

Shutter Jitter History Measured from INTFLATS

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ABSTRACT

Apparent sporadic variations in the closed position of the two WFPC2 shutter blades were detected by examining the light reflected from the shutter in internal flats (INTFLATS). To characterize this phenomenon, we developed a simple algorithm to measure the history of the shutter jitter using INTFLATS. We found the position jitter in the direction of shutter motion to be minimal, indicating stable behavior. In contrast, the positions along the axis perpendicular to the direction of shutter motion exhibit greater jitter, and the amplitude of the jitter has been increasing with time. In addition, much larger sporadic departures from the nominal position are seen beginning in 1999 and continuing to the present time. We hypothesize that these variations in the closed shutter position result from mechanical wear and degradation. However, no direct connection between the jitter history and the shutter anomaly has been determined.

Introduction

In August of 2000 the WFPC2 began experiencing sporadic failures of the shutter mechanism resulting in blank exposures. The failure of the shutter to properly open was traced to an error in reading the status of the shutter blade “A” position sensor. By October the rate of failures had increased and it was apparent that we were beginning to see collisions of the two shutter blades, with the A blade occasionally pushing the B blade out of position. A software patch was devised and installed to provide the sensor more time to read the shutter status; this appears to have successfully alleviated the problem. During the course of the post-patch analysis of WFPC2 calibration exposures (e.g., dark frames, vis-flats, internal flats, photometry monitor, etc), an apparent variation in the closed position

of shutter B was discovered using the light reflected from the shutter in internal flats (INTFLATS).

Here we present a study of the history of the stability and jitter in the closed shutter position as measured from these INTFLATS, with the hope that it may provide a diagnostic of the degradation of the shutter mechanism.

Measurement of the Closed Shutter Position

The shutter assembly of WFPC2 is depicted in Figure 1. Internal flats are obtained by commanding either shutter into the closed position and exposing the CCDs to the light of an internal lamp reflected against the closed shutter. Corrugations and rivets can be seen as out-of-focus images in the INTFLATS. These features are significantly more apparent in the WF2 chip when shutter B is closed, and in WF4 when shutter A is closed, due to the apparent position of these features within the WFPC2 field of view. A sample INTFLAT from WF2 when shutter B is closed is shown in Figure 2.

