Operations and Flight Calibration of the Swift X-ray Telescope (XRT)

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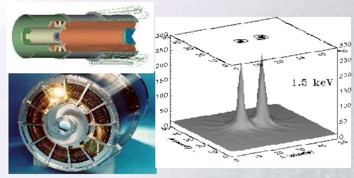
Abstract:

We present the current on-orbit operational plans and calibration plans for the Swift XRT. The XRT is a largely autonomous instrument and requires very little manual commanding for normal operations. A detailed calibration plan is being developed to verify the instrument performance on-orbit, including effective area, point spread function, vignetting, spectroscopic performance, and timing accuracy. Operational plans include regular calibration measurements using on-board sources as well as periodic calibration observations using celestial targets.

The Swift XRT has three key science goals:

1) Determine GRB position with 5 arcsecond accuracy and transmit position to the ground within 100 s of the burst.
2) Measure the afterglow lightcurve
3) Obtain X-ray spectroscopy of the afterglow

PSF

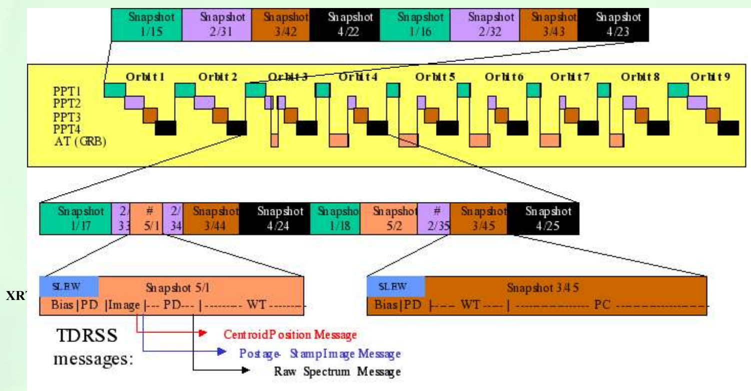


XRT mirror module design (top left); XRT mirror bottom left); measured PSF (right)

The Point Spread Function (PSF) of the XRT telescope has been measured at the Panter calibration facility (see insert above) as a function of off-axis angle and energy and will be verified on orbit using the sources listed below.

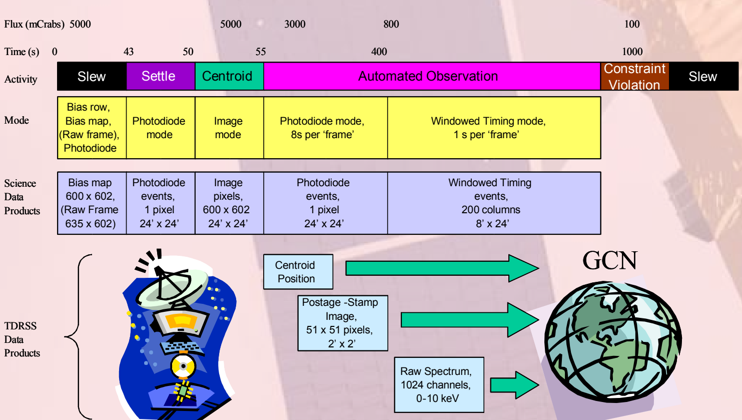
Source	Count Rate (cps)	Mode	Exposure (ks)	Purpose
PKS 0537-441	0.45	PC	5	First light, XRT/UVOT co-alignment
NGC 2516	0.002 - 0.01	PC	50	Accurate boresight, plate scale
PKS 0312-770	0.08	PC	80	PSF core
RXJ0720.4-3125	0.16	PC	30	PSF core
GX1+4	5.0	PC	20	PSF wings
RXS J1708-4009	7.2	PC	20	PSF wings

