1 (“non-SV”), and the second was obtained during the second half of Cycle 2 through Cycle 3 (dubbed *closure flats*).



Care must be taken in choosing the best flatfield to use; flatfields generated from earthcalcs taken with the neutral density filters (F122M or F8ND) can contain gradients of 20-30%. See “Choosing Among Available Flats” on page 45-15 and “Flatfield Anomalies” on page 46-7 for details on the available flatfields.

45.3.9 Photometry Keywords

The photometry keywords are listed in Figure 45.3, below; the first two keywords are in the ASCII header (both `d0h` and `c0h`) while the last five keywords are group parameters (use the IRAF tasks **imheader** or **hedit** to examine the group keywords). (See “Converting Counts to Flux or Magnitude” on page 3-15).

Figure 45.3: Photometry Keywords

Header parameters	<pre>DOPHOTOM= 'YES ' / Fill photometry keywords: YES, NO, DONE PHOTTAB = 'wtab\$cbj15281w.cw0' / name of the photometry calibration table 'PHOTMODE' / Photometry mode (for example, PC,5,F,DN,F1042M,OPEN,CAL) 'PHOTFLAM' / Inverse Sensitivity (erg/sec/cm²/Å for 1 DN/sec) 'PHOTPLAM' / Pivot wavelength (angstroms) 'PHOTBW ' / RMS bandwidth of the filter (angstroms) 'PHOTZPT' / Photometric zeropoint (magnitude)</pre>
Group parameters	

The PHOTTAB keyword is set by the PODPS pipeline during generic conversion; all other photometry keywords are blank or contain values of zero in the `.d0h` files. If the image is being recalibrated, use the StarView Calibration screens and consult the Reference File Memo on WWW for a listing of new photometry tables available for use.

Setting DOPHOTOM to “YES” instructs **calwfp** to populate the photometry-related keywords; no operations are performed on the actual images. The first step is to form the PHOTMODE keyword based on the values of other keywords (CAMERA, DETECTOR, FILTNAM, etc.) in the header. The **calwfp** task then searches the photometry table specified in PHOTTAB for the matching mode; the PHOTFLAM, PHOTZPT, PHOTPLAM, and PHOTBW values in the table are written into the `c0h` group keywords (see Table 44.3). If no matching PHOTMODE is found in the table specified by PHOTTAB, the keywords remain blank or zero. For more information about improving the photometric calibration, see “Improving the Photometric Calibration” on page 46-17.

45.3.10 Histograms

If this operation is requested (by setting DOHISTOS=YES), histograms of the raw data, the A/D corrected data, and the final calibrated output data are created and stored in the `.c2h/.c2d` image. This is a multigroup image with one group for each group in the calibrated data file. Each group contains a 3-line image

where row 1 is a histogram of the raw data values, row 2 is a histogram of the A/D corrected data, and row 3 is a histogram of the final calibrated science data.

45.3.11 Data Quality Files

Each calibrated science dataset contains a *data quality file* (.c1h for WF/PC-1). The **calwfp** software will bit-wise OR all of the raw data quality files (.q0h, .q1h) with the reference file data quality files (.b2h, .b3h, etc.), in order to generate the calibrated science data quality file (.c1h). The flag values used are defined in Table 45.2. The final calibrated data quality file (.c1h) should be examined (for example, using SAOimage or **imexamine**) to identify which pixels may be bad in the science image.



The bad pixels flagged in the .c1h file are not fixed up in the .c0h file. The STSDAS task **wfixup** can be used to interpolate across bad pixels in the science image; note however, that this results in a loss of information and can have adverse effects on any photometry using those pixels.

Table 45.2: WF/PC-1 Data Quality Flag Values

Flag Value	Description
0	Good pixel
1	Reed-Solomon decoding error
2	Calibration file defect
4	Permanent camera defect
8	A/D converter saturation
16	Missing data
32	Bad pixel

45.4 Should You Recalibrate?

Although some users will find that the calibrated data produced by the RSDP pipeline—the standard calibration—are adequate, most users will want to consider recalibrating. The pipeline calibrated the data with the most up-to-date, WF/PC-1-specific calibration reference files available at the time the data was pipeline processed. However, updated or timely reference files frequently did become available after the data were processed (e.g., new dark reference files and

the “closure” flatfields). Certainly if there are unusual features in the data or if the analysis requires a high level of accuracy, recalibration is necessary.