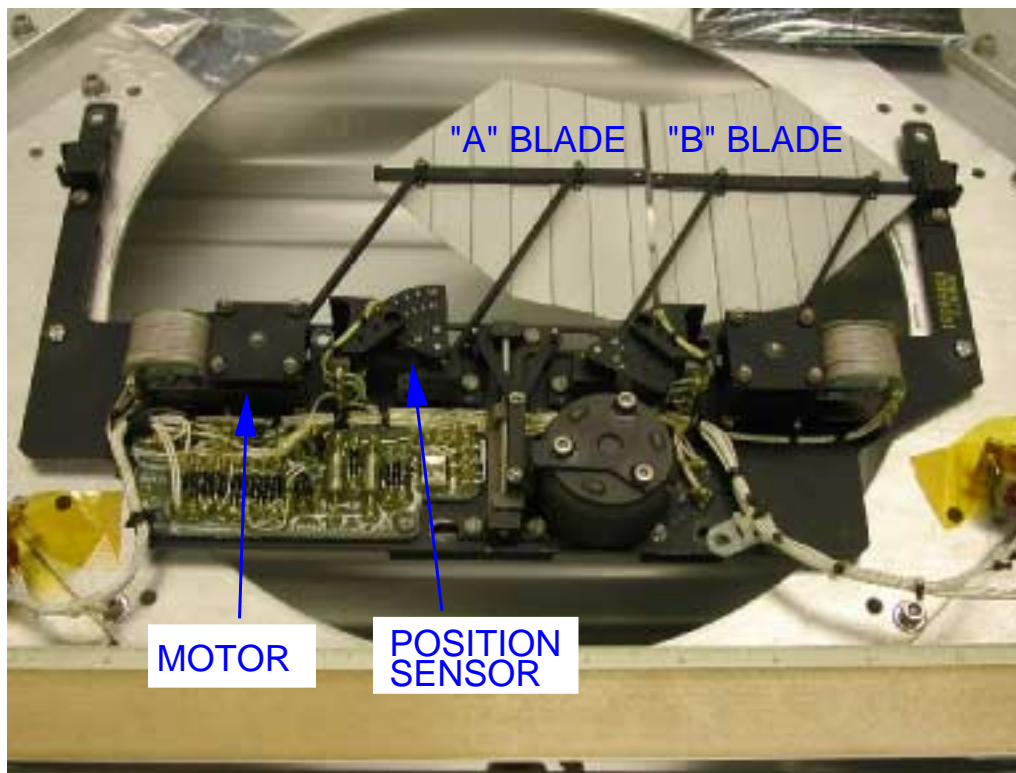


Figure 1: WFPC2 Shutter Assembly

We have defined a new Cartesian coordinate system which is rotated 45 degrees with respect to the rows and columns of the CCD and is shown in Figure 2. This coordinate system was chosen because the corrugations of the shutter are nearly parallel to the axes of this coordinate system. The apparent jitter discovered during the post-patch analysis

appeared as an image shift along the w-axis. Here we describe a simple algorithm used to measure jitter along either axis.

