SWIFT-XRT-CALDB-01
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SWIFT XRT CALDB REV 5.0 RELEASE NOTE

SWIFT-XRT-CALDB-01: Bad Pixels

1. Component Files:

FILENAME	VALID DATE	RELEASE DATE	CAL VERSION
swxbadpix20010101v001.fits	1-Jan-2001	15-Oct-2004	003
swxonboardbp20010101v001.fits	1-Jan-2001	15-Oct-2004	003
swxbadpix20010101v005.fits	27-May-2005	12-Oct-2005	004
swxonboardbp20010101v005.fits	27-May-2005	12-Oct-2005	004
swxbadpix20010101v006.fits	27-May-2005	1-Dec-2005	005
swxonboardbp20010101v006.fits	27-May-2005	1-Dec-2005	005

2. Scope of Document:

This document contains a description of the latest update of the XRT bad pixel map which is installed in the XRT pipeline bad pixel calibration file as well as in the XRT on-board bad pixel table.

3. Changes:

New hot pixels have been identified from analysis of on-orbit scientific data. Single hot pixels are seen as a result of normal degradation of the CCD as well as several hot columns produced by an anomaly which occurred on May 27, thought to be a micrometeorite impact. An appendix has been added outlining the algorithms for transforming between the various XRT-related coordinate systems (copied from XRT-PSU-037, XRT Science Agorithms).

4. Scientific Impact of this Update:

Because the masked out hot columns and other individual hot pixels occur unfortunately near the center of the CCD, there is a significant chance that the point spread function of the intended target may fall partially on the masked out columns or other hot pixels. The hot pixels which are defined in the CALDB badpix and onboardbp files are excluded from telemetry and consequently not processed by the XRTPIPELINE software. In XRTPIPELINE version 0.9.9 (released 10-November-2005) and earlier, no exposure map correction is made to account for the decreased collecting area in such a situation. Thus any user wishing to perform a proper exposure map correction on their data must be aware of the masked out pixels/columns identified in this calibration product and adjust their data accordingly.

5. Caveat Emptor:

It is noted that a secondary (i.e., lower) level of instability exists in some pixels on the XRT CCD. These pixels are not included in the bad pixel tables to be strictly excluded from processing since, for much of the time, these pixels report values consistent with normal operation. These 'flakey' pixels will be tracked in a separate file which is not part of the standard processing CALDB.

6. Expected Updates:

It is expected that radiation damage during the orbital lifetime of Swift will degrade the XRT CCD by introducing more bad pixels. Periodic updates to the Bad Pixel table files will be made to account for these changes.

7. Initial Bad Pixel Table:

The initial bad pixel table created and uploaded by PSU (David Burrows) in June 2003 consists of 1 partial bad column (209 pixels in extent) and 1 other bad pixel, mapped through both the A and B amplifier:

Table 1: Original pre-launch bad pixel list

RawX	RawY	AMP	Y-extent
453	391	1	209
146	391	2	209

RawX	RawY	AMP	Y-extent
453	390	1	1
146	390	2	1

8. Update Analysis:

(12 October 2005)

The XRT CCD contains several dead, hot or warm pixels. Dead pixels are those that do not effectively register charge for x-rays which strike them. Hot pixels are those that produce noise levels which are too high to use effectively at all temperatures. Warm pixels are those which produce a higher noise level than normal pixels but which are still able to be used for science observations below particular XRT CCD temperatures. In the case of warm and hot pixels, the anomalous behavior is due to charge traps in the lattice which cause the pixels to overproduce dark current as compared to normal pixels. For temperatures high enough that the dark current charge produced exceeds the event threshold, these warm pixels can appear as x-ray events to the flight software. For the XRT CCD, it seems that most of the charge traps which produce warm pixels are frozen out below temperatures of about -52^{o}C. Furthermore, the onboard software allows an upload of hot pixel co-ordinates to a bad pixel map, so that they may be eliminated from the count rate evaluation and removed from the telemetry stream. The ground processing software also determines hot pixels as pixels persistent from frame to frame of an observation. The hot pixel upload is thus a trade-off between mitigating the effects of the warm pixels at high temperatures and reducing the effective area of the CCD at lower temperatures for which the effects of the warm pixels are largely frozen out. It should be noted that the effects of a particular warm pixel are most severe in PC mode where the readout time is the longest. In the higher resolution timing modes (WT and LrPD), the contribution of particular warm pixels are much less significant due to the much faster clocking of the CCD.