Finding that a calibration reference file has changed since the data were calibrated doesn’t always mean that recalibration is necessary. The decision depends very much on which calibration image or table changed, and whether that kind of correction is likely to affect the analysis. Retrieving and comparing the recommended and used calibration files to examine any differences can help in the decision to recalibrate. (The table tools in the STSDAS **ttools** package can be used to manipulate calibration tables; the images can be manipulated in the same ways as the science data.)

45.5 Improvements to Calibration Reference Files

All of the installed reference files contain HISTORY keywords at the end of the header which can be viewed using the IRAF **imhead** task. These keywords contain more detailed information about how the file was created and installed in the database.

Several types of reference files and their associated calibration processes have been improved substantially. The following lists types of calibrations that may benefit from recalibration due to the improvements:

- Improved BLEV correction, as of February 1992. **calwfp** determines and removes odd and even column levels separately.
- Bias reference files for PC and WF were improved in August 1993: 40% lower noise than previously.
- Preflash reference files for PC and WF also improved in August 1993: noise was reduced by a factor of two.
- Since the WF/PC-1 darks were found to be time-variable (see *WF/PC-1 Instrument Science Report 93-01*), additional calibration observations were obtained and dark reference files generated for specific time intervals. There are now more than a dozen dark reference files for each camera, covering the time period July 1991 through November 1993. Please refer to the WWW Reference File Memo to identify the best dark to use for the data based on the date the science observation was taken (DATE-OBS keyword in .d0h file).
- Many new and improved flatfields were generated and installed in the Archive after the end of the WF/PC-1 mission (see sections “Choosing Among Available Flats” on page 45-15, and “Improving the Flatfield Correction” on page 46-15); the WWW Closure Flatfield and Reference file memos offer more details about these files and their use. Note that many of the early flatfields were generated from earthcals taken with a neutral density filter (F122M or F8ND); these flats can have residual intensity gradients of up to 20–30% across the field of view.



See the following sections and Chapter 46 for information on the various error sources in WF/PC-1 calibrated data and suggestions for further improving the calibration, particularly the flatfielding.

45.6 Determining the “Best” Reference Files

We refer to a “best” reference file for a given dataset. This section explains what “best” means and how the best files can be determined for WF/PC-1 data, using both the WWW memos and StarView.

Calibration reference files are specific to each instrument configuration and observing mode; in addition, monitoring has shown that some instrumental properties change with time. Therefore, calibration reference files can be time-tagged, indicating that they should be used with data taken within a specific range of dates. The best set of reference files for calibrating the observation (according to the pipeline) will therefore depend on the instrument configuration and observing mode that was used and the date when the observation was taken.

StarView, the interface to the HST catalog and Archive, can be used to determine the current best available reference files for any dataset and to retrieve those files from the HST Archive (Chapter 1 describes how to use StarView to access the HST catalog and archive). The Calibration Reference screens (one per instrument) in StarView can be used to obtain a listing of the current best reference files for any dataset and a listing of the files that were originally used to calibrate the dataset by the RSDP pipeline. Figure 45.4 shows StarView being used to determine the best and used calibration reference files for one particular WF/PC-1 observation. Either the used or the recommended (or both) reference files can be marked for retrieval and fetched from the Archive using FTP, as shown in the StarView tutorial in Chapter 1.

45.6.1 When is “Best” Not the Best?

The current limitation of StarView, and the reference files chosen automatically by the pipeline, is that only one “best” reference file can be specified. Frequently, there are several possible reference files that are appropriate and the files used may not be the optimal calibration files for some purposes, depending upon the scientific objectives.

For this reason, we highly recommend checking the Reference File and other memos on WWW, at:

http://www.stsci.edu/ftp/instrument_news/WFPC/wfpc1_memos.html

This memo suggest possible alternate reference files that can be used for recalibration. These memos summarize the file names and histories of available

reference files, as well provide more detailed information about the nature and quality of each reference file. For high accuracy in the science analysis, it is best to try using several different reference files to calibrate the data, to see which ones give the best results and to empirically determine the degree of uncertainty in the data attributable to the choice of reference file.