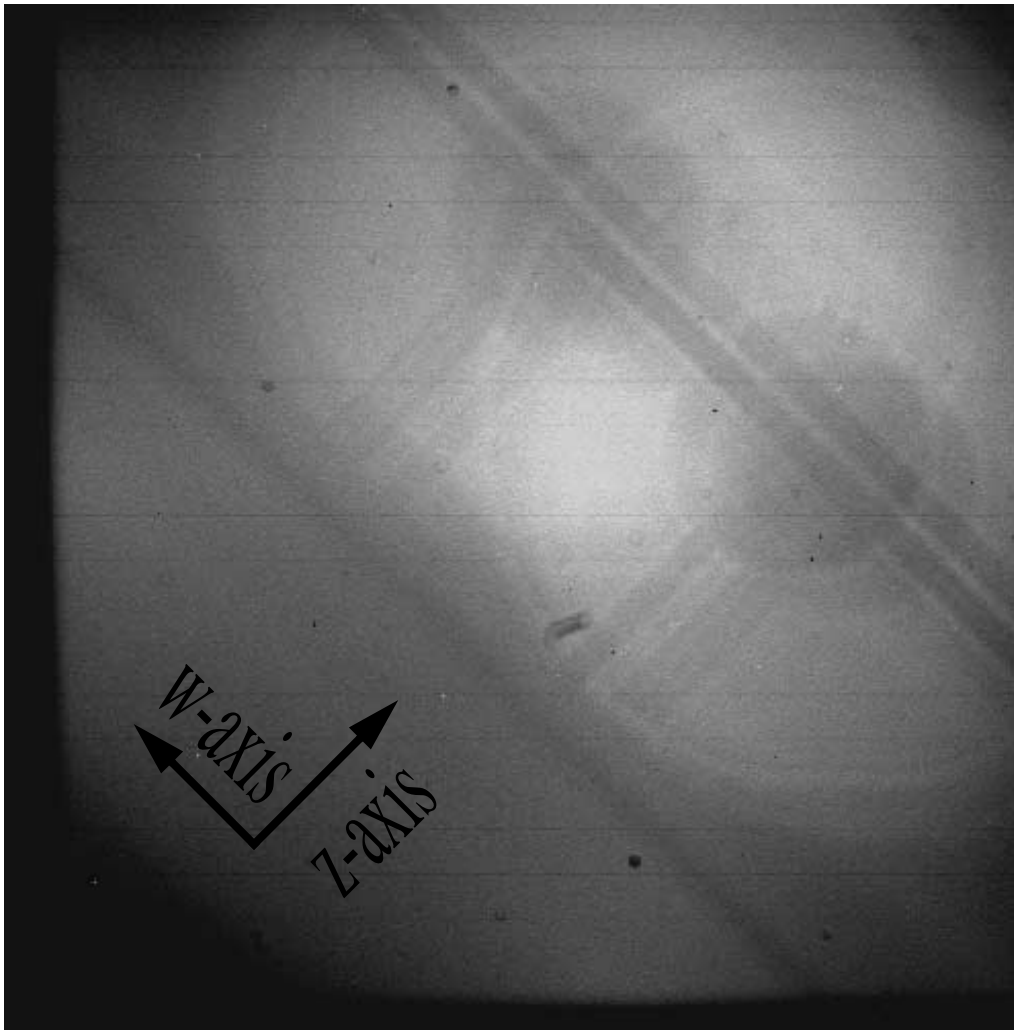


Figure 2: Internal Flat showing strongly defocused image of shutter B.

We first divided all INTFLATS by the external calibration channel flat (VISFLAT) to remove the pixel-to-pixel and large scale variations in the CCD sensitivity. Next we defined a digital filter using the IDL procedure `digital_filter(flow,fhigh,gibbs,nterms)`. Flow and Fhigh are the lower and upper frequency of the filter as a fraction of the Nyquist frequency. Gibbs is the size of Gibbs phenomenon wiggles in -db. Nterms is the order of the filter. By experimentation we found that the values `flow=0.04,fhigh=0.05,gibbs=50`, and `nterms=30` produced a bandpass filter which, when convolved with the image (multiplied in Fourier space), isolated the features with a spatial scale corresponding to the shutter features (i.e., small scale features and noise were removed). Next we rotated the

INTFLATS by 45 degrees to align the columns and rows with our rotated coordinated system. A typical result is shown in Figure 3. Next, we “collapsed” the image to a single data vector by averaging the central 200 columns or rows. The result is a vector of so-called “fringes” corresponding to the relative position of the rivets, corrugations, and other features on the shutter blade. To remove any remaining large-scale undulations (i.e., on scales larger than the shutter fringes, e.g. >100 pixels) we fitted and then subtracted a fourth order polynomial from the vector.