The XRT bad pixel list at the time of launch consisted of one partial dead column (composing 209 out of 600 pixels in one column) and one additional bad pixel, defined from ground calibration data collected at -100^{o}C. At the actual on-orbit operating temperature of XRT, several more hot pixels have become apparent. The number of noise events detected in each XRT pixel follows an exponential function with respect to CCD temperature. For most pixels the function remains below the XRT event threshold of 80DN at temperatures up to -50^{o}C. A small fraction of the pixels do exceed the event threshold at temperatures colder than -50^{o}C; these are designated as warm pixels. The most extreme of these ‘warm pixels’ have been added to the calibration database bad pixel list. Furthermore, an isolated event on May 27th, possibly a micrometeorite strike to the XRT detector or extremely high energy charged particle, damaged two additional partial columns. It is expected that the number of pixels which exceed the event threshold within the operating temperature regime of the XRT will increase slowly throughout the mission due to normal instrument degradation. It is also possible that the severity of the excess charge seen in the pixels affected by the May 27th event may change over time. The state of these warm/hot pixels of interest will be tracked throughout the course of the mission to note any changes in state (for better or worse) so that they may be added or removed from the bad pixel lists accordingly.

(01 December 2005)

The XRT on-board bad pixel list Cal Version 5 (swxbadpix20010101v006.fits and swxonboardbp20010101v006.fits) introduces the addition of the 5 masked out hot columns as well as 10 new masked out hot pixels to the CALDB. Cal Version 5 consists of the pixels defined in the Table 2 below. Table 3 shows the additional pixels which are listed in the badpix CALDB product to define the region of the 'burnspot' on the XRT CCD. The burnspot is a region of anomalously warm pixels slightly off-center from the XRT boresight which produce a noticeable excess number of events above temperatures of approximately -60C.

A warm pixel tracking algorithm has been developed to monitor the performance of all pixels on the XRT CCD throughout normal daily operations of the instrument. Most XRT observations are performed in the photon-counting (PC) operational mode of the instrument. In this mode, each event recorded by the CCD above the event threshold is position tagged and telemetered to the ground. Because typical noise levels are 0.01 counts per second over the entire CCD the likelihood of any individual pixel recording multiple events during the course of a single orbit is extremely low unless the events recorded are due to thermally generated charge produced by the pixel itself. Thus, a search is performed on each orbit of PC data and pixels which record events in greater than 10% of the PC mode frames are collected. Bright sources such as gamma ray bursts and other observing targets do not cause false identification of hot pixels because multiple targets (typically 4-6) are observed during a single orbit at slightly different locations on the XRT CCD due to the ~ 3 arc minute pointing accuracy of the spacecraft. Sample trending figures from the XRT warm pixel tracking algorithm are shown in the figure below.

Table 2: On-orbit bad pixel file

RawX	RawY	Y-Extent
453	391	209
146	0	599
177	0	599
291	0	599
292	0	599
319	0	599
345	224	1
260	246	1
304	265	1
389	271	1
236	301	1
306	303	1
230	306	1
301	332	1
289	361	1
347	390	1
453	390	1
479	240	1
581	329	1
172	345	1
432	444	1
148	477	1
599	528	1
585	565	1

