ACIS Memo # 183
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To: ACIS Team
From: Catherine Grant
Subject: Preliminary Analysis of ACIS Squeegee Mode Test
Date: 25 April 2000

On Saturday, April 15 a real time CAP was executed to perform a series of observations testing the squeegee readout mode on the S0 CCD. The squeegee mode has been shown to improve the charge transfer efficiency of a radiation-damaged CCD in the lab. The results from the flight test show that the squeegee mode is also effective in improving performance of the flight CCDs.

S0, the CCD used for the flight tests, has the worst CTI of all the flight devices. Devices with better performance initially would most probably have much better final performance. Two squeegee modes were tested using a 16-row squeegee and an 8-row squeegee. As expected, the 16-row squeegee is more effective than the 8-row squeegee, presumably because it collects more charge. Observation details of the test are listed in the following table along with those of a normal CTI run used for comparison. The high energy amplitude reject rate (cts/frame) is also listed which is an indication of the particle background level during the observations. The comparison dataset may have a slightly lower background but the effect should be negligible.

Table 1: Test Parameters

ObsID	Mode	No. of frames	Start time (GMT)	S0 HE rej. rate (cts/frame)
62803	16-row squeegee	958 @ 3.3 sec	105:22:55	129.0
62892	8-row squeegee	968 @ 3.3 sec	106:00:16	132.2
62094	normal CTI	544 @ 3.2 sec	096:08:16	121.2

1 Bias Images

An image of the overclock-corrected bias frame for the 16-row squeegee run is shown in Figure 1. The top 16-rows are the location of the squeegee charge which is never clocked out of the image area and is therefore never readout. Any charge in these rows in the bias frame accumulated in the framestore during readout. Below the squeegee is a region of 'spillover' of charge from the squeegee. This is similar to the trailing charge seen behind X-ray events from trap re-emission. A cut along column 400 is also shown which illustrates this spillover.

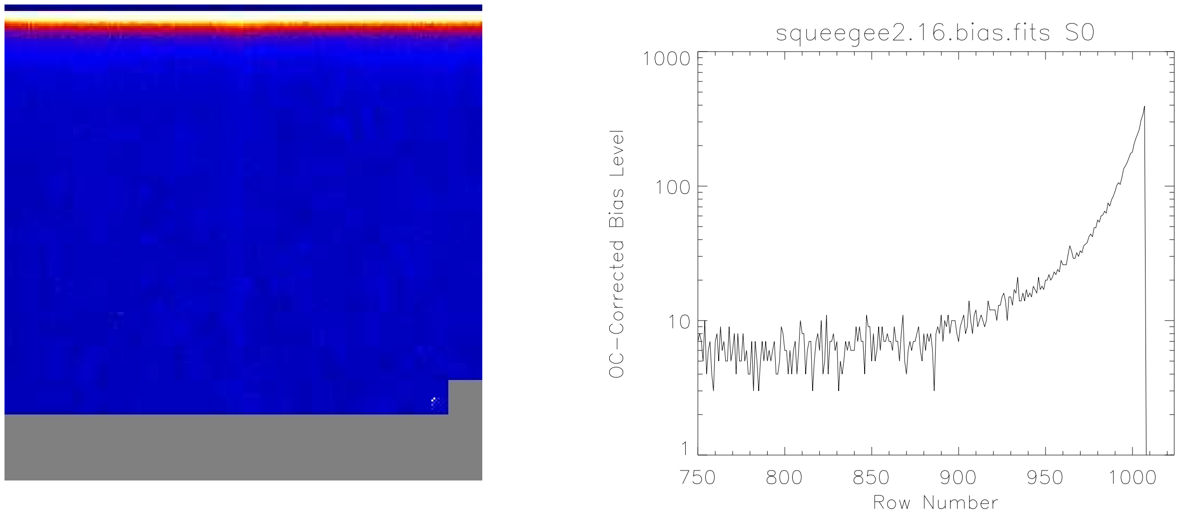

Figure 1: Characteristics of the squeegee mode bias frame. (Left) Image of overclock-corrected bias frame from 16-row squeegee mode test. (Right) The overclock-corrected bias level along column 400, a representative column, showing the squeegee spillover.

2 Time-dependence of Squeegee Bias Level

In the flight experiment a time dependence of the squeegee effectiveness was noticed. This effect may be a residual charge which decays away over 10s-100s of minutes. It is believe this residual can be removed by resetting the CCD voltages in a particular order at the start of a science run. The result of the residual charge is that the bias level is high at the beginning of a run and much lower at the end. The bias frame itself is much higher than any of the science exposures, and has excessive squeegee spillover. The decaying bias level is best seen in Figure 2.