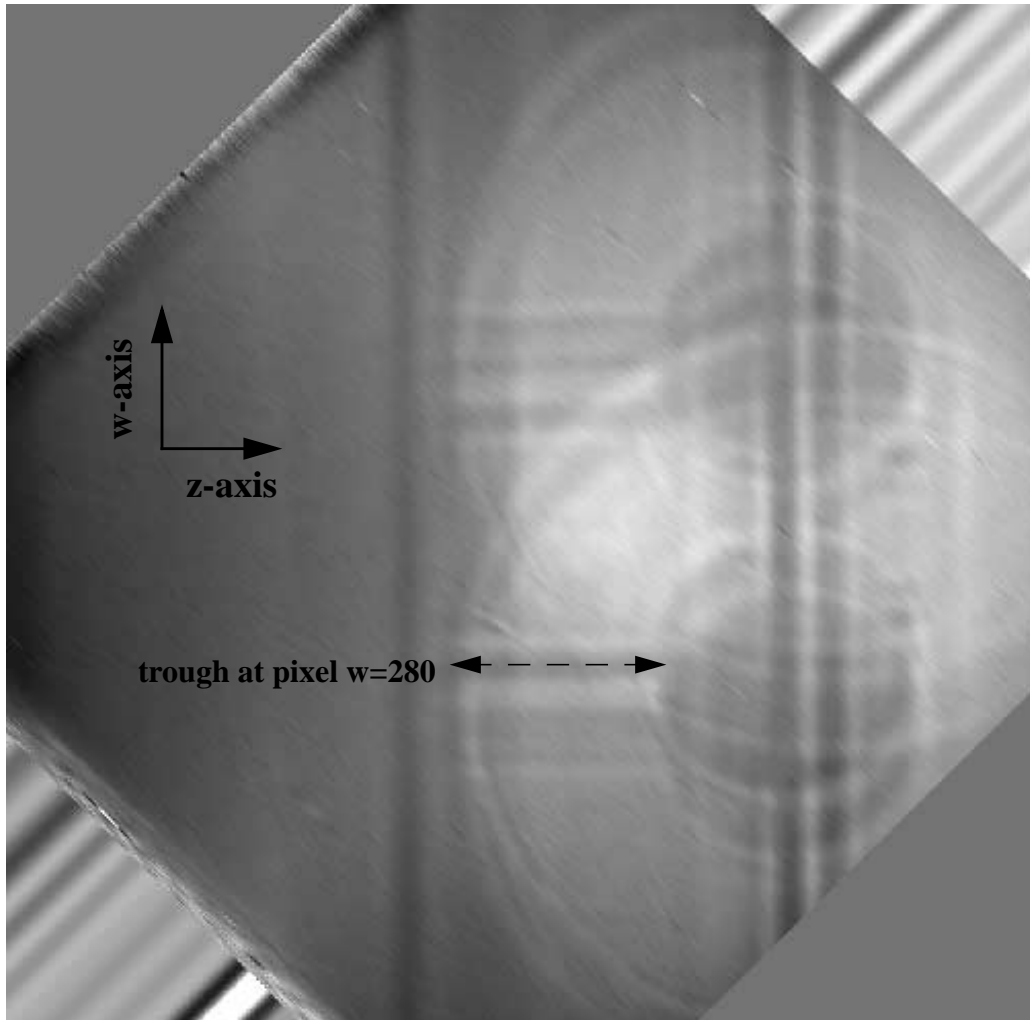


Figure 3: Digitally-filtered, rotated INTFLAT from WF2, shutter B.

The resulting positions of the shutter fringes are readily apparent. Figure 4 shows the region of the fringe vector around a specific feature indicated in Figure 3. While some very minor variations in the intensity of fringes can be seen among different INTFLATS, by far the most apparent variation is a mean relative shift in the position of the whole pat-

tern of fringes (as seen in Figure 4). We have measured the relative positions of the shutter fringes by cross-correlating the fringe vectors in the INTFLATS. As an example, for the 3 INTFLATS shown in Figure 4, two of the fringe vectors differ in their alignment by 0.1 pixels, while the third discrepant vector differs by 4 pixels in the mean position of the fringes.

