SWIFT-XRT-CALDB-01
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SWIFT XRT CALDB REV 8.0 RELEASE NOTE

SWIFT-XRT-CALDB-01: Bad Pixels

1. COMPONENT FILES

FILENAME	VALID FROM	VALID UNTIL	RELEASE DATE	CAL VER
swxbadpix20010101v005.fits	1-Jan-2001	27-May-2005	12-Oct-2005	001
swxonboardbp20010101v005.fits	1-Jan-2001	27-May-2005	12-Oct-2005	001
swxbadpix20050527v001.fits	27-May-2005	9-Jun-2005	17-Apr-2006	001
swxonboardbp20050527v001.fits	27-May-2005	9-Jun-2005	17-Apr-2006	001
swxbadpix20050609v001.fits	9-Jun-2005	18-Jan-2006	17-Apr-2006	002
swxonboardbp20050609v001.fits	9-Jun-2005	18-Jan-2006	17-Apr-2006	002
swxbadpix20050609v002.fits	18-Jan-2006	9-Feb-2006	17-Apr-2006	003
swxonboardbp20050609v002.fits	18-Jan-2006	9-Feb-2006	17-Apr-2006	003
swxbadpix20050609v003.fits	9-Feb-2006	12-Apr-2006	17-Apr-2006	003
swxonboardbp20050609v003.fits	9-Feb-2006	12-Apr-2006	17-Apr-2006	003
swxbadpix20050609v004.fits	9-Jun-2005	15-Jun-2006	8-Nov-2006	004
swxonboardbp20050609v004.fits	9-Jun-2005	15-Jun-2006	8-Nov-2006	004
swxbadpix20060615v001.fits	15-Jun-2006	13-Feb-2007	8-Nov-2006	004
swxonboardbp20060615v001.fits	15-Jun-2006	13-Feb-2007	8-Nov-2006	004
swxbadpix20060615v002.fits	13-Feb-2007	23-Oct-2007	29-Mar-2007	005
swxonboardbp20060615v002.fits	13-Feb-2007	23-Oct-2007	29-Mar-2007	005
swxbadpix20071023v001.fits	23-Oct-2007	30-Oct-2007	1-Nov-2007	006
swxonboardbp20071023v001.fits	23-Oct-2007	30-Oct-2007	1-Nov-2007	006
swxbadpix20071030v001.fits	30-Oct-2007	present	1-Nov-2007	006
swxonboardbp20071030v001.fits	30-Oct-2007	present	1-Nov-2007	006

2. SCOPE OF DOCUMENT

The description of the XRT bad pixels is contained in two files in CALDB. The file swxonboardbp*.fits (from here forward *swxonboardbp*) contains all bad pixels uploaded to the instrument and contained in the onboard bad pixel map, the second file, swxbadpix*.fits (from here forward *swxbadpix*), contains both the pixels loaded onboard and some additional pixels which should be ignored by the ground processing. These two files have three extensions describing the bad pixels for each of the following modes: Photon Counting (PC) Mode, Windowed Timing (WT) Mode and Imaging Mode. For each mode, each bad pixel identified in the CCD array is described in RAWX and RAWY co-ordinates relative to each of the two CCD amplifiers. This document contains a description of the latest updates installed in the XRT pipeline bad pixel calibration file and in the XRT on-board bad pixel Tables.

2. CHANGES IN RELEASE VERSION 8.0

Substrate Voltage change

The loss of the CCD active cooling system shortly after launch has forced the instrument to rely on the passive cooling provided by the radiator to operate the detector in the -75C to -50C temperature range. The main effect is a significant level of dark current and CCD noise at low energies with an increasing number of hot and "flickering" pixels at higher temperatures. The XRT camera has also suffered damage caused by a micrometeoroid impact on 27 May 2005, resulting in the appearance of new hot pixels and hot columns that are now masked on board.

The XRT team has planned and performed a substrate voltage (SSV) change from 0 V to 6 V to reduce the background noise (Osborne et al., 2005). The XRT has been collecting data with the raised SSV starting on August 22nd, 2007. The monitoring of the instrument performance after the SSV change has shown a decrease in the background noise level, allowing the collection of useful scientific data at CCD temperatures as high as -48C.