Both the squeegee tests have negative corner pixel centroids indicating that the original bias frames taken before the start of the science exposures had a higher level of residual charge. The centroid continues to drop as the residual charge in the image drains away.

Not only does the overall bias level change during the squeegee test, the vertical structure of the charge 'spillover' seen in the original bias frame decreases with time. Shown in Figure 3 is the centroid of the corner pixel distributions of the bottom and top rows of the CCD for the 16-row squeegee test as a function of time. The size of the corner pixel decay is much larger for the top rows (near the squeegee) than the bottom rows (near the framestore). This differential causes an increase in measured CTI also shown in Figure 3. The bias-subtracted pulseheights are too low everywhere on the CCD, however events at the top of the CCD are reduced more than events at the bottom of the CCD due to the 'spillover' structure in the original bias frame.

As the bias level, measured by the corner pixel values, decreases, the event island is less likely to produce a split event, thus G0 events become more plentiful and G2, G6 and G7 events, whose numbers have been increased due to CTI-induced charge trailing (also known as grade morphing), become less numerous. This becomes important to remember when trying to measure the FWHM of spectral lines using the summed pulseheight of G02346 events. While the total number of G02346 events does not change during the squeegee test, the grade distribution of these events does. Near the end of the squeegee test, the CTI-induced trailing charge in the top pixel is no longer above the split threshold for many events and is not included in the summed pulseheight. An increase in FWHM for G02346 events is seen at the end of the squeegee test which is due to the short term

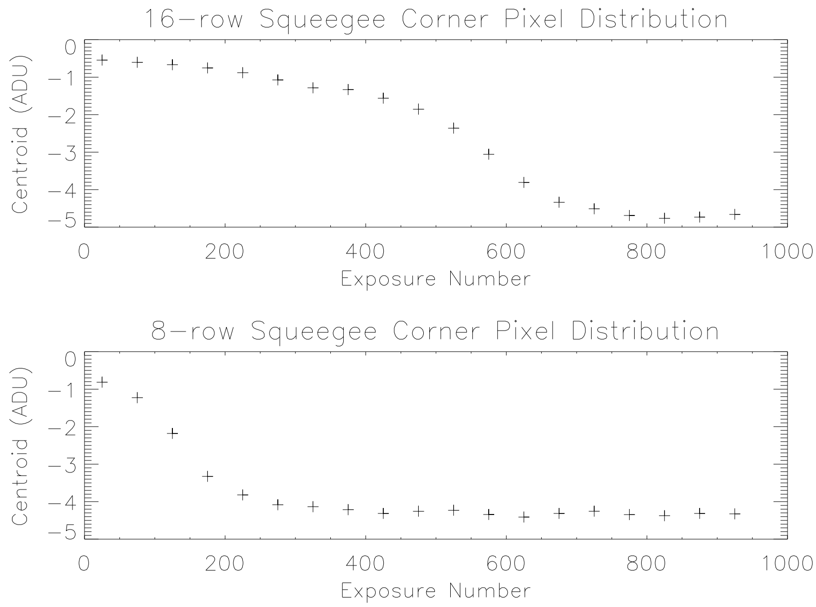

Figure 2: Time-dependence of the centroid of the corner pixel distribution for both the 16-row and 8-row squeegee tests. The negative values for the centroids indicates that the original bias frame has a higher bias level than the exposures and that this excess charge is slowly decaying away.

trap re-emission not being included in the event pulseheight.

Shown in Figure 4 is a comparison of the pulseheight in the top pixel of the event island for standard readout and 16-row squeegee mode for the first 400 frames and the last 300 frames. The dotted vertical line indicates the normal split threshold of 13 ADU. The top plot is from a standard CTI science run with normal readout mode. The Gaussian centered around 0 ADU is the normal CCD noise. The tail extending to higher pulseheights is from both CTI-induced charge-trailing and true vertical split charge. The top pixels in the squeegee run have an additional negative pulseheight tail as a result of the large amount of residual charge contaminating the original bias frame and the strong vertical gradient of that charge. That charge in the top of the CCD decays much more rapidly than the bottom, thus increasing the spread of the negative bias-subtracted top pixel values. If a bias frame from a normal CTI measurement is used instead of the squeegee bias, the negative tail disappears and the top pixel distribution looks much like that for the standard readout.