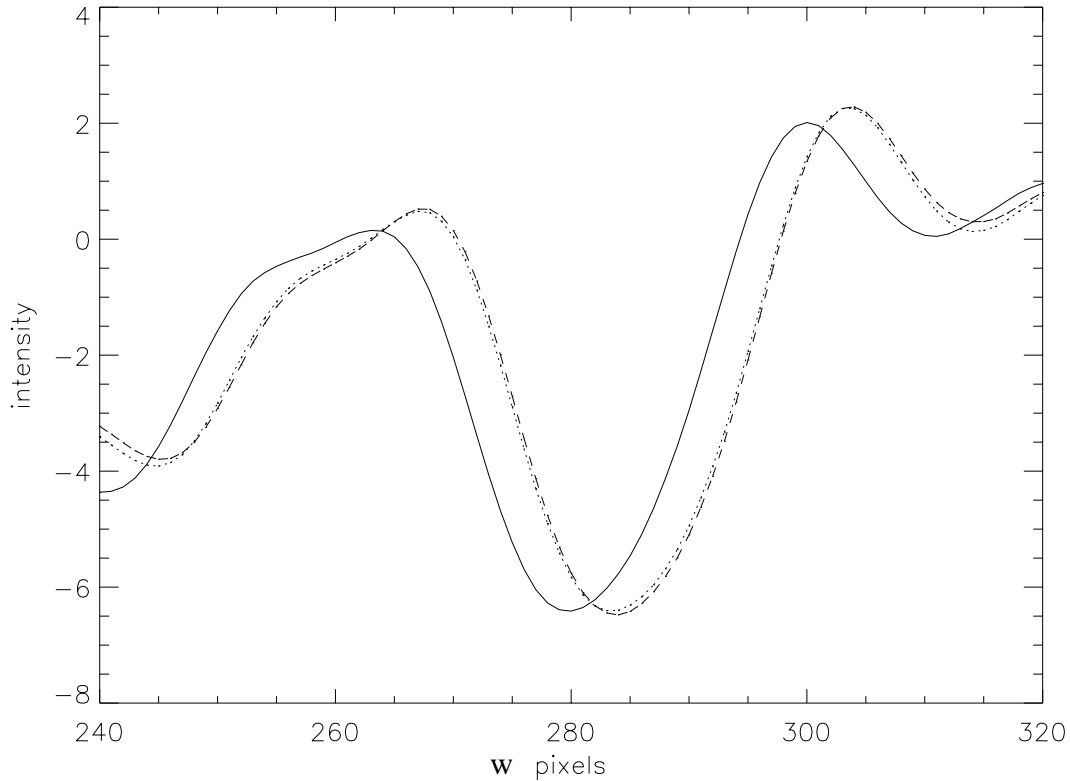


Figure 4: Shutter fringe vector derived from INTFLATS, WF2, shutter B.

By choosing a single INTFLAT to define the fiducial fringe vector, we determined the relative pixel shift of any other INTFLAT by cross-correlating it against the fiducial. We measured the positional jitter using a large set of past INTFLATS taken from the HST archive.

We performed four versions of this exercise to measure the jitter along either the w- or z-axis when either shutter A or B is closed. The results can be seen in Figures 5 and 6.

