# Memory requirement for a 12 hour scan mode of Scanning Sky Monitor with down-link once in every four orbits

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**Abstract**

This is a report on the estimation of the requirement of the on-board memory for all the three cameras of the Scanning Sky Monitor (SSM) assembly aboard ASTROSAT. We have used the $4^{th}$ UHURU catalog for the list of sources and 12 hour scan mode of SSM, with the orbital period of the satellite being 100 minutes.

Based on the software for simulating the sky dynamically using spherical transformations (refer to the report: RRI_SSM_0010), the sum of the flux values due to all the sources present in the fields of view in each of the three cameras of the SSM assembly are listed as a function of time, as the SSM assembly is rotated from $0^\circ$ – $360^\circ$, the readings being taken at the intervals of $0.5^\circ$. For this, the sky populated with the sources from the $4^{th}$ UHURU catalog[1] has been used and the following relationship has been assumed: 1 crab = 946 UHURU counts. The sum of the source-flux values in a field of view (FOV) were calculated only after they were corrected for:
(*i*) the effective source illumination area on the detector[2] and
(*ii*) the Projection factor[3], which decides the effective fraction of the source flux illumination on the camera depending on where the source is located in the FOV.
The cant angle[4] has been assumed to be $25^\circ$. A provision has also been made in the software to list the entries in the input source-catalog of those sources which happen to be in those fields of view in which the total flux exceeds a pre-specified value (in the present case, this value was chosen as 5000 counts).

Assuming a 12 hour scan mode of the SSM assembly, (which corresponds to the rate of rotation of $\left(\frac{1}{120}\right)^\circ \mathrm{s}^{-1}$, the slowest proposed), the time per reading, $t_s$ is given by, (noting that the total number of readings is 720, as they are taken at the intervals of $0.5^\circ$):

$$t_s = \frac{12 \times 3600}{720} = 60 \text{ s} \tag{1}$$

The integrated counts from the Crab nebula for the operating energy range of the SSM in the units of cnts $\mathrm{s}^{-1}$ will be:

$$C_s = 3.75 \times (9.6 \times 6) \times 0.5 \times 0.8 = 86.4 \text{ cnts s}^{-1} \tag{2}$$

where,

- 3.75 cnts $\mathrm{cm}^{-2}$ $\mathrm{s}^{-1}$ is the integrated counts from the Crab nebula for SSM as per the Preliminary Design Review document.
- $9.6 \times 6$ $\mathrm{cm}^2$ is the SSM detection area.
- 0.5 is the transparency of the coded mask (though in reality, because of the support structures it could be a little less than 0.5).
- 0.8 is the detection efficiency of SSM.

Using 1 crab = 946 cnts and $C_s$ = 86.4 cnts $\mathrm{s}^{-1}$ (eqn 2), the ratio of the UHURU counts to the SSM flux is given by,

$$U_S = \frac{946}{C_s} \approx 10.95 \text{ s} \tag{3}$$

For every reading noted down at the intervals of $0.5^\circ$ of the boom rotation, the three values of the sum of the fluxes due to all the sources in the fields of view of each of the three SSM cameras, are added in the following manner:

$$f_t = (f_b + f_{s1} + f_{s2}) \times \left(\frac{t_s}{U_S}\right) \tag{4}$$

where,

| | | |
|---|---|---|
| $f_t$ | $\equiv$ | Total flux in all the three fields of view |
| $f_b$ | $\equiv$ | Total flux in the FOV of the boom camera (SSM 3) |
| $f_{s1}$ | $\equiv$ | Total flux in the FOV of the slanted camera 1 (SSM 1) |
| $f_{s2}$ | $\equiv$ | Total flux in the FOV of the slanted camera 2 (SSM 2) |
| $t_s$ | $\equiv$ | Time per reading = 60 s (equation 1) |
| $U_S$ | $\equiv$ | Ratio of UHURU counts to SSM flux $\approx$ 10.95 s (equation 3) |

The satellite orbital period has been assumed to be 100 minutes and it has been assumed that the payload data will be downloaded once in every four orbits. Hence, the number of samples of readings that must be added at a time is given by,

$$n = \frac{4 \times 100 \times 60}{t_s} = 400 \text{ s} \tag{5}$$

[1] see Appendix A on page 3
[2] see section B.1 on page 4
[3] equation B.5 of section B.2 on page 5
[4] Cant Angle is the complement of the angle between the boom pointing direction and the direction of common normal to the two slanted cameras (SSM 1 and SSM 2)

where,

- 4 is the number of orbits per data down-link.
- 100 minutes is the satellite orbital period.
- $t_s$ is the time per reading = 60 s (equation 1)

The total number of boom-pointing directions chosen are 54 as shown in the figure 1.