3 Measured CTI & FWHM

Results of analysis of the squeegee mode data are shown below. Because of the changing bias level and structure just discussed, it is unclear how best to characterize the change in CCD performance due to the squeegee mode. Except where specifically mentioned, the squeegee bias is used, however this may not be the best representation of the true performance of the squeegee mode. CTI is calculated from the center pixels values alone, while FWHM is calculated using the summed pulseheight from G02346 events and a locally derived gain so the FWHM is already an overestimate. While both squeegee modes improve the total charge lost to each event (better CTI), only the 16-row squeegee mode has a significant affect on the FWHM @ Mn-K. The FWHM results are replaced by an ellipsis when the data quality precludes an easy fit usually because of low numbers of photons.

Splitting the data into two groups, one near the beginning (frames 2-400) and one near the end

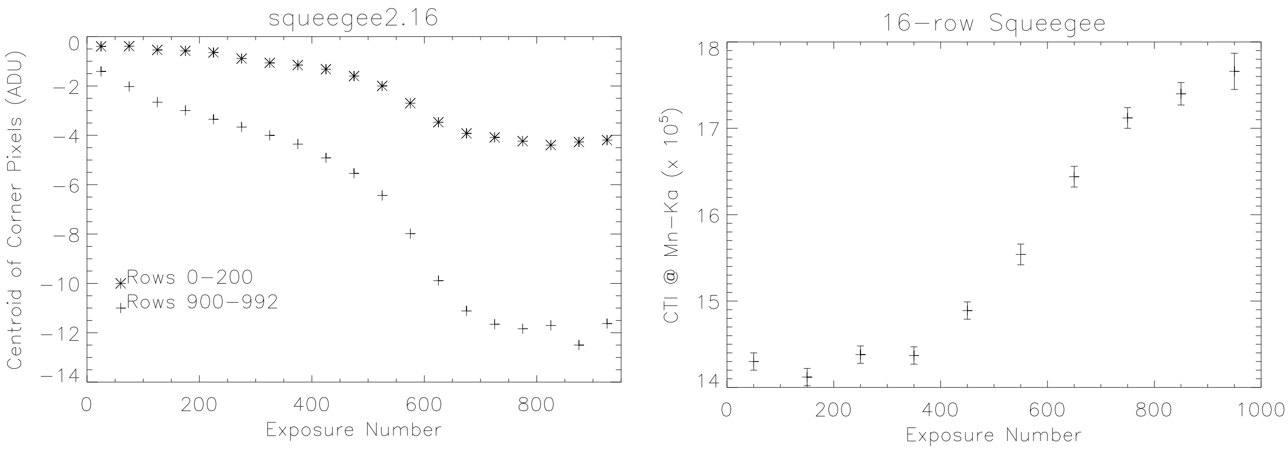

Figure 3: The change in corner pixel values during the squeegee tests is much larger at the top of the CCD (near the squeegee) than at the bottom of the CCD (near the framestore). (Left) The bottom 200 rows show less bias decay than the top 92 rows. (Right) This differential charge decay increases the measured CTI

(frames 650-958), the changing bias level becomes quite apparent. The second group has much worse measured characteristics than the first group. In order to study how much of this difference is due to the incorrect bias frame, a bias frame from a normal CTI measurement was used instead of the squeegee bias. While this does improve the measured performance considerably, there may still be vertical bias structure in the data that the bias frame is not removing even at the end of the science run. Any additional bias structure would increase both the CTI and the FWHM. A more accurate method would be to reconstruct the bias level for each event individually using the corner pixel values. This would take care of both the temporal and spatial variability of the bias level.

Mode	CTI @ Mn-K (x 10^{-5})	CTI @ Al-K (x 10^{-5})	Mn-K FWHM @ Row 928 (eV)				Al-K FWHM @ Row 928 (eV)			
16-row squeegee	15.60 ± 0.03	27.39 ± 0.17	392	459	499	481	230	246	356	318
8-row squeegee	17.71 ± 0.04	34.07 ± 0.18	537	617	604	567	279	326	286	297
standard readout	20.24 ± 0.05	38.76 ± 0.23	547	591	598	599	272	...	271	252
16-row squeegee										
frames < 400	14.24 ± 0.04	23.35 ± 0.20	320	308	337	325	160	153	140	141
frames > 650	17.21 ± 0.06	33.18 ± 0.30	421	510	507	379	259	269	250	196
16-row squeegee w/normal bias										
all frames	15.21 ± 0.03	26.40 ± 0.17	398	445	507	432	...	348	391	287
frames < 400	13.96 ± 0.04	22.52 ± 0.21	249	...	292	...	...	...	180	170
frames > 650	16.52 ± 0.05	30.79 ± 0.28	345	...	427	325	230	200	259	172