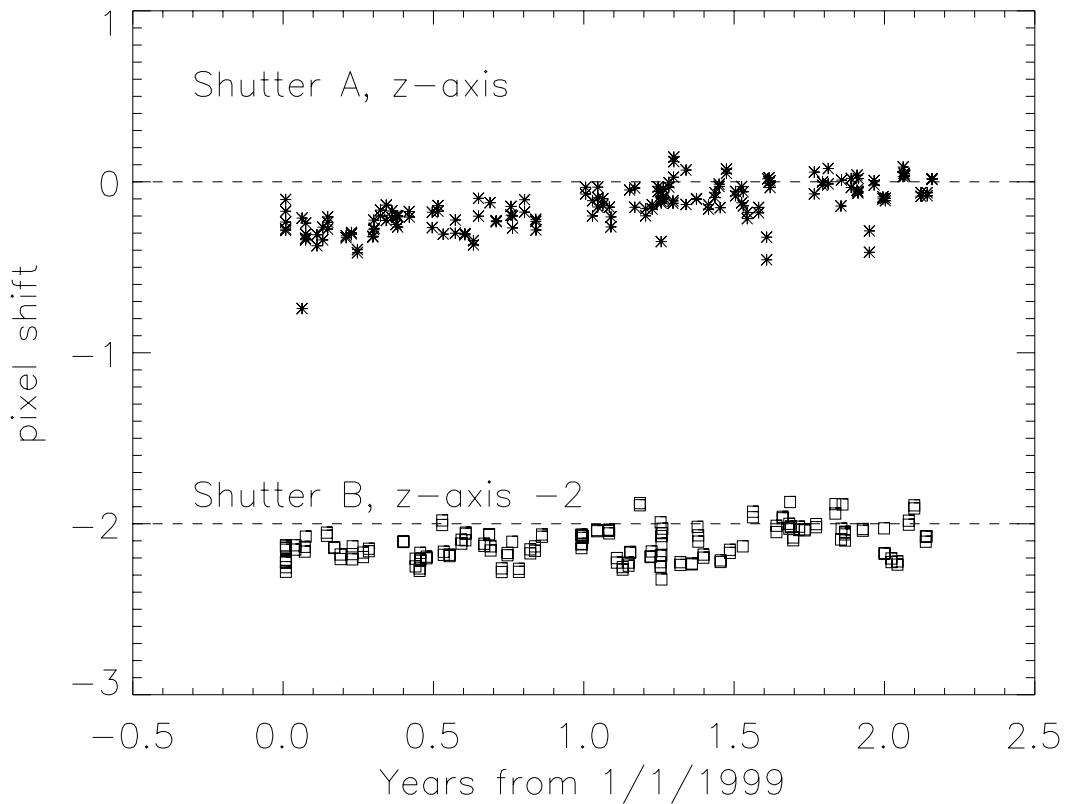


Figure 5: Shutter jitter for shutters A and B along z-axis (parallel to travel). The shutter B values were offset by 2 pixels for clarity.

As seen in Figure 5, for jitter measurements along the z-axis when either shutter A or B is in the closed position, there is very little variation in the shutter position with time. From this we conclude that the closed position of either shutter has been very stable in the z-axis direction. The z-axis corresponds to the direction in which the shutters move when they close or open. This stability in the z positions could, for example, result from the shutters being restricted in their z motion by contact of the shutter keels with each other, and contact against the mechanical (rubber) stops that limit their travel in the open position (similar to a train at the end of the track; see Figure 1).

Significantly more shutter jitter is seen in the position of the closed shutter along the w-axis, the direction perpendicular to the motion of the shutter when it is closing or opening. As seen in Figure 6, when shutter A is closed, the jitter along this axis is greater than it is along the z-axis and there is some indication that the amplitude of the jitter has been growing. In addition, there are a few sporadic, large shifts in the position of the closed shutter (see Figure 6). These large shifts are first seen in the beginning of 1999. There is

no detailed correlation between the large shifts and times of the shutter anomalies. We can only say that the two phenomena are roughly coeval, and begin in the 1999 - 2000 timeframe.

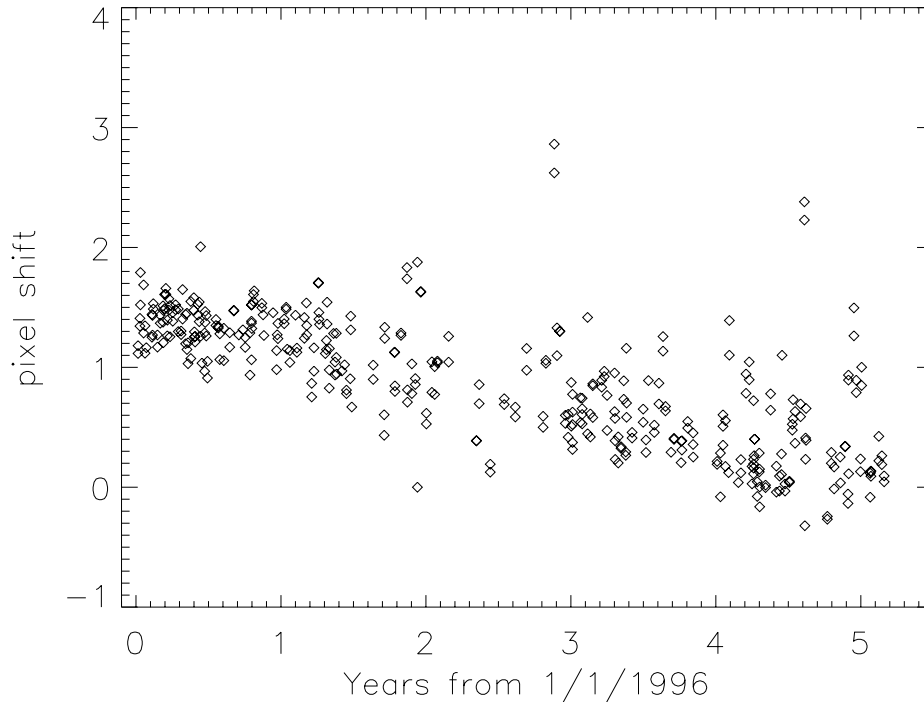


Figure 6: Shutter jitter for shutter A along w-axis (normal to travel).