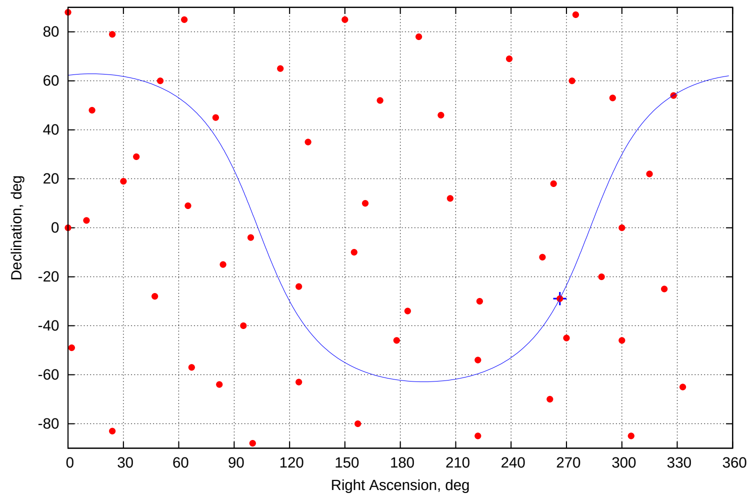



Figure 1: 54 Boom Pointings chosen are shown as (red) filled circles: 2 of them on the equator, 25 of them in the northern hemisphere and 27 in the southern hemisphere. The galactic plane is indicated with the (blue) line and the galactic center is indicated with the (blue) plus sign.

The $720 \times 54$ values of $f_t$ are subject to a running-window sum with a sample-size of $n = 400$ (eqn 5). These sum-values are shown in figure 2. The maximum among these sum values is found and thus the maximum memory required for storing the raw data from all the three SSM cameras on-board the satellite is calculated, with the information that 6 bytes of memory are used to represent one event. In this exercise, this maximum memory has been found to be 134.177 MegaBytes of memory, which is about a third of 400 MegaBytes, the total on-board memory of the SSM assembly.

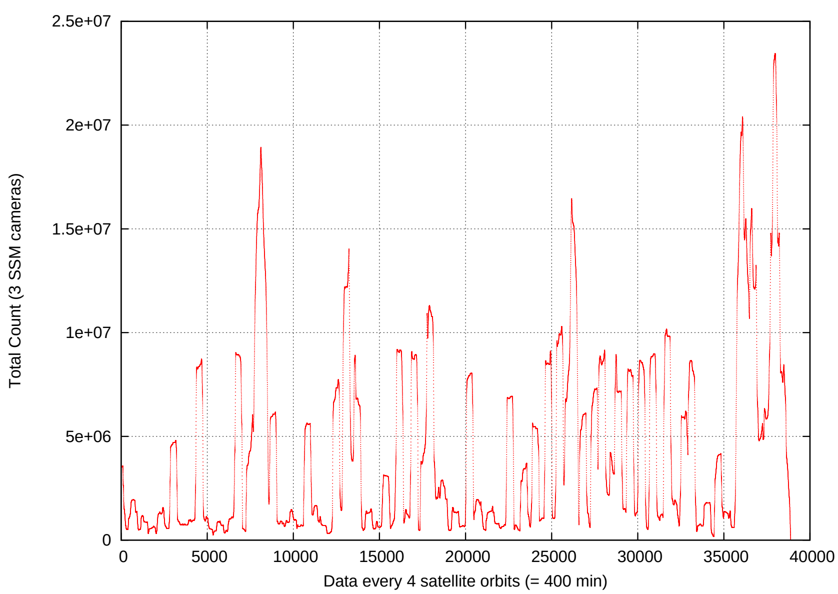
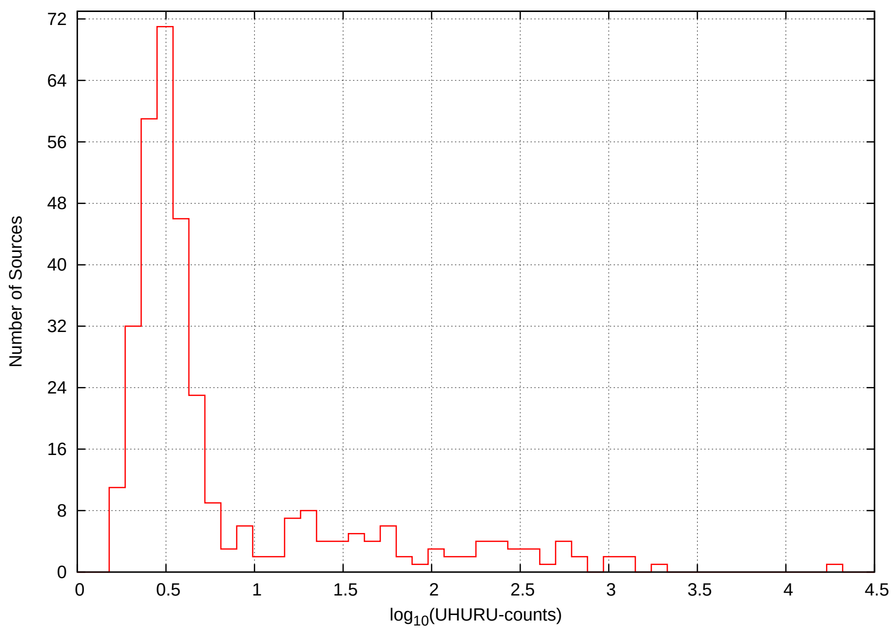