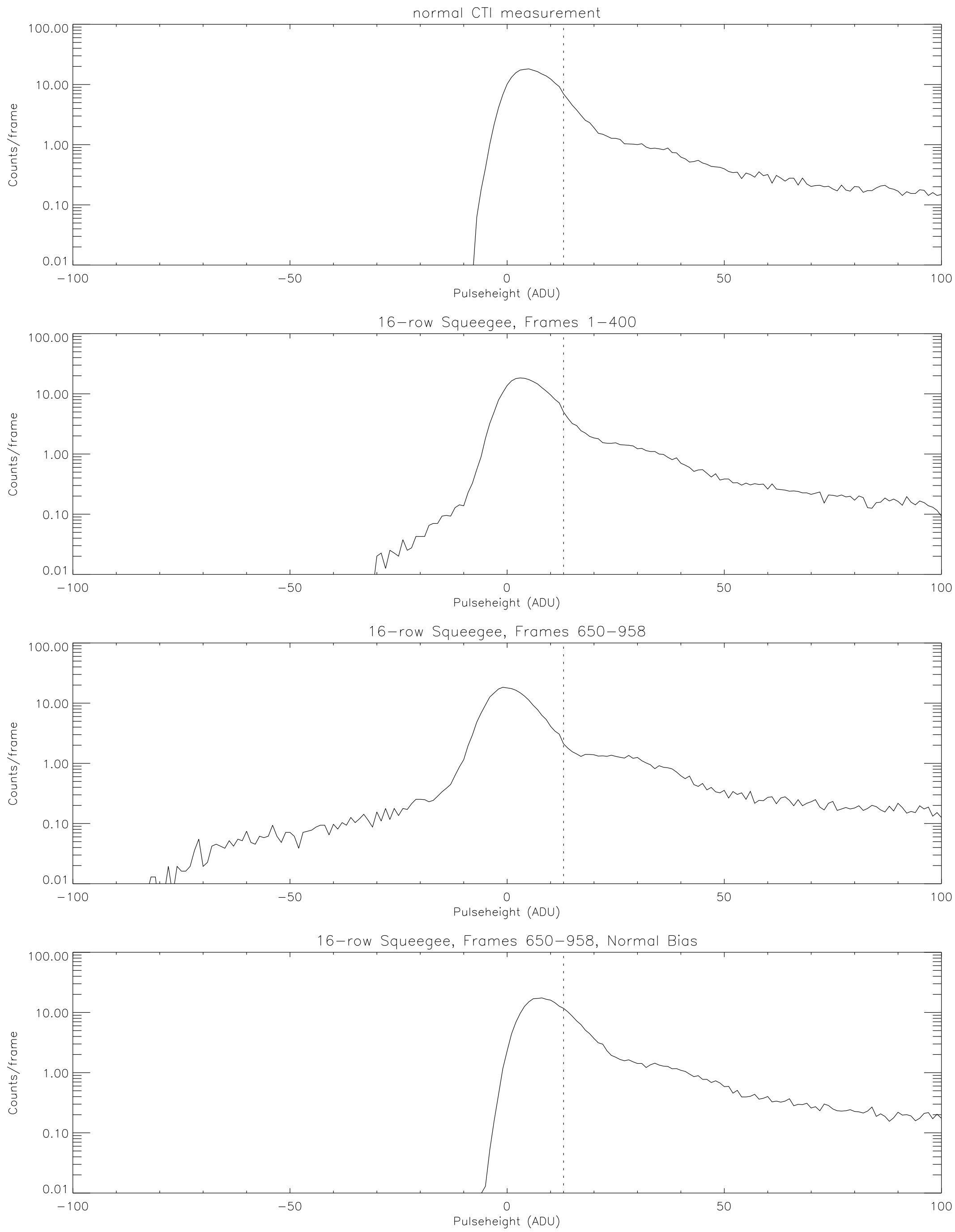

Figure 4: The distribution of pulseheights in the top pixel of each event island. From the top to the bottom, a normal CTI measurement, exposures 2-400 of the 16-row squeegee test, exposures 650-958 of the 16-row squeegee test, and exposures 650-958 of the 16-row squeegee test using the bias frame from the normal CTI measurement.