Similarly, the jitter along the w-axis when shutter B is closed has been increasing with time (see Figure 7). Again we see large departures in the closed position occurring sporadically beginning towards the end of 1999. The variations in shutter position are greatest for shutter B which shows the greatest increase in jitter with time and the greatest number of large departure states. We note that the largest excursions in Figure 7 of ~ 3 pixels correspond roughly to 100 microns in the position of the shutter blade.

In the w-axis direction the shutter movement is ultimately terminated by the tension of the skeletal arms connected to the shutter and the shutter motor by rivets and bearings (an out of focus image of the rivets can be seen in Figures 2 and 3). We speculate that over time and with mechanical wear, more “play” is developing either in the bearings or in the solenoid motors, or both. That such evidence is seen for both shutter A and B gives some weight to this scenario.

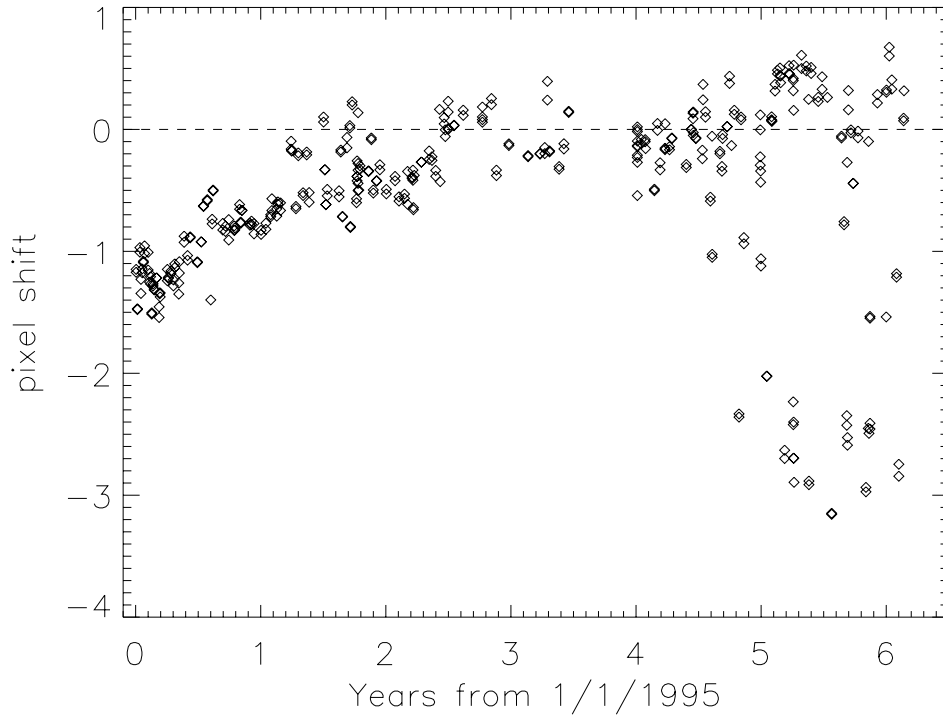


Figure 7: Shutter Jitter for shutter B along the w-axis (normal to travel).

Since the onset of the observed jitter in the INTFLATs, and hence mechanical wear in the shutter mechanism, roughly precedes the advent of the shutter anomalies, we can infer that these phenomena may be related in some general sense. For example, increasing play in the mechanical linkage might cause the encoder wheel to occasionally block the light path of the position sensor LED / phototransistor, hence producing an anomaly event. However, at this point we cannot claim any direct detailed connection between the jitter and anomalies. Nonetheless, it is evident from this work that mechanical wear is occurring, and that the INFLATs can provide an interesting diagnostic of this process.

References

Casertano, et al., WFPC2 ISR, in preparation.

Long, C., "WFPC-2 Shutter-A Position Sensing Fault Isolation," STScI Interim External Report 00-332 / Revision 00-340.