Figure 2: Every point in this figure represents the total number of events accumulated over four satellite orbits each of duration 100 minutes in all the three cameras of SSM assembly. The peaks are seen mainly when SCO-X1, which was in an active state with 17000 UHURU counts in the $4^{th}$ UHURU catalog, appears in the fields of view of more than one SSM camera.

# Appendix A

## UHURU catalog

The 4$^{th}$ UHURU catalog has 339 sources and the following figure shows their distribution in terms of their flux in the units of UHURU-counts.



# Appendix B

# Correction factors

## B.1 Effective area on the detector

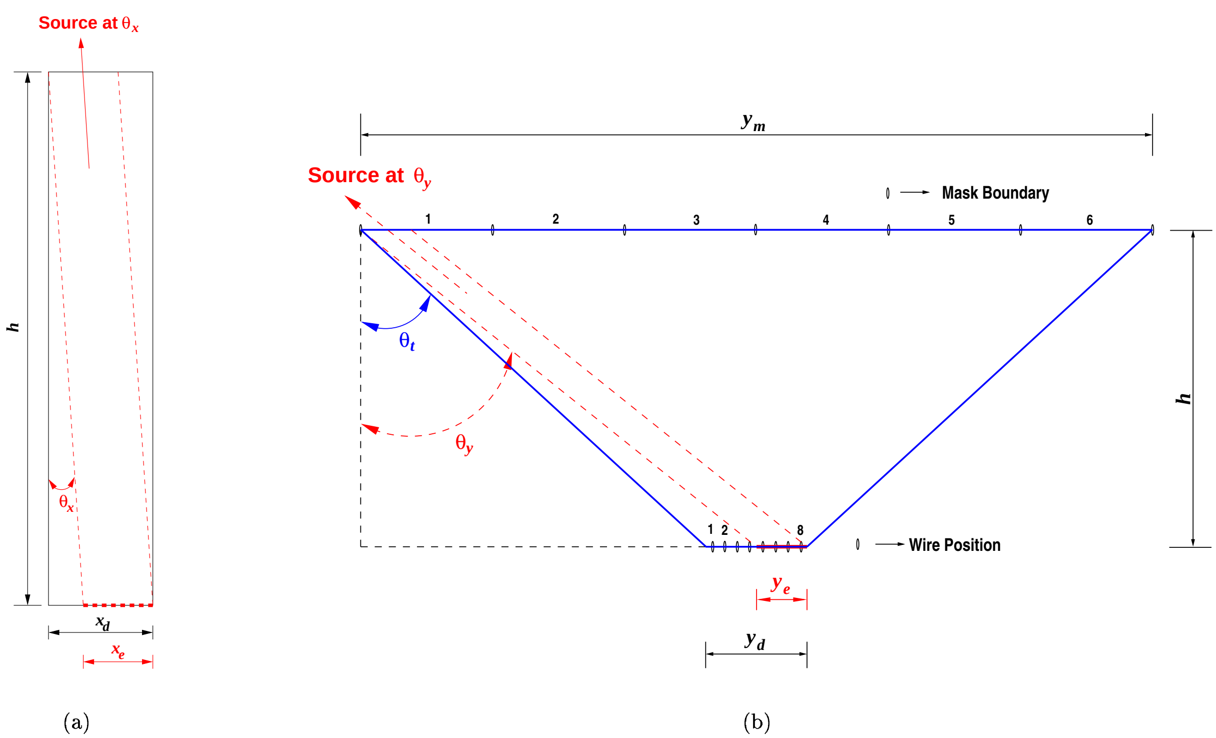



Figure B.1: Effective length of the shadow on the detector (a) along the mask coding direction and (b) across that direction, for a given source incidence angle.

The figure B.1 shows the effective length of the shadows $x_e$ and $y_e$ along and across the mask coding directions respectively for a given source at coordinates, $\theta_x, \theta_y$. When the flux due to that source is to be considered one should scale the flux value by the factors $\left(\frac{x_e}{x_d}\right)$ and $\left(\frac{y_e}{y_d}\right)$, where $x_d$ and $y_d$ are the lengths of the detector along and across the mask coding directions respectively.

From figure B.1(a),

$$\left(\frac{x_e}{x_d}\right) = 1 - \left(\frac{h}{x_d}\right) \times |\tan\theta_x|$$

From figure B.1(b),

$$\left(\frac{y_e}{y_d}\right) = \begin{cases} 1 - \left(\frac{h}{y_d}\right) \times (|\tan\theta_y| - \tan\theta_t) & \text{if } |\theta_y| > \theta_t \\ 1 & \text{if } |\theta_y| \leq \theta_t \end{cases}$$