Figure 45.4: Finding Best Reference File Using StarView

< WFPC Reference Files – Search Results >

File Searches Constraint View Retrieve Customize Options Comments Help

PI : WESTPHAL Proposal ID : 4769

Target : 3C273-OFFSET

Rootname: W19C0101T Filter1: 29 Camera: PC Mode: FULL

Filter2: 0 Clock: OFF Shutter: B

Orien,A : -15,528 Orien,B: 74,383d Orien,C: 165,483 Orien,D: -105,02

	USED	RECOMMENDED	PERFORMED
A-to-D Correction:	WREF#C261402TW,R1H	C261402TW,R1H	DONE
Bias Correction:	WREF#C261403LW,R2H	D8C0826NW,R2H	DONE
Dark Current Correction:	WREF#C6116491W,R5H	D9G1345QW,R5H	NO
Flat Field Correction:	WREF#C191643EW,R6H	C191643EW,R6H	DONE
Static Pixel Mask:	WREF#BB61518LW,R0H	BB61518LW,R0H	DONE
Preflash Correction:	WREF#C8E0940GW,R3H	D8C08267W,R3H	DONE
Purge Reference File:	WREF#9CK10279W,R4H	9CK10279W,R4H	NO
Engineering File:	WCAL#W19C0101T,X0H		DONE
Photometry Cal. Table:	WTAB#CBJ15281W,CW0	CBJ15281W,CW0	DONE

Step Forward Step Back Mark USED Files for One Dataset

Scan Forward Scan Back Mark RECOMMENDED for One Dataset

Edit Search Constraints Mark USED Files for All Datasets

Write Search Results to File.. Mark RECOMMENDED for All Datasets

Retrieve Data Strategy Unmark All Files for One Dataset

Record 1 of 1 (in progress) Unmark All Files for All Datasets

Exit Screen ^Z

Use up/down arrow keys in data area to scroll full list of calibration files.

MESSAGE: More records available. Use record controls to view search results

45.6.2 Choosing Among Available Flats

A history of all flatfield reference files generated and delivered to the HST Archive is maintained in the Reference File memo on WWW, at:

http://www.stsci.edu/ftp/instrument_news/WFPC/wfpc1_memos.html

This file is updated as new files are added. The flatfields listed in the memo include those used in the pipeline as well as some alternate flatfields, which were never used in the pipeline but which may be of use in recalibration. The Reference File memo provides a single one-line history comment for all files; for example, some reference file changes only involved keyword changes to the header and do not affect the data. On the other hand, some flatfield reference files were mere placeholders until data could be obtained and a flatfield generated and delivered. These placeholder flatfield files contained only values of 1 in order to prevent the routine pipeline processing from crashing yet avoid applying an improper correction. The same wfpc1_memos WWW site also provides links to more detailed memos concerning specific reference files listed in the Reference File memo, such as the Closure Flatfields, the Super-Sky (MDS) Flatfields, and the Delta Flat Corrections.



See Chapter 1 for information about how to retrieve the flats (and other reference files) from the HST Archive. See Chapter 46 for more information on improving the calibration of WF/PC-1 data.

There were two main epochs of flatfields, dubbed “SV” and “non-SV” (Science Verification), and “closure” flats. The SV flats were generated from data taken between July 1991 and January 1992 and delivered to STScI in early 1992 by the WF/PC-1 Investigation Definition Team (IDT) (see *OV/SV Report*). All of these flats were reformatted and installed in CDBS (the Calibration Data Base); camera and filter combinations are given in Table 45.3. The STScI WF/PC-1 group generated and installed into the pipeline, flatfields for the non-SV camera and filter combinations (also referred to as “Cycle 1”); these are listed in Table 45.4.

Table 45.3: SV Flatfield Camera and Filter Combinations

Camera	Filters						
WF	F230W	F284W	F336W	F375N	F439W	F487N	F502N
	F547M	F555W	F622W	F631N	F656N	F658N	F673N
	F702W	F785LP	F889N				
PC	F230W	F284W	F336W	F469W	F487N	F502N	F517N
	F555W	F656N	F658N	F664N	F673N	F702W	F718M
	F785LP	F889N					

Table 45.4: Non-SV Flatfield Camera and Filter Combinations

Camera	Filters						
WF	F492M	F502N	F569W	F588N	F606W	F673N	F675W
	F725LP	F791W	F814W	F850LP	F875M	F889N	F1042M
	F1083N						
PC	F368M	F413M	F517N	F569W	F588N	F606W	F631N
	F648M	F664N	F675W	F718M	F725LP	F791W	F814W
	F850LP	F875M	F1042M				