Update of hot pixels files

The analysis of DN values of hot pixels previously masked on-board has revealed that 8 hot pixels have returned to normal function and have been removed from the onboard XRT bad-pixel map on October 22nd 2007. Three new hot pixels have been identified from analysis of on-orbit data and were uploaded to the XRT bad pixel map on October 22nd 2007. During XRT centroiding tests on a few occasions the partial hot column at coordinate RAWX=453 caused an incorrect position to be reported by the XRT on-board centroiding algorithm. The hot column has been partially masked on-board in IMAGE mode, from coordinates RAWY= 486 to RAWY= 550. On October 22nd the degrading hot column at RAWX= 290, already masked in Photon Counting mode, was also masked on-board in Windowed Timing mode. During the October 22nd upload the RAWX=294 column was incorrectly masked onboard in Windowed Timing mode. The column RAWX= 294 was unmasked onboard in WT mode on October 30th. The on-board changes are included in the CALDB files *swxbadpix20071023v001.fits* and *swxonboardbp20071023v001.fits* (valid during the period 23rd-29th October 2007, while the RAWX=294 column was masked in WT mode) and *swxbadpix20071030v001.fits* and *swxonboardbp20071030v001.fits* (valid since October 30th, after the unmasking of the column 294) released on November 1st 2007.

3. IDENTIFICATION OF HOT, BAD AND FLICKERING PIXELS

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 that are too high to use effectively at all temperatures. Warm pixels are those that 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 are identified as X-ray events by the flight software. For the XRT CCD, it appears that most of the charge traps which produce warm pixels are frozen out below temperatures of about -54 °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 task *xrthotpix* 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 mode (WT), 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 ºC. 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 80 DN at temperatures up to -54 °C. A small fraction of the pixels do exceed the event threshold at temperatures colder than -54 °C; these are designated as warm pixels. The most extreme of these ‘warm pixels’ have been uploaded to the XRT and added to the CALDB bad pixel list.

Tab.2 shows the additional pixels, which are listed in the *swxbadpix* CALDB product to define the region of the 'burn-spot' on the XRT CCD. The burn-spot 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 -60 °C.

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 PC mode. 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 arcminute pointing accuracy of the spacecraft.

4. SCIENTIFIC IMPACT OF BAD PIXELS

The masked out pixels may occur near the center of the CCD, so that 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 swx*onboardbp* files are excluded onboard from the telemetry and the pixels defined in swx*badpix* are not processed by the XRTPIPELINE software. In XRTPIPELINE versions prior to version 0.9.9 (released 10-November-2005), 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. XRTPIPELINE version 0.9.9 and after correctly account for the exposure.

As a result of the re-inventory of bad pixel uploads throughout the mission (performed prior to the release of document SWIFT-XRT-CALDB-01_v5 – see that document for further details), bad pixel information contained in this CALDB release is different and more accurate than the information contained in releases previous to 27-April-2006. The changes made are outlined in Section 9.

5. CAVEAT EMPTOR

XRT bad pixels are highly temperature dependent and as a result, some pixels which are not contained in these CALDB products may appear anomalous at higher temperatures than those used to identify bad pixels for inclusion in the CALDB. Hot pixels are identified at temperatures at or below -54 °C, so data taken at temperatures above this level may show additional bad pixels. The XRTPIPELINE task *xrthotpix*, identifies and eliminates these pixels from an observation.

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. The XRT team will closely monitor the evolution of the instrumental background after the implemented after the SSV change.

7. PRE-LAUNCH BAD PIXEL TABLE

Prior to launch the XRT CCD bad pixels consisted of 1 partial bad column (209 pixels in extent) and 1 other hot pixel. In CALDB bad pixel files after the 27th May 2005*, the dead column is marked only in the on-ground bad pixel table.and the single bad pixel is included in *swxbadpix* and *swxonboardbp* files, mapped through both the A and B amplifier. These are shown in Tab.1.

Tab.1: Original pre-launch bad pixel and dead pixel list

RawX	RawY	AMP	Y-extent
453	391	1	209
146	391	2	209
453	390	1	1
146	390	2	1

8. ON ORBIT BAD PIXELS

May 27th 2005

Between the 25th and 27th May 2005, new flight software was uploaded to the XRT, such that in PC Mode, a source countrate is only evaluated within a small window in the centre of the CCD. This means that only the bad pixels within the central 200x200 pixel window need to be uploaded to the flight software. The hot pixels in the outer region of the CCD are telemetered and identified either in the *swxbadpix* file or from running the *xrthotpix* task in the XRT Pipeline. Prior to this time all the bad pixels in the 600x600 pixel array had to be identified.