where $h$ is the height of the camera (distance between the anode plane and the top surface of the mask plate) and $\tan\theta_t = \left(\frac{y_m - y_d}{2\times h}\right)$ ($y_m$ is the width of the mask plate across the coding direction).

## B.2 Projection factor

From the figure B.2, the relationship between the Cartesian coordinates $x, y, z$ and the Polar coordinates at unit distance $\theta, \phi$ is given by,

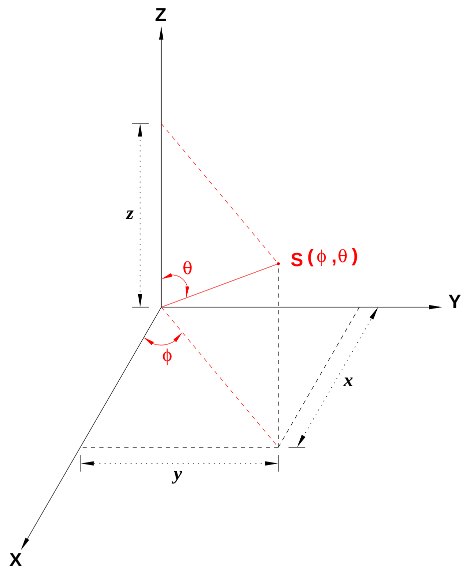



Figure B.2: Cartesian – Polar coordinates

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} \sin\theta\cos\phi \\ \sin\theta\sin\phi \\ \cos\theta \end{pmatrix} \tag{B.1}$$

Further, the Cartesian co-ordinates, ($x$, $y$, $z$) are related to the angles $(\theta_x, \theta_y)$ (figure B.1) in the following manner:

$$\begin{pmatrix} \cos\theta_x \\ \cos\theta_y \end{pmatrix} = \begin{pmatrix} \frac{z}{\sqrt{x^2+z^2}} \\ \frac{z}{\sqrt{y^2+z^2}} \end{pmatrix} \tag{B.2}$$

$$\begin{aligned} \text{Using equations B.2, } \sec^2\theta_x + \sec^2\theta_y &= \frac{x^2+z^2}{z^2} + \frac{y^2+z^2}{z^2} \\ &= \frac{(x^2+y^2+z^2)+z^2}{z^2} \end{aligned} \tag{B.3}$$

Also,

$$x^2 + y^2 + z^2 = 1 \tag{B.4}$$

Using equations B.4 and B.1 in the equation B.3,

$$\cos\theta = \frac{1}{\sqrt{\sec^2\theta_x + \sec^2\theta_y - 1}} \tag{B.5}$$

To obtain the count rate of a source at $(\theta_x, \theta_y)$ its flux value should be multiplied by the Projection factor of equation B.5.