Earthcal observations for the final Cycle 2 and 3 closure flatfield set were taken after August 2, 1993. The closure flats were generated in the same manner as previous cycles, using the IRAF/STSDAS tasks **streakflat** and **normclip**. In addition, the STSDAS **wfixup** task was used to interpolate across known bad pixels (the fixed pixels are flagged in the flatfield DQF file, suffix b6h/b6d). As for all reference files, users are encouraged to refer to the HISTORY records in the file headers for details about the generation of the file. The closure flats were installed in CDBS, the Reference File Memo updated, and a detailed Closure Flats Memo posted on WWW; filter and camera combinations are given in Table 45.5.



Closure flatfields are not only useful for 1993 WF/PC-1 data, but along with an appropriate delta flat, are useful for recalibrating older data as well.

Table 45.5: Closure (Cycle 3) Flatfield Camera and Filter Combinations

Camera	Filters						
WF	F336W ^a	F368M ^b	F375M ^{ab}	F413M ^{cd}	F439W ^d	F487N ^{ab}	F502N ^{ab}
	F517N ^c	F547M ^{cd}	F555W ^c	F569W ^{cd}	F588N ^{ab}	F606W ^d	F622W ^{cd}
	F631N	F648M ^c	F673N ^b	F702W ^d	F785LP ^d	F791W ^c	F850LP ^d
	F889N ^{ab}	F1042M ^{ab}					
PC	F336W	F368M ^a	F413M ^a	F439W ^a	F492M ^{cd}	F517N ^{ab}	F547M ^b
	F555W ^{cd}	F569W ^c	F606W ^{cd}	F622W ^{cd}	F648M ^c	F664N ^b	F673N
	F675W ^{cd}	F702W ^{cd}	F718M ^c	F725LP ^c	F785LP ^c	F791W ^c	F814M ^c
	F875M ^{ab}	F889N ^{cd}	F1042M				

a. Multiple versions of flatfields available: one taken without the F8ND filter and one taken with F8ND.

b. Multiple versions of flatfields available: one taken without the F122M filter and one taken with F122M.

c. Flatfield generated from data taken only with neutral density filter F122M.

d. Flatfield generated from data taken only with neutral density filter F8ND.

Particularly for science data taken in the same epoch as the streakflats (August 2, 1993 to December 1993), the closure flats will generally be the best choice for flatfielding. For data taken between the August 7, 1992 and August 2, 1993 decontaminations, the closure flatfields may be the better choice, as long as an appropriate delta flat is used as well. The older Cycle 0 and 1 flatfields may be most appropriate for data taken before February 1992, before the appearance of the “permanent measles”, since the closure flats do contain the measles features. Delta flats, discussed in the next section, may be used to correct any epoch of flatfield to any science data epoch.

In addition, some of the closure flats are considered to be “high-fidelity”, that is, they are flatfields where various features (such as the 30% intensity gradient due to the F122M filter) in the input earthcals have been removed; in addition, an attempt was made to remove the ~5% artifacts present in some earthcals due to short exposure reciprocity failure. Filter and camera combinations for high fidelity flatfields available from the HST Archive are given in Table 45.6. Please refer to the Closure Flat memo on WWW for names and details of specific flatfields; the memo outlines the history of all closure flatfields as well as the procedure for creating additional high fidelity flatfields if needed:

http://www.stsci.edu/ftp/instrument_news/WFPC/wfpc1_memos.html

Table 45.6: Closure “High Fidelity” Flatfield Camera and Filter Combinations

Camera	Filters						
PC	F336W	F368M	F413M	F439W	F492M	F517N	F547M
	F555W	F569W	F606W	F622W	F648M	F664N	F673N
	F675W	F702W	F718M	F725LP	F785LP	F791W	F814W
	F875M						

45.6.3 Choosing and Generating Delta Flats

Observations taken during one epoch (time period between decontamination events) and processed with flatfield reference files created from data taken during a different epoch may require a delta flat correction to correct for QE changes that occurred during the decontaminations³. A delta flat, generated from ratios of INTFLATs, can also be used to reduce, although not eliminate, the effects of the measles contamination. In practice, since the pipeline flatfields are inverse flats (**calwfp** multiplies the science data by the FLATFILE specified in the .d0h header), the delta flat correction is the ratio of an INTFLAT of the same epoch as the flatfield calibration file divided by an INTFLAT taken close in time and wavelength to the science observation to be corrected. The calibrated pipeline image is multiplied by the appropriate delta flat: $F = C \times D$ where F is the final

3. Decontamination events occurred January 1991, May 1991, July 1991, February 1992, March 1992, August 1992, and August 1993 (see Table 46.1 for details).

image, C is the calibrated pipeline product image (.c0h) which has had the flatfield reference file applied, and D is the delta flat.