An isolated event on May 27th 2005, possibly a micrometeorite strike to the XRT detector

* For the bad pixel files prior to 27th May 2005 the dead columns is listed in both swxonboardbp and swxrtbadpix

or extremely high-energy charged particle, damaged several additional pixels and columns. It is 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 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. 4 hot columns were uploaded for PC Mode and Imaging mode and 4 hot columns were identified in the onboard WT bad pixel row. Bad pixels from the 27th May 2005 are shown in Tab.3, Tab.16, Tab.29 and Tab.40.

9th June 2005

From observing the hot columns uploaded to the XRT on the 27th May for PC mode, WT Mode and Imaging Mode, it became apparent that there was an off-set of one column between PC mode and WT Mode (SWIFT-XRT-CALDB-08). The hot columns identified onboard were corrected for this fact on the 9th June 2005 (Tab.4; Tab.17; Tab.30; Tab.41).

18th January 2006

At temperatures above -56 ºC, the hot columns in the center of the CCD were found to be overflowing into additional columns in PC Mode and causing mode-switching between PC Mode and WT Mode. To minimize this effect, a partial column was uploaded in PC Mode (Tab.5; Tab.18; Tab.31; Tab.42).

9th February 2006

Eleven bad pixels were uploaded to the onboard bad pixel map for PC Mode and Imaging Mode and an additional hot column was uploaded to the WT Mode bad pixel row. These pixels are listed in Tab.6, Tab.19, Tab.32 and Tab.43.

12th April 2006

Eight bad pixels were uploaded to the onboard bad pixel map for PC Mode and Imaging Mode. These pixels are listed in Tab.7 and Tab.20.

15th June 2006

Nine bad pixels were uploaded to the onboard bad pixel map for PC Mode and Imaging Mode and two pixels were unmasked from the onboard bad pixel map for PC and Imaging Mode. These pixels are listed in Tab.8, Tab.9, Tab.21 and Tab.22.

29th September 2006

Thirteen bad pixels were uploaded to the onboard bad pixel map for PC Mode and Imaging. These pixels are listed in Tab.10 and Tab.23.

17th October 2006

Five bad pixels were uploaded to the onboard bad pixel map for PC Mode and Imaging Mode. These pixels are listed in Tab.11 and Tab.24.

13th February 2007

The degradation of the column partially masked on 18th January 2006 started causing mode-switching between PC and WT Mode at lower CCD temperatures. The entire column was uploaded in PC Mode and Imaging Mode**.** Nine bad pixels were uploaded to the onboard bad pixel map for PC Mode and Imaging Mode. These pixels are listed in Tab.12 and Tab.25.

22nd October 2007

The raised SSV had the effect of a decrease in the instrumental background. Eight previously uploaded hot pixels had returned to normal functioning after the SSV change and could be unmasked onboard (Tab.14 and Tab.27). Three new bad pixels were uploaded to the onboard bad pixel map for PC Mode and Imaging Mode. These pixels are listed in Tab.13 and Tab.26.
The degrading column at RAWX=290 was masked in WT mode (Tab.38 and Tab.49) and the RAWX=294 column was incorrectly masked on board. A partial hot column was partially masked in Imaging mode (Tab.15 and Tab.28).

30th October 2007

The column RAWX=294, incorrectly masked on-board in WT mode on the 22nd October 2007, was un-masked (Tab.39 and Tab.50).

9. CALDB UPDATES

12th October 2005

The XRT on-board and ground bad pixel lists *swxonboardbp20010101v005.fits* and *swxbadpix20010101v005.fits* contain the partial dead column, the hot-spot region and several hot pixels that were uploaded to the XRT. Hot columns and hot pixels due to micrometeroid damage were not included in these files.