Table 3: Additional 'burnspot' badpixels in badpix CALDB

RawX	RawY	Y-Extent	RawX	RawY	Y-Extent
307	256	54	328	256	54
308	256	54	329	256	54
309	256	54	330	256	54
310	256	54	331	256	54
311	256	54	332	256	54
312	256	54	333	256	54
313	256	54	334	256	54
314	256	54	335	256	54
315	256	54	336	256	54
316	256	54	337	256	54
317	256	54	338	256	54
318	256	54	339	256	54
319	256	54	340	256	54
320	256	54	341	256	54
321	256	54	342	256	54
322	256	54	343	256	54
323	256	54	344	256	54
324	256	54	345	256	54
325	256	54	346	256	54
326	256	54	347	256	54
327	256	54	348	256	54

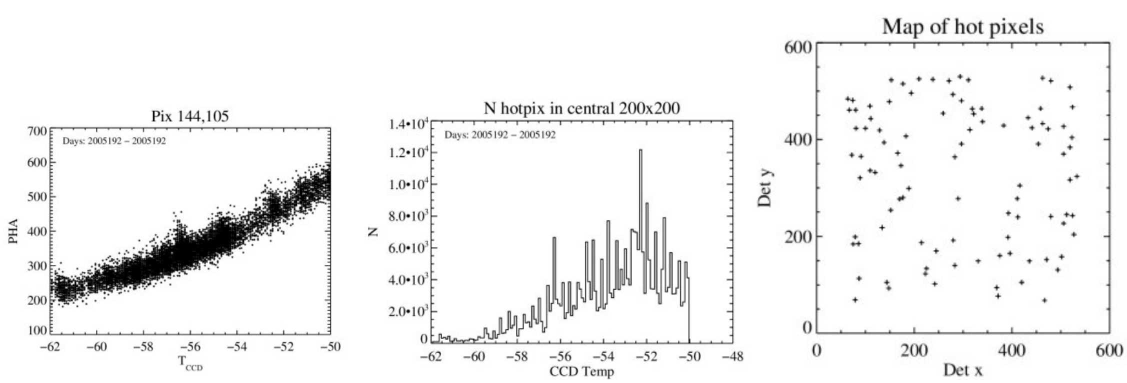

Figure: Sample plots from XRT hot pixel tracking software. The leftmost plot shows the behavior of the background from a single pixel versus XRT CCD temperature. The middle panel plots a histogram of the number of hot pixels appearing on the XRT CCD versus temperature. The rightmost plot shows a CCD map of all hot pixels identified.

Appendix – Coordinate Transformation Algorithms

We copy here the coordinate transformation algorithms from XRT-PSU-037, XRT Science Algorithms for the convenience of the reader:

- X_{raw}, Y_{raw}: These are raw detector coordinates of the image area. Pixels are numbered (0:599, 0:601) and are relative to the output amplifier. The conversion from *chip* to *raw* coordinates is:

  $$X_{raw} = X_{chip} - 6 \qquad \text{for } (6 \leq X_{chip} \leq 605)$$

  2.1

  $$Y_{raw} = Y_{chip}$$

  This is the coordinate system reported by the flight software in Low Rate Photodiode Mode and Windowed Timing Mode.

- X_{det}, Y_{det}: These are focal plane coordinates of image area in pixels, numbered (1:600, 1:602), so they can be compared with pixel numbers from image display software like *ds9*. Pixels are numbered relative to physical location on the CCD, not to amp readout. The conversion from *raw* to *det* coordinates is:
  - Amp 1:

    2.2

    $$X_{det} = X_{raw} + 1$$
    $$Y_{det} = Y_{raw} + 1$$
  - Amp 2:

    2.3

    $$X_{det} = 600 - X_{raw}$$
    $$Y_{det} = Y_{raw} + 1$$
- X_{foc}, Y_{foc}: These are focal plane coordinates in millimeters from the center of the detector. The conversion from *det* to *foc* coordinates is

  $$X_{foc} = A + K*X_{det}$$

  2.4

  $$Y_{foc} = B + K*Y_{det}$$

  where

  K = 0.0400 = pixel scale in mm/pixel
  A = -300.5 * K = pixel offset in mm
  B = -300.5 * K = pixel offset in mm