Swift Observation Scenario

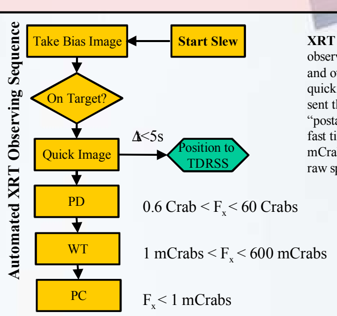


Pictorial diagram of a typical "day in the life" of *Swift* observations covering 9 orbits. The middle box (yellow) shows a timeline for a sequence of snapshots of 5 different targets, four Pre-Planned Targets (PPTs) loaded into the on-board flight timeline, and one Automated Target (AT) representing a newly discovered GRB. Targets are color-coded for clarity. The top bar shows an expanded view of the first two orbits. Snapshots are identified by a target number and a snapshot number (target/snapshot). These PPTs would typically represent follow-up observations of GRBs discovered over the previous week. In Orbit 3 a new GRB is discovered by the BAT, and the Figure-of-Merit (FOM) task (the on-board automated scheduler) assigns it a target number of 5 and schedules an immediate observation, interrupting the previously-scheduled snapshot 34 for target #2. The automated observation of target #5 continues until it is interrupted by an observing constraint, at which time the FOM resumes the interrupted observation of target #2 with snapshot #34. On Orbit 4, target #5 is observed as soon as it becomes visible, and preempts time from both target #1 and target #2. The bottom bar shows the sequence of *XRT* events for an AT (target #5) and a PPT (target #3). For the AT, the *XRT* updates its bias row and bias map during the slew and then switches into Photodiode (PD) mode. As soon as the slew ends, the *XRT* takes an image, centroids the image to determine the source position, and sends this to the ground through TDRSS, along with a postage-stamp image of the source. It then switches back to Photodiode mode until the flux drops low enough for Windowed Timing (WT) mode, at which point it sends a cumulative raw spectrum to the ground through TDRSS. The sequence of events for a PPT is similar, except that no Image Mode data are collected and no TDRSS messages are generated.

XRT Observation Timeline



Timeline of an *XRT* observation of an Automated Target (newly-discovered GRB). The new Snapshot begins when the observatory begins to slew to the new target. A typical slew will take between 20 and 50 s; here we show a slew time of 43 s followed by a worst-case settle time of 7 s. The *XRT* takes up to 5 s to determine the GRB centroid, and then begins the balance of an automated observation. As the flux decays (top line), the *XRT* modes switch accordingly. The Snapshot ends when a constraint violation triggers another slew. *XRT* mode and data products are shown in the center and bottom bars, respectively. TDRSS messages are shown in the bottom graphic. In this case, the Centroid Position message is generated at about 55 s and the Spectrum message is generated at about 400s.

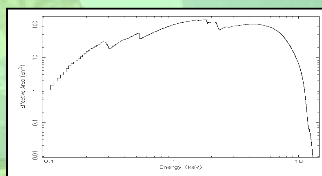


XRT automated operations: this is a simplified flow-chart of an XRT observation of a new GRB. During the S/C slew we collect bias images and other calibration data. When the S/C arrives at the target we take a quick piled-up image, calculate the source centroid in RA and Dec, and sent the position to the GCN via TDRSS. We also send a 51x51 pixel "postage-stamp" image of the source to the GCN. We then switch into our fast timing mode (Photodiode Mode, or PD) until the flux drops below 600 mCrabs. We then switch into Windowed Timing (WT) mode and issue a raw spectrum through TDRSS to the GCN.

When the flux drops below 1 mCrabs we switch to Photon-Counting mode (PC; similar to the ACIS Timed Exposure mode) and issue another cumulative raw spectrum via TDRSS to the GCN.

PSU UL OAB

Effective Area



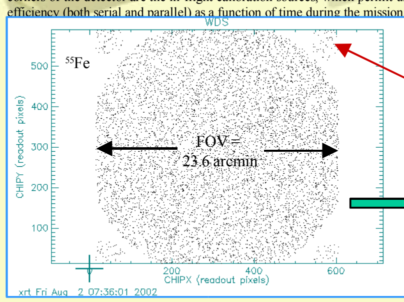
XRT Effective Area vs Energy

The Effective Area of the XRT telescope has been measured at the Panter calibration facility as a function of off-axis angle and energy (left) and will be verified on orbit using the sources listed below.

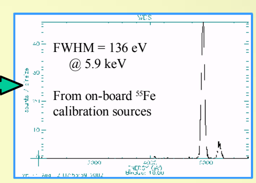
Source	Count Rate (cps)	Mode	Exposure (ks)	Purpose
Cas A	21	PC, WT	150	Effective area, gain, vignetting
2E0102-7212	4	PC, WT	126	Effective area, gain, vignetting
Crab	790	PD	10	Effective area, gain, vignetting

Energy Resolution

The in-flight performance of the instrument will be monitored daily using ^{55}Fe calibration sources illuminating the corners of the CCD. An image collected during thermal vacuum testing in July 2002 is shown below. The central circular region shows the circular field of view of the instrument (slightly truncated by the edges of the CCD), illuminated by Mn K-α and K-β X-rays at 5.9 and 6.4 keV (see spectrum below) from a ^{55}Fe source located on the camera door. During flight this source is moved away when the camera door is opened, and this portion of the CCD views the sky. The four circular regions in the corners of the detector are the in-flight calibration sources, which permit us to measure resolution, gain, and transfer efficiency (both serial and parallel) as a function of time during the mission.



Spectral resolution will also be measured using the celestial sources listed below.



Source	Count Rate (cps)	Mode	Exposure (ks)	Purpose
AB Dor	3.9	WT	20	Spectral resolution
HD 35850	0.9	PC	20	Spectral resolution

Additional calibration targets will measure timing accuracy and will provide cross-calibrations to RXTE, Chandra, and XMM. The total XRT calibration program uses about 1 Ms of observing time.