24th April 2006

The XRT on-board and ground bad pixel lists identified in Section 1 (*swxbadpix20050609v003.fits* and *swxonboardbp20050609v003.fits*) include the 12th October update covering launch until 27th May 2005 and the re-inventory all of the bad pixels and also the 9th February upload to the XRT. A re-inventory of all bad pixels that have appeared from launch through 9th February 2006 has been done to correct discrepancies that existed between the true bad pixel list and the values that had been loaded into the CALDB Tables. Discrepancies were found in both the positions of some bad pixels and in the exclusion times (time/date at which a particular bad pixel is designated as having become unusable) of some bad pixels. The current bad pixel lists contained in the CALDB represent the best and most accurate catalog of bad pixels throughout the history of the mission. This catalog is detailed in Tab.3-7, Tab.16-20, Tab.30-34 and Tab.40-44 below. Tab.3-7 show the PC/Image mode bad pixels in the ground bad pixel catalog. Tab.16-20 show the PC/Image mode bad pixels in the onboard bad pixel catalog. Tab.30-34 show the WT bad pixels in the ground bad pixel catalog. Tab.40-44 show the WT bad pixels in the onboard bad pixel catalog. All bad pixels are listed only showing their positions as read out through amplifier #1, though the CALDB products also contain the complementary bad pixel entry for the detector as read out through amplifier #2. The 'Time' column in the tables below represents the mission elapsed time (MET) at which the pixel is first considered as bad. 'RAWX' and 'RAWY' identify the position of the bad pixel in raw detector coordinates (see Appendix for an explanation of the various XRT coordinate systems). 'Amp' defines to which amplifier the current CALDB row corresponds (only Amp1 entries are listed below for brevity, though both Amp1 and Amp2 entries are contained in the CALDB). 'Type' defines whether the CALDB row refers to an individual bad pixel (1) or a partial or full bad column (2). 'Yextent' describes the length of the column of detectors masked out in cases where Type=2 (starting at the RawX, RawY position and extending in the +RawY direction).

In the current release of the CALDB, 8 badpixel files are included, 4 ground and 4 on-orbit. The reason for having 4 files of each type is that the XRTPIPELINE does not currently read the 'Time' column of the CALDB file to identify whether a particular bad pixel should be applied to a given dataset. Because this functionality is not yet included, a work-around method has been developed using 4 files of each type whereby the filenames are used to select between the appropriate bad pixel Table to use for each time period. When the functionality to read the 'Time' column from the CALDB Tab.s is included in the XRTPIPELINE in a future release, only one CALDB file of each type will be required and the others will be removed at that time.

8th November 2006

The XRT on-board and ground bad pixel lists identified in Section 1 (*swxbadpix20050609v004.fits*, *swxonboardbp20050609v004.fits*, *swxbadpix20060615v001.fits* and *swxonboardbp20060615v001.fits*), include the 12th April 2006, 15th June 2006, 29th September 2006 and 17th October 2006 updates.

29th March 2007

The XRT on-board and ground bad pixel lists identified in Section 1, *(swxbadpix20060615v002.fits* and *swxonboardbp20060615v002.fits)* including the 13th February 2007 update. The two bad pixels unmasked onboard on 15th June 2006 were unmasked in the CALDB file *swxbadpix20060615v001.fits* but not in the *swxonboardbp20060615v001.fits* released on 8th November 2006. In the 29th March 2007 CALDB update they were also excluded in the file *swxonboardbp20060615v002.fits*.

1st November 2007

This release includes the *swxbadpix20071023v001.fits* and *swxonboardbp20071023v001.fits* CALDB files, valid from the 23rd to the 30th October 2007, containing XRT on-board and ground bad pixel lists identified in Section 1 and the RAWX=294 column incorrectly masked on-board in WT mode; the release includes the files *swxbadpix20071030v001.fits* and *swxonboardbp20071030v001.fits,* with the RAWX=294 column un-masked, valid from the 30th October 2007.

Tab.2: Burn Spot warm pixels

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

Tab.3: May 27th 2005 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
138844800	236	301	1	1	1
138844800	260	246	1	1	1
138844800	301	332	1	1	1
138844800	306	303	1	1	1
138844800	345	224	1	1	1
138844800	347	390	1	1	1
138844800	389	271	1	1	1
138844800	230	306	1	1	1
138844800	289	361	1	1	1
138844800	304	265	1	1	1
138844800	453	391	1	2	209
138844800	307	256	1	2	54
138844800	308	256	1	2	54
138844800	309	256	1	2	54
138844800	310	256	1	2	54
138844800	311	256	1	2	54
138844800	312	256	1	2	54
138844800	313	256	1	2	54
138844800	314	256	1	2	54
138844800	315	256	1	2	54
138844800	316	256	1	2	54
138844800	317	256	1	2	54
138844800	318	256	1	2	54
138844800	319	256	1	2	54
138844800	320	256	1	2	54
138844800	321	256	1	2	54
138844800	322	256	1	2	54
138844800	323	256	1	2	54
138844800	324	256	1	2	54
138844800	325	256	1	2	54
138844800	326	256	1	2	54
138844800	327	256	1	2	54
138844800	328	256	1	2	54
138844800	329	256	1	2	54
138844800	330	256	1	2	54
138844800	331	256	1	2	54
138844800	332	256	1	2	54
138844800	333	256	1	2	54
138844800	334	256	1	2	54
138844800	335	256	1	2	54
138844800	336	256	1	2	54
138844800	337	256	1	2	54
138844800	338	256	1	2	54
138844800	339	256	1	2	54
138844800	340	256	1	2	54
138844800	341	256	1	2	54
138844800	342	256	1	2	54
138844800	343	256	1	2	54
138844800	344	256	1	2	54