The INTFLATs were taken by illuminating the backside of one of the two shutter blades (A or B) with internal lamps. Due to variations in the shutter blade reflectivities, all INTFLATs used in a delta flat must have been taken with the same shutter blade (given by SHUTTER keyword). Since the flatfields and measles features have been found to depend on wavelength, the delta flat (or INTFLATs) closest in filter to the observation will provide the best possible correction. Note that prior to the development of the persistent measles in February 1992, regular INTFLATs were being obtained using a relatively small number of filters; therefore, INTFLATs for the baseline epoch, and thus the resulting delta flats, are available for only a small number of filters. However, after February 1992, the delta flat proposals were greatly expanded in order to obtain INTFLATs in nearly 20 filters in each camera; these may allow the correction of the closure flatfields to data taken prior to August 1993.

Delta flats that have been generated were archived into CDBS and can be retrieved from the HST Archive; delta flat file suffixes are r8h/b8h for the data file and its data quality file, respectively. Listings of the file names can be found in the delta flat memo that is currently available through the World Wide Web at:

http://www.stsci.edu/ftp/instrument_news/WFPC/wfpcl_memos.html

For some epochs, there are two types of delta flats available for use, *average delta* and *individual delta flats*. The average delta flats were created by averaging all the individual delta flats taken between decontaminations (dates of all decontaminations are listed in the delta flat file). These average delta flats are partially corrected for cosmic rays, and therefore, should be used whenever possible. The closure delta flats, generated from INTFLATs taken August 8, 1992 through November 1993, have all been cosmic ray corrected using the STSDAS **crrej** task and **wfixup** to average across questionable pixels. Note that a subset of the closure flats already include the appropriate delta flat correction; the Closure Flat Memo flags these appropriately.



Custom delta flats can be generated from internal flats observations retrieved from the HST Archive using StarView.

One use of the delta flats is to back-correct the Closure flats for use with earlier Cycle science data. For example, to adjust a hi-fi Cycle 3 flat for use with Cycle 1 data, find 2-3 INTFLATs for a nearby filter near the time of the science observations, and find 2-3 INTFLATs taken during Cycle 3 (after Aug 2, 1993). After retrieving and recalibrating these INTFLATs with the best reference files, removing cosmic rays and combining (e.g., with STSDAS **crrej**), the Cycle 1 “high-fidelity” flatfield is created by simply multiplying the Cycle 3 hi-fi flatfield by the ratio of the cleaned internals (e.g., with IRAF **imcalc**). Since the flatfields used by calwfp are inverse flats, the ratio is Cycle 3 divided by Cycle 1, that is:

$$\text{Hi-Fi (Cycle 1)} = \text{Hi-Fi (Cycle 3)} * (\text{clean Cycle 3 intflat}) / (\text{clean Cycle 1 intflat})$$

45.7 Recalibrating WF/PC-1 Data

This section describes the mechanics of doing a recalibration. The steps in recalibrating a dataset include choosing and assembling any necessary reference files or tables and the raw data files, setting the desired switches and updating the calibration reference file names in the header of the `.d0h` (raw data) file, and finally, running the calibration software, **calwfp**.

In order to recalibrate the data, *all* of the reference files and tables that are used by the calibration steps to be performed should be retrieved (see previous section for advise on choosing reference files). We suggest copying the raw data files required for input to the calibration routines and the required reference files and tables to a subdirectory to be used for recalibration. This will preserve the original files. How to identify and retrieve the calibration reference files necessary to recalibrate the data was described in the previous section.

The next step is to set the calibration switches and reference keywords in the header of the raw data file (`.d0h`); these control how the data is recalibrated and which reference files are used at each step in the process. The switches and keywords are changed with the **chcalpar** task but can also be done with **hedit**.