138844800	345	256	1	2	54
138844800	346	256	1	2	54
138844800	347	256	1	2	54
138844800	348	256	1	2	54
138931200	147	0	1	2	599
138931200	178	0	1	2	599
138931200	293	0	1	2	599
138931200	320	0	1	2	599

Tab.4: June 9th 2005 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	236	301	1	1	1
139968000	260	246	1	1	1
139968000	301	332	1	1	1
139968000	306	303	1	1	1
139968000	345	224	1	1	1
139968000	347	390	1	1	1
139968000	389	271	1	1	1
139968000	230	306	1	1	1
139968000	289	361	1	1	1
139968000	304	265	1	1	1
139968000	146	0	1	2	599
139968000	177	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
139968000	453	391	1	2	209
139968000	307	256	1	2	54
139968000	308	256	1	2	54
139968000	309	256	1	2	54
139968000	310	256	1	2	54
139968000	311	256	1	2	54
139968000	312	256	1	2	54
139968000	313	256	1	2	54
139968000	314	256	1	2	54
139968000	315	256	1	2	54
139968000	316	256	1	2	54
139968000	317	256	1	2	54
139968000	318	256	1	2	54
139968000	319	256	1	2	54
139968000	320	256	1	2	54
139968000	321	256	1	2	54
139968000	322	256	1	2	54
139968000	323	256	1	2	54
139968000	324	256	1	2	54
139968000	325	256	1	2	54
139968000	326	256	1	2	54
139968000	327	256	1	2	54
139968000	328	256	1	2	54
139968000	329	256	1	2	54
139968000	330	256	1	2	54

139968000	331	256	1	2	54
139968000	332	256	1	2	54
139968000	333	256	1	2	54
139968000	334	256	1	2	54
139968000	335	256	1	2	54
139968000	336	256	1	2	54
139968000	337	256	1	2	54
139968000	338	256	1	2	54
139968000	339	256	1	2	54
139968000	340	256	1	2	54
139968000	341	256	1	2	54
139968000	342	256	1	2	54
139968000	343	256	1	2	54
139968000	344	256	1	2	54
139968000	345	256	1	2	54
139968000	346	256	1	2	54
139968000	347	256	1	2	54
139968000	348	256	1	2	54
140313600	291	0	1	2	599

Tab.5: January 18th 2006 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	236	301	1	1	1
139968000	260	246	1	1	1
139968000	301	332	1	1	1
139968000	306	303	1	1	1
139968000	345	224	1	1	1
139968000	347	390	1	1	1
139968000	389	271	1	1	1
139968000	230	306	1	1	1
139968000	289	361	1	1	1
139968000	304	265	1	1	1
139968000	146	0	1	2	599
139968000	177	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
139968000	453	391	1	2	209
139968000	307	256	1	2	54
139968000	308	256	1	2	54
139968000	309	256	1	2	54
139968000	310	256	1	2	54
139968000	311	256	1	2	54
139968000	312	256	1	2	54
139968000	313	256	1	2	54
139968000	314	256	1	2	54
139968000	315	256	1	2	54
139968000	316	256	1	2	54
139968000	317	256	1	2	54
139968000	318	256	1	2	54
139968000	319	256	1	2	54

139968000	320	256	1	2	54
139968000	321	256	1	2	54
139968000	322	256	1	2	54
139968000	323	256	1	2	54
139968000	324	256	1	2	54
139968000	325	256	1	2	54
139968000	326	256	1	2	54
139968000	327	256	1	2	54
139968000	328	256	1	2	54
139968000	329	256	1	2	54
139968000	330	256	1	2	54
139968000	331	256	1	2	54
139968000	332	256	1	2	54
139968000	333	256	1	2	54
139968000	334	256	1	2	54
139968000	335	256	1	2	54
139968000	336	256	1	2	54
139968000	337	256	1	2	54
139968000	338	256	1	2	54
139968000	339	256	1	2	54
139968000	340	256	1	2	54
139968000	341	256	1	2	54
139968000	342	256	1	2	54
139968000	343	256	1	2	54
139968000	344	256	1	2	54
139968000	345	256	1	2	54
139968000	346	256	1	2	54
139968000	347	256	1	2	54
139968000	348	256	1	2	54
140313600	291	0	1	2	599
159235201	290	199	1	2	91

Tab.6: February 9th 2006 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	236	301	1	1	1
139968000	260	246	1	1	1
139968000	301	332	1	1	1
139968000	306	303	1	1	1
139968000	345	224	1	1	1
139968000	347	390	1	1	1
139968000	389	271	1	1	1
139968000	230	306	1	1	1
139968000	289	361	1	1	1
139968000	304	265	1	1	1
139968000	146	0	1	2	599
139968000	177	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
139968000	453	391	1	2	209
139968000	307	256	1	2	54

139968000	308	256	1	2	54
139968000	309	256	1	2	54
139968000	310	256	1	2	54
139968000	311	256	1	2	54
139968000	312	256	1	2	54
139968000	313	256	1	2	54
139968000	314	256	1	2	54
139968000	315	256	1	2	54
139968000	316	256	1	2	54
139968000	317	256	1	2	54
139968000	318	256	1	2	54
139968000	319	256	1	2	54
139968000	320	256	1	2	54
139968000	321	256	1	2	54
139968000	322	256	1	2	54
139968000	323	256	1	2	54
139968000	324	256	1	2	54
139968000	325	256	1	2	54
139968000	326	256	1	2	54
139968000	327	256	1	2	54
139968000	328	256	1	2	54
139968000	329	256	1	2	54
139968000	330	256	1	2	54
139968000	331	256	1	2	54
139968000	332	256	1	2	54
139968000	333	256	1	2	54
139968000	334	256	1	2	54
139968000	335	256	1	2	54
139968000	336	256	1	2	54
139968000	337	256	1	2	54
139968000	338	256	1	2	54
139968000	339	256	1	2	54
139968000	340	256	1	2	54
139968000	341	256	1	2	54
139968000	342	256	1	2	54
139968000	343	256	1	2	54
139968000	344	256	1	2	54
139968000	345	256	1	2	54
139968000	346	256	1	2	54
139968000	347	256	1	2	54
139968000	348	256	1	2	54
140313600	291	0	1	2	599
159235201	290	199	1	2	91
161136001	220	231	1	1	1
161136001	237	253	1	1	1
161136001	245	354	1	1	1
161136001	258	204	1	1	1
161136001	284	205	1	1	1
161136001	298	364	1	1	1
161136001	320	238	1	1	1
161136001	344	398	1	1	1

161136001	364	310	1	1	1
161136001	392	247	1	1	1
161136001	400	383	1	1	1

Tab.7: Pixels added on April 12th 2006 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
166492810	218	326	1	1	1
166492810	221	350	1	1	1
166492810	224	324	1	1	1
166492810	289	277	1	1	1
166492810	311	296	1	1	1
166492810	318	210	1	1	1
166492810	377	261	1	1	1
166492810	391	295	1	1	1

Tab.8: Pixels added June 15th 2006 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
172022410	201	203	1	1	1
172022410	201	335	1	1	1
172022410	201	361	1	1	1
172022410	205	256	1	1	1
172022410	220	394	1	1	1
172022410	229	204	1	1	1
172022410	284	273	1	1	1
172022410	339	299	1	1	1
172022410	400	277	1	1	1

Tab.9: Pixels removed June 15th 2006 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
161222400	258	204	1	1	1
161222400	304	265	1	1	1

Tab.10: Pixels added September 29th 2006 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
181180810	207	308	1	1	1
181180810	221	208	1	1	1
181180810	231	339	1	1	1
181180810	252	332	1	1	1
181180810	255	235	1	1	1
181180810	258	270	1	1	1
181180810	263	385	1	1	1
181180810	298	330	1	1	1
181180810	310	302	1	1	1
181180810	321	220	1	1	1
181180810	336	353	1	1	1