The **chcalpar** task in the STSDAS **hst_calib.ctools** package takes a single input parameter—the name(s) of the image files to be edited. When the **chcalpar** task is started, it will automatically determine the instrument used to produce that image and will open one of several parameter sets (psets) that will load it with the current values of the header keywords. The WF/PC-1 pset is **ckwwfpc**.

For example, one method of editing the calibration keyword values would be:

1. Start the **chcalpar** task, specifying the image(s) in which the keyword values require changing. If more than one image is specified, for example using wildcards, the task will take the initial keyword values from the first image. For example, to change keywords for all WF/PC-1 raw science images in the current directory (with initial values from the first image), use the following command:

```
wf> chcalpar w*.d0h
```

2. When **chcalpar** begins, it will bring up **epar**—the IRAF parameter editor, which can be used to edit the pset of calibration keywords. Any of the values of the calibration switches, reference files or tables to the values can be changed as desired for recalibration.
3. To exit the editor, type `:q` two times. The task will inquire whether the current settings are correct. Typing “y” will save the settings and return the IRAF CL prompt. Typing “n” will bring back the editor, to re-define the settings. Typing “a” will return the IRAF CL prompt without saving any changes. For additional examples of updating the calibration keywords, check the online help by typing `help chcalpar`.

The calibration reference file names in the header of the raw data (i.e., the `d0h` file) are typically preceded by five characters (e.g., `wref$` for calibration images and `wtab$` for calibration tables) which are pointers to the location on disk where

the files are to be found by the calibration software. Before running the calibration routines, these variables must be set to the location of the reference files (and x0h/q1h raw data files). For WF/PC-1 data, the variables to set are:

```
to> set wref = "/nemesis/hstdata/"
to> set wtab = "/nemesis/hstdata/"
to> set wcal = "/nemesis/hstdata/"
or, on VMS
```

```
to> set wtab = "DISK$SHARE:[HSTDATA]"
```

where the directory name in double quotes is the local directory where the calibration reference files and tables reside.

Once the calibration keywords in the header of the raw data file are set properly, the data can be recalibrated. The WF/PC-1 calibration software, **calwfp**, is executed by typing the name of the task followed by the *rootname* of the observation dataset. For example, to recalibrate the dataset w0w10e02t and write the log of the results to the file calwfp.c.log (rather than to the screen), type:

```
hr> calwfp w0w10e02t > calwfp.c.log
```



To avoid overwriting existing calibration files, specify a different output file name, for example:

```
wf> calwfp w0w10e02t wfpc_out > wfpc.c.log
```

For more information about how these routines work, use the on-line help:

```
cl> help calwfp
```

45.7.1 Calculating Absolute Sensitivity for WF/PC-1

If DOPHOTOM is set to NO before running **calwfp**, then the values of the inverse sensitivity (PHOTFLAM), pivot wavelength (PHOTPLAM), RMS bandwidth (PHOTBW), zero point (PHOTZPT), and observation mode (PHOTMODE) will not be written to the header of the recalibrated data file. The DOPHOTOM calibration step does not alter the values of the data (which are always counts or data numbers in the calibrated file), but only writes the information necessary to convert counts to flux into the header file. Therefore, unless the absolute sensitivity for the observation must be recomputed (e.g., because a more recent throughput table exists for the observing mode), the keyword values from the original calibrated file can be used.

To recalculate the absolute sensitivity, set DOPHOTOM=YES in the .d0h file before running **calwfp**, or alternately, use the tasks in the **synphot** package of STSDAS.



See “Improving the Photometric Calibration” on page 46-17 for suggestions on improving the WF/PC-1 photometric calibration.

To calculate the absolute sensitivity, **calwfp** and the **synphot** tasks use a series of component lookup and throughput tables. These tables are not part of STSDAS itself, but are part of the **synphot** dataset, which can be easily installed at your home site (see “Getting the synphot Database” on page A-15 for information about how to do this).



The **synphot** dataset *must* be installed in order to recalculate absolute sensitivity for WF/PC-1 data using **calwfp** or **synphot**.

Table 46.4 provides a summary of the expected accuracy of calibrated WF/PC-1 data produced by the pipeline. For a more in depth discussion of the origin of these accuracies, of problems which can prevent these levels of accuracies from being obtained, and of ways to achieve higher accuracy than those routinely obtained, see Chapter 46.