181180810	345	236	1	1	1
181180810	362	283	1	1	1

Tab.11: Pixels added October 17th 2006 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
182736010	258	85	1	1	1
182736010	371	76	1	1	1
182736010	382	428	1	1	1
182736010	388	495	1	1	1
182736010	453	390	1	1	1

Tab.12: Pixels added February 13th 2007 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
193017600	207	395	1	1	1
193017600	225	397	1	1	1
193017600	228	386	1	1	1
193017600	248	355	1	1	1
193017600	300	287	1	1	1
193017600	346	307	1	1	1
193017600	370	240	1	1	1
193017600	383	246	1	1	1
193017600	398	342	1	1	1
193017600	290	0	1	2	599

Tab.13: Pixels added October 22th 2007 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
214790400	249	270	1	1	1
214790400	352	283	1	1	1
214790400	374	364	1	1	1

Tab.14: Pixels removed October 22th 2007 PC/IM ground

Time	RawX	RawY	Amp	Type	Yextent
214790400	221	350	1	1	1
214790400	237	253	1	1	1
214790400	245	354	1	1	1
214790400	263	385	1	1	1
214790400	289	277	1	1	1
214790400	300	287	1	1	1
214790400	377	261	1	1	1
214790400	391	295	1	1	1

Tab.15: Pixels added October 22th 2007 IM ground

Time	RawX	RawY	Amp	Type	Yextent
214790400	453	486	1	2	64

Tab.16: May 27th 2005 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
138844800	236	301	1	1	1
138844800	260	246	1	1	1
138844800	301	332	1	1	1
138844800	306	303	1	1	1
138844800	345	224	1	1	1
138844800	347	390	1	1	1
138844800	389	271	1	1	1
138844800	230	306	1	1	1
138844800	289	361	1	1	1
138844800	304	265	1	1	1
138931200	147	0	1	2	599
138931200	178	0	1	2	599
138931200	293	0	1	2	599
138931200	320	0	1	2	599

Tab.17: June 9th 2005 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	236	301	1	1	1
139968000	260	246	1	1	1
139968000	301	332	1	1	1
139968000	306	303	1	1	1
139968000	345	224	1	1	1
139968000	347	390	1	1	1
139968000	389	271	1	1	1
139968000	230	306	1	1	1
139968000	289	361	1	1	1
139968000	304	265	1	1	1
139968000	146	0	1	2	599
139968000	177	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
140313600	291	0	1	2	599

Tab.18: January 18th 2006 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	236	301	1	1	1
139968000	260	246	1	1	1
139968000	301	332	1	1	1
139968000	306	303	1	1	1
139968000	345	224	1	1	1

139968000	347	390	1	1	1
139968000	389	271	1	1	1
139968000	230	306	1	1	1
139968000	289	361	1	1	1
139968000	304	265	1	1	1
139968000	146	0	1	2	599
139968000	177	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
140313600	291	0	1	2	599
159235201	290	199	1	2	91

Tab.19: February 9th 2006 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	236	301	1	1	1
139968000	260	246	1	1	1
139968000	301	332	1	1	1
139968000	306	303	1	1	1
139968000	345	224	1	1	1
139968000	347	390	1	1	1
139968000	389	271	1	1	1
139968000	230	306	1	1	1
139968000	289	361	1	1	1
139968000	304	265	1	1	1
139968000	146	0	1	2	599
139968000	177	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
140313600	291	0	1	2	599
159235201	290	199	1	2	91
161136001	220	231	1	1	1
161136001	237	253	1	1	1
161136001	245	354	1	1	1
161136001	258	204	1	1	1
161136001	284	205	1	1	1
161136001	298	364	1	1	1
161136001	320	238	1	1	1
161136001	344	398	1	1	1
161136001	364	310	1	1	1
161136001	392	247	1	1	1
161136001	400	383	1	1	1

Tab.20: Pixels added April 12th 2006 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
166492810	218	326	1	1	1
166492810	221	350	1	1	1
166492810	224	324	1	1	1
166492810	289	277	1	1	1

166492810	311	296	1	1	1
166492810	318	210	1	1	1
166492810	377	261	1	1	1
166492810	391	295	1	1	1

Tab.21: Pixels added June 15th 2006 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
172022410	201	203	1	1	1
172022410	201	335	1	1	1
172022410	201	361	1	1	1
172022410	205	256	1	1	1
172022410	220	394	1	1	1
172022410	229	204	1	1	1
172022410	284	273	1	1	1
172022410	339	299	1	1	1
172022410	400	277	1	1	1

Tab.22: Pixels removed June 15th 2006 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
161222400	258	204	1	1	1
161222400	304	265	1	1	1

Tab.23: Pixels added September 29th 2006 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
181180810	207	308	1	1	1
181180810	221	208	1	1	1
181180810	231	339	1	1	1
181180810	252	332	1	1	1
181180810	255	235	1	1	1
181180810	258	270	1	1	1
181180810	263	385	1	1	1
181180810	298	330	1	1	1
181180810	310	302	1	1	1
181180810	321	220	1	1	1
181180810	336	353	1	1	1
181180810	345	236	1	1	1
181180810	362	283	1	1	1

Tab.24: Pixels added October 17th 2006 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
182736010	258	85	1	1	1

182736010	371	76	1	1	1
182736010	382	428	1	1	1
182736010	388	495	1	1	1
182736010	453	390	1	1	1

Tab.25: Pixels added February 13th 2007 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
193017600	207	395	1	1	1
193017600	225	397	1	1	1
193017600	228	386	1	1	1
193017600	248	355	1	1	1
193017600	300	287	1	1	1
193017600	346	307	1	1	1
193017600	370	240	1	1	1
193017600	383	246	1	1	1
193017600	398	342	1	1	1
193017600	290	0	1	2	599

Tab.26 : Pixels added October 22th 2007 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
214790400	249	270	1	1	1
214790400	352	283	1	1	1
214790400	374	364	1	1	1

Tab.27: Pixels removed October 22th 2007 PC/IM on-orbit

Time	RawX	RawY	Amp	Type	Yextent
214790400	221	350	1	1	1
214790400	237	253	1	1	1
214790400	245	354	1	1	1
214790400	263	385	1	1	1
214790400	289	277	1	1	1
214790400	300	287	1	1	1
214790400	377	261	1	1	1
214790400	391	295	1	1	1

Tab.28: Pixels added October 22th 2007 IM ground

Time	RawX	RawY	Amp	Type	Yextent
214790400	453	486	1	2	64

Tab.29: May 27th 2005 WT ground

Time	RawX	RawY	Amp	Type	Yextent
138931200	291	0	1	2	599
138931200	292	0	1	2	599
138931200	293	0	1	2	599

138931200	319	0	1	2	599

Tab.30: June 9th 2005 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599

Tab.31: January 18th 2006 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599

Tab.32: February 9th 2006 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.33: April 12th 2006 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.34: June 15th 2006 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.35: September 14th 2006 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599

161136001	293	0	1	2	599

Tab.36: October 17th 2006 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.37: February 13th 2007 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.38: October 22nd 2007 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599
214790400	290	0	1	2	599
214790400	294	0	1	2	599

Tab.39: October 30rd 2007 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599
214790400	290	0	1	2	599

Tab.40 : May 27th 2005 WT on-orbit

Time	RawX	RawY	Amp	Type	Yextent
138931200	291	0	1	2	599
138931200	292	0	1	2	599
138931200	293	0	1	2	599
138931200	319	0	1	2	599

Tab.41: June 9th 2005 WT on-orbit

Time	RawX	RawY	Amp	Type	Yextent

139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599

Tab.42: January 18th 2006 WT on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599

Tab.43: February 9th 2006 WT on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.44: April 12th 2006 WT on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.45: June 15th 2006 WT on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.46: September 14th 2006 WT on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.47: October 17th 2006 WT on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599

139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.48: February 13th 2007 WT on-orbit

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599

Tab.49: October 22nd 2007 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599
214790400	290	0	1	2	599
214790400	294	0	1	2	599

Tab.50: October 30th 2007 WT ground

Time	RawX	RawY	Amp	Type	Yextent
139968000	291	0	1	2	599
139968000	292	0	1	2	599
139968000	319	0	1	2	599
161136001	293	0	1	2	599
214790400	290	0	1	2	599

REFERENCES

J. Osborne *et al*., “The in-flight spectroscopic performance of the *Swift* XRT CCD camera”, *Proc. SPIE*, **5898**, 352